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CORAL THANATOCOENOSES AND DEPOSITIONAL ENVIRONMENTS IN THE UPPER TRESKELODDEN BEDS OF THE HORNSUND AREA, SPITSBERGEN

(plates 5-22)

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Field observations made in 1975 supplement existing data and make possible a new interpretation of depositional environments of the upper Treskelodden beds. It is demonstrated that the entire coral fauna in all "Coral Horizons" represents redeposited assemblages. Transportation in same cases was sufficient to abrade and round individual colonies; others were simply overturned from growth position.

The upper Treskelodden beds were deposited in very shallow marine environments although some beds and parts of the studied area may have been temporarily exposed above sea level. Environmental changes observed are developed on a local scale only. Tectonic factors are interpreted herein as causing the faunal and sedimentological variations observed rather than the global climatological mechanisms suggested by earlier workers. This interpretation is supported by the small scale and character of the sedimentological variations observed.

Key words: Lower Permian, Spitsbergen, coral thanatocoenoses, depositional environments.

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TANATOCENOZY KORALOWE I WARUNKI SEDYMENTACJI GÓRNYCH WARSTW TRESKELODDEN W REJONIE HORNSUNDU, SPITSBERGEN

Streszczenie. — Badania terenowe przeprowadzone przez autora w okolicach fiordu Hornsund w 1975 r. dostarczyły nowych danych na temat warunków sedymentacji i stanu zachowania koralowców — najliczniejszej grupy zwierząt w dolnopermskich warstwach Treskelodden. Stwierdzono, że cała fauna koralowa uległa redepozycji. Dystans, zróżnicowany w poszczególnych pakietach warstw koralonośnych, malał ku górze profilu. W najwyższym pakiecie liczne kolonie mogły być tylko nieznacznie przemieszczone. Kształt kolonii i rzeźba powierzchni koralitów posłużyły do zrekonstruowania czasu trwania depozycji jednej z warstw tego najwyższego pakietu.

Obserwacje sedymentologiczne, chociaż niekompletne, potwierdziły opinię, że warstwy Treskelodden nie są osadem cyklicznym w sensie ląd—morze—ląd, a poszczególne poziomy występowania fauny są raczej pakietami warstw niż horyzontami. Stan zachowania fauny koralowej, udział poszczególnych form wzrostu w zespołach i charakter zmian

pośmiertnych umożliwiły podjęcie próby zrekonstruowania pierwotnych środowisk koralowych, warunków transportu i środowisk sedymentacji. Stwierdzono stopniowe zanikanie różnic pomiędzy tymi środowiskami w poszczególnych pakietach warstw, aż do przypuszczalnego zrównania warunków w 5 pakiecie warstw koralonośnych. Zmiany powyższe były odbiciem zmian w konfiguracji wybrzeży, a te z kolei wypływały z lokalnych i bardziej ogólnych uwarunkowań tektonicznych. Na tektoniczne, a nie klimatyczne podłoże zmian, przyjmowane uprzednio, wskazuje zarówno ich lokalny charakter, jak i obserwowana sekwencja warstw ku północy regionu badań.

INTRODUCTION

Comparatively recent investigations of lithology, stratigraphy and palaeontology of the upper Treskelodden beds in the Hornsund area (fig. 1) produced several contradictory opinions as to both the age and depositional environments of the unit (BIRKENMAJER 1959, 1964; BIRKENMAJER and CZARNIECKI 1960; LISZKA 1964; FEDOROWSKI 1964, 1965; HEINTZ *in* FEDOROWSKI 1967; SIEDLECKA 1968; CZARNIECKI 1969). Several of these opinions were based on, or were related to studies on rugose corals, the most common faunal element of the unit. Prior to 1975, however, no field investigations had been made by a coral specialist and the main aim of my visit to Spitsbergen was therefore to study the palaeoecology of this coral fauna. It soon became

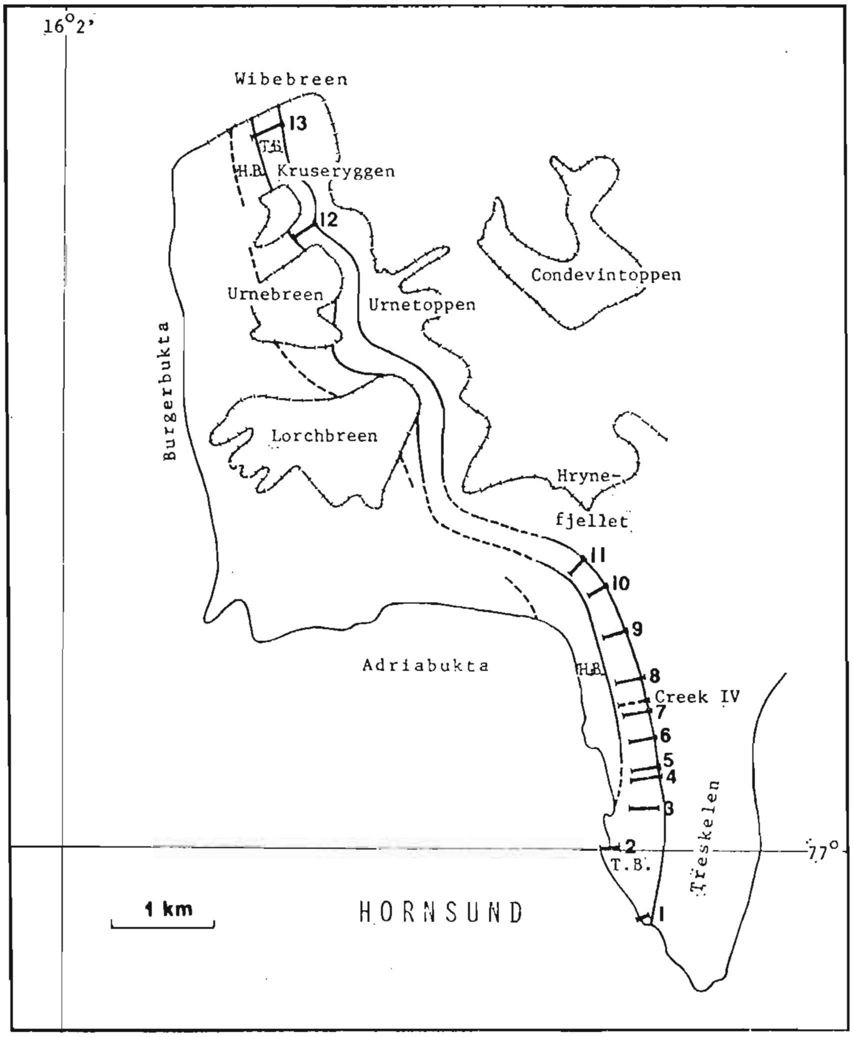

Fig. 1
Sketch map of the studied area. Deposits other than Hyrnefjellet beds and Treskelodden beds not shown.

clear, however, that most (and as afterwards discovered, **all**) of the coral fauna was redeposited, and the study became biostratonomical and sedimentological rather than ecological, excercise.

My observations and results are based on eighteen measured geological sections. Thirteen of these are presented in figures 2 and 3. The section of Creek IV, although one of the most complete and important, is not published here as nothing new can be added to the detailed petrographical description of SIEDLECKA (1968). Controversial and/or new observations made in Creek IV, especially those concerning the coral fauna, are presented on the following pages in a discussion of particular units.

Descriptions of geological sections and the general discussion start from the oldest deposits under consideration. The stratigraphical subdivision of BIRKENMAJER (1964) is only in part followed.

For the reasons discussed by NYSAETHER (1977) I shall in this paper use the term Treskelodden beds as originally suggested by BIRKENMAJER (1959, 1964) instead of the term Treskelodden Formation as proposed by CUTBILL and CHALLINOR (1965).

All photographs, taken both in the field in order to illustrate particular phenomena and in the laboratory, are unretouched.

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HISTORICAL

The following remarks are restricted to a few papers which have presented a new data and interpretations of the coral faunas and their depositional environments in the upper Treskelodden beds in the Hornsund area. All older papers were reviewed in the comprehensive paper by BIRKENMAJER (1964) and by CZARNIECKI (1969) and further discussion is unnecessary. Some of BIRKENMAJER'S (1964) conclusions were discussed by SIEDLECKA (1968) and CZARNIECKI (1969). The most important of them are as follows:

1. BIRKENMAJER (1964) divided the Treskelodden beds into 5 major cycles of intercalated continental and marine deposits. The above concept was adopted by SIEDLECKA (1968) but it was criticized and rejected by CZARNIECKI (1969) who did not find any marine to continental sequences in particular sets of beds.

2. BIRKENMAJER (1964) introduced the term "Coral Limestone Horizon" for the marine part of each major cycle which contained coral fauna. Because the coralliferous beds in lower horizons are not limestones, SIEDLECKA (1969) proposed the more neutral term "Coral Horizon". CZARNIECKI (1969) maintained that only some of these "Coral Horizons" are more or less persistent, while most are developed locally and are not traceable over any great distance.

3. The climate was interpreted by BIRKENMAJER (1964) as warm and seasonally dry. Coral faunas were given suitable growth conditions during warm and humid periods. Colonies in the "Coral Horizons" were referred to as "bioherms" and were thought to be *in situ* in growth position. This opinion was mostly accepted by both SIEDLECKA (1968) and CZARNIECKI (1969) who described majority of coral colonies as occurring *in situ* in growth positions. According

to studies on stratigraphical equivalents of the Treskelodden beds (SIEDLECKA 1972; FOLK and SIEDLECKA 1974; NYSAETHER 1977), the climate was predominantly arid.

4. The source area for clastic components of the upper Treskelodden beds was deduced by BIRKENMAJER (1964) as eastwards or south-eastwards of Treskelen-Hyrnefjellet region. This point of view has either not been discussed or has been accepted by subsequent investigators. It must be pointed out here that new investigations (HELLEM and WORSLEY 1978) show that Treskelodden beds equivalents are also developed in Sørkappland. This necessitates a reconsideration of BIRKENMAJER'S (1964) palaeogeographical reconstruction of the Lower Permian southwards of the Hornsund area. HELLEM and WORSLEY (1978) suggest that the margins of the Hornsund-Sørkapp High (to the west of Treskelen) were tectonically active during the deposition of the Treskelodden beds and WORSLEY (pers. comm.) considers this high to be the source for these clastics.

5. BIRKENMAJER (1964) interpreted changes in depositional environments as being caused by alternating glaciation and deglaciation in the southern hemisphere. This interpretation was not discussed by SIEDLECKA (1968) and CZARNIECKI (1969), but it was accepted by NYSAETHER (1977).

In my previous publication (FEDOROWSKI 1964) contemporaneously with but independent of LISZKA (1964) I identified the age of the upper Treskelodden beds as Lower Permian. This point of view was accepted by BIRKENMAJER (1964) but it was strongly and tendentiously criticized by CZARNIECKI (1969). I maintain my view as to the Lower Permian age of the upper Treskelodden beds although it is now thought to be older than Artinskian. A detailed analysis of this problem will be presented when the entire new collection of the rugose coral fauna is described. More comprehensive paper (FEDOROWSKI 1965) brought detailed description of the coral fauna which confirmed my earlier opinion as to the Permian age of the upper Treskelodden beds. In addition to some paleobiological studies on corals it also contains some remarks concerning paleoecology and paleogeography. The former are now largerly retracted, while the more general part of the latter is still thought to be correct.

In a short foreword to my paper (FEDOROWSKI 1967) Profesor A. HEINTZ wrote: "All the corals seem to have been transported and deposited in a secondary layer. Many of them have eroded surfaces, some are rolled, cracked or damaged in other ways. It is, however, quite understandable that corals — typical marine animals as they are — could not live in the fresh or brakish water, where the coarse sediments of the red series were deposited. The corals certainly originated from older marine deposits lifted up and eroded". The above interpretation is diametrally opposed to that of BIRKENMAJER (1964) and later workers.

SIEDLECKA (1968) presented comprehensive petrographical and sedimentological studies of the deposits in Creek IV on Treskelen and interpreted the depositional environments of Hyrnefjellet and Treskelodden beds. She envisaged the Treskelodden beds as representing a natural continuation of sedimentation which produced the Hyrnefjellet beds but with increased marine influence. Accepting BIRKENMAJER'S (1964) concept of cyclic sedimentation, SIEDLECKA (1968:88) wrote: "The general picture of the Treskelodden beds based on subsequent major and minor cycles will be a little more complicated if the character of the cement of these deposits is taken into account. Clastic quartzitic series as well as calcite- and dolomite-cemented series may be distinguished. The sequence quartzitic sandstones-dolomitic sandstones — calcareous sandstones occur several times in the cross section, but they coincide only in part with sedimentation cycles distinguished by BIRKENMAJER (*o. c.*). This differentiation being strictly connected with diagenesis of sediments is due to the marine influence". SIEDLECKA (1968) interpreted the depositional environment of the Treskelodden beds as a lagoonal area, hypersaline under periods of high evaporation or brackish when more intense inflow of fresh water occurred. Temporary connections between these lagoons and the open sea were marked by carbonate deposition.

CZARNIECKI (1969) described the geology and brachiopod fauna of the Hornsund area and paid special attention to the Tresjkelodden beds. He introduced a new unit the "Transitional Conglomerates", discussed sedimentary conditions of the Treskelodden beds and reconstructed paleoecology of corals and brachiopods. Several of his opinions were mentioned above. Several others, not confirmed here, will be discussed later.

NYSAETHER (1977) described Upper Palaeozoic deposits of two geological sections in the middle part of the Torell Land, compared them with the Treskelodden beds in the Hornsund area and produced a general interpretation of the Permo-Carboniferous rock-sequence. He accepted BIRKENMAJER'S (1964) concept concerning both, the cyclic marine to continental sedimentation of the Treskelodden beds and the glacial control of the sedimentation. He considered the non-fossiliferous beds overlying the coralliferous beds in the Burgerbukta area as continental deposits. BIRKENMAJER (1979) interpreted the distribution pattern and growth conditions of the coral fauna in the upper Treskelodden beds. This interpretation is evaluated in detail on pp. 47—49 of this paper.

DESCRIPTION OF SECTIONS

SECTION 1

(140/17 S, southernmost outcrop)

Upper Treskelodden beds

----- Sea level.
1.50 Upper part of pinkish calcareous conglomerates with large, flat colonies and fragmented solitary rugose corals and rare gastropods.
0.80 Gray, resistant, non-fossiliferous calcareous sandstone.
5.60 Gray quartzitic sandstones. Lenses of very coarse quartzitic sandstones and conglomerates are more abundant in the middle part of the unit. Cross bedding occurs locally in sandstones.

Kapp Starostin Formation

0.0 — 0.2 Calcareous conglomerate of erosional base.
4.3 — 4.5 Cherty limestones with brachiopod fauna.

SECTION 2

(150/22 W, near "Treskelodden" of CZARNIECKI 1969)

Upper Treskelodden beds

2.50 Dark-gray quartzitic sandstones with intercalations of pebbly sandstones lowermost and with abundant iron staining ("Gray Conglomerate Horizon").
4.80 Pale-gray and gray to reddish thinly bedded, fine-grained calcareous and dolomitic sandstones of sharp base.
0.45 — 1.30 Calcareous pebbly and cobbly sandstones passing gradually upwards into pale-gray, medium- and fine-grained calcareous sandstones. Abraded and rounded coral colonies are abundant lowermost. Fragmented branches of fasciculate colonies occur in sandstones together with rare, spherical colonies of calcareous algae.
1.40 Pale-gray to red (colours interchange laterally), fine-grained and thinly bedded, bioturbated calcareous and dolomitic sandstones of gradational base.
1.50 Sandstones as beneath, but not bioturbated.
0.10 Gray shales.
1.55 Gray, fine-grained calcareous and dolomitic sandstones with thin lenses of very coarse-grained sandstones and with impersistant intercalations of red shales.

3.40 Pinkish calcareous conglomerates composed mainly of subrounded and often imbricated pebbles and cobbles of gray quartzitic sandstones and white chert with occasional subrounded blocks of gray quartzitic sandstones (approximately 60 cm in diameter). Some pebbles are overgrown by calcareous algae. Corals are abundant in one conglomerate unit and comprise of large (< 2.70 m), flat massive colonies and broken fragments of solitary corals.

SECTION 3

(172/36 E, a composite section based on exposures located 1, 050-1,100 m S of Creek IV)

Upper Treskelodden beds

2.50 Dark-gray, cross-bedded quartzitic sandstones with abundant iron staining. Lenses of quartzitic pebbly sandstones are present in the lower part of the unit ("Gray Conglomerate Horizon").
8.30 Covered by scree.
0.50 Pale gray or yellowish, commonly cross bedded calcareous sandstones with scattered clasts of white chert and with rare, very fragmented corals, mainly derived from fasciculate colonies.
5.50 Debris of thinly bedded, yellow calcareous sandstones. In the middle part of the area several slabs of calcareous sandstones with fragmented fasciculate colonies occur.
2.50 Gray calcareous sandstones with abundant pebbles either scattered and/or forming intercalated small lenses.
3.00 Covered by scree.
2.80 Yellowish-gray calcareous conglomerates (with a block of calcareous sandstone over 1 m in maximum diameter); these conglomerates grade down- and up-wards into yellowish calcareous sandstones. Rare corals (all small colonies of *Protolonsdaleiastraea*) occur lowermost.
7.00 Covered by scree.
1.60 Two beds of whitish quartzitic sandstones. The upper bed's top has intercalated pebbly sandstones with dominant chert clasts.
18.30 Covered by scree.
1.00 Gray calcareous sandstone with lenses of gray limestone, with abundant crinoid columnals and broken brachiopod shells and a few fragments of solitary and colonial corals.
16.00 Covered by scree.

Kapp Starostin Formation

2.80 Cherty limestones of uncertain thickness (scree cover).

SECTION 4

(160/38 E, southern part of Creek II, 820 m S of Creek IV)

Upper Treskelodden beds

1.70 Gray quartzitic sandstones with plane lamination in the lower part, intercalated with gray pebbly quartzitic sandstones. Individual lenses, 10-15 cm thick disappear laterally.
1.20 Dark quartzitic sandstones with iron staining ("Gray Conglomerate Horizon").
6.70 Covered by scree.
1.10 Gray (weathering brownish) cross-bedded calcareous sandstones containing subrounded and rounded pebbles and fragmented, rounded, massive coral colonies (12 × 10 cm maximum) lowermost.
15.00 Covered by scree with poorly exposed sandstones. Approximately 5 m above the formerly described coralliferous bed there exists a poorly exposed bed of gray (weathering yellow) calcareous sandstone with colonies of *Protolonsdaleiastraea*.
0.15 Pale gray or yellowish calcareous sandstone grading upwards into
1.85 gray calcareous pebbly sandstone with rare fragmentes of solitary corals.
0.50 Gray-pinkish micritic limestone.
1.30 Covered by scree.
0.60 Gray (weathering yellowish) cross-bedded calcareous sandstones.
5.50 Covered by scree.
3.00 A lens of steel-gray, irregularly bedded, quartzitic pebbly sandstones with lenses of cross-bedded sandstones and intercalated conglomerates with the largest cobble 21 cm in diameter. The unit grades upwards into
0.30 steel-gray quartzitic sandstones.
7.00 Covered by scree.
0.30 Gray calcareous pebbly sandstone with subrounded clasts up to 3 cm in diameter. All corals (occurring mainly in lower part of the bed) are fragmented.

0.30 Poorly exposed, dark, bituminous limestone packed with corals, brachiopods and crinoid columnals. The true thickness is greater than that exposed.
6.50 Covered by scree of black marly shales.
1.40 Light gray, thickly bedded quartzitic sandstones.
17.0 Covered by scree.

Kapp Starostin Formation

— Cherty limestones mostly covered by scree, not measured width of exposure approx. 1 m.

SECTION 5

(150/30 E, 770 m south of Creek IV, northern side of Creek II)

Upper Treskelodden beds

1.35 Gray (weathering yellowish), cross-bedded quartzitic sandstone with lenses of quartzitic pebbly sandstones lower most.
1.00 Dark gray hard quartzitic sandstone with abundant iron staining.
6.00 Covered by scree.
1.00 Gray (weathering yellowish and platy) cross-bedded calcareous sandstones grading upwards into
0.10 poorly sorted, gray calcareous pebbly sandstones with one clast 22 × 10 cm in diameter, but with average ones smaller than 3 cm. Small fragments of solitary corals are usually angular.
0.70 Gray (weathering yellowish) thickly bedded sandstones of sharp base, grading upwards into
0.30 brownish pebbly sandstone.
4.30 Covered by scree. In lower part there are poorly exposed (not measured) thinly bedded calcareous sandstones with fragments of fasciculate colonies of rugose corals.
3.60 Gray (weathering brownish) locally cross-bedded calcareous sandstones with flat lenses and intercalations of pebbly sandstones grading upwards into
2.30 gray (weathering yellowish) cross-bedded calcareous sandstones with lenses of pebbly sandstones several centimeters to some meters long. The unit grades upwards into .
1.40 gray calcareous pebbly sandstone passing laterally into calcareous sandstones or calcareous conglomerates. Abundant large fragments of solitary corals and rare fragments of colonial corals occur in upper part of the bed.
0.15 Gray shales.
0.60 Gray-pinkish micritic limestone with rare fragments of coral colonies.
1.30 Thick bed of gray-brownish calcareous sandstone with abundant clasts of chert and with rare fragments of rugose corals.
3.80 Covered by scree.
1.50 Dark gray quartzitic sandstones in beds 30-40 cm thick, passing northwards into conglomerate and upwards into
1.45 whitish quartzitic sandstone passing laterally into pebbly sandstone and upwards into
0.70 steel-gray quartzitic conglomerate with subrounded pebbles, composed mainly of white chert, 9 cm in maximum diameter.
2.10 Covered by scree.
0.40 Pale gray thinly bedded quartzitic sandstone, platy when weathered.
0.60 Gray (weathering brownish) calcareous sandstones with clasts of chert and fragments of solitary corals in its lower part.
10.70 Covered by scree. In the middle part poorly exposed, dark gray coralliferous limestones.
1.10 Pale gray quartzitic sandstones, thinly bedded in the upper part.
12.50 Covered by scree.
1.20 Whitish quartzitic sandstone in two beds.
3.50 Covered by scree.

Kapp Starostin Formation

4.70 Cherty limestones with brachiopod fauna; the base is not exposed.

SECTION 6

(170/42 E, a composite section based on exposures located 400-420 m S of Creek IV)

Upper Treskelodden beds

0.50 Poorly exposed dark gray quartzitic sandstone.
10.00 Covered by scree.

0.50 Gray (weathering brownish) sandstone with clasts of chert.
1.80 Covered by scree.
0.40 Brownish ferruginous-calcareous sandstones passing laterally into thin- and cross-bedded calcareous sandstones with intercalations of pebbly sandstones.
4.00 Covered by scree.
0.85 Gray cross-bedded calcareous pebbly sandstone passing laterally into calcareous sandstones. Fragments of solitary corals and fasciculate colonies are rare and scattered.
0.40 Gray-pinkish micritic limestone.
1.60 Covered by scree.
0.40 Gray-yellowish calcareous sandstone with local cross-bedding and with rare, scattered clasts of chert.
4.00 Covered by scree.
0.35 Whitish quartzitic sandstone.
9.70 Covered by scree.
0.50 Gray (weathering yellowish) calcareous sandstone grading upwards into
0.30 gray calcareous pebbly sandstone grading upwards into
0.20 yellowish marly sandstone.
0.50 Calcaroeus medium- and coarse-grained sandstones grading upwards into gray limestone. Fragments of solitary and colonial corals occur both in limestone and in sandstone.
5.00 Covered by scree.
2.10 Whitish quartzitic sandstones, thickly and cross-bedded in the upper part with elongated lenses and intercalations of quartzitic pebbly sandstones.
7.20 Covered by scree.
2.00 Whitish cross-bedded quartzitic sandstones, more massive and thickly bedded in the upper part.
2.50 Covered by scree.
0.20 Poorly sorted conglomerate or pebbly sandstone with pebbles up to 7 cm in maximum diameter.
1.80 Covered by scree.
1.00 Gray calcareous sandstone with rare, small fragments of colonial corals and with comparatively abundant fragments of brachiopod shells.
0.60 Gray calcareous sandstone with rare colonial corals.
0.50 Gray sandy limestone with abundant colonial corals.
0.30 Gray sandy limestone with karst wash outs and fissures on the upper surface and with intercalations of calcareous sandstones. Small fragments of colonial corals occur both in limestone and in sandstone.

Kapp Starostin Formation

0.05-0.20 Calcareous conglomerate with erosional base.
4.50 Cherty limestone with brachiopod fauna.

SECTION 7

(170/53 E, 120 m south of Creek IV)

Upper Treskelodden beds

3.30 Dark gray cross-bedded quartzitic sandstones in beds of varying thickness. Lenses of quartzitic pebbly sandstones are more abundant in the middle part of the unit.
4.50 Covered by scree.
0.10 Gray-yellowish calcareous pebbly sandstone with scattered fragments of solitary and colonial rugose corals grading upwards into
0.90 gray-yellowish thinly- and cross-bedded calcareous sandstones.
2.40 Scree with reddish and gray calcareous sandstones poorly exposed locally.
0.40 Gray (weathering yellow) calcareous sandstone with 0.5-2.0 cm clasts lowermost and with rare, massive colonies of rugose corals.
8.50 Covered by scree.
1.00 Grayish cross-bedded sandstones. A deep erosive wash-out within them is filled up with conglomerate.
11.50 A low heap of dark waste with approximately a 2 m wide belt of gray-brownish coralliferous, calcareous sandstone and dark-gray coralliferous limestone.
8.40 Covered by scree. Some loose material is derived from dark coralliferous limestone.
1.50 White quartzitic sandstone, thinly bedded in the middle part, grading upwards into
0.60 pale gray, coarse-grained quartzitic sandstone.
4.70 Covered by scree.

0.85 Whitish, fine-grained quartzitic sandstone.
3.20 Covered by scree.
0.60 A bed of calcareous sandstone with clasts of chert.
3.00 Covered by scree.
1.00 Gray calcareous sandstone with abundant solitary corals in its upper part.
2.00 Gray calcareous fine-grained sandstone with lenses of gray pebbly sandstones and with scattered brachiopods and rugose corals.
3.00 Gray sandy limestones with lenses and intercalations of calcareous sandstones. A fauna of colonial and solitary rugose corals is especially abundant in the upper part of the unit. Karst wash-outs and fissures are developed uppermost.

Kapp Starostin Formation

0.05-0.20 Calcareous conglomerate of erosive base.
4.60-4.80 Cherty limestones with brachiopod fauna.

SECTION 8

(162/55 E, somewhat composite, 180-240 m N of Creek IV)

Upper Treskelodden beds

3.30 Dark to pale gray, often cross-bedded quartzitic sandstones with lenses and intercalations of quartzitic coarse-grained pebbly sandstones. ("Gray Conglomerate Horizon").
5.00 Covered by scree.
0.40 Gray calcareous pebbly sandstones grading upwards into cross-bedded calcareous sandstones with rare fragments of rugose corals.
0.60 Gray-yellowish calcareous sandstones with lenses of ferruginous sandstones.
2.20 Covered by scree. In the middle of the scree there are traces of yellow and red shales.
0.35 Gray (weathering yellow) calcareous sandstones with clasts of whitish chert (fines upwards). Massive colonies, fragments of fasciculate colonies and solitary rugose corals occur in coarser sandstone lowermost.
1.50 Covered by scree. Calcareous sandstones similar to above are exposed locally.
0.20 Gray (weathering yellowish) calcareous sandstone.
5.50 Mostly covered by scree. Slabs of yellowish calcareous sandstones, 15-20 cm thick are occasionally seen.
0.75 Pale gray cross-bedded calcareous sandstone passing gradually upwards into pebbly sandstone with rare fragments of rugose corals.
18.50 Covered by scree.
0.90 Gray limestones with large, overturned, fasciculate colonies of rugose corals in the bottom part, grading upwards into
0.70 gray sandy limestone with small crinoid columnals and with 2-3 cm thick intercalations of calcareous sandstones. Rare fragments of solitary and colonial rugose corals are present both in sandstones and in limestones.
14.50 Covered by scree.
1.65 Whitish quartzitic sandstones, thinly-bedded in the upper and cross-bedded in the lower part of the unit.
3.20 Covered by scree.
0.30 Dark gray quartzitic sandstone with clasts of whitish chert up to 4 cm in diameter.
1.60 Covered by scree.
0.20 Gray quartzitic, cross-bedded sandstone.
6.30 Poorly exposed, gray sandy limestones with rare solitary corals and with abundant massive colonial rugose corals with very large corallites. The largest colony is 1.10 m in diameter and 50 cm in height.

Kapp Starostin Formation

------ Cherty limestones, not measured, mostly covered by scree. The contact with the Upper Treskelodden beds is not exposed.

SECTION 9

(162/65 E, approximately 700 m N of Creek IV)

Upper Treskelodden beds

Note: Several beds in the following section, especially those of the lower part are poorly exposed. The succession is as deposited, although thickness of particular units may be incorrect.

2.70 Gray thickly-bedded, quartzitic pebbly sandstone composed mainly of subrounded clasts of whitish chert and gray quartzitic sandstones. Fines upwards into
1.60 gray thinly-bedded quartzitic sandstones, mostly scree covered ("Gray Conglomerate Horizon").
5.00 Yellowish to reddish thinly-bedded calcareous sandstones, mostly scree covered.
0.70 Poorly exposed yellowish cross-bedded calcareous sandstones with abundant clasts of chert lowermost.
2.60 Covered by scree.
0.70 Scree of gray (weathering yellow) calcareous sandstones with small clasts of chert and massive colonies of rugose corals. Fines upwards.
5.00 Covered by scree of thinly-bedded sandstones with clasts of whitish chert.
0.30 Reddish conglomerate with pebbles 7 cm in maximum diameter and with fragments of solitary corals.
8.00 Covered by scree.
0.40 Gray irregularly bedded conglomerate with clasts of whitish chert and gray quartzitic sandstones attaining 10 cm in diameter.
1.80 Pale gray thickly bedded quartzitic sandstone.
1.00 A thick bed of calcareous sandstone; iron staining common.
9.00 Covered by scree that is mainly composed of thinly-bedded, fine-grained sandstones.
1.70 Pale gray thickly bedded calcareous sandstones with large colonies of rugose corals abundant uppermost.
1.20 Pale yellowish thickly bedded calcareous sandstones with local thin lenses of ferruginous sandstones; both, massive and fasciculate colonies of rugose corals are present.
0.80 Poorly exposed, thinly-bedded calcareous sandstones.
2.10 Pale-gray thickly-bedded quartzitic sandstones.
0.50 A bed of pale gray pebbly sandstone grading upwards into cross-bedded sandstone.
1.50 Gray very coarse-grained sandstones intercalated with thin beds of pale gray medium- and fine-grained, cross-bedded sandstones.
13.70 Poorly exposed, gray and pale gray quartzitic sandstones in beds 20-40 cm thick, possible with local sandy shales.
2.00 Three beds of gray quartzitic sandstone. The upper bed (1.3 m thick) shows intercalated calcareous sandstones which are more abundant uppermost.
4.50 Poorly exposed gray sandy limestones showing local cross-bedding and containing abundant fauna of rugose and tabulate corals.
2.00 Gray thickly-bedded, sandy limestone with intercalated ferruginous and calcareous sandstones, which also fill vertical fissures (clastic dikes?) in limestones. Abundant coral fauna composed mainly of massive colonies of rugosans occur in local accumulations.
4.80 Poorly exposed, gray sandy limestones with intercalated yellowish calcareous sandstones up to 15 cm thick (clastic dikes?). Coral fauna is not abundant and is restricted to sandy limestones.

Kapp Starostin Formation

----- Charty limestones, not measured, mostly scree covered.

SECTION 10

(160/58 E, lower part of the southern slope of Hyrnefjellet)

Upper Treskelodden beds

---- Gray quartzitic sandstones and conglomerates ("Gray Conglomerate Horizon"), not measured.
20.00 Covered by scree.
1.30 Gray calcareous pebbly sandstones grading upwards into coarse-grained calcareous sandstone with 2 cm clasts uppermost.
0.45 Gray (weathering yellowish) sandy limestone with colonies of *Tschussovskenia.*
0.55 Gray (weathering yellowish) sandy limestones with small, scattered bioclastic fragments.
10.20 Covered by scree.
0.55 A bed of brownish medium-grained calcareous sandstone.
1.20 Brownish calcareous sandstones in beds 5-20 cm thick with rare clasts of chert (up to 1.5 cm) and with scattered solitary rugose corals.
1.55 A bed of brownish calcareous sandstone with rare, scattered solitary corals which show a predominantly N—S lineation.
0.35 Gray-brownish medium-grained calcareous sandstone.
1.35 A bed of gray sandy limestone with up to 2 cm clasts lowermost, with abundant crinoid columnals, rounded massive colonies of rugosans (30×9 cm maximum) and fragments of bryozoan colonies deposited in local accumulations.

8.80 Covered by scree.
1.70 Gray to yellowish thickly-bedded, fine-grained calcareous sandstones.
4.20 Dark and pale gray quartzitic sandstones with clasts up to 2 cm in diameter.
2.50 Covered by scree.
1.20 Brown coarse-grained calcareous sandstone with a 10 cm thick bed of pebbly sandstone lowermost. Another pebbly sandstone intercalation in the middle part of the sandstone contains large fragments of solitary corals.
2.10 Gray sandy limestone with rare solitary corals and crinoid columnals.
3.00 Yellowish calcareous sandstones with lenses of gray limestones and sandy limestones.
4.00 Gray sandy limestone grading upwards into limestone with ferruginous sandstone "veins" (clastic dikes?). Rare rugose corals and crinoid columnals occur in the limestone.
2.00 Gray (weathering yellow) sandy limestone composed mainly of angular fragments of massive coral colonies and some fragments of solitary corals (biogenic breccia).
3.00 Gray thickly bedded sandy limestone with abundant but fragmentary brachiopod shells, frequent colonial corals, rare solitary corals and many crinoid columnals. Thin intercalated yellowish calcareous sandstones also fill vertical fissures in the limestone (clastic dikes?).
0.30 Gray calcareous sandstone with poorly seen cross-bedding and with rare brachiopod fragments.
2.60 Gray thickly-bedded limestones with intercalated brownish calcareous sandstones more common lowermost. Similar sandstone infilling vertical fissures in the limestones (clastic dikes?). Colonies and, less frequently, solitary rugose corals are more abundant lowermost.
1.60 Gray thickly-bedded sandy limestones with fissures (clastic dikes?) and coral fauna as in the underlying unit. Karst phenomena (wash-outs and fissures) developed uppermost.

Kapp Starostin Formation

0.30 Calcareous conglomerates of erosional base.
6.00 Cherty limestones with brachiopod fauna.

SECTION 11

(162/60 E, upper part of the southern slope of Hyrnefjellet)

Upper Treskelodden beds

— Dark gray quartzitic, thickly bedded sandstones and pebbly sandstones ("Gray Conglomerate Horizon"), not measured
2.50 Covered by scree.
1.00 Gray (weathering brownish) thinly bedded quartzitic sandstone.
0.30 Gray calcareous pebbly sandstone composed of rounded chert grading upwards into
0.90 gray (weathering yellowish) thickly cross-bedded sandstone.
0.35 A bed of gray calcareous, fine-grained sandstone.
0.15 Gray pebbly sandstone composed mainly of chert.
0.40 Red calcareous, thinly-bedded sandstones.
0.40 Yellow calcareous, thinly-bedded sandstones.
2.00 Pale gray pebbly sandstone (cobbles 10-15 cm maximum) fines upwards into calcareous sandstone with abundant, well preserved solitary corals.
0.20 Gray sandy limestone with abundant solitary and colonial corals; fasciculate colonies most common.
1.70 Yellowish and brownish fine-grained calcareous sandstones in beds 20-50 cm thick with cross-bedding lowermost.
2.00 Red and yellow thinly-bedded sandstones intercalated with sandy shales.
0.30 Pale gray and pinkish pebbly sandstone, coarser in the middle part, with incomplete solitary and colonial corals.
5.00 Brownish and yellowish thinly-bedded sandstones intercalated with similar sandy shales.
1.45 Gray to pinkish conglomerates with largest cobbles 14 cm in diameter. Fines irregularly upwards.
1.50 A bed of pinkish fine-grained calcareous sandstone.
0.40 Gray sandstones in beds 5-10 cm thick.
2.30 Pinkish thickly-bedded calcareous sandstones.
1.40 Gray sandy limestones with abundant pink crinoid columnals and yellowish coral colonies (60 cm maximum diameter).
0.60 Gray (weathering yellowish) calcareous sandstones.
0.75 Gray-green shales.
3.10 Pale gray cross-bedded sandstones in beds up to 80 cm thick.
0.50 Red shales.
1.20 Red ferruginous, cross-bedded sandstone.
2.85 Gray thickly-bedded sandstones.

1.80 Gray thinly-bedded sandstones.
2.00 Pale gray cross-bedded quartzitic sandstones.
3.00 Covered by scree.
1.40 Gray calcareous sandstones with abundant clasts (< 2 cm) lowermost and with a thin lens of fragmented corals in the middle part.
1.80 Gray sandy limestone with scattered corals.
3.30 Gray (weathering brownish) calcareous sandstones in beds 20-40 cm thick grading upwards into a gray limestone covered by an irregular, thin bed of ferruginous sandstone.
1.40 Gray to brownish calcareous sandstones with solitary and colonial rugose corals.
1.30 Gray to pinkish biosparite with many crinoid columnals and both, solitary and colonial corals.
3.00 Covered by scree.
1.60 Gray thickly-bedded limestones, somewhat sandy with colonial corals and calstic dikes (?)
3.10 Gray thickly-bedded, sandy limestones with intercalated yellowish calcareous sandstones, which also fill vertical fissures in the limestone (clastic dikes?). The scattered coral fauna is composed mainly of massive colonies of rugosans. The uppermost surface of the unit was eroded prior to the Kapp Starostin Formation deposition.

Kapp Starostin Formation

0.20 Calcareous conglomerates of erosional base.
5.30 Cherty limestone with brachiopod fauna.

SECTION 12

(Measured by Mr. K. Małkowski, M. Sc. along the ridge between Urnebreen and Krusebreen)

Upper Treskelodden beds

— Several meters of conglomerates, pebbly sandstones and sandstones; not measured.
1.00 Gray laminated, non-fossiliferous calcareous sandstone.
1.50 Gray to pinkish or reddish micritic limestone.
2.00 Pale gray thickly bedded sandstones.
2.00 Gray non-fossiliferous marls.
4.00 Whitish-gray pebbly sandstones. Fining up.
1.00 Gray non-fossiliferous marls.
5.00 Pale gray non-fossiliferous marly sandstones with thin intercalated limestones.
10.00 Gray calcarenite with solitary and, less common, colonial corals. Colonies are smaller than those of the overlying beds.
6.00 Gray nodular limestones medium to thickly bedded. Large (< 80 cm in diameter) massive colonies of rugose corals are especially abundant lowermost.
2.00 Dark gray mainly nodular limestones with rare solitary and colonial rugose corals and with some tabulate corals.
3.00 Gray coarse-grained, non-fossiliferous limestone.
2.50 Covered by scree.
2.50 Pale gray, non-fossiliferous, plane-laminated sandy limestones or calcareous sandstones, more calcareous uppermost.
0.35 Dark gray non-fossiliferous marls.
0.80 Gray nodular, non-fossiliferous marly limestone.
1.70 Gray (weathering yellow) non-fossiliferous marly limestones.

Kapp Starostin Formation

— Cherty limestone and their basal conglomerates (detailed description: Małkowski (1982).

SECTION 13

(Northern slope of Kruseryggen, above Wibebreen)

Upper Treskelodden beds

— Some dozen meters of unmeasured clastic deposits, mainly quartzitic pebbly sandstones, conglomerates and minor sandstones. Lower part of them may well belong to the lower Treskelodden beds.
1.20 Gray quartzitic pebbly sandstones passing laterally and vertically into sandstones.

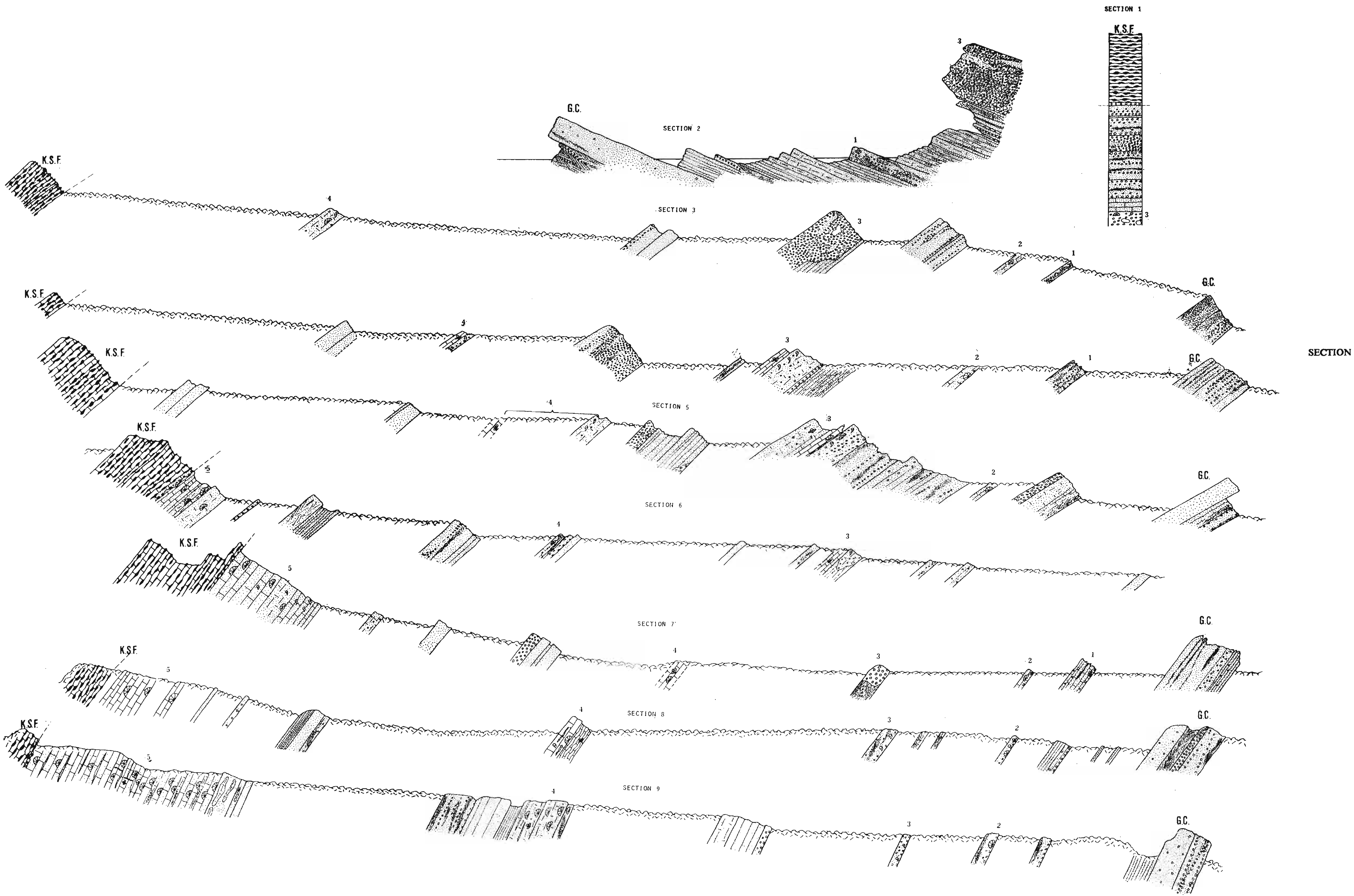

Fig. 2.
Geological sections of the upper Treskelodden beds on Treskelen. Legend as for the figure 3.

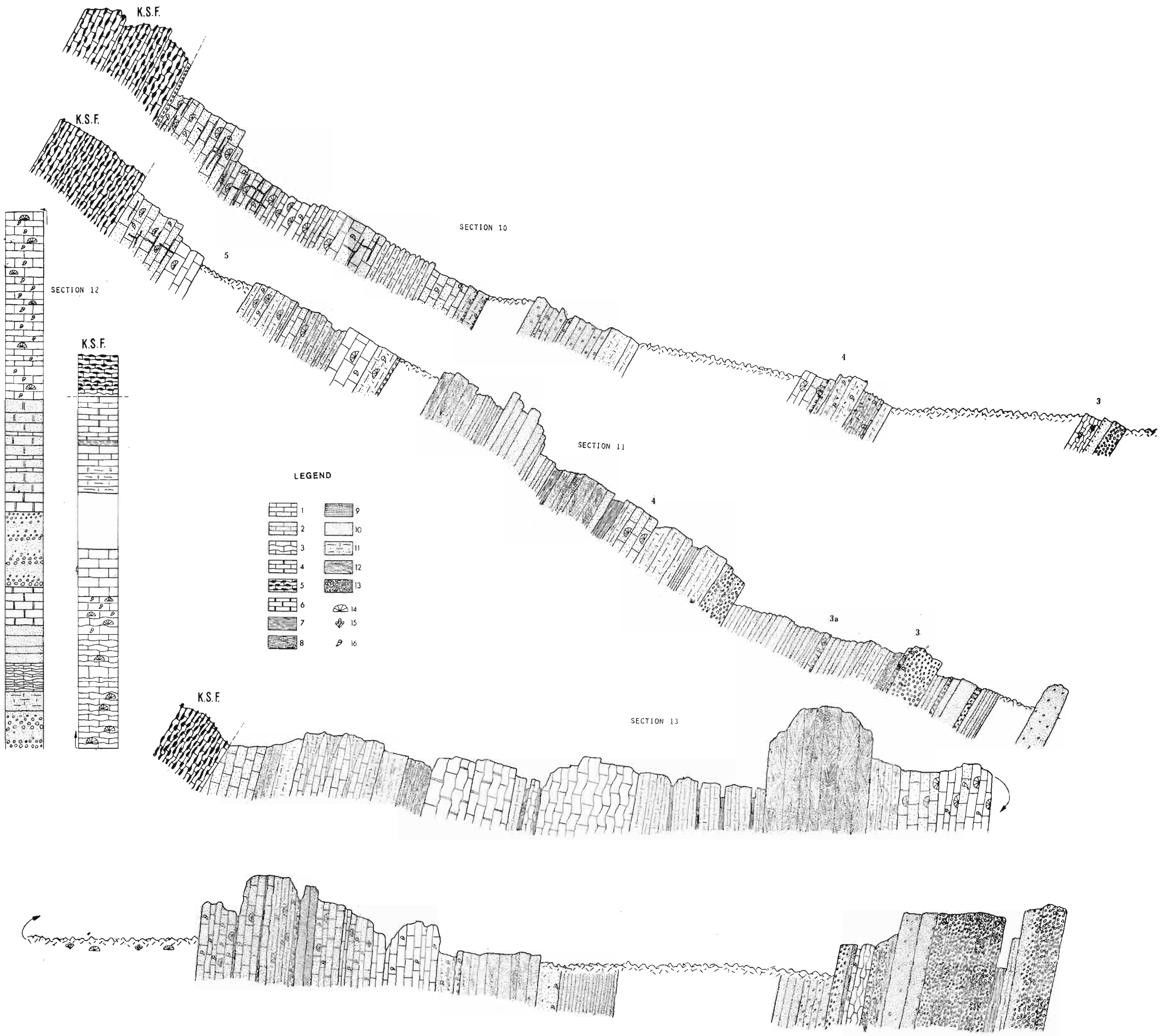

Fig. 3

Geological sections of the Upper Treskelodden beds on Hyrnefjellet (Sections 10 and 11) and in the Burgerbukta area. Section 12 along the ridge between Urnebereen and Krusebreen. Section 13 on the northern slope of Kruseryggen. Legend: *1* limestone, *2* sandy limestone, *3* nodular limestone, *4* marly limestone, *5* cherty limestone of Kapp Starostin Formation, *6* marl, *7* shale, *8* shale with limestone nodulae, *9* thin-bedded sandstone or sandy shale, *10* quartzitic or other non-calcareous sandstone, *11* calcareous sandstone, *12* cross-bedded sandstone, *13* conglomerate, *14* cerioid coral colony, *15* fasciculate coral colony, *16* solitary coral, KPF — Kapp Starostin Formation, G. C. — Grey Conglomerate "Horizon", numbers *1-5* individual sets of coralliferous beds.

0.50 A bed of brownish calcareous sandstone.
0.60 Greenish-gray shales.
3.70 Reddish thickly-bedded pebbly sandstones and conglomerates composed mainly of rounded pebbles of whitish chert and minor pebbles of quartziting sandstones, grading upwards into
0.80 brownish to whitish quartzitic sandstones with small clasts.
1.10 Greenish-gray dolomitic sandstone with small clasts of chert.
0.90 Gray cross-bedded calcareous sandstones with a bifurcating intercalation of a very coarse-grained sandstone in its middle part.
0.20 Reddish calcareous pebbly sandstone with broken solitary corals, more abundant in coarser upper part
0.60 Pinkish micritic limestone.
0.30 Gray calcarenite composed mainly of fragmented brachiopods and incomplete solitary corals.
0.20 Yellowish cross-bedded, fine-grained calcareous sandstone grading upwards into.
0.70 gray very coarse-grained calcareous sandstone with clasts of chert up to 2 cm in diameter.
1.10 Gray quartzitic sandstones with abundant small (< 2 cm) clasts, grading upwards into
1.20 brownish quartzitic sandstones in three beds.
3.00 Gray (weathering yellowish) thinly-bedded sandstones.
1.20 Gray (weathering reddish) thickly-bedded calcareous sandstones with rare solitary corals and with clasts of chert up to 2 cm in diameter lowermost.
4.20 Reddish and yellowish (lowermost greenish) fine-grained sandstones with cross-bedding developed in some beds.
0.30 Pinkish calcareous pebbly sandstone with small fragments of solitary corals.
1.00 Gray (weathering yellowish) sandy limestones with weak cross-bedding and with randomly distributed solitary corals.
2.80 Gray marly, bituminous limestones in 40-50 cm, thick, lenticular beds with scarce fauna of brachiopods and solitary corals.
0.70 Gray limestones with large (< 60 cm in diameter) colonies of calcareous algae, developed mainly in the lower part of the bed.
1.40 Gray sandy limestones highly fossiliferous: crinoid columnals, solitary corals and, less commonly, colonial corals.
0.40 Gray thinly-bedded sandy limestones with abundant crinoid columnals, bryozoans and brachiopods.
1.40 Gray marly and sandy limestones (in beds 30-40 cm thick) with solitary and colonial corals in the upper part.
0.90 Pale gray thickly-bedded quartzitic sandstones.
0.10 Gray calcareous pebbly sandstone with solitary corals grading upwards into
1.50 gray calcareous sandstones with colonial and solitary rugose corals.
3.70 Gray sandy limestones intercalated with thin beds of calcareous sandstones. Abundant solitary and, less frequent colonial corals occur in the upper part of the unit.
9.30 Scree of gray sandy and marly limestones with abundant colonies of *Tschussovskenia* and solitary corals.
2.80 Gray thickly-bedded (more or less sandy) limestones with solitary and colonial corals.
2.10 Gray (weathering yellowish) limestones in beds 20-50 cm thick with solitary corals.

Non-fossiliferous series (= ? Unit 2 of NYSAETHER 1977)

0.10 Gray pebbly sandstone composed of whitish chert and gray quartzitic sandstones, grading upwards into
1.50 gray medium to thickly cross-bedded calcareous sandstones.
5.50 Gray thickly-bedded quartzitic sandstones with well developed cross-bedding.
7.00 Gray (weathering yellowish) dolomitic and calcareous sandstones in beds 10-70 cm thick with four intercalations of shales.
5.20 Gray thickly-bedded marly limestone.
0.10 Gray shales with nodules of dolomitic limestone.
0.90 Gray nodular, dolomitic limestone grading upwards into
0.30 gray shales with nodules of dolomitic limestone.
0.60 A bed of gray sandstone.
4.50 Gray nodular, thickly-bedded, marly and dolomitic limestones.
1.50 Gray thickly-bedded sandstones.
1.40 Gray dolomitic cross-bedded sandstones in beds 20-40 cm thick.
4.30 Gray thickly-bedded (up to over 1 m) sandy limestones passing laterally into marls.
1.80 Gray thickly-bedded dolomitic sandstones with cross-bedding in its middle and upper parts.
2.00 Gray thickly-bedded, nodular, dolomitic and sandy limestone.

Kapp Starostin Formation

— Cherty limestones and their basal conglomerate of erosional base; not measured.

THE CORAL FAUNA IN INDIVIDUAL SETS OF BEDS

The present chapter is concentrated on the biostratonomy of corals and contains discussion on particular sets of coralliferous beds. The sedimentological interpretation of clastic sequences is not discussed in detail. Only some generalized sedimentological remarks are introduced to make the discussion more complete.

The Lower Permian sections in the Hornsund region form two natural groups, i. e. those of the southern outcrop area of the Treskelen Peninsula and those of the northern area consisting of Urnetoppen, Kruseryggen and possibly also of isolated Permian outcrops on Triasnuten and Braemfjellet. The following three characters distinguish the northern group of outcrops: 1) a lack of the two lowermost sets of coralliferous beds which are distinguishable on Treskelen, 2) much greater thickness of coralliferous limestones, and 3) an appearance of the non-fossiliferous unit uppermost. The intermediate sections on Hyrnefjellet are more like the southern sections in their facies development.

Investigation of the northern group of outcrops is too incomplete to analyse it in more detail, thus the following discussion is concentrated mainly on southern and intermediate groups of outcrops. Individual Coral Horizons introduced by BIRKENMAJER (1964) as stratigraphical units are not traceable in the same facies over a wide area and naturally interfinger with other facies (the four lower horizons) or differ in thickness and in content when individual sections are compared (V Coral Horizon). Most of these horizons, distinguished on Treskelen, are not comparable with coralliferous sets in the northern group of outcrops. For these reasons the concept of BIRKENMAJER (1964) is not followed here. It has to be pointed out, however, that the coralliferous deposits form some widely spreaded sets, occupying similar levels in particular geological sections (figs. 2 and 3). These sets, for a convenience of the following discussion, will be numbered similarly to the Coral Horizons of BIRKENMAJER (1964).

THE GRAY CONGLOMERATE "HORIZON"

This unit is, in spite of its name, composed mainly of gray medium to very coarse-grained quartzitic sandstones. At Treskelen and Hyrnefjellet true conglomerates are only sporadically developed in local lenses. The term "horizon" should not be applied to this unit for the reasons discussed later for the "Coral Limestone Horizons". More neutral term is not proposed, however, because the lower limit of the unit was not studied in adequate detail.

In the southernmost outcrop (Section 2) the Gray Conglomerate consists mainly of dark gray, thickly-bedded quartzitic sandstones with cross-bedding in their lower, coarser, more conglomeratic parts. In the upper dark sandstones there is abundant iron staining and common small fragments of carbonized plants. The deposits became gradually paler and more variable northwards. Retaining a sandy texture they became lenticular, often cross-bedded with lenses of conglomerates composed of pebbles up to 4 cm in diameter and with fragments of plants up to 30 cm long. In spite of these changes in grain size and rock texture the total thickness of the unit remains almost constant. The high degree of rounding of pebbles in the Gray Conglomerate has already been mentioned by BIRKENMAJER (1964) and SIEDLECKA (1968). Sand grains in the Conglomerate are angular and poorly sorted (pl. 22:4). It is possible that larger clasts and pebbles were recycled from the older deposits and further rounded, while sand grains were freshly derived from a primary source. There is no proof that any of the conglomerates of the northern slope of Kruseryggen are equivalent to the Gray Conglomerate Horizon, but this seems probable on the basis of their position in the section. This suggests gradual decrease of grain size southwards.

THE FIRST SET OF CORALLIFEROUS BEDS

The coral fauna of this set was found for the first time in the western limb of the Hyrnefjellet anticline by the author (Section 2). Corals also appear to be much more widespread than was supposed previously in the eastern limb of the same anticline.

In the southernmost section of this set (Section 2) the coralliferous sediments are exposed only at low tide. Maximum thickness of the unit reaches 1·3 m, but it thins quickly towards SE. The bed is not completely wedged out, however, remaining 40-50 cm thick along the last 30-40 m accessible for study. Largest pebbles are concentrated in the lower part of the bed (pl. 5:3, 6). Conglomerates appear to have sharp but non-erosive contacts with underlying beds. Pebbles of white chert and gray quartzitic sandstones are most common. They are often flat and subrounded with lineation 310°-330° (pl. 5:3, 6).

The unequal conglomeratic layer grades up into lenticular gray and pale gray calcareous and dolomitic, fine-, medium- and coarse-grained sandstones (pl. 5:2, 3, 5, 6). The sedimentation of the coralliferous deposits ends with fine-grained, pale calcareous sandstone with numerous bioclasts of crushed brachiopod shells, fragments of calcareous algae and small fragments of fasciculate coral colonies. Lower in the unit several pleurotomariacean gastropods are found with vertically oriented columellae. Brachiopods occur mainly in the lower, conglomeratic part of the unit. More complete colonies of calcareous algae are not frequent, but several of them were found in sandstones (pl. 14:7, 8).

The abundant coral fauna consists of rare massive colonies of Tabulata and common branching and massive colonies of Rugosa (pl. 5:2-6). All these colonies are abraded, rounded (sometimes irregularly, pl. 5:4), and flattened. Lineation of their long axes agrees with that of other clasts. Fragmented, cylindrical, single branches of colonies show long axes oriented generally E—W in over 90 p. c. cases. They appear in two impersistent horizons, traceable for a distance of a few meters (pl. 5:2, 5) and are also irregularly scattered throughout the sandy part of the unit (pl. 5:3, 5, 6).

The first set of coralliferous beds on the eastern limb of the Hyrnefjellet anticline is exposed (except for scree cover) from Creek II, approximately 1100 m south of Creek IV, to over 200 m north of this Creek. The thickness of coralliferous beds varies from 0·05 m in most part of the area to 0·9 m at Creek IV. Along most of the outcrop from Section 3 to Section 8 there are only thin (5-10 cm) inconstant conglomeratic intercalations between thinly bedded calcareous sandstones (pl. 6:1-4). The given intercalations form more or less well traceable horizons from several meters to several dozens of meters long. It is impossible to be certain, however, whether particular horizons of the scree isolated outcrops are coeval. It is clearly seen from the fig. 2 that they are all located within a small thickness of the set. Coral fragments found in these conglomeratic intercalations are often spaced over dozens or so meters. They consist mostly of fragmented branching colonies of Rugosa. Fragmented solitary corals and well rounded massive colonies are rare (pl. 6:5). Well rounded cobbles of white chert (up to 20 cm in diameter) or gray quartzitic sandstones are also seen occasionally (pl. 6:1).

As suggested by Siedlecka (1968) and Czarniecki (1969) the sediments of Creek IV are exceptional when compared with other parts of Treskelen peninsula. This is especially true of the first set of coralliferous beds, the sediments of which are much thicker than those seen nearby; although highly variable, they contain an abundant coral fauna, composed mainly of branching colonies of rugose corals and rare massive colonies of rugose and tabulate corals. No solitary rugosans have yet been found in this set in Creek IV. In spite of earlier opinions the whole coral fauna is redeposited. Although the distribution of the fauna is much wider than previously suppose it should be noted that the amount of biogenic remains decreases rapidly both northwards and southwards. No massive colonies of rugose corals occur north of Creek IV and fragments both of branching colonies of rugosans and massive colonies of tabulate corals became successively smaller (pl. 8:7); after some 40 meters all are replaced by small single twigs of fasciculate colonies. SIEDLECKA (1968:76) noted a large variation in the development of "I Coral Horizon" around Creek IV and suggested that it probably wedged out both to the south and north.

The present observations refute the statement by SIEDLECKA (1968:77) that"... the corals are here externally very well preserved and are discernibly *in situ*, in position of their growth and development". Neither in Creek IV or elsewhere is there a coral colony in the first set of coralliferous beds which is complete and/or preserved *in situ*. A few colonies which apparently lie in growth position show clear evidence of being transported and so stopped by obstacles on the sea bottom, e. g. by a large cobble (pl. 7:2). Such an "arrested" colony presents an obstacle for subsequent pebbles or fragments of colonies (pl. 7:3). The randomly oriented pebbles, fragments of coral colonies and intraclasts of gray limestone are seen to form a small enbankment (pl. 8:3). Most of the colonies described by SIEDLECKA (1968:78) as "rooted usually in the bottom part of the sandstone layer and only the largest of them reach to its top" rest in fact on their sides as indicated by the arrangement of their corallites (pl. 7:5). In addition to the large fragments of colonies there are also seen randomly oriented smaller fragments (pl. 7:4, 8; pl. 8:8) or intertwined fragments of different colonies (pl. 7:6) or disorderly accumulations of individual twigs of branching colonies (pl. 7:7; pl. 8:1). Some fragments of branching colonies show signs of abrasion (pl. 7:4, middle part). Such pebble-like fragments are less common in Creek IV than in the Section 2. In contrast to the latter Section, the matrix which fills spaces within branching colonies in Creek IV or that in aggregates of accumulated, broken twigs, is usually similar to that of the surrounding rock. No colonies were observed to show calices preserved. One large colony of *Protolonsdaleiastraea* exhibits characters which suggest that some polyps survived transportation. This colony was redeposited upside down (pl. 9:1) and abrasion of certain surfaces suggests that it was probably moved by traction over the sea bottom in this inverted position. Directions of regenerated growth of corallites (shown by arrows on pl. 9:1) suggest their continued growth after redeposition. This may also suggest that the primary life environment of this colony cannot have been far from its present position. The ability of rapid regeneration of a colony from small surviving fragments which is observed in Scleractinia (pl. 10:5) supports this interpretation.

Deposits immediately under the first set of coralliferous beds show local erosive structures with a lateral extent of 1-2 m (pl. 8:2). More often this boundary is sharp, but not clearly erosional (pl. 7:4). Sometimes it can be interpreted as gradational (pl. 8:8). Local erosive structures have also been observed within the first set of coralliferous beds in Creek IV (pl. 8:4, 8).

The last fragment of a coral colony was found 220 m north of Creek IV. Northwards from this point the equivalents of the first set of coralliferous beds do not contain fossils although their character remains similar to that observed southernmore on Treskelen.

Two observations should be stressed to summarize the above discussion: 1) The deposition of the coral fauna is uneven. Being scattered, rare and very fragmented along most of the area, corals are accumulated as large fragments only in two separated points: in Creek IV and in Section 2. This accumulation is accompanied by a local increase of thickness of coralliferous deposits. 2) There is a mixture of remanié, reworked and drifted assemblages of corals observed as being accompanied either by colonies of calcareous algae or by a coral colony possibly transported *in vivo*.

NON-FOSSILIFEROUS DEPOSITS

Beds immediately overlying the first set of coralliferous beds are often exposed, but higher units are usually scree covered. In Section 2 the coralliferous beds are overlain by 2·9 m of fine-grained calcareous sandstones showing lateral and vertical colour variations from gray to dark red. The lower 1·4 m of these sandstones is highly bioturbated by small tunnel systems (pl. 21:1, 2). Tunnel walls are enriched in carbonates. Bioturbations extend 20 cm down into individual units and therefore suggest rapid deposition of each bed.

Beds immediately overlying the first set of coralliferous beds in the eastern limb of the Hyrnefjellet anticline with a lateral outcrop over 500 m northwards of Section 3 consist of cross-bedded calcareous sandstones, similar to those underlying the coralliferous beds. Calcareous sandstones pass laterally into quartzitic sandstones (developed over a distance of 400 m, pl. 6:2-4). Higher up in the unit local development of gray and red shales interfingering with sandstones could be observed. Deposits immediately under the second set of coralliferous beds became again more sandy with carbonate cement.

THE SECOND SET OF CORALLIFEROUS BEDS

This set, very incompletely exposed, extends from Section 3 on Treskelen to the lower part of southern slope of Hyrnefjellet. The better preserved coralliferous beds, 15-50 cm thick, consist of gray (weathering yellow) calcareous sandstones coarser lowermost, with no traces of cross-bedding. Corals (mainly rounded colonies of *Protolonsdaleiastraea*) were randomly found elsewhere, but only outcrops in Creek IV are complete enough for more detailed investigations. The random observations made in the poorly outcropped area outside this Creek could be summarized as follows: 1) The lithological character of this set is comparatively constant. 2) Corals are more abundant and preserved in larger fragments north of Creek IV. Some fragments of *Protolonsdaleiastraea* measured in the vicinity of Creek I reach 40 cm in diameter. Scattered solitary rugose corals and fragmented brachiopods are present between Creeks I and IV, while none were found southernmore.

The entire coral fauna of this set is redeposited. Even the largest coral colony of *Protolonsdaleiastraea* (80 × 35 cm), which seemingly rests in growth position shows an eroded lower surface and sides and no calices of corallites are preserved. Its present mushroom-like shape, which suggests a horizontal or even inverted (downwards) direction of growth in its lower part (pl. 9:2, right side) results from destruction. This is indicated by the arrangement and direction of growth of individual corallites in that marginal part of the colony. They grew obliquely upwards and sidewards from an area which no longer exists in the colony (bounded by dashed line on pl. 9:2). Both lower and upper parts of corallites are destroyed (pl. 9:4). The original colony was probably hemispherical in form.

Quite abundant massive colonies of Tabulata show similar destruction. A colony resting in apparent growth position (pl. 9:2, left side) shows a destroyed lower surface (pl. 10:2) with individual corallites not growing from each other but being cut far above their offsetting points. Clearly overturned colonies (pl. 9:3) and fragments of massive and branching colonies are also seen. All larger biogenic fragments are grouped together with larger clastic pebbles in the lower part of the beds. Fragments of twigs of branching colonies, although most frequent lowermost, are also scattered locally throughout the whole bed (pl. 10:4). Orientation of these cylindrical fragments may indicate a general (?) or local (?) transport direction towards the south. Current direction is also indicated by the concentration of coarser fraction on the lee side of a tabulate coral colony (pl. 9:2).

The second set of coralliferous beds is only exposed in a 3 m long outcrop on the southern slope of Hyrnefjellet (pl. 10:5). Most of the bed consists of randomly oriented twigs and small parts of branching colonies and of angular fragments of massive colonies of rugose corals in a fine-grained calcareous sandstone. The entire sediment resembles biogenic breccia (pl. 10:3). More detailed study here was not possible because of inadequate exposure.

In Creek IV, approximately 1·8 m above the afore-described coralliferous bed of second set, there is a 9 m long and 60 cm thick lens built of white chert and gray quartzitic sandstones pebbles (pl. 12:1). It contains an abundant fauna of redeposited, mostly fragmented, large, solitary corals and rare fragments of *Protolonsdaleiastraea* colonies. This lens passes laterally into very coarse calcareous sandstone, which eventually disappears between medium- and fine-grained calcareous sandstones.

NON-FOSSILIFEROUS DEPOSITS

Sediments overlying the second set of coralliferous beds are poorly exposed. On Treskelen they consist mainly of thin cross-bedded, light gray or yellowish calcareous sandstones with randomly distributed, small pebbles. Small lenses of very coarse-grained sandstones are frequently observed. The upper part of this unit is best exposed in the northern part of Creek II (Section 5, pl. 13:1*a*, *b*, 2*a*, *b*). Thin beds of light gray or yellowish calcareous sandstones are there cross-bedded and very variable, passing laterally into very coarse-grained sandstone lenses. Individual clasts, consisting mainly of whitish chert are subrounded and vary between 0·2-2·0 cm in diameter. Pebbles 3-4 cm in diameter occur sporadically.

The unit is also exposed on the upper slope of Hyrnefjellet (Section 11). Sediments there are quartzitic and only the uppermost 1·3 m of the unit resembles beds of the Treskelen sections in their content of thinly-bedded calcareous sandstones.

As the first and second sets of coralliferous beds were not found on Urnetoppen and Kruseryggen, it should be mentioned that the third set of coralliferous beds is underlain there by more or less calcareous sandstones, over 1 m thick.

The similarity of deposits underlying the first set of coralliferous beds on Treskelen and to a lesser degree also on Hyrnefjellet to those dividing the two coralliferous sets and overlying the second set is stricking and well demonstrates an episodic character of the two lower sets of coralliferous beds. It also shows that sediments on that area, deposited between the Gray Conglomerate and the third set of coralliferous beds should be treated as a single unit, what has already been done by BIRKENMAJER (1964, Table 3). The occurrence of this unit is restricted, however, and its corrrelation with the northern part of the area seems especially uncertain as far as its lower limit is concerned.

THE THIRD SET OF CORALLIFEROUS BEDS

Deposits assignable or equivalent to this set are widespread over the entire studied area. The unit is always marked by a bed of calcareous conglomerates or pebbly sandstones, which either rest with erosive contact on underlying beds or show a direct gradation from these or, rarely, interfinger with them. In the western limb of Hyrnefjellet anticline (Sections 1 and 2; pl. 5:1) conglomerates of this set are mainly composed of gray quartzitic sandstones pebbles; whitish chert pebbles are less frequent. The maximum diameter of subrounded, imbricated cobbles reaches 25-30 cm. In addition to them two blocks of gray sandstones, up to 60 cm in diameter were also observed. Conglomerates contain several irregular lenses of sandstones with lateral extents of 1 to 6 meters. The lower 3·0-3·5 m of these conglomerates contain no fauna. Very abundant colonial and solitary corals, accompanied by rare gastropods and calcareous algae (pl. 6:6) occur in a thickness of approximately 15 cm of conglomerates which otherwise do not differ from under- and over-lying units. Coral colonies are all flat and very wide. The largest preserved, incomplete colony was 192 × 127 cm in diameter with the long axis directed N—S. As with most other colonies in this unit it is preserved upside down (pl. 11:3). The long axes of all colonies show similar lineation independent of their attitude (pl. 11:4). Maximum observed height of colonies is 10 cm. Original height was obviously only a little greater as indicated by the arrangement of corallites, vertical in the middle, and almost horizontal in the peripheral parts of colonies. The exposed surfaces of colonies are now being modified by present costal erosion (pl. 11:2-5), but the pre-depositional abrasion of these colonies was also frequently observed. Colonies of similar shape and size have not been found in other outcrops of the set discussed.

The colonies noted above are accompanied by other redeposited faunal elements such as solitary rugose corals (mainly *Pseudotimania*, pl. 11:7, 8), fragments of colonies of tabulate corals and fragmented brachiopod and gastropod shells. Pebbles overgrown by calcareous algae also occur (pl. 10:7). One of such pebbles of gray calcareous, fine-grained sandstone contains a fragment of solitary coral. Although both, the sandstone and the bioclast are overgrown (pl. 10:6*a*), the latter protrude well above the pebble surface and do not penetrate the sandstone deeply. This may suggest that the pebble was unconsolidated when transported and was armed with the coral fragment. Such an interpretation corresponds with the other observations. Most of the fauna, especially solitary corals, shows only slight traces of rounding, being rather fragmented than abraded. The majority of solitary rugosan skeletons are fragmented lengthwise, as they often are by impact. No trace of exotic matrix on any surface of fauna or flora was observed.

In the southernmost outcrop on Treskelen (Section 1) the coralliferous conglomerates are covered by a bed of hard, gray, dolomitic to calcareous sandstone with no fauna. This bed is here considered an equivalent to the upper part of the set, developed further to the north in the form of calcareous sandstones and/or micritic limestone with fossils.

The development of the third set of coralliferous beds in the eastern limb of the Hyrnefjellet anticline is observed on most of Treskelen starting from Section 3 up to the upper southern slope of Hyrnefjellet (Section 11). The coarse clastic deposits of the conglomeratic beds of this set became reduced in thickness along this distance. This is accompanied by a decrease of grain size. Finest fractions are developed near the foot of Hyrnefjellet where maximum clast size is 2 cm. The unit again coarsens northwards, starting from Section 11 on Hyrnefjellet and in the Burgerbukta area. The thickness of the conglomeratic beds does not increase in the northern region, however. A detailed petrographical analysis of conglomerates of this set was presented by SIEDLECKA (1968:79). The cement and solitary corals are coloured by ferruginous precipitates, while coral colonies remain white.

The relation of the third set of coralliferous beds to the underlying sandstones varies, sometimes rapidly within an interval of several meters. In the vicinity of Section 3, for example (pl. 12:1, left) a lateral exposure 15 m wide shows underlying sandstones either interfingering with the conglomerates (pl. 12:2*a*, *b*) or erosion of the former by shallow channels oriented approximately W—E (pl. 12:4). In the same outcrop a large block of yellowish calcareous sandstone was found (pl. 12:15). The lithology of this block suggests that it is probably derived from the "II Clastic Horizon". Corals in the area discussed above are rare and are restricted to the base of the conglomerate unit. They consist solely of flat, discoidally rounded colonies of *Protolonsdaleiastraea* (pl. 12:3). Conglomerates interfinger upwards with calcareous sandstones similar to the underlying unit (pl. 12:2*a*, *b*) and are eventually replaced by these.

Further to the north the development of clastic deposits of the set in question and their relation to the underlying beds are similar to that described above. In Creek II (pl. 13:1*a*, *b*; 2*a*, *b*) a further decrease in grain size is observed. Units also show a great variation in lateral development. Section 4 (pl. 13:2*a*, *b*) and 5, which are 50 m apart (pl. 13:1*a*, *b*) are quite different (compare descriptions), and demonstrate rapid lateral changes. For example a lens of conglomerate (maximum thickness 80 cm) has lateral persistance of only 5 m and is replaced by calcareous sandstones. No wash outs were observed in Creek II and the lower layer of the third set differs from the underlying beds only by a rapid increase in grain size and by the presence of corals. Most corals in this outcrop occur in the upper part of the conglomeratic unit. Solitary Rugosa prevail. Colonial taxa are represented by small fragments of *Protolonsdaleia-*

straea. All corals are redeposited; although somewhat fragmented, they show few traces of rounding. Directions of long axes of some solitary corals are as follows: 0, 6, 25, 65, 90, 120 and 140° (pl. 12:6). This random lineation may result from the different shapes of the measured fragments, ranging from cylindrical through long and short conical to horn-shaped forms.

Further to the north, i. e. between Creeks II and IV, the set is mostly covered by scree. Isolated poor outcrops show a further reduction in grain size. In the vicinity of Section 6, the lower unit is composed mainly of cross-bedded calcareous sandstones with intermittent conglomeratic lenses. Corals are rare and are represented by small fragments of solitary specimens, found mainly in conglomerates. A similar development is observed in the only outcrop of this set found between Creek IV and Hyrnefjellet. Small exposures protruding from the scree 180 north of Creek IV (pl. 13:4) consist of 70 cm of calcareous cross-bedded thin sandstones with some coarser clasts and small fragments of solitary corals. The relation of this bed to underlying units is uncertain.

The development of the third set of coralliferous beds in Creek IV differs from the adjacent exposures, a feature already noted in the two lower sets of coralliferous beds. Detailed descriptions of the development in this section were given by BIRKENMAJER (1964), SIEDLECKA (1968) and CZARNIECKI (1969), and only a few additional remarks are presented here.

The contact between the third set and uderlying beds varies here locally. In the southern part of Creek IV there is a channel structure (pl. 14:3), noted by earlier authors, but in northern exposures the conglomeratic unit is much thinner (15 cm) and there is no apparent erosion of the underlying calcareous sandstone. However, the boundary between the third set of coralliferous beds and underlying beds in Creek IV is sharper than in the outcrops described above. A rich fauna of redeposited solitary and colonial rugose corals is found in the conglomeratic unit. Most of these broken and slightly rounded specimens are concentrated in the upper part of the bed. No corals are present in the conglomerate which fills the channel structure.

The succession from the conglomeratic unit to the overlying deposits of the set is clearly displayed at Treskelen. In some exposures there are thin layers of shales with limestone nodules (Creek IV) or without them (northern side of Creek II). In other exposures the conglomerates grade upwards into calcareous sandstones (Sections 1, 10, 11) or are sharply overlain by gray-pinkish limestone (Section 4). The petrography of the gray-pinkish limestone in Creek IV was described in detail by SIEDLECKA (1968:79). It should be noted that: 1) The two units of this limestone distinguished by her represent a local development in Creek IV and were not seen by the present author further south. 2) The thickness of this unit is highly variable increasing from 1·35 m in the southern to 1·65 m in the northern part of this Creek. The limestone thins southwards (see descriptions of sections) and it wedges out approximately 80 m south of Section 4 to be replaced by calcareous sandstones. 3) This bed shows paracontemporaneous deformation with limonitic denser layers (pl. 13:3, 5). Corals are very rare in the limestone, but the first appearance of *Protowentzelella* colonies in the upper Treskelodden beds (pl. 13:5) is noteworthy.

The described limestone becomes more sandy upwards and grades into a thickly-bedded, calcareous sandstone with scattered, well rounded clasts 0·5-1·5 cm in diameter. This sandstone, seen in all good exposures between Creeks IV and II was described by BIRKENMAJER (1964) as the lowermost layer of the "III Clastic Horizon". SIEDLECKA (1968) included it into the "III Coral Horizon", an interpretation supported by the presence of scattered corals. It passes up into thinly-bedded, fine-grained calcareous sandstones and shales. CZARNIECKI (1969:223) divided the thickly bedded sandstone into two: a lower (75 cm) and an upper unit (25 cm); the upper unit "fills erosional troughs in the lower and contains abundant well rounded grains of quartz and fragments of single corals". Neither the present author, BIRKENMAJER (1964) or SIEDLECKA (1968) found "erosional troughs" in this sandstone and the corals are mostly not "single" (= solitary), but consist of fragmented twigs of branching colonies. Massive colonies, described by CZARNIECKI (1969) as being "in original position" are all found as rounded pebbles (pl. 14:1). However, some of the colonies found in the sandier upper part of the calcareous sandstone unit are large and were redeposited in apparent life position. Cylindrical twigs of branching colonies, best seen on a bedding plane of the thickly bedded calcareous sandstone in Creek II, show N-S long axes lineation (pl. 13:7).

The third set of coralliferous beds on the southern slope of Hyrnefjellet shows a variable development (see Sections 10 and 11 in this paper, also BIRKENMAJER, 1964:84 and CZARNIECKI, 1969:227). In comparison to Treskelen, there is an increase in fine clastic content and a different pattern of colour. The gray-pinkish limestone, developed above the conglomeratic unit at Treskelen, is replaced by a yellow calcareous sandstone. Increase of clastic component is, however, accompanied by a decrease in maximum grain size. There are no clasts larger than 2 cm in Section 10 and no pebbles larger than 4 cm were found along the southern slope of Hyrnefjellet. Along the lower part of the slope (up to Section 10), no corals were found in the lower and middle beds of the set, but north of Section 10 scattered solitary corals start to appear (pl. 14:4). They are mostly fragmented, without calices but are either slightly rounded or non-abraded. Most long axes show N—S lineation. In Section 11 a gray conglomerate with crushed fragments of corals passes upwards into a 10 cm thick bed of gray calcareous sandstone rich in well preserved solitary corals which often show both, calices and proximal ends preserved. A preliminary identification suggests that all belong to a single species. This accumulation does not represent biocenosis as individuals are not in life positions, but transportation has not been significant. The gray sandstone passes laterally into gray sandy limenstone (weathering yellowish or brownish) crowded with broken twigs of branching colonies of Rugosa. These fragments are concentrated either in the upper (Section 10) or in the lower (Section 11) parts of the unit. Large solitary corals and flat fragments of massive colonies occur sporadically within this coquina. Although the entire fauna of this unit is redeposited, the massive colonies are only slightly abraded and were originally small and discoidal in shape. Most bioclasts consist of twigs of branching colonies which show sharp, broken edges and no or little abrasion of lateral surfaces. A parallel lineation of many cylindrical twigs is mainly W—E. Transportation effects, although not extreme, were sufficient to fragment the colonial corals and large fragments of branching colonies are not seen.

In the vicinity of Section 11 (i. e. in the upper part of the southern slope of Hyrnefjellet) there occurs 30 cm thick bed of coralliferous calcareous pebbly sandstone (pl. 15:3). The coral fauna consists of solitary corals and flat, abraded massive colonies of rugosans; corals are found in the middle part of the bed, either together with coarser pebbles or just above them. This bed has a lateral exposure of 15-20 meters. It is not found southwards and its northwards development is unknown because of a lack of exposures; it is therefore impossible to correlate this bed to the Burgerbukta area and it has no equivalents at Treskelen.

The development of sediments interpreted here as the third set of coralliferous beds in the Burgerbukta area was studied on the ridge between Urnebreen and Krusebreen (Section 12, measured by K. MALKOWSKI) and on the northern slope of Kruseryggen. In both localities it shows a similar development to that seen in Creek IV on Treskelen. The development of pinkish-gray limestone immediately above coralliferous conglomerates is here used as an important correlative factor. The greater thickness of conglomerates (without massive coral colonies) and the lesser thickness of the limestone unit constitute the main differences between sections from the northern part of Kruseryggen and those from Treskelen (e. g. Creek IV). The regional development of the third set of coralliferous beds which is suggested by present studies indicates that this is the most appropriate unit to correlate the otherwise differently developed northern and southern parts of the Hornsund area.

The development and the coral fauna of deposits overlying the third set of coralliferous beds in the Burgerbukta and Treskelen-Hyrnefjellet regions will be discussed separately below. Detailed correlation must await the results of systematical studies now in progress on large collection made by the author in 1975.

The following observations should be stressed to summarize the above discussion: 1) The third set of coralliferous beds is developed on a regional scale. 2) The scattered coral and other fauna is distributed laterally and vertically at random, becoming more abundant only in some parts of conglomeratic beds. 3) *Protowentzelella*, the most characteristic coral genus of the two upper sets of coralliferous beds appears first.

THE TRESKELEN-HYRNEFJELLET REGION

NON-FOSSILIFEROUS BEDS

The gradational contact between the third set of coralliferous beds (described as III Coral Limestone Horizon) and the III Clastic Horizon, i. e. the beds now discussed, was noted by BIRKENMAJER (1964) and by SIEDLECKA (1968). Sediments of this non-fossiliferous set of beds show appreciable lateral variation, but thinly-bedded calcareous/dolomitic sandstones are most common. Quartzitic sandstones and sandy shales and red or yellow shales are subordinately developed. Their lateral development is not clear because of poor exposure, but they are obviously laterally impersistent. Sandstones (often cross-bedded) interfinger with lenticular conglomerates. In the vicinity of Creek II a large lens of gray quartzitic conglomerate (3·3 m maximum thickness) has a lateral development 10 m approximately (pl. 13:1*a*, upper left corner) with local pockets of coarser and finer pebbly sandstones and sandstones. Pebbles are small, mainly less than 4 cm in diameter, composed of whitish chert and, subordinately, of black chert and gray quartzitic sandstone. This lens is unique on Treskelen. A gradual transition from conglomerates of this lens into quartzitic sandstones is observed both, laterally and vertically.

The uppermost sediments of the discussed unfossiliferous beds are poorly exposed. They consist mainly of fine-grained calcareous and quartzitic sandstones and of yellow, gray and red shales. The contact between this unit and the overlying fourth set of coralliferous beds is not clear. Also BIRKENMAJER (1964) gave no comments concerning that contact.

A comparison of sections from the upper Treskelodden beds on Treskelen (fig. 2) indicates a regularity in thickness which should be discussed. The three lower sets of coralliferous beds are easily recognizable along most of the peninsula and the intervals between them are more or less constant, or at least regularly spaced. The thickness of non-fossiliferous beds overlying the third set of coralliferous beds varies, but variation is regular and they are the thickest in the southern (Section 3) and the northern (Section 9) parts of the peninsula. Unfortunately both these areas have poor exposures and measurements are somewhat uncertain. Nevertheless and independently of the fact that the true thickness of the fourth set of coralliferous beds is unknown (only the most resistant deposits are marked on fig. 2 as belonging to this set) the vicinity of Creek IV is the area where the sections above the third set of coralliferous beds are the thinnest. There are two possible explanations for this situation: 1) Erosion of a part of the "III Clastic Horizon" of BIRKENMAJER (1964), 2) Primary thin development in the middle part of the peninsula. Although definite conclusions are hindered by poor exposure, the slightly better exposed base of the fourth set of coralliferous beds in Creek IV with no trace of erosion indicates that the second possibility is more probable.

THE FOURTH SET OF CORALLIFEROUS BEDS

This is the most poorly exposed unit on Treskelen. A complete description of its development in Creek IV was given by SIEDLECKA (1968:80-82). The southernmost exposure of this set has been described herein together with Section 3. Gray calcareous sandstones in the latter outcrop show intraformational clasts of dark gray limestones with numerous, large (0·2-2·0 cm in diameter) crinoid columnals, fragments of brachiopod and gastropod shells and fragments of twigs from branching colonies of rugose corals. In Section 3 this bed is closer to the bottom of the Kapp Starostin Formation than the outcrops of this set located further to the north. This is due to a deeper erosion of the upper Treskelodden beds in the southern area. The bed discussed is interpreted here as belonging to the upper part of the set. This is confirmed by the occurrence of similar fauna and its constant relation to a bed of white quartzitic sandstone which is seen in both areas (fig. 2). Poor exposure just beneath the above described calcareous sandstone show only clastic deposits with no fauna.

The next, incomplete exposures of the fourth set of coralliferous beds were observed between Creeks II and IV (see descriptions of Sections and fig. 2). Its base is always marked by a gray or reddish pebbly sandstones with graded bedding, passing upwards into calcareous, locally cross-bedded sandstones (pl. 15:1). Pebbles in these sandstones are rounded or subrounded, composed mainly of whitish chert. Pebbly sandstones are locally (Section 5) replaced by gray calcareous sandstones containing incomplete solitary corals. Redeposited and damaged fossils occur mainly in the coarser fraction. Fragments of solitary corals show long axes oriented mainly E—W. Massive colonies are rounded and preserved as fragments. These colonies are never found in beds where pebbly sandstones are totally replaced by medium- or fine-grained calcareous sandstones. Comparatively abundant twigs of branching colonies are oriented similarly to solitary corals. Small broken fragments of solitary corals and fragments of massive colonies, flattened by abrasion, are sporadically present also in the calcareous sandstones above the pebbly sandstones. They may be accompanied sometimes by twigs of *Tschussovskenia* (pl. 15:2).

In the southern part of Treskelen (Sections 4 and 5) the contact between the conglomeratic basal bed of the fourth set and overlying sandy and shaly deposits is covered. Judging from loose blocks the latter consists of dark thinly-bedded limestones or calcareous shales with numerous crinoid columnals and isolated solitary corals. Similar crinoidal limestone with thin sandstone laminae is well exposed approximately 350 m south of Creek IV. It is there overlain by 0·7 m thick bed of dark, nodular limestone, crowded with fragmented bryozoan colonies and accumulations of brachiopods; corals are not present. The limestone passes laterally into thinly-bedded, dark limonitic limestones and its development is local. Branching bryozoans are frequent elsewhere in the upper part of the fourth set, however. In scree which overlies the bryozoan/brachiopod bed there occur abundant coral colonies, many of which reach 50 cm in diameter. They came from a weathered dark sandy limestone situated above the former bed.

Further to the north the fourth set of coralliferous beds is almost completely covered by scree. Sporadically exposed, reddish calcareous sandstones with isolated pebbles and solitary corals belong to the lower part of the set. Above that level there exists a low ridge (20-30 cm) which can be followed laterally 300 m towards Creek IV. Debris of black crinoidal limestone and abundant corals found along the ridge could be compared with the uppermost coralliferous beds of this set distinguished in Creek IV. It should be noted that flat colonies of Tabulata (up to 1 m in diameter) and branching colonies of Rugosa (up to 60 cm in diameter) found along the ridge were much larger than those in Creek IV. *Tschussovskenia* is the most common component of the fauna. In the upper part of the fourth set in Creek IV (for detailed description see SIEDLECKA 1968) and further north along the Treskelen peninsula, the clastic content of these beds increases and at the Section 9 yellowish calcareous sandstones are the most common sediments. Concurrent with increasing clastic content is increasing a thickness of coralliferous sediments. The faunal composition of Section 9 also differs from that of the more southern parts of the peninsula. In the lower part, especially in conglomerates, solitary corals and branching colonies of *Tschussovskenia* are still most common, but higher up large (over 1 m high) colonies of "*Stylastraea*" dominate. Several redeposited fasciculate colonies, now resting on their sides, show a gradual decrease in flattening and destruction of corallites towards the top of the bed (pl. 15:5).

Colonies in the upper part of the fourth set found in the area discussed are not always complete enough for detailed investigations. Several are certainly overturned and transported in spite of their large sizes (often 1 m in diameter and/or in height). Most of these colonies belong to a single species of "*Stylastraea*" with very small corallites. The uppermost coralliferous bed, lithologically similar to the underlying calcareous sandstones with large colonies, contains only small, redeposited colonies, accompanied by fragments of *Tschussovskenia.*

The lithologies and coral fauna briefly noted above differ both from those of the more southerly outcrops on Treskelen and from those of Hyrnefjellet. The lithology of the coralliferous sediments of the latter area is especially variable and the two sections made by the present author differ both from each other and from the sections measured by BIRKENMAJER (1964) and CZARNIECKI (1969). The former is more similar to Section 10 of this paper. Both contain 1·35 m thick bed of sandy limestone with branches of bryozoans and flat, rounded coral colonies. This bed starts with approximately 10-20 cm of conglomerates, composed mainly of whitish chert clasts 2·5-3·0 cm in maximum diameter. The bed lies 18 m below the bottom of the fifth set of coralliferous beds (= V Coral Limestone Horizon of BIRKENMAJER, 1964) and not 30 m as figured by BIRKENMAJER (1964). Most of that interval is covered by scree (see Section 10). The presence of a 3·65 m thick, brown calcareous sandstone with corals in the middle part below the afore noted bed forms the main difference between Section 10 and BIRKENMAJER'S (1964) description. Corals are rare in the brown sandstones and are represented by scattered solitary forms and by fragments of branching colonies. In Section 11 a non-fossiliferous, 5·10 m thick unit of quartzitic and calcareous sandstones is here considered to be a lateral equivalent to the brown sandstones of Section 10.

All corals in the fourth set of Sections 10 and 11 are redeposited. No complete solitary corals have been found there and none rest in life position. Some show traces of rounding, but most are only broken with slightly broken edges. Massive colonies are all more or less rounded and flat. The arrangement of corallites indicates however that the colonies had an original platy form.

The following observations should be stressed to summarize the above discussion: 1) Lithology of this unit changes laterally and vertically, but the conglomeratic layer is invariably present as the lowermost. 2) Coral and other fauna, much richer than in lower coralliferous deposits, is variably distributed with some taxa prevailing in one spot and subordered or absent in others; this is often accompanied by differences in lithology. 3) Although damage and redeposition of fossils is especially obvious at the lowest level, abrasion, destruction and redeposition of corals is observed throughout the set.

NON-FOSSILIFEROUS BEDS

Non-fossiliferous sediments overlying the fourth set of coralliferous beds, composed mainly of light quartzitic sandstones and conglomerates, with minor calcareous sandstones, show a gradual transition from the underlying beds. The upper boundary of them is more sharp; no angular disconformity or erosive surfaces were observed, but this may result from poor exposures.

Two good correlative levels can be distinguished within the discussed sediments. These are the white or light gray quartzitic sandstones which pass locally (mainly in the southern part of Treskelen) into conglomerates. The lower unit of these sandstones occurs approximately 5 m above the dark limestones of the fourth set of coralliferous beds and is separated from them by soft sandy shales, often with calcareous cement. Shales are also developed locally. The quartzitic sandstone form a clear ridge along most Treskelen south of Creek IV. It is not seen northwards of that Creek, possibly because of poor exposure. No equivalent of the quartzite is developed on Hyrnefjellet, however.

The upper unit of the resistant quartzitic sandstones is exposed from Creek II to 200 m north of Creek IV. The southern exposures are much more conglomeratic. The unit disappears south of Creek II, probably as a result of erosion prior to deposition of the Kapp Starostin Formation. The bed, when seen, is 0·2 to 1·2 m thick and occurs approximately 2·5-3·5 m below the fifth set of coralliferous beds. The unit is also seen on the southern slope of Hyrnefjellet at a similar horizon. Both the resistant units described show either graded bedding or are thickly-bedded and apparently structureless. Weak traces of cross-bedding are seen locally. BIRKENMAJER (1964:88) noted a "concretionary structure visible at weathered surface" of sandstones of the lower level.

Deposits developed between the two resistant units and above the upper one on the Treskelen peninsula, consist mainly of poorly exposed, thin, cross-bedded quartzitic and calcareous (mainly in the upper part) sandstones with conglomeratic lenses. Shales, mainly sandy, are frequent. Almost complete exposure of these sediments in the upper part of southern slope of Hyrnefjellet (Section 11) indicates a variable regime alternating rapidly between conglomerates and red shales with calcareous cement.

THE FIFTH SET OF CORALLIFEROUS BEDS

BIRKENMAJER (1964) subdivided the V Coral Limestone Horizon (= the fifth set of coralliferous beds) into subhorizons "a", "b" and "c" and distinguished individual beds within the first two subhorizons. This subdivision was not followed by CZARNIECKI (1969). SIEDLECKA (1968:82-83) followed BIRKERNMAJER'S (1964) terminology, but described an additional bed of biocalcarenite beneath subhorizon "a" in Creek IV. The lack of good outcrops between Creek IV and Hyrnefjellet and between the last hill and the Burgerbukta area together with a wide lateral variability in lithology and fauna distribution, makes a regional correlation of these subhorizons uncertain.

Outcrops of the fifth set of coralliferous beds extend over 400 m southwards of Creek IV, i. e. to Section 4 (pl. 15:4). Judging from the presence of gray limestones beneath the Kapp Starostin Formation in the scree-covered area, it may also extend a further 100 m southwards. Beds immediately under the fifth set are mainly composed of friable shales which are covered by scree.

The set in question in the southernmost outcrop (Section 6) consists of four beds, 2·4 m thick (pl. 15:4). Erosion prior to deposition of the overlying Kapp Starostin Formation cut most of these beds obliquely producing hollow later filled by sediment of that formation. Corals (exclusively massive colonies of rugosans), are present in all four beds, but their distribution is uneven. In the lower, most sandy bed, there are only small, unidentified fragments of colonies, accompanied by abundant, sometimes well preserved brachiopods. Corals are most common in a gray calcarenite which forms third bed in the section. Two kinds of cerioid colonies occur in this unit: small, hemispherical, slightly rounded colonies and large (up to 1 m in diameter) widely conical colonies. Both types show evidences of fragmentation and rounding, and both are commonly overturned and/or superimposed on each other (pl.15:6). The uppermost bed is again more sandy with elongated lenses of sandstones and small, rounded fragments of cerioid colonies.

The fifth set of coralliferous beds thickens laterally to 6 m approximately 150 m north of Section 6. Sandy interbeds are similar to those described above: the lowermost bed is most sandy, but in contrast to the former outcrop it contains solitary rugose corals and pebbles of white chert. Solitary rugosans appear again in the upper part of the outcrop, while the middle, less sandy unit, is crowded with colonial corals. Brachiopods, often small clusters (pl. 15:7) are present elsewhere in the Section. All corals and most possibly also brachiopods, are redeposited. Colonies up to 1·2 m in diameter rest on their sides or are overturned (pl. 16:3). Some fragments of colonies found lie so closely packed that they appear to form a single colony (pl. 16:1). Transportation cannot have been great, however, as the colonies show few signs of rounding. The presence of only small fragments of *Tschussovskenia* indicates greater transport of that genus than the cerioid colonies. Flat cerioid colonies found at the junction between the limestone and the uppermost calcareous sandstone show irregular but pronounced rounding which cut both the lower and the upper parts of the corallites (pl. 16:2, 4).

Further to the north (Section 7) the fifth set remains more sandy in its lower part. Individual beds consist of laterally interfingering lenses of sandy limestones. Solitary corals are still most frequent in the lower part where no colonies were found. Colonies are especially abundant in the upper part of the unit, immediately below the Kapp Starostin Formation. All fauna elements show evidence of redeposition. The section described here, although less than 100 m from Creek IV differs from the latter section (cf. BIRKENMAJER, 1964:87 and SIEDLECKA, 1968:82) in the absence of colonial corals in the lower part and in the presence of clusters of small brachiopods.

The fifth set of coralliferous beds is poorly exposed between Creek IV and Hyrnefjellet. BIRKENMAJER (1964:86) pointed out the abundant occurrence of large coral colonies from subhorizon Va in Creek I. Because a similar fauna is found elsewhere on Treskelen higher in the section and because no contact with the deposits underlying the fifth set are found in Creek I, this fauna is not assigned herein to any particular part of the set.

The set thins from the lower to upper parts of the southern slope of Hyrnefjellet (19·8 to 16·9 m). Sections measured there by the present author as well as those of BIRKENMAJER (1964) and CZARNIECKI (1969) differ in many details. This is probably because of great vertical and lateral variability in development. Individual beds are lenticular in forms and wedge out laterally; each may extend from 10 to over 100 m laterally. Variability in faunal distribution accentuates these changes.

The lower part of the set is more sandy. Solitary corals prevail there, although they are not abundant. Colonial corals are most common in the most calcareous middle and upper parts of the unit. In the upper beds of the set there are hard, dark gray micritic limestones developed locally, while the uppermost part of the unit is again more sandy. In almost all beds and lenses, except for the yellow-brownish sandstones (see below) there are abundant bioclasts, ranging in size from 0·1 mm to large fragments of brachiopod shells, fragments of coral colonies and crinoid columnals. Most bioclasts show slight rounding, but large fragments of corals are angular (pl. 16:5, 6). Most of the available lithological data are included in the descriptions of Sections 10 and 11. Only studies of the coral fauna and restricted sedimentological observations are discussed on the following pages.

All solitary corals observed were overturned and in most the calices and proximal ends were broken off. The most common orientation of their long axes is E—W. The redeposition of those corals is obvious. The attitudes of the colonies requires further discussion in the light of the comments by BIRKENMAJER (1964:102): "...colonial corals. The latter form bioherms separated with detrital or homogeneous limestone with brachiopods." Adoption of term "bioherm" and subsequent discussion of the depositional environments of individual coral horizons (BIRKENMAJER, 1964:104-105) indicates that coral colonies were thought to be *in situ* and in growth position. CZARNIECKI (1969:238) wrote: "In the uppermost fossiliferous complex colonies in original position are frequent, some colonies are overturned (fig. 27) but no fragments of massive colonies were seen. It is striking that in the upper part of the complex other groups of sessile benthos are absent; this could be explained by very rapid deposition". The present author disagrees with these observations on the coral colonies. Also CZARNIECKI's (1969) observations concerning other faunal elements are incorrect. Both BIRKENMAJER (1964: 83) and the present author found abundant brachiopods and crinoid columnals and also some rare gastropods (pl. 19:2). Fragmented coral colonies were found in all coralliferous beds of the fifth set, but they are most common in the lower part, where they form an almost continuous bed of organic breccia. In this breccia, in addition to the predominating fragments of massive colonies, there are also sparse remains of solitary corals and broken brachiopod shells (pl. 16:5, 6). The redeposition of majority of small and medium size (up to 50 cm in diameter) coral colonies is obvious, as they either rest on their side (pl. 17:6) or are overturned or, sporadically, are not only overturned but also clearly packed into each other forming an apparently single colony (pl. 18:1). Some medium size colonies rest in natural position (pl. 17:3*a*) but this is not their growth position. Detailed studies show that the lower surface of individual corallites in the lower part of the colony (pl. 17:3*b*) are abraded.

In addition to small and medium size colonies there are also large and very large colonies on the southern slope of Hyrnefjellet. One of such colonies, 110 cm high and 125 cm in maximum diameter, photographed previously by CZARNIECKI (1969) is shown in his paper (text-fig. 26) and by me (FEDOROWSKI 1965, pl. 15:3). It was described by both authors as resting *in situ*. Field work in 1975 made it possible to correct both, the interpretation of this colony and several general remarks introduced previously (FEDOROWSKI 1965:158). First, the colony is not in the life position. It occurs almost throughout the entire thickness of a bed of limestone which dips 58°-60° E. Its long, left side (pl. 17:2) does not stand obliquely up, as it would do in true life position, but rests on the underlying bed and shows several sings of obvious fragmentation. The colony occurs in the organic breccia noted above and it is now interpreted as being moved, partly fragmented along its margins and redeposited as a large, angular block. According to studies of recent carbonate sediments, large blocks of coral colonies may be broken, removed and redeposited by hurricanes (BELL *et al.*, 1967). Such process may be sometimes so intensive as to form new islands.

The so called "stoppages of growth of coralla" or "old surfaces of corallum covered by sediments" (FEDOROWSKI 1965:158) are nothing but mechanical, probably diagenetically caused cracks of the corallum. They are not exactly parallel to its surface, as interpreted previously, and are not connected to temporary intensifications of offsetting. On the contrary, offsets are only incidentally involved in the crack areas (pl. 18:4). In the case of deeper cracks individual corallites are not only destroyed in the vicinity of the cracks, but the two broken parts are displaced (pl. 18:3). The above observation made obvious the diagenetic character of the observed lines. Cracks (the seeming "old surfaces of coralla") similar to the discussed ones (pl. 17:1) or even more distinct (pl. 19:3, 4*b*) were also observed in 3 very large colonies found in the middle part of the set. In one of these colonies (pl. 17:5) local destruction of the living colony was observed as being overgrown by curved adjacent corallites. The largest colony reaches 1·6 m in observed height and 2·8 m in diameter of their upper part. This and the other two very large colonies are widely, asymmetrically cone- or fan-shaped. Two of these colonies rest in apparently growth position (pl. 18:5), the third is obviously overturned (pl. 19:4*a*). The redeposition of the latter (the largest) colony is also marked by the arrangement of corallites on its presently lower and originally lateral surface (pl. 19:4*b*, *c*).

The other two very large colonies rest close to each other (pl. 20:5). An analysis of the corallite arrangement in lower parts of these colonies and their relation to the underlying substrate clearly indicate that they are redeposited. The well exposed contact of these colonies with the underlying bed (pl. 19:1) show that its lower surface apparently follows the contours of the substrate. This feature is not, however, caused by natural growth of corallites over the substrate, but results from compaction which forced the substrate into the colony and caused destruction of corallites (pl. 19:1, lower part). This is demonstrated both by the curvature and flattening of corallites above the most prominent parts of the underlying bed (pl. 19:1, right arrow) and by the fact that corallites filling depression in the substarte are cut off from the remainder of colony (pl. 19:1, left arrow).

These three very large colonies are accompanied by several small (5-10 cm in diameter) fragments of cerioid colonies. Neither the large colonies nor the small fragments of colonies show traces of rounding. This indicates a short distance of transportation. It is possible that the very large colonies were only slightly removed from growth position.

Upper beds of limestones of the set discussed contain two types of sediment veins which were only briefly investigated by myself and need further study. The most commonly observed veins are restricted to the uppermost part of the unit. Their direct connection to the erosive surface structures and the infilling fabric were already described by earlier workers as karst phenomena (BIRKENMAJER 1964; CZARNIECKI 1969).

Veins of the second type, frequent in Hyrnefjellet and observed also in the vicinity of Section 9 and just south of Creek IV in Treskelen, are not connected with the surface abrasion. They occupy 4-6 meters of limestone thickness and penetrate particular beds vertically and horizontally. Individual horizontal sediment veins expand from a few to dozens of meters. Their thickness varies from a few milimeters to over 20 cm with the large majority not exceeding 3-4 cm. Horizontal veins are often connected by vertical structures composed of exactly the same fabric, i. e. of fine-grained calcareous and limonitic sandstone. The described pattern of veins breaks limestones into sharp-edged, large blocks, differentiated in size. They are never so small as to form breccia, however. No fauna was found in the sediment veins.

The structures described are temporarily interpreted as clastic dikes, slightly similar to those described by DŻUŁYNSKI and RADOMSKI (1957) from the Carpathian flysh. They may have been developed by means of penetration of quicksands into craks of limestones. The origin of quicksands, i. e. whether they came from a single liquefied bed of sand or if there were several beds of sand, the remainings of which form recent horizontal sediment veins, is left unsolved. Detailed sedimentological study may also introduce a different interpretation of these structures. The so called "flowage structures" of SIEDLECKA (1968, text-fig. 11*a*) are interpreted here as clastic dikes.

THE BURGERBUKTA AREA

Investigations have been made in this area by BIRKENMAJER (complete data not yet published), CZARNIECKI (1969) and the present author. The differences between the last two authors in correlation of the lowermost coralliferous deposits of Kruseryggen with those of Treskelen-Hyrnefjellet have been discussed above. Individual sections, viz. that measured by CZARNIECKI (1969) on the NW ridge of Krusebreen cirque, that of the present author from the northern slope of Kruseryggen and the slightly schematized section measured by Mr. K. MAŁKOWSKI (in this paper) on the ridge between Krusebreen and Urnebreen differ in many details. In each of them, however, sediments overlying the third set of coralliferous beds are quite distinct from those of the southern area. The most important differences are: 1) Much greater thickness of coralliferous sediments. 2) Occurrence of non-fossiliferous deposits uppermost.

The lithologies described by CZARNIECKI (1969:229-230) differ from those of the northern slope of Kruseryggen (Section 13) by: 1) the lack of characteristic gray-pinkish micritic limestone, 2) the higher clastic content of the lower part of the section, and 3) the presence of large, massive coral colonies in the lowermost coralliferous conglomerate. CZARNIECKI'S (1969) section was not reinvestigated in this work and the above differences are interpreted here as reflecting lateral facies variations. Variability is so great that general descriptions of individual sets of coralliferous and non-fossiliferous beds, such as those given above for the southern area, are impossible. Comments presented below (see pp. 51, 55-59) are mainly based on the description of Section 13 presented in this paper and on the personal observations made in the Burgerbukta area.

GROWTH RATES OF CORAL COLONIES AND ESTIMATION OF RATES OF SEDIMENTATION

The following remarks are introduced only as the contribution to the future discussion on the rates of sedimentation of the upper Treskelodden beds. Results achieved concern only one bed of the fifth set of coralliferous beds.

As noted above the largest colonies investigated are thought to be only slightly moved from life position. This means that life and depositional environments may have been similar or identical. An attempt has therefore been made to estimate the life span of these colonies and from this deduct possible sedimentational rates of the appropriate bed of limestone. The estimate made is purely numerical and is based on the supposition that tiny growth rings, composed of pairs of ridges and narrowings on coral epithecae correspond to diurnal variations in skeletal secretion (WELLS 1963; SCRUTTON 1965, 1978; SCRUTTON and HIPKIN 1973). In addition to these growth rings, SCRUTTON (1965) also noted bands on coral epithecae which he interpreted as periodic growth phenomena connected to lunar (monthly) breeding periodicity. On this basis SCRUTTON (1965:557) calculated "that the moon circled the earth thirteen times in the course of a Middle Devonian year with a lunar cycle of 30 1/2 days". In a recent contribution SCRUTTON (1978) summarizes all data attained so far and makes his previous conclusions more completely supported.

Of these two characteristics only growth rings could be taken into account in the present study. Band-like features also present on the surfaces of colonial corals (pl. 21:3: pl. 22:1-3) are so irregularly developed and contain so varied number of ridges (10-36), that they cannot represent monthly cycles. These bands rather reflect growth disturbances resulting from local variation in the corals' life environment.

Individual ridges are well developed and can easily be counted over intervals of 5-15 mm. Counts of ridges on the surfaces of different corallites, taken from different parts of the largest colony and other colonies show little variation (from 112 to 116 rings per centimeter in the largest colony, pl. 22:2). The mean frequency (114) and the height of the colony (160 cm) suggest a total of 18, 240 rings in this colony. If these rings are accepted as representing diurnal cycles, a life span of 45-50 years is indicated (the former based on the Devonian 399 day year suggested by WELLS 1963; the later based on the present 365 day year). These outer limits are insignificant in terms of the present discussion.

The pronounced cone- or fan- (not hemispherical) shape of these colonies and the lack of any anchorage adaptations on their surfaces indicate that growth must have been accompanied by partial burial of earlier parts of the colony during life. Evidence of transport indicates that the colonies were removed from life positions suggesting that the growth substrate was not yet cemented. The shape of the largest colony studied suggests that approximately the lower half of the colony was buried at the time of death and transportation. Consequently, some 80 cm of calcareous mud, quartz grains and bioclastic debris (the primary fabric for the today's bed of sandy limestone) was deposited in the course of approximately 45-50 years. The above calculation, although restricted to a single bed could probably be applied to the whole fifth set of coralliferous beds in the Treskelen-Hyrnefjellet area. It is not applicable to the whole Treskelodden beds, however, or even to the limy deposits of the fourth set of coralliferous beds. The character of deposits below the fifth set indicates an extreme sedimentological situation with many periods of null netto sedimentation (how long?), periods of local erosion both between and within particular sets of beds (e. g. first and third sets of coralliferous beds), and periods of sedimentation. Speed of the sediment accumulation varied greatly both laterally and vertically, but the appreciable thicknesses of the sediment were produced during short periods of rapid sedimentation. The situation described made impossible any estimation of period of the Treskelodden beds accumulation.

DISCUSSION

For construction purposes several controversies were discussed in the chapter "The coral fauna in individual sets of beds" (pp. 30-34) and will not be repeated. Earlier opinions adopted here will be mentioned in the following chapter.

Interpretations of the depositional environments of the Treskelodden beds in the Hornsund area differ considerably. BIRKENMAJER (1964) proposed a model of cyclic, marine to continental sedimentation, while CZARNIECKI (1969) considered sedimentary conditions of those beds as entirely marine and found no cyclicity in their development. SIEDLECKA (1968:88) although generally following BIRKENMAJER'S (1964) concept, pointed out that several "sequences of quartzitic sandstones — dolomitic sandstones — calcareous sandstones only in part coincide with sedimentation cycles distinguished by BIRKENMAJER".

My interpretation given in the following chapter is intentionally simplified because of almost complete lack of purely sedimentological studies. I agree with CZARNIECKI (1969) as far as an absence of the widely observed cyclic sedimentation in the common meaning is concerned. It must be pointed out, however, that individual coralliferous and non-fossiliferous sets of beds form easily traceable levels and distribution of corals in particular "horizons" is much wider than that reported by him. A character of carbonate cement in the lower part of section of the upper Treskelodden beds reported by SIEDLECKA (1968, text-fig. 4) also supports CZARNIECKI'S (1969) opinion. The same is true for additional coralliferous lenses found by myself in Creek IV and in Hyrnefjellet, which do not fit into BIRKENMAJER'S (1964) sequences. The lenticular character of beds within sets, a very variable lateral lithology of the latter and traces of local erosion and interruptions in sediment accumulation prevent the consideration of individual sets of beds as geological horizons (for definition see Glossary of Geology, 1972: 337).

Explaining changes in sedimentary conditions observed in the development of the upper Treskelodden beds, BIRKENMAJER (1964:110) stressed climatic changes. "The fluctuations of the sea level may have been linked with growth and decay of polar ice sheets (glacial control of the sedimentation) of southern hemisphere"... "The coral limestones could have developed during interglacial phases of high sea level when the land erosion ceased transgressively upon deltaic and limnic deposits formed during periods with seasonal aridity, corresponding to the glacial periods." In my opinion this climatological interpretation cannot be applied to the reconstruction of these depositional environments, because: 1) It involves an unequal scale for the whys and wherefores. The appearance caused by globe-wide reasons must be widely noted, while the changes observed in the Hornsund area are local. In fact this time is marked elsewhere in Spitsbergen by regression from open marine carbonates to evaporites of Gipshuken Formation. 2) The climatic changes are slow, while sedimentation in the Hornsund area bears characteristics of being fast with several local (?) interruptions and with rapid increases of the energy intensity at the beginning of each set of coralliferous beds. Corals of the three lower sets and those of the lowermost beds of the two upper sets form reworked and/or remanié assemblages with only rare data of individual samples to be drifted prior to burial in the bottom mud. 3) Differences in development of southern and northern parts of the Hornsund area cannot be explained as caused by climatological factors.

The location of the base of the upper Treskelodden beds was questioned by CZARNIECKI (1969) who introduced a new unit, the "Transitional Conglomerates" which includes the lower Treskelodden beds, the Gray Conglomerate "Horizon" and dark quartzitic sandstones and conglomerates which overlie the latter horizon and are very restricted to weathering.

Regardless of the necessity of this new unit I accept CZARNIECKI'S (1969) opinion that dark quartzitic sandstones and conglomerates should not be grouped with the overlying shales (as BIRKENMAJER 1964 did); the similar character of and the gradational contact between the dark sandstones and the Gray Conglomerate "Horizon" should be noted. Almost all sections discussed here start with these beds, as they are most easily recognizable in the field. However, the name Gray Conglomerate "Horizon" is adopted for them by widening the concept of this unit.

The BIRKENMAJER'S (1979) paper is discussed here in detail because of similar problems investigated and different results achieved.

Solitary corals. I agree with BIRKENMAJER'S (1979:48) opinion concerning position of some corallites in his Coral Horizons IV and V (= fourth and fifth sets of coralliferous beds). However, the environment in the fourth set was so complex that any general consideration seems impossible. The vicinity of Creek II (see Interpretation, p. 58) was the only studied area which offered an opportunity for solitary corals to rest unattached on the sea bottom. Rare corals were observed there by myself as resting almost in life position. I have found no corals in the fifth set which can be considered as either resting *in situ* or being only "tilted or overturned *post mortem* or during their life" (BIRKENMAJER, p. 48). The character of the sediment indicates, however, that there were some potential opportunities for solitary corals to grow in the position reconstructed by BIRKENMAJER.

I cannot agree with BIRKENMAJER'S (1979:48, 50) interpretation and reconstruction (fig. 3) of life positions of solitary corals in the south-western part of Treskelen. This outcrop was described herein as the lowermost part of Section 1, the uppermost part of Section 2 and the area between these sections. This conglomeratic unit could not have offered suitable life conditions for such corals as those which have been observed there by BIRKENMAJER (fig. 3) and myself. None of the specimens observed possessed any type of attaching processes, talons or attaching flattenings. None of such horn-shaped corals were able to live unattached in such turbidite conditions as those in the conglomerate deposition. All their characters are identical with those discussed earlier as typical for quiet water conditions. Streaks of sandstones among conglomerates where BIRKENMAJER found the cluster of corals discussed (fig. 2) were certainly not shadowed enough to offer such conditions. Similar clusters, not necessarily located in streaks of sandstones, however, are comparatively common in that unit. They should rather be called accumulations, because individual corallites show not only traces of recent abrasion, pointed out by BIRKENMAJER (p. 49), but demonstrate first of all ancient mechanical destruction. The majority of them have been broken along the areas of alar pseudofossulae, where thick septa of cardinal quadrants are replaced by thin septa of counter quadrants. From these two parts, only the most resistant cardinal quadrants were accumulated as large fragments, which in turn were abraded by recent erosion when exposed. More complete cross sections are rare. There was not a single specimen found by myself to possess a calice and/or proximal end preserved, although observations in that region were carefuly conducted during several days and the collection accumulated is considerable.

Colonial corals. The photographic documentation included (see individual pictures on pls 5-12) seems adequate to demostrate that the BIRKENMAJER'S statement (p. 50): "Small compact turves or discs of colonial corals without any traces of overturning and/or reworking do often occur in situ in gravely-arenaceous calcarenite of coral horizons I, II and III" cannot be accepted. In fact there was not a single massive colony examined in these horizons (= first to third sets of coralliferous beds) by myself as showing any original surface preserved. All these colonies were abraded and several were crushed and rounded to the form of pebbles.

Fasciculate colonies in the discussed horizons (= sets of beds), and especially in the first set, where they are best preserved, do not show "indications that some of these coral colonies grew in agitated environment above wave base" (BIRKENMAJER, p. 50). On the contrary, their delicate, long, straight branches, completely separated from each other, with no connecting processes indicate a quiet environment of their life. Also "the attachment of particular colonies to buried pebbles" stated by BIRKENMAJER (p. 51) as "often visible" is not an attachment by overgrowth. There was not a single colony observed as having been attached to a pebble by a protocorallite and first generations of corallites (the only relation of the colony *in situ* to the hard substrate). On the contrary, these astogenetically youngest parts of colonies were invariably destroyed and are never observed. Pebbles were simply acting as obstacles which anchored the transported colonies and/or their fragments causing destruction of their lower parts, pushed by traction agents into contact with these pebbles (pl. 8:6).

Fasciculate colonies of the type observed were not able to develop on such an unstable sea floor as that offered by megaripples (BIRKENMAJER, fig. 4). Moreover, there was not a single colony observed in the horizons (= sets of beds) discussed as resting *in situ*, although some of them were shown herein on plates 7 and 8 as deposited in positions identical with their former life positions. Many samples are not colonies but accumulations of separated, transported branches (see discussion and illustrations to the first set of coralliferous beds). The biogenic remains in the ripple troughs, if the megaripple concept is accepted, were only drifted accumulations. It should also be pointed out that there were local paracontemporaneous wash outs observed as located within the corals bearing megaripple-like structures (pl. 8:5).

Massive colonies from IV-th and V-th coral horizons (=fourth and fifth sets of coralliferous beds) were called by BIRKENMAJER (p. 51) "monospecific, hemispheroidal or conical bioherms up to 2 m in diameter, in growth position." The term "monospecific bioherms" is unfortunate and may be misleading, although it seems obvious from the rest of the sentence and from the further remarks that just massive coral colonies are discussed.

Two points must be clarified prior to any further discussion upon these corals: 1. All large massive colonies of rugose corals found in the fifth set of coralliferous beds are conical, although some of them are so wide as to form fan-shaped structures uppermost. None of these colonies show any kind of attaching processes or flattenings, which can be interpreted as surfaces of attachement. Anchorage in the sea bottom mud by having the lowermost 1/3 or more part buried high in the sediment, is the only position evidenced for similar Scleractinia and reconstructed for Rugosa. The influence of rates of sedimentation is demonstrated by their narrow (higher rate) or "cauliflower" (lower rate) shapes. 2. Hemispherical colonies, found in the fourth and fifth sets of coralliferous beds are all small (up to 10-15 cm in diameter). Although none of the samples observed possessed attaching surfaces preserved, an occurrence of such surfaces during their life time can be deduced from corallite patterns in these colonies. Rarity of such colonies makes them non representative for the units discussed. They have also not been considered on BIRKENMAJER's figures 5-9 and will therefore be omitted in the following discussion.

BIRKENMAJER's figures 5-7 dealing with the top of the V-th horizon (=fifth set of coralliferous beds) most possibly demonstrate karst phenomena. The biogenic remains washed out from the upper Treskelodden beds either collapsed into erosive channels or were trapped and buried in them by the subsequent accumulation. Both processes took place prior to or at the beginning of the Kapp Srarostin Formation accumulation and are commonly observed as present in the uppermost 0·5-1·0 m of thickness of the fifth set of coralliferous beds. The colony on BIRKENMAJER's figure 6B illustrates well the common state of preservation of colonies of that level. Both surfaces of colonies (upper and lower) were eroded, which is demonstrated by parallel, starting from nowhere instead of naturally descending, corallites (left side of the figured colony). Similar colonies and fragments of them are also illustrated in this paper (pl. 16:2, 4; pl. 17:2; pl. 19:3, 4).

Colonies in the lower and middle part of the fifth set of coralliferous beds are by far not as closely connected with veins of calcareous sandstones as those in the top part, which is also well demonstrated on BIRKENMAJER's figures 6 and 7. My interpretation of the occurrence of these calcareous and ferrugineous sandstones as clastic dykes can be complemented (or changed) in accordance with BIRKENMAJER's (fig. 8) observations. He interpreted these structures as the sea bottom channels. It seems very possible, however, that some of these sandstones, even if deposited in such a manner as proposed by BIRKENMAJER, might have been transferred into quicksands which penetrated vertical cracks in limestones in a way discussed in this paper (p. 44). Otherwise the sharply-edged contours of many blocks of limestones, divided by vertical, narrow clastic veins, will be hardly understandable.

Judging from shape and position in rocks, the colony illustrated by BIRKENMAJER on fig. 6A is one of the largest colonies, figured herein on pl. 19:1. Slight destruction of this colony (and similar ones, e. g. pl. 19:4), relations of corallites of such colonies to the substrate and, consequently, the subsequent movement of them from life positions were discussed in detail above and will not be repeated.

Positions of coralla illustrated by BIRKENMAJER on figs. 7C, D and interpreted by him as only seemingly overturned, show characteristics which exclude such an interpretation. In order to be originally positioned as drawn by BIRKENMAJER, they should have hung above the sea bottom and have grown downwards. This is in disagreement with the shape of colonies, weight of their skeletons, lack of attaching surfaces and destruction of calices of corallites. The cessation of growth of such hanging colonies could have taken place either by fast accumulation of sediments or by natural extending of them to the sea bottom by growth. In both cases the calices would have been protected against destruction.

The summarizing model of BIRKENMAJER (fig. 9) although partly acceptable as a local variant of the original life area of some colonies, cannot be accepted as the general reconstruction of sedimentary and life environments of the upper Treskelodden beds. In addition to the discussion which showed a drifting character of the coral fauna, it must be pointed out that:

1. Relation of coralla and corallites in the middle part of the discussed model to the current direction is in disagreement with all the so far conducted observations on living and ancient corals. Polyps and calices are always directed current-ward, since this is the main source of food and oxygen. This is also the direction of growth of corallites and colonies.

2. Positions of colonies and corallites on the right and left sides of the model, ecologically identical, seem acceptable as a possible local variant of growth positions of some small colonies of a given shape. It must be pointed out, however, that in spite of almost two weeks of careful examination, not a single colony was seen by myself in the field as resting in such a situation and position. The closest picture is shown here on pl. 19:1. This colony was already discussed earlier as moved from its life position, however. The depression it rests in was said to have resulted from deposition of the colony on a comparatively soft, muddy bottom.

3. The channels were presumed by BIRKENMAJER as having been "gouged by submarine erosion in hardened calcarenite" (p. 51). The small depth of channels read from Birkenmajer's figures makes one presume that the seafloor must have been hard ground in order to be gouged that way, what is not evidenced. Supposing, however that such fast hardening of calcareous mud took place, two forms of preservation of the conical, unattached colonies, occurring in great mass everywhere in the unit discussed should be expected: 1. It should be presumed that they were able to find suitable life conditions only in the low velocity channels, characterized by comparatively high rates of sedimentation. This necessitates the seafloor to be literally fragmented by such channels in order to offer hospitality for so many colonies as observed, what is not evidenced. 2. It should be predicted that lower parts of these colonies have been embedded in the fastly hardened mud, protecting them from uprooting. In this case abundant root parts of colonies and/or complete colonies should be observed as present in life positions everywhere in the deposits discussed, which also has not been evidenced. Channelling of the sea bottom was present, but rather on a restricted scale and corals were neither dependent nor involved in the system of channels, but were widely scattered on the sea bottom in a carpet-like manner.

In addition to disagreements with SIEDLECKA's (1968) opinions in some details (see p. 55 in this paper), her general reconstruction of ecological conditions of development of corals and accompanied fauna in the upper Treskelodden beds (SIEDLECKA 1968:86-88) is also not accepted here. Although supported correctly by studies on Recent corals, it is not applicable to the area and strata in question, because of redeposition of the fauna. However, the rapid burial and reworking of the fauna presumed by her, could be well accepted as one of the possible variants of the reconstruction.

In addition to those discussed above (pp. 36, 37) several other observations and opinions of CZARNIECKI (1969) are not confirmed by the present investigations. It has not been observed that "Between Creek IV and Creek III Horizon III and the overlying terrigenic, non fossiliferous rocks have been gradually eroded before the deposition of dark limestones of Horizon IV". Third set of coralliferous beds and the overlying non-fossiliferous deposits are well developed in that area (fig. 2).

It is not clear from CZARNIECKI'S (1969) paper whether he correlated coralliferous conglomerates of his profiles "Moraine" (= approximately Section 2 in this paper) and "Treskelodden" (= Section 1 in this paper) with the lowermost coralliferous deposits of Creek IV or with IV Coral Horizon of BIRKENMAJER (1964). From CZARNIECKI'S (1969) text-fig. 8 the first possibility seems likely, but in the text (p. 239) he wrote: "There followed a period of optimal life conditions, when dark fossiliferous limestones have been formed. The flat coral colonies occurring in the upper surface of the conglomerates on Treskelen are probably coeval." Thus he clearly correlated "IV Coral Horizon" of the middle part of Treskelen with "III Coral Horizon" of the southern part of that peninsula. He further noted that "The positions of the uppermost and the lowermost fossiliferous intercalations in Creek IV and in Hyrnefjellet appear to be identical". An analysis of the coral fauna and observations made in the field rather show that the lowermost exposed coralliferous sediments in Hyrnefjellet should be correlated with second set of coralliferous beds.

There are several misunderstandings or simplifications in that part of CZARNIECKI'S (1969) work which concerns depositional environments and rates of sedimentation of the upper Treskelodden beds (pp. 237-239). Most conclusions were based on the supposition that the coral fauna was preserved in life position and that fossiliferous layers in the "Coral Horizons" I to III are distributed in primary patches: "In the Treskelodden beds the lenses of sandy coral limestones correspond to the patches covered and stabilized by organisms, and layers of cross-bedded sandstones, lenses and intercalations of conglomerates correspond to the shifting sands. In the course of sedimentation of the lower part of the Treskelodden beds the position of both changed frequently." Because of this suggested distribution he then mentioned that the lower part of the upper Treskelodden beds "... is strikingly analogous to the distribution of benthonic organisms observed by N. D. NEWELL *et al.* (1951) in the zone between the reef and the shore of the Andros Island of the Bahamas". In my opinion this analogy is incorrect first because the coral colonies "whose height reaching a few score centimeters almost equals the thickness of particular layers" (CZARNIECKI, 1969:238) are all redeposited. Some rest on their sides, others are overturned. Several are not even colonies but represent drifted accumulations of broken branches of fasciculate colonies of rugose corals. All biogenic material now seen was produced and accumulated by physical factors and its present distribution has nothing in common with patchy organic accumulations. The dominance of quartzitic sand both in "Coral Horizons" I and II and in the lower and upper parts of "Coral Horizons" III (the only calcareous components are cement and bioclasts), mechanical damage of the fauna and its distribution are additional arguments against CZARNIECKI'S (1969) reconstruction of the upper Treskelodden beds depositional environment.

As it has already been mentioned most of my earlier remarks on palaeogeography (FEDOROWSKI 1965) are now retracted. Only the conclusion concerning the geographical position of the Svalbard Archipelago (approximately 30° and 35°N) are still thought to be correct. The new information presented here also negates the earlier comparison between the upper Treskelodden beds and the Upper Devonian of Ardennes (FEDOROWSKI 1965:157).

The lack of fauna identification prevents acceptation of NYSAETHER'S (1977) correlation of the Torell Land and the Hornsund area deposits, although his opinion seems probable.

It should also be stressed that in contrast to his meaning, the overwhelming majority of the non-fossiliferous deposits underlying the Kapp Starostin Formation in the Burgerbukta area are marine sediments. The dolomitic and marly limestones, described herein from the northern slope of Kruseryggen (fig. 3) bear no trace of continental origin.

INTERPRETATION

DEPOSITIONAL ENVIRONMENTS BELOW THE THIRD SET OF CORALLIFEROUS BEDS

The lithological character and geographical distribution of the upper Treskelodden beds limited the following remarks in respect to some regions and units. The Gray Conglomerate "Horizon", clearly recognizable on Treskelen and Hyrnefjellet, is the lowermost unit discussed. This is the only regionally developed unit of the upper Treskelodden beds, the continental origin of which was documented. Dr. J. SKOCZYLAS (see Appendix) demonstrated the mountain rivers regime of sedimentation of the upper part of this unit (here the accepted meaning). Because the lithology of its lower part does not differ significantly, the whole unit is supposed here to have developed under similar conditions. BIRKENMAJER (1964:100) also considered the Gray Conglomerate as possible river deposits. The presence of this unit in the Burgerbukta area seems very possible, although it has not been documented. It is preasumed here that the upper part of the thick conglomeratic series under the first appearance of corals in the Burgerbukta area is an equivalent of the Gray Conglomerate and deposits described by BIRKENMAJER (1964:Table 3) as II Clastic Horizon.

All deposits developed in Treskelen-Hyrnefjellet area between the Gray Conglomerate "Horizon" and the third set of coralliferous beds form a natural unit. The boundary between it and the Gray Conglomerate "Horizon" is in all exposures sharply accentuated in the Recent morphology. This is mainly due to a rapid change in the rock texture from medium- or coarse-grained quartzitic sandstones to very fine-grained, thinly-bedded sandstones and/or siltstones. The amount of calcium carbonate cement, accompanied by an increase of grain size becomes greater fastly but gently upwards. Deposits became lenticular and commonly cross-bedded. Two lowermost coralliferous sets of beds are included in this sequence as episodic events. The lithology of coralliferous beds does not differ from that of coarser-grained, non-fossiliferous calcareous sandstones of the unit. Corals are mixed with pebbles and quartz grains and must be treated as clasts. The distribution of individual sets of coralliferous beds is uneven. The first set starts farther to the south and does not proceed as far north as the second (fig. 2).

There are no certain criteria as to the marine or continental origin of the deposits discussed. The two sets of coralliferous beds were almost univocally (except for HEINTZ, *in* FEDOROWSKI 1967) considered as marine. Although this is also my opinion, the redeposition of the fauna makes all earlier reconstructions of depositional environments of these two sets of beds unsupported.

The environmental requirements of all of the coral faunas studied here as to the water temperature and salinity is assumed as similar to the requirements of the hermatypic Scleractinia. This point of view is generally accepted as far as colonial rugosans are concerned and does not need special discussion. Corals supplement NAIRN'S (1960) palaeomagnetic and SMITH, *et al.* (1973) plate-tectonic reconstructions of the Permian geographical position of the Svalbard Archipelago in the Subtropics.

The position, state of preservation, faunal composition and external characters of corals from the first and second sets differ and should be discussed separately. The fauna of the first set bears the following characteristics: 1) Large, bushlike, fasciculate colonies or fragmented branches predominate. 2) Cerioid colonies are absent, while plocoid ones are small and often flattened. 3) The accompanied fauna and flora are found sporadically in isolated places.

The colonies mentioned above indicate at least two different ecological niches of their origin. Fasciculate colonies are mostly of the shape illustrated by HUBBARD (1974, fig. 1E) as characteristic for irregularly compacted *chondrites* churned wackestone substrates. They could also be compared to colonies of G-type on fig. 4 of the same paper, but mainly in respect of high sedimentation rates. As colonies of this shape and form of growth predominate, it could be assumed that their life area was characterized by rather quiet water and considerably high rates of sediment deposition. Existence of such conditions could well be expected in a rather narrow bay that possibly extended between the Hornsund-Sörkapp High and the land eastwards of the studied area. The arid climate, reconstructed by SIEDLECKA (1972) and FOLK and SIEDLECKA (1974) makes it possible to presume that the fresh water supply of rivers was practically none and corals were given suitable conditions to develop. The flattened plocoid colonies could have inhabited shallower parts of the sea bottom, more exposed to the activity of waves (HUBBARD 1974, colonies B, C). The terrigenic fabric could have been transported to the bay due sea activity (waves, currents), by seasonal rivers and perhaps by winds. The reconstructed sedimentary environments could be to some extent compared to the shelf environment of the Persian Gulf (FRIEDMAN and SANDERS 1978), possibly except for a less warm climate.

SIEDLECKA (1968:87) already pointed out that "within the littoral zone of the Upper Carboniferous, Lower Permian sea, developed in the present vicinity of the Treskelen peninsula, no coral reefs could have been formed." I agree with that conclusion in spite of the fact that it was based not on the living but on the depository conditions of corals. It could be speculated, however, that there were also no reefs in the life area of corals, because of lack of potential frame work organisms or pebbles of reef limestone in the corals bearing calcareous sandstones.

The organic remains now found in the studied area were all transported, but their origin and ways of transportation were different. This determined their recently observed scattering throughout the most part of the discussed set of coralliferous beds and their denser accumulation in restricted areas (Creek IV and the vicinity of Section 2) where rich thanatocoenoses have been formed. The following categories of transported organic remains can be distinguished: Corals: 1) Rounded fragments of fasciculate colonies with the infilling matrix possibly introductory litified prior to the exhumation. 2) Comparatively large fragments of fasciculate colonies with no traces of rounding or exotic fabric (possibly not buried). 3) Small fragments of fasciculate colonies, not covered with the exotic fabric but slightly rounded sometimes. 4) Massive colonies, commonly better rounded than fragments of fasciculate colonies, but also without exotic fabric. 5) A single colony interpreted to has been transported *in vivo*. Other fauna and flora, found only in the vicinity of Section 2: 1) Variously preserved brachiopods. Complete specimens were found only in the lower, coarser part of the unit. Incomplete specimens and small fragments are scattered throughout the unit. 2) Gastropods, rather rare but often well preserved, were found throughout the unit. 3) Calcareous algae occur either as small colonies or as broken fragments throughout the unit. 4) Undeterminable carbonized fragments of plants occur mainly in the upper part of the unit.

Observations in Creek IV (see earlier discussion) indicate that the life area of corals deposited within it could not have been very extended and that the transportation has been marine rather than any other (a colony transported *in vivo*). The distribution of organic remains within the Creek and in its vicinity was caused by the sea floor configuration: the Creek area itself formed a shallow ditch, constructed perhaps just after the Gray Conglomerate "Horizon" deposition. The exposure is too restricted to be able to ascertain if this ditch was parallel or perpendicular to the sea shore. It served as a depository area for the coarsest transported clasts and for most of the organic remains both transported directly to it and washed into it from the slightly higher vicinity areas. Although trapped in the ditch, the inorganic sediment and organic remains were subjected to further processes (local wash outs, aggregations, etc., described earlier).

In the vicinity of Section 2 the accumulation of organic remains bears a slightly different character. The brachiopod-gastropod fauna is in a state of preservation (see above) which rather excludes their longer transportation. It is presumed here that this fauna has been buried almost on place by rapid sedimentation of coarse sand and pebbles. Some of these pebbles are massive rounded colonies of corals and rounded fasciculate colonies. The state of preservation and position within deposits allows one to regard all the corals observed as sedimentological clasts of a different origin. The matrix filling up the rounded fasciculate colonies, although similar to the surrounding matrix, does not mix with the latter. This indicates at least introductory consolidation of the primary coralliferous deposits prior to their erosion and redeposition. Temporary emergence of such sediments seems most possible, but underwater lithification could not be excluded (BATHURST 1975; FRIEDMAN and SANDERS 1978). In the last case a single colony, the shape of which indicates that it must have been buried during its life-time for at least 1/3 of its height, could have supplied material for both, pebbles (the buried part of a colony) and drifted remains (upper 2/3 parts of a colony). The fragmented branches and most probably also massive colonies, never showing traces of exotic matrix on their surfaces, were only reworked and either have never been buried or have been washed out from unconsolidated mud. Two possibilities may be presumed then: 1) The remanié assemblage is slightly older geologically not only than the brachiopods and gastropods, but also than the small fragments of branches of fasciculate colonies found in the unit. 2) In spite of their recent state of preservation, the whole fauna is approximately of the same age. Although the first possibility seems more probable the time span between the two groups of corals (rounded fasciculate colonies and fragmented branches) is too short (if present) to proove it by being reflected in the coral taxonomy.

The scattered corals between Section 2 and Creek IV and northwards of the latter should be considered as transported prior to the lithification. This is indicated not only by a lack of the exotic fabric on them, but first of all by a destruction of several skeletons, which took place due to a pressure on coralla and individual corallites prior to the infilling of their interstructural spaces.

Similarly as in the first, the coral fauna of the second set of coralliferous beds is all redeposited and no "bioherms" of SIEDLECKA (1968 :78) exist there. The accompaning fauna, mainly brachiopods, is poor, scattered and often broken. The lithology of this unit along most of Treskelen is so uniform that it could well be treated as a single bed. In contrast to the first set of coralliferous beds, it does not show as variable lenticular morphology, but it also does not contain any evidence of fauna or flora, which could directly confirm its marine origin.

The character of the coral fauna differs from that of the first set. This concerns mainly the growth form and shape of corals, because the taxonomy of the newly collected material is not yet studied. Colonial forms predominate and among them the massive colonies of the plocoid type are most common. Solitary corals are rare and were found only in a single place, slightly north of Creek IV. Fasciculate colonies are present mainly in a form of separated branches (along Treskelen) or aggregates of branches and small fragments of colonies (Hyrnefjellet). Massive colonies of rugose and tabulate corals, although often incomplete and with eroded surfaces, show hemispherical shape, similar to the type illustrated by HUBBARD (1974:fig. 4A). Although not so regular as those of HUBBARD (1974), the colonies discussed could have developed only on a rather hard bottom with low rates of sedimentation. Individual irregularities in colony shapes were caused by local differences in food or light supply and have no major importance for the discussion herein. Scleractinian colonies of the type discussed grew in shallow water of rather low energy (GOREAU 1959). Although found along most of the Treskelen peninsula (see discussion above) as comparatively large but rare and scattered samples, the colonies discussed are more frequent between Creek IV and Hyrnefjellet.

The life area of solitary corals was characterized by slightly different factors. The water energy was low, but the sedimentation rate should had been faster than in the case discussed above, and the bottom was not rocky but possibly muddy. This is documented by the narrow, elongated shape of specimens, by skeletons rather heavy in their lower parts, allowing stabilization in the mud and by a lack of talons or any other kind of attaching processes.

Branches of fasciculate colonies are too fragmentary to characterize directly any environment. A lack of attaching processes on the lateral sides of twigs and long, non-offsetting fragments could indirectly indicate rather quiet conditions of their development.

The above discussion can only to a restricted characterize degree the prevalent life conditions. It can be presumed that the rocky bottom area inhabited by massive colonies existed comparatively close to the ancient depository and the recent study area. This can be documented by both the number and the state of preservation of these corals. The area was not exposed to strong activity of waves, but it was open for more or less radial food supply and was cleaned by local currents from excess of sediment. Separated, shadowed places of the same area, characterized by higher rates of sedimentation could well have been life areas of solitary corals. Although the number of samples is restricted, it can be stressed that several specimens possessed preserved external walls and parts of calices, which determines their short transport. Fasciculate colonies were also inhabitants of rather quiet water, but their advanced destruction indicates a longer way of transportation. They may well have grown in a deeper, seawards parts of the area. All the deduced ecological niches could well have existed in a bay, which has already been mentioned in the discussion upon the first set of coralliferous beds.

None of the samples observed show any exotic fabric on their surface, which rather excludes their pre-drifting burial, lithification and exhumation. Several massive colonies, especially those on Treskelen are rounded, however.

The lithology and fauna of the discussed unit indicate a short period of rapid sedimentation, possibly restricted to a single impuls that caused uprooting, transportation and deposition of drifted and mixed skeletons and inorganic clasts: sand grains and small pebbles. There is no direct indication as to marine transportation of fabric and sedimentation of this unit, but this can be deduced. The observed texture, character of calcareous cement and the state of preservation of corals, especially of the solitary forms, rather exclude flooting or other river sedimentary conditions. Also the lake environment, although possible when only the rock texture is considered, should be excluded. There are no signs on the coral and other fauna that they have been subjected to so many steps of reworking and transportation which are required to have translocated it from the purely marine life area to a lake depository.

The meaning presented here is in agreement with CZARNIECKI'S (1969) rather than to BIRKENMAJER'S (1964) reconstruction of sedimentary conditions. The often observed gradual transition from unfossiliferous to coralliferous deposits and the episodic character of the latter argue, in my opinion, for considering the whole "II Clastic Horizon" of BIRKENMAJER (1964) as developed under conditions generally similar, but variable in details. A very shallow shelf with a generally marine environment, but with separated parts of the area temporarily exposed above the sea level, seems most probable to consider. I agree with BIRKENMAJER (1964) that very little differences in the sea level could have caused considerable environmental changes in such a shallow area. The field observations and the above deductions do not confirm the more general land-sea successions within the unit discussed, which could be considered as sedimentary cycles in the meaning accepted by Glossary of Geology (1972:177; 608).

A small coralliferous lens found by myself in Creek IV above the second set of coralliferous beds (see discussion above) can serve as additional argument against cyclicity of the discussed deposits. The development of this very local structure in Creek IV, which has earlier been considered as a local ditch, and a lack of its equivalents elsewhere is considered here as a simple function of coastal and marine bottom diversity against the hydrodynamic agents. Consequently lack of the fauna in calcareous sandstones and calcareous pebbly sandstones equivalent to this lens, as well as in other similar beds or lenses developed so frequently on different levels of the unit discussed, is not due to a change of the general depositional environment. It rather has taken place due to local characteristics, such as distance from the life to the depository area of the fauna, changes of main directions of transportation, traps (ditches, channels) on the sea bottom along the way of transportation, inadequate energy, or these and other factors combined. Presence of this lens and the episodic character of the earlier discussed coralliferous deposits demonstrated above, makes it possible to presume that the number of such coralliferous intercalations increases westwards and those of the studied area resulted only from the transportation ability more effectively aroused in these than in other periods of sedimentation of the unit discussed.

As it has already been pointed out in the preceeding chapter most of the changes observed are considered as being tectonically controlled. Two kinds of tectonic activity can be distinguished: 1) A slow and differentiated downwarping of the depository basin, which produced a transgressive sequence from the continental deposits of the Hyrnefjellet beds into interfingering, continental to marine facies, finally into purely marine environments in the upper Treskelodden beds, or at least the upper part of the latter. 2) Tectonic impacts developed on a local scale, caused by fault movements. The first of the two listed components is so far confirmed by: 1) Accumulation of approximately 15-20 m of clastic deposits of the unit discussed without any major changes of depositionary environments. This must be noted that similar results would be achieved by an increase of the sea level. 2) Northwards translocation of the sedimentary basin axis, documented by distribution of the two so far discussed sets of coralliferous beds. This can only be explained as caused by tectonic factors. It is much better documented above the third set of coralliferous beds.

The second tectonic component is documented by introductory stages of all sets of coralliferous beds, the fauna of which was derived from life areas, often broken or abraded, mixed with coarse clasts and redeposited. The fault movements along the main faulting area westward of Hornsund is here regarded as responsible for the energy increase which allowed to derive the fauna and to transport all the material mentioned. I agree with WORSLEY'S (personal comm.) supposition that the Hornsund/Sörkapp High was a source area for at least part of clastic deposits of the upper Treskelodden beds.

DEPOSITIONAL ENVIRONMENTS IN THE THIRD SET OF CORALLIFEROUS BEDS

In contrast to the local development of the two lower sets of coralliferous beds, the third set is more regional in scale involving both northern (Burgerbukta) and southern (Treskelen-Hyrnefjellet) parts of the Hornsund area. Although bearing some intermediate characteristics, such as the first appearance of elongated limestone lenses, it belongs to the same kind of regional and local tectonic activity as that involving lower sets. This is documented both by the character and thickness of deposits. The coral and other fauna must still be treated as sedimentological clasts, transported from western directions to the near shore region and deposited. Redeposition of this fauna was already pointed out by SIEDLECKA (1968:89). The reconstruction of the life conditions of this fauna given by her, is not accepted here, however.

The fauna of the unit discussed is much more complex than that of the preceding one containing foraminiferal, bryozoan and crinoid remains in addition to the formerly existing corals, brachiopods and gastropods. Most of this fauna, except for corals, is taxonomically unidentifiable because of advanced fragmentation. The coral fauna varies greatly in taxonomy, shape, form of growth and in recent distribution both vertically and laterally.

The most diversified and the richest fauna is that of the lower conglomeratic unit and among it the large solitary corals without talons and/or attaching processes, conico-cylindrical in shape and with calices much deeper on their concave sides are most widely distributed throughout the area. Characteristics of these corals indicate that they were derived from a rather quiet environment of low rates of sedimentation. They rested on the sea bottom, perhaps partly buried in mud, with only calices protruding and directed current-wards. Observations of HUBBARD (1966, 1970) and HUBBARD and POCOCK (1972) confirm this reconstruction. The corals discussed exhibit either almost no traces of mechanical damage (Section 11) or are fragmented but commonly not rounded or only slightly rounded.

The next in importance are medium and small plocoid colonies, mostly originally flattened, but often distinctly rounded in accordance to this flattening. They are distributed throughout the studied area, except for the Burgerbukta and the southernmost part of Treskelen, between Sections 1 and 3. These colonies and a single hemispherical colony found in Creek IV just above the coarsest fraction of the sediment, are directly comparable to those, characterized earlier for the first and second sets and were derived from similar environment.

The very large, flat colonies found between Sections 1 and 2 are restricted only to that area. They are incrusting colonies, characteristic for a high energy regime (Types B of HUBBARD 1974, fig. 4) and were derived and transported as light, nonlithified coralla with no sediment in the intrastructural spaces of corallites. This is indicated by their interrelation the coarse sediment of the depository area, which was pressed into the lowermost parts of skeletons during deposition and compaction. This was observed in colonies resting in seemingly natural positions, as well as in those resting upside down. It must be stressed that not only the discussed colonies, but also all other coral skeletons, transported prior to having their interstructural spaces infilled, exhibit hydrodynamic relations different than heavy clasts. They could have been transported by saltation or partly in suspension over the sea bottom. This made abrasion of such skeletons rather small by comparison to their size and the distance of transportation.

Accumulations of fragmented branches and small parts of fasciculate colonies have been found only in the upper part of the southern slope of Hyrnefjellet. These fragments are of the same characteristics as those discussed earlier for branching corals of the second set of coralliferous beds, and can serve the same purpose of deduction of their original habitat.

The distribution pattern and the character of the coral fauna briefly discussed above, brings some information as to the environment of the coral and other fauna life area, lenght and kind of transportation, depositional environments and, indirectly, impulses conditioning redeposition.

The environment in general seems to have been similar to that of the preceding coralliferous unit. It could be supposed, however, that the elevated area, inhabited by the massive, flattened colonies was in the case of the discussed unit located slightly more seaward. The area inhabited by solitary corals and locally also by fasciculate colonies was not only closer to the depository area, but it was also more widely developed. This may have been a long belt of sandy or muddy sea bottom parallel to the sea shore, shadowed from the sea side by the mentioned elevation and cleaned by weak currents from sediment excess. This reconstruction, although hypothetical, is supported by the character of the coral fauna and by the lithology of the algae encrusted pebble (pl. 10:6*a*, *b*) perhaps derived from the area close to the life area of the solitary corals. A patchy distribution of massive and fasciculate colonies and their different resistance against destruction, produced the pattern of occurrence observed. The very large colonies of the southern part of Treskelen were probably derived from the most seaward parts of the elevation mentioned. Their light and flat skeletons produced only slight resistance against water allowing long distance transportation either by suspension or by saltation or by both combined. They were deposited with solitary corals, characterized by heavier skeletons and shapes which enabled rather anchorage on the sea bottom than a long way transport.

The pebbles encrusting calcareous algae seem to be the best criterium for marine sedimentation of the deposits discussed. The often observed gradational transition into it from the underlying deposits (see discussion above) may form an additional indirect argument for the marine origin of most of the former unit. It must be mentioned, however, that there also are channels and erosive surfaces observed both beneath and within the now discussed unit, indicating a much more complex sedimentary environment than briefly discussed herein.

The upper part of the third set of coralliferous beds is characterized by thickly-bedded deposits lacking large clasts. Lateral development of calcareous sandstones and very long lenses of limestones reflect either diversity of the sea shore line, located eastwards, or diversified intensity of the clastic fabric supply. The available data do not permit to solve this question. Corals are very rare in this part of the unit but the drifted colony of *Protowentzelella* found in the limestone, announces the future richness of this genus. The uppermost part of the unit is again more sandy and is characterized by very rare and scattered branches of fasciculate colonies, derived from somewhere and transported by waves and currents.

DEPOSITIONAL ENVIRONMENTS ABOVE THE THIRD SET OF CORALLIFEROUS BEDS

As in the case of non-fossiliferous deposits below the third set of coralliferous beds, there is no certain sedimentological and petrographical information as to the marine or continental depositional environment of the non-fossiliferous deposits above that set. A slow transition between these two units and the variable lithology, described above, make local development of several habitats, starting from purely marine to lagoonal, estuary or near-shore lakes, most likely.

Depositional environments above the third set are interpreted here as being tectonically controlled, but with lesser influence of local tectonic impacts than in the lower units and with the general tendency of the whole area to subside much faster in its northern part. The southern part of Treskelen was downwarped very little or was almost immobile. The mentioned downwarping tendency was accompanied by a contemporaneous movement of the shore line eastwards, which made the connection of the discussed area with north-western seas more open. These two tendencies established new depositional environments, best seen in the fifth set of coralliferous beds.

Development of the fourth set of coralliferous beds could only briefly be reconstructed, because of comparatively poor exposure. It is characterized by a considerable lateral and vertical variability in the lithology and faunal composition and by the appearance of almost completely new coral fauna, especially as far as colonial forms are concerned. This may have been caused by an immigration of new taxa into the vicinity of the studied area and/or by the mentioned movement of the sea shore, making the life areas of that new fauna closer to the depository area, or by both factors combined.

Redeposition of the fauna available for study seems certain, but its origin and transportation distance were differentiated. The fauna of the lowermost part of the unit on Treskelen and all specimens on Hyrnefjellet are accompanied by sandy deposits and show advanced destruction and/or rounding. Judging from growth forms observed, it could have been derived from ecological niches analogous to those reconstructed above for the second and third sets of coralliferous beds.

Using HECKEL'S (1972) criteria, the depository and transport conditions could be again only indirectly deduced as marine and caused by an rapid increase of the transportation ability at the beginning of the unit. The further development of the unit was most probably dependent of the distance to the clastics and fauna source areas or on the shore line configuration. The amount of clastic fabric admixture on Hyrnefjellet is the largest. It is accompanied there by patchy distribution of the redeposited fauna, derived from rather turbidit area (massive colonies) and from more quiet areas (solitary forms and twigs of branching colonies), then transported, mixed and accumulated or scattered in accordance to the local hydrodynamic conditions, sea bottom configuration, etc. Corals are accompanied by broken and worn brachiopod shells and for the first time in the upper Treskelodden beds, by larger amount of well preserved crinoid columnals. The Hyrnefjellet area was probably located closer to the sea shore from all places studied.

Decrease of clastic admixture southwards, accompanied by a slow increase of "fine magnetic aggregations dispersed throughout the rock" (SIEDLECKA 1968:81) and changes in the fauna composition make it possible to establish some kind of zonation. The vicinity of Section 9 formed a shallow but comparatively open depository area, large cone-shaped, massive colonies and large fragments of fasciculate colonies of rugosans were carried into. Delicate skeletons and mentioned shapes of colonies indicate a quiet environment of their life area with comparatively high rates of a fine-grained sedimentation. The sudden increase of hydrodynamic energy derived them from their habitats, transported for a short distance, accumulated and buried by quartzitic sand supplied in greater amount.

Poor exposures nearby and south of Creek IV show predomination of calcareous deposits in the middle part of the unit and an increase of quartzitic sand admixture uppermost. The lithology, preservation of fauna and its composition could well be compared to the widely distributed elsewhere shallow shelf carbonate facies (e. g. GEORGE 1972; HECKEL 1972; RAMSBOTTOM 1973; FRIEDMAN and SANDERS 1978). This facies is soon replaced southwards by dark, thinly-bedded limestones with scattered fauna, composed mainly of slightly curved solitary corals with oblique calice bottoms, wide colonies of branching Tabulata and Rugosa and of numerous crinoid columnals. The shape and growth form of corals coincide with the character of sediment, although all samples observed (the number of observations were restricted due to poor exposure) were moved from life positions. The depository area was perhaps almost identical or identical with the life area of the fauna, forming a comparatively deep or separated, quiet and poorly aerated part of the bay. The coral fauna discussed could have perhaps lived under such conditions releasing itself from the sediment (HUBBARD and POCOCK 1972). It was only slightly moved from place by strong waving generated by storms or distant fault movements. It may have also been transported by these waves along a short distance, which did not caused major destruction of coral skeletons, although other fauna, possibly drifted into the area from its vicinity was more fragmented.

Shallow and more open marine conditions uppermost are documented by lighter, more sandy deposits and by accumulations of bryozoans and drifted corals. Poor exposures do not allow to demonstrate to what extent the coral fauna of this level was damaged by transportation. Its taxonomic character is similar to that of the next coralliferous unit. The sandstones overlying the fourth set of coralliferous beds were already described by SIEDLECKA (1968:90) as deposited in the basin deeper than the preceding ones and more open in character, but less saline. She did not precise whether the presumed depository environments were marine, but this supposition seems most likely.

In the fifth set of coralliferous beds after a short initial period of clastic sedimentation, accompanied by longer transported solitary corals, the volume and size of exotic clasts became reduced and a more constant marine regime was established. As manifested by calcareous benthonic algae found in one bed in the Burgerbukta area, the depth of the sea probably did not exceed 30-40 meters during that limestone deposition. Similarities in lithology allow to extend that observation onto the other limy deposits of this unit. Several of them show characteristcs of even shallower water depository environments. The temporary increase of downwarping of the sea floor led to the deeper water sedimentation of shales. Reduction of the speed of subsidance or more active fault movements might have caused an increase of volume of quartzitic sand deposition in small clastic intercalations. As it was already discussed above, the coral fauna of this unit was redeposited. This seems most probable, however that the depositional environments were not much (if at all) different from the life areas of the fauna and the latter form drifted assemblages. In some cases, e. g. where very large colonies are considered, transportation may have taken place only along a dozen or so meters and may have been caused by rapid increase of wave activity, underwater floats or by both these factors combined. The impacts were not necessarily tectonic. A "biogenic breccia" of Hyrnefjellet is here interpreted as a sample of a high energy waving destruction and accumulation caused by a hurricane.

The cone-shaped, large and medium sized cerioid rugose coral colonies form the most common component of the fauna. Large solitary corals are the next in frequency. Tabulate corals are represented mostly by small, hemispherical, fasciculate or subcerioid colonies and by very large colonies of irregular shape, often asymmetrically elongated. Fasciculate colonies of rugose corals are rare and scattered. Fauna other than corals, although diversified, is not numerous and is often fragmented. Some portions of many coral colonies are damaged in a way indicating compaction and high pressure of the sediment on the empty skeletons.

A shallow, diversified shelf area, located not far from the sea-shore could be deduced from the so far discussed observations as both life and depository environments of the fauna. The rates of sedimentation, conditioned by configuration of the sea floor and the supply of the clastic fabric varies, but its average, calculated above from growth striae of corallites, was high. These high rates of sedimentation were probably conditioned by the location of the depository basin in a bay, the supply of sediment drifted into and produced on place (activity of organisms) was much higher than its delivery. The downwarping tendency of the area, better accentuated in its northern part, caused a northward succession of deposits. Within the fifth set of coralliferous beds on Treskelen and Hyrnefjellet this sucession is so far demonstrated only by northward increasing thickness, but their most possible equivalents on Kruseryggen (see section 13) also show an increase of number of beds and differentiation in sedimentology caused by factors not reflected in the southern part of the area. The non-fossiliferous, often dolomitic deposits, developed only in northern part show that the southern part of the area was probably already uplifted and exposed for erosion at that time. Deposition of these non-fossiliferous, intercalated dolomitic and clastic beds could have taken place in more or less isolated remainings of the former large bay of the upper Treskelodden beds time. Higher salinity (dolomitic beds) or higher supply of clastic fabric, accompanied perhaps by lower salinity (sandstones and conglomerates) may have been conditioned by temporary higher evaporation replaced by a higher supply of fresh water and quartzitic sand transported occasionally by seasonal rivers. The correlation of the afore discussed unit with the Unit 2 of NYSAETHER (1977), although temporary, seems likely.

SUMMARY

1. Deposits of the upper Treskelodden beds are divided into several sets of beds according to their origin. Although often comparable to BIRKENMAJER'S (1964) "Horizons", they cannot be called that, because of their complexity.

2. The coralliferous and non-fossiliferous character of deposits cannot be explained by their marine versus continental origin. All upper Treskelodden beds sediments, except for the Gray Conglomerate "Horizon", are considered here as generally marine, although local emersions above the sea level most possibly have taken place.

3. Tectonic control of sedimentation is documented by rapid and short increases of hydrodynamic energy, manifested by levels of conglomerates, accompanied several times by drifted faunas, and by the differentiated speed of downwarping of the southern and northern parts of the studied area.

4. The growth form and shape of individual groups of corals indicate that they were derived from different ecological niches due to a commonly acting strong agent and were mixed together during transportation to the depository areas. A part of the coral fauna in the lowermost set was transported in the form of partly lithified pebbles, while other corals of this and all corals of higher sets of coralliferous beds were transported as fresh, mostly empty skeletons. At least part of that fauna may have been transported in suspension, what prevented its rounding.

5. Due to a general downwarping tendency of the depository area, the shore line has moved eastward and individual sets of coralliferous beds became located successively closer

to the fauna life areas. Some parts of the fourth set and most of the fifth set could be almost equalled to the life areas of corals.

6. Rates of sedimentation of limestones of the fifth set of coralliferous beds, calculated from growth of coral colonies are very high. Also other deposits bear characteristics of being fast or even rapid. However, the total time of deposition of the upper Treskelodden beds could not be calculated by simply adding the thicknesses of individual beds or sets of beds, because of the unknown time spans of gaps in sedimentation and effects of local and general (prior to the Kapp Starostin Formation) erosion.

7. The northward translocation of the sedimentary basin axis, caused by downwarping tendency accentuated more strongly in the northern part of the studied area has taken place during the whole time span of the upper Treskelodden beds deposition. It was finally resulted in the exposition of the southern part of the studied area for erosion, while accumulation of sediments in the northern part has taken place in an isolated basin of variable, supersaline and brackish (?) regime (the non-fossiliferous deposits between the upper Treskelodden beds and the Kapp Starostin Formation).

APPENDIX

JANUSZ SKOCZYLAS

ANALYSIS OF TWO SAMPLES FROM THE GRAY CONGLOMERATE "HORIZON"

Two samples were granulometrically investigated for size and morphology of grains. The achieved results are composed in the enclosed table in accordance to the nomenclature of GRADZIŃSKI *et al.* (1976) and KRYGOWSKI (1964).

Sample	granulation			morphology		
	GSS	GSO	GSK	GSP	Wo	Nm
1	2·67	1.34	−0·28	0.91	510	5·0
2	2.77	1.84	−0.009	0·57	630	4·2

The above data show the fine grain size of both samples (GSO). According to FOLK and WARD (1957) classification, the sediments are poorly sorted. The negative skewness (GSK) excludes an aeolian origin of that sand.

The results were compared to the following diagrams:

1. Interdependence of skewness and mean grain size for beach and dune sands (FRIEDMAN 1961). Both samples were placed in a field of beach sands.
2. Interdependence of standard deviation and mean grain size (MAIOLA and WEISER 1968). Both samples were placed in the field of river sands.
3. Interdependence of the above factors in accordance to FRIEDMAN (1961) for river and dune sands. Both samples were placed in the field of river sands.
4. Interdependence of mean diameter and coefficient of sorting for different environments (BULLER and MC MANUS 1972) namely for aeolic sands, quiet water deposits, beaches and river sands. In this diagram both samples were placed in the quiet water deposits field.

In investigations on morphology of quartz grains KRYGOWSKI's (1964) method was applied. According to that method it can be stated that dominative grains of Sample 2 are placed in the sharp-edged (L_2) class and those of Sample 1 are placed in a very sharp edged class (L_1). The heterogeneity index (Nm) indicates a regime of constant but low ability for selection. In accordance to the above investigations both these samples are placed in the field of diagram indicating a mountain river regime.

Summarizing the achieved results it could be stated that the sands investigated contain badly sorted and sharp or very sharp edged grains and are composed of debris fabric which underwent short transportation in rivers.

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EXPLANATION OF PLATES 5-22

All the photographs except when otherwise stated were made by J. Fedorowski

PLATE 5

1. The general view of Section 2. Symbols: *GC* Gray Conglomerate "Horizon"; *I CS* the first set of coraliferous beds; *III CS* the third set of coralliferous beds with the level of the coral fauna marked by the dashed line.

2-6. Different parts of the first set of coralliferous beds in Section 2.

2. The thickest exposed fragment of outcrop with regular level of branches of fasciculate colonies and a fragment of massive colony (arrow). Long axes of specimens are directed W—E.
3. The northern part of set enriched with large cobbles; corals are marked as follows: *S* solitary, *F* fasciculate colony, *C* — massive colony.
4. Southern part of the outcrop; two irregularly rounded, massive colonies of rugose corals (contoured) are embedded in coarse-grained calcareous sandstone with scattered clasts of white and black chert.
5. The level of well oriented twigs of fasciculate colonies of rugose corals in the lower part and scattered twigs and a solitary coral (*S*) in the upper part of the set. The long axes of all specimens show W—E lineation.

6. The lower, conglomeratic part of set with a flately rounded fasciculate coral colony, approximately 70 cm in maximum diameter, showing N—S lineation of the long axis.
7. Section 3; the coarse-grained calcareous sandstone of the first set of coralliferous beds with the irregular lens of fine-grained calcareous sandstone and with a fragment of solitary coral (arrow).

PLATE 6

The first set of coralliferous beds

1. 550 m south of Creek IV. A large (over 20 cm in diameter) well rounded clast in 5 cm thick level of coralliferous pebbly sandstone with fragments of fasciculate coral colonies (arrows).
2. 500 m south of Creek IV. Thinly-bedded calcareous sandstones with 5-10 cm thick coralliferous intercalation are covered by 30-40 cm thick bed of quartzitic sandstone.
3. 850 m south of Creek IV. The lithology as above. The coralliferous intercalation is marked by the compass (arrow).
4. 900 m south of Creek IV. The lithology and sequence as above.
5. 600 m south of Creek IV. The rounded colony of *Protolonsdaleiastraea* (1/2 nat size; photo. A. PIETURA).
6. Cross-bedding in the colony embedded sandstone (nat. size; photo. A. PIETURA).

PLATE 7

The first set of coralliferous beds in Creek IV

1. The large, well rounded pebble of gray, quartzitic sandstone.
2. The fasciculate colony of rugose corals in seemingly growth position "arrested" by the large cobble of whitish chert. Corallites in the lower part of the colony present advanced mechanical destruction.
3. Two colonies in seemingly growth position with lower parts destroyed and the upper surfaces cut off by a fastly transported sand (see also pl. 8:6).
4. The originally uneven thickness of the coralliferous pebbly sandstone with fragments of fasciculate colonies of rugose corals. Note the sharp (possibly erosive) boundary with the underlying thinly-bedded, fine-grained calcareous sandstones.
5. Two large, overturned and partly destroyed fasciculate colonies of rugose corals occupying almost the whole thickness of the bed.

6, 7. Disorderly accumulations of individual twigs of fasciculate colonies of rugose corals.

8. Three differently oriented fragments of fasciculate colonies of rugose corals (arrows) and several small fragments of twigs (right).

PLATE 8

The first set of coralliferous beds in Creek IV and its vicinity

1. The disorderly accumulation of twigs of fasciculate colonies of rugose corals. Arrows indicate distal ends of twigs.
2. The local erosive structure in deposits immediately under the accumulation of individual twigs of fasciculate colonies.
3. The accumulation of well oriented individual twigs.

4. Fines upwards calcareous sandstone in southernmost part of Creek IV with overturned and partly abraded fasciculate colony and abraded massive colony of rugose corals lowermost.
5. The detail of fig. 8 (arrow) showing a small wash out within the first set of coralliferous beds.
6. The close view on the colony illustrated on pl. 7:3 (left) showing destruction of its lower part.
7. 35 m north of the place presented on fig. 4. The northernmost found large fragments of rugose coral colonies in the set discussed.
8. Small wash outs in the coralliferous bed and immediately under deposits (see also fig. 5).

PLATE 9

All pictures taken in Creek IV except when stated

1. The first set of coralliferous beds. The overturned colony of *Protolonsdaleiastraea* deposited together with the upper part of the conglomerate. Directions of growth of some corallites (arrows) suggest that their polyps survived transportation.

2-5. The second set of coralliferous beds. *2* Large colonies of *Protolonsdaleiastraea* (right) and *Roemeripora* (left), both in seemingly growth position. The concentration of coarser fraction on the lee side of the tabulate colony indicates N→S direction of paleocurrent. *3* The overturned and partly destroyed colony of *Roemeripora*. *4* The marginal, left part of the *Protolonsdaleiastraea* colony illustrated on fig. 2 (right) enlarged to show abrasion of its surface. The dashed line marks direction and possible original extension of corallites. *5* The small exposure in the lower part of southern slope of Hyrnefjellet (see also pl. 10:3).

PLATE 10

1. The second set of coralliferous beds in northern part of Creek IV. Tabulate coral.
2. The lower part of *Roemeripora* colony illustrated on pl. 9:2 enlarged to show its abrasion. Individual corallites do not arise from each other.
3. The biogenic breccia of the second set of coralliferous beds composed of large (right) and small (lower left) fragments of *Protolonsdaleiastraea* colonies and fragments of branches of *Tschussovskenia* (upper left). (1/2 nat. size; photo. A. Pietura).
4. Fines upwards calcareous sandstone of the second set of coralliferous beds in Creek IV with scattered branches of fasciculate colonies (*F*) and solitary rugose corals (*S*).
5. The fragment of massive colony of scleractinian coral from the Pleistocene deposits of Key Largo (Florida Keys) showing ability of the colony to reconstruct rapidly.
6. The third set of coralliferous beds in Section 2; *a* the fragment of a coral containing pebble overgrown by calcareous algae, *b* another side of the same sample (nat. size).
7. The locality as above. The colony of calcareous algae.

PLATE 11

1. Creek IV. The lens of coralliferous pebbly sandstone (indicated by hammer), developed 1·8 m above the second set of coralliferous beds.

2-8. The conglomeratic unit of the third set of coralliferous beds in the vicinity of Section 2. *2* The coralliferous level of conglomerates. *3* The upside down deposited colony of *Protolonsdaleiastraea* 145 × 90 cm in diameter. *4* Another colony of *Protolonsdaleiastraea*, 157 × 103 cm in diameter. Long axes of colonies are directed N—S. *5* Remainings (white) of the *Protolonsdaleiastraea* colony showing clasts pressed into its skeleton during deposition and compaction. *6* The accumulation of fragmented corals and gastropods. *7, 8* Recently abraded surfaces of solitary rugose corals (nat. size).

PLATE 12

1-5. The third set of coralliferous beds in the vicinity of Section 3. *1* The general view of exposures. Details shown on figs. 2-5 are indicated by arrows. *2a, b* A transition from non-fossiliferous calcareos sandstones into conglomerates of the third set of coralliferous beds. *3* The abraded colony of *Protolonsdaleiastraea* (next to the compass) in the bottom part of conglomerates. *4* A wide wash out filled up with conglomerates (left arrow on the fig. 1). *5* The large (over 1·20 × 0·8 m), irregular block of calcareous sandstone in conglomerates (right arrow on the fig. 1).

6. The calcareous conglomerate of the third set of coralliferous beds in southern part of Creek II. Randomly oriented solitary corals are contoured white to better show their positions.

PLATE 13

1. Northern part of Creek II showing gradual transition from non-fossiliferous clastic deposits to conglomerates of the third set of coralliferous beds. Symbols: *Cl*: non-fossiliferous clastics; *Cg* coralliferous conglomerates; *Cs* coralliferous calcareous sandstones; *L+S* pinkish-gray micritic limestone with gray shales at the bottom. Rocks on the lower-right site of fig. 1a are fallen down loose blocks.

2a, b. Southern part of Creek II. Symbols as above.

3. A solitary coral in pinkish-gray micritic limestone of the third set of coralliferous beds.
4. The third set of coralliferous beds exposed 180 north of Creek IV.
5. The *Protowentzelella* colony in the limestone illustrated on fig. 3.
6. The third set of coralliferous beds. The southernmost exposure of pinkish-gray micritic limestone 860 m south of Creek IV (above white line). A bed of coralliferous conglomerate beneath the line is here reduced in thickness.
7. Creek II. A fragment of N—S directed twig of fasciculate colony in calcareous sandstone of the third set of coralliferous beds.

PLATE 14

1. The conglomeratic layer of the third set of coralliferous beds in Creek IV with massive colony of rugose coral rounded to form a clast (arrow).
2. Gradual transition from calcareous sandstones of non-fossiliferous clastic deposits into coralliferous pebbly sandstone of the third set.
3. Creek IV. The wash out in the upper part of the non-fossiliferous clastic deposits filled up with conglomerate of the third set of coralliferous beds.
4. The upper part of southern slope of Hyrnefjellet. Coralliferous coarse-grained sandstone of the third set of coralliferous beds.

5. The basal conglomerate of the fourth set of coralliferous beds approximately 300 m south of Creek IV fines up into calcareous sandstone with densely scattered twigs of *Tschussovskenia.*
6. A small drifted or reworked assemblage of fauna in the uppermost coralliferous sandstone of the third set in Creek IV. Symbols *G* gastropod, *M* massive colony of rugose corals, *S* solitary rugose coral.
7, 8. Colonies of calcareous algae from the first set of coralliferous beds in Section 2.
9. Upper part of the northern slope of Kruseryggen. Conglomeratic layer of the third set of coralliferous beds.

PLATE 15

1. 400 m south of Creek IV. The coralliferous pebbly sandstone of the fourth set of beds grading upwards into cross-bedded calcareous sandstones.
2. 820 m south of Creek IV. A slightly rounded colony of *Protowentzelella,* a fragment of twig of *Tschussovskenia* (lower left corner) and a fragment of solitary coral in the sandy limestone of the fourth set of coralliferous beds.
3. Upper part of the southern slope of Hyrnefjellet. Lens of the coralliferous pebbly sandstone separated from the third set of coralliferous beds by 3·7 m of non-fossiliferous deposits.
4. The southernmost outcrop of the fifth set of coralliferous beds 400 m south of Creek IV. Note relation of these deposits (left) to the overlying Kapp Starostin Formation (right).
5. The finning up calcareous pebbly sandstone of the fourth set of coralliferous beds in Section 9. The overturned colony of *Tschussovskenia* shows gradually decreasing flattening of corallites (1/2 nat. size; photo. A. PIETURA).
6. The fifth set of coralliferous beds 400 m south of Creek IV. Two large, massive colonies of rugose corals, drifted and deposited on each other.
7. A cluster of small brachiopods in the fifth set of coralliferous beds 250 m south of Creek IV.

PLATE 16

The fifth set of coralliferous beds

1. 250 m south of Creek IV. Two fragments of massive colonies of rugose corals drifted and deposited so close to each other as to form an apparent single colony (not to scale).
2,4. Massive colonies of rugose corals (arrows) flattened by abrasion. Approximately 200 m south of Creek IV.
3. A large, overturned colony of rugose corals. Approximately 250 m south of Creek IV.
5, 6. Lower part of the southern slope of Hyrnefjellet. A biogenic breccia composed of sharply-edged fragments of massive colonies of rugose corals and rare fragments of solitary rugose corals (fig. 6, upper left corner).
7. The locality and bed as above. The massive colony of rugose corals broken after deposition. Note the V-shaped slit in the upper left part of the colony (nat. size; photo. A. PIETURA).

PLATE 17

The fifth set of coralliferous beds in the southern slope of Hyrnefjellet

1. The arrangement of corallites and the so called "old surfaces of corallum" or "repeated stoppages of growth" (FEDOROWSKI 1965:158).
2. The colony illustrated by FEDOROWSKI (1965, pl. 15:3) and CZARNIECKI (1969, text-fig. 27) as resting *in situ* in growth

position. In fact the colony rests on its side exhibiting mechanical destruction (left). Note that the "old surfaces of corallum" are oblique to the direction of growth of corallites.

3a. The medium size colony in seemingly growth position.

3b. The enlarged lower part of the colony showing its abrasion and relation of the colony to the bed of glauconite enriched calcareous sandstone (arrow).

4. The fines up basal pebbly sandstone with small fragments of solitary (*S*) and colonial (*C*) rugose corals.

5. The overgrowth of wounded part of the colony by adjacent corallites.

6. The overturned, medium size, massive colony of rugose corals.

PLATE 18

The fifth set of coralliferous beds in the southern slope of Hyrnefjellet

1. Two colonies of different genera of rugose corals deposited so closely to each other as to form an seeming single colony in growth position. Note also the so called "stoppages of growth".
2. Arrangement of corallites in the middle part of the very large, massive colony of rugose corals.
3, 4. The close view on "stoppages of growth" of the colony illustrated on pl. 17:2 showing the diagenetic nature of these phenomena.
5. Fragments of two very large colonies of rugose corals resting in seemingly growth position. Both of them show "stoppages of growth".

PLATE 19

The fifth set of coralliferous beds in the southern slope of Hyrnefjellet

1. Lower part of the very large colony (compare pl. 18:5, right) with two complexes of corallites cut off from it (two left arrows) and other corallites pressed and crushed (right arrow) during deposition and compaction.
2. The gastropod shell located between two very large colonies.
3. The lowermost fragment of the very large colony showing mechanical destruction of its lower surface and the diagenetic origin of the so called "old surfaces of corallum".
4. *a* The largest found rugose coral colony (over 2·70 m in diameter) resting on its side. The ontogenetically youngest part of the colony is contoured white. Arrows indicate parts of the colony enlarged on figs. *b*, *c*.
   b, *c* Mechanical destructions of corallites and their obviously secondary direction towards the bottom.

PLATE 20

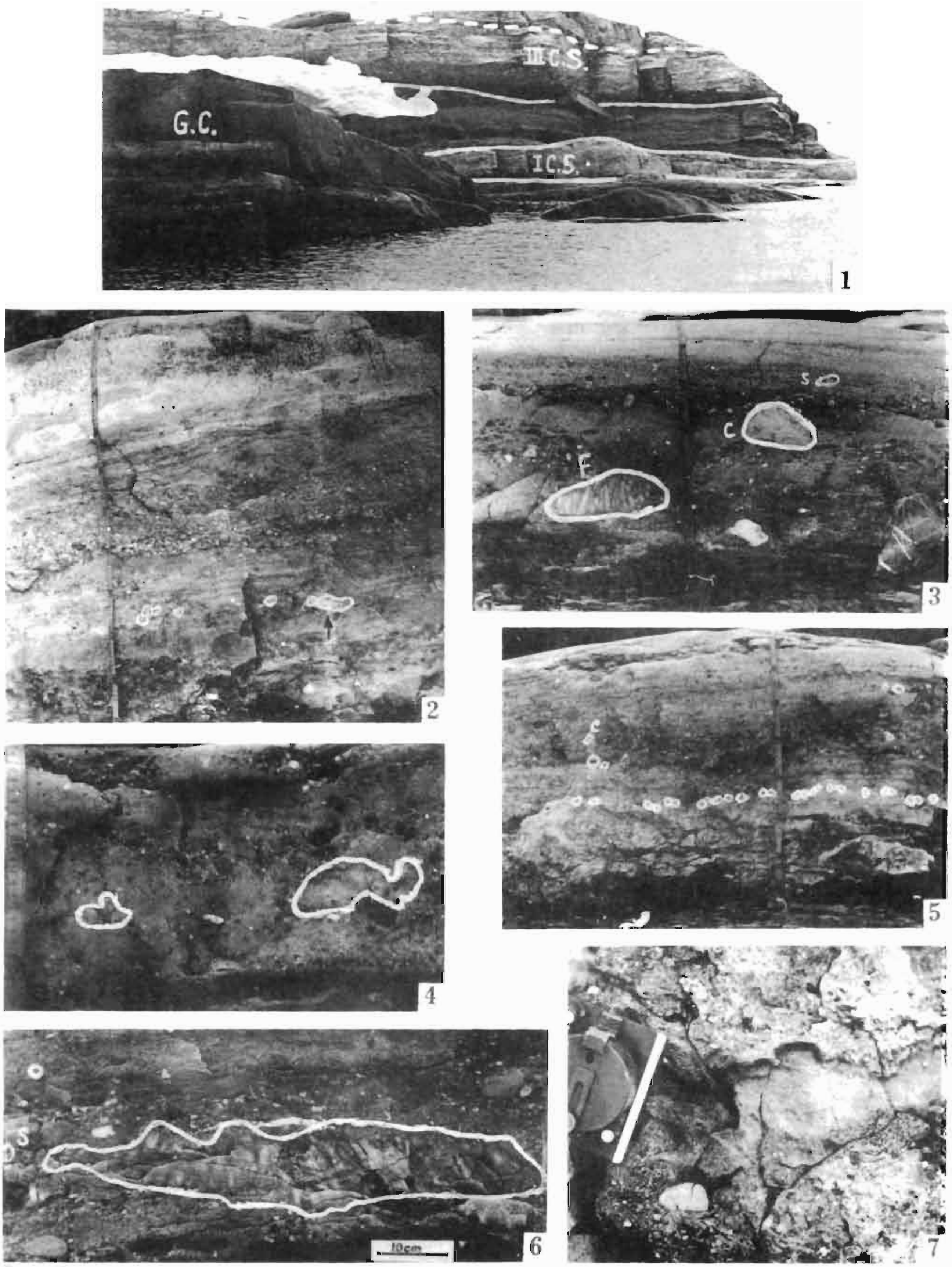
1. The northern slope of Kruseryggen. The overturned, massive colony of rugose corals in the middle part of the upper Treskelodden beds.
2. The 60 cm high colony of calcareous algae; locality as above.
3. The Krusebreen cirque. Symbols: *H. B.* Hyrnefjellet beds, *T. B.* Treskelodden beds + non-fossiliferous series (not divided), *K. S.* Kapp Starostin Formation, *T* Triassic.
4. The northern slope of Kruseryggen above Wibebreen. Symbols as above, and *U. C.* non-fossiliferous series. Note the presence of several local faults.

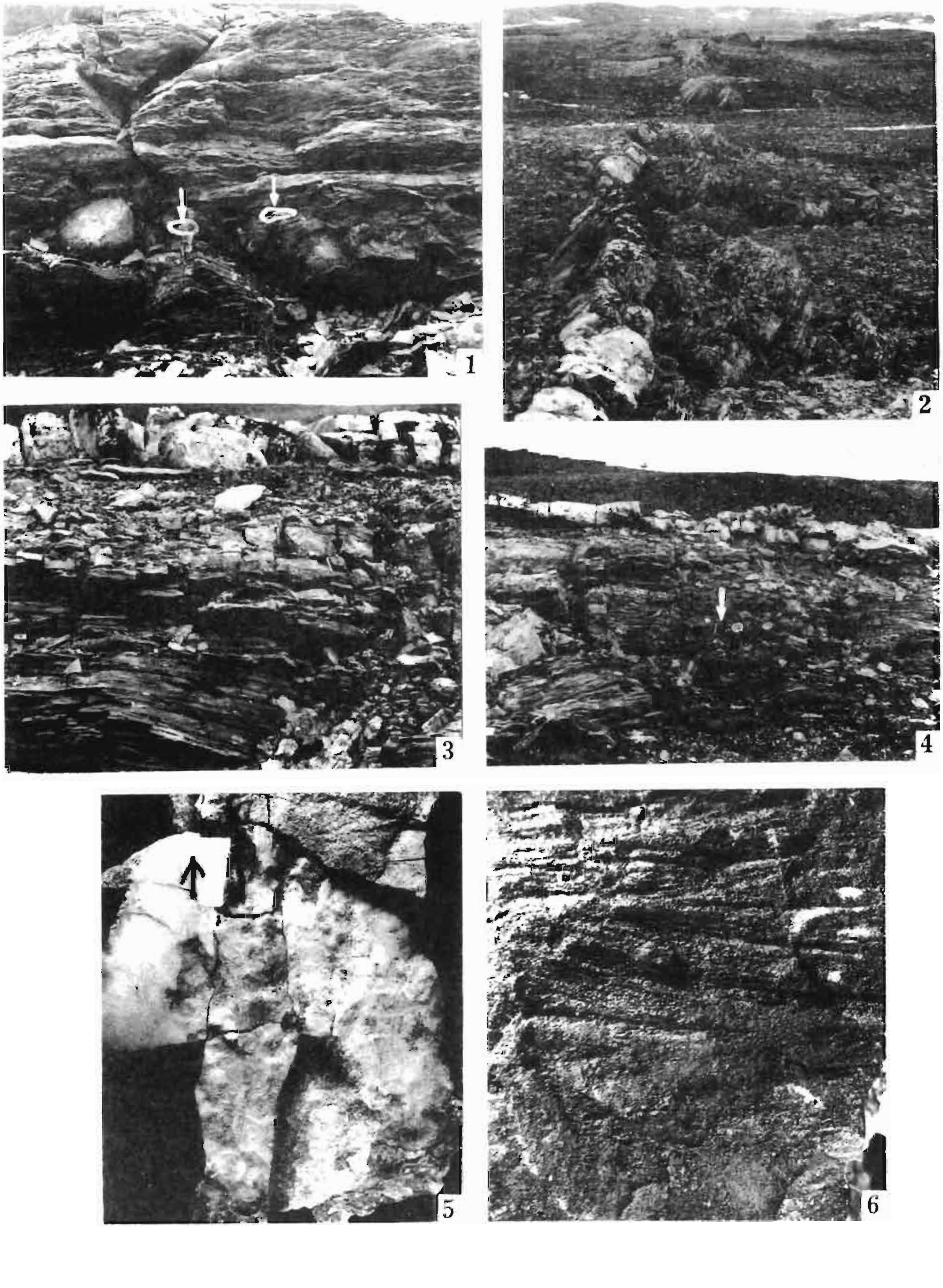
PLATE 21

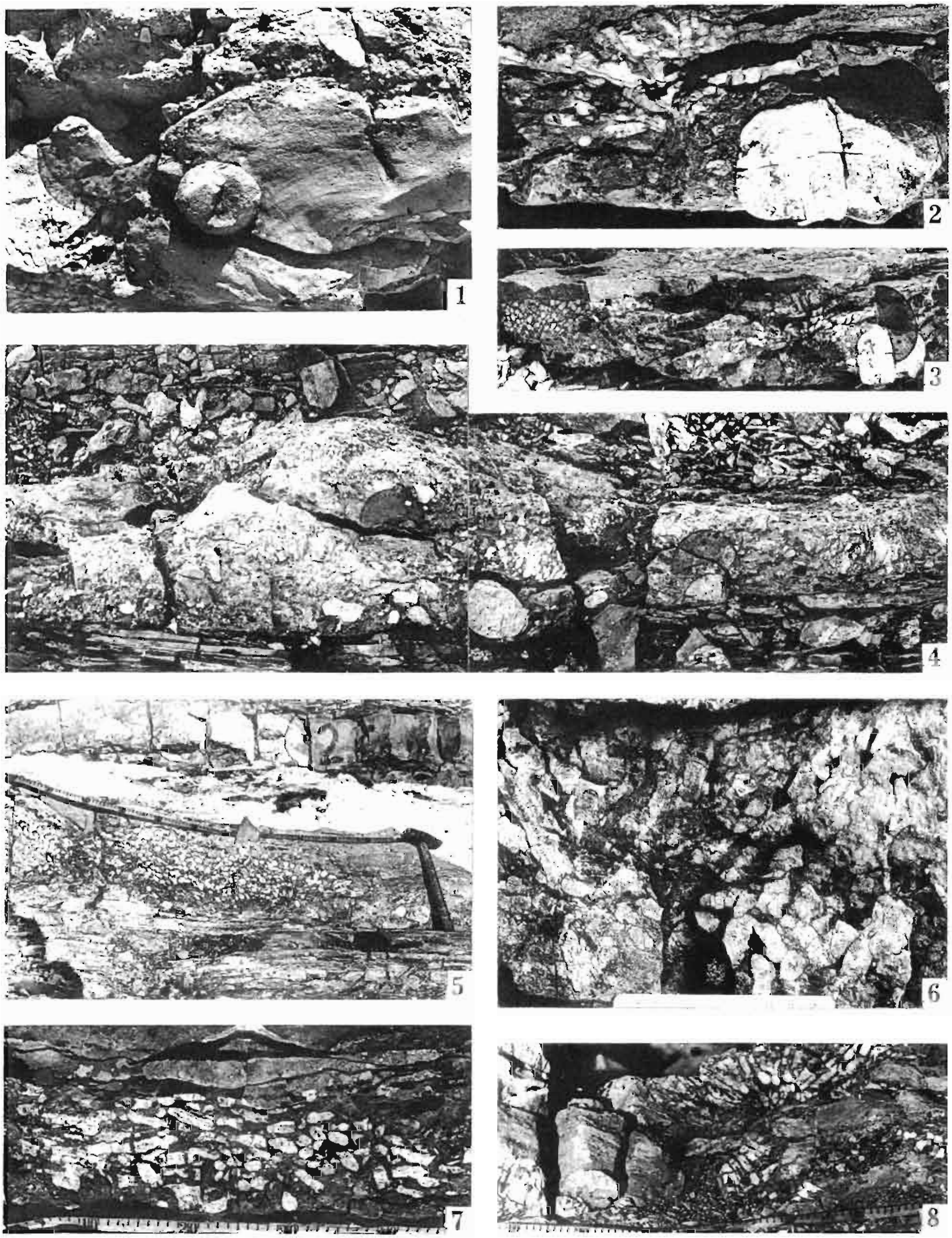
1, 2. Bioturbated sandstones in Section 2. 1*a*, 2*a* × 3, 1*b*, 2*b* × 20.
3. Corallite surfaces of *Protowentzelella* from the fifth set of coralliferous beds showing growth rings grouped in unequal bands, × 5.

PLATE 22

1. The fragment of corallite from the very large colony of the fifth set of coralliferous beds showing growth rings of the epitheca and growth lines of septa (obliquely oriented lines on the lower right side), × 10.
2. Fragments of two corallites of the largest found colony (compare pl. 19:4) showing growth rings grouped in unequal bands, × 10.
3. Another specimen of the *Protowentzelella* colony illustrated on pl. 21:3, showing growth rings grouped in unequal bands, × 5.
4. Section 3. Quartzitic sandstone of the upper part of the Gray Conglomerate "Horizon", × 20.


III C.S.
G.C.
I C.S.
1
S
C
F
3
2
5
4
10cm
6
7

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7
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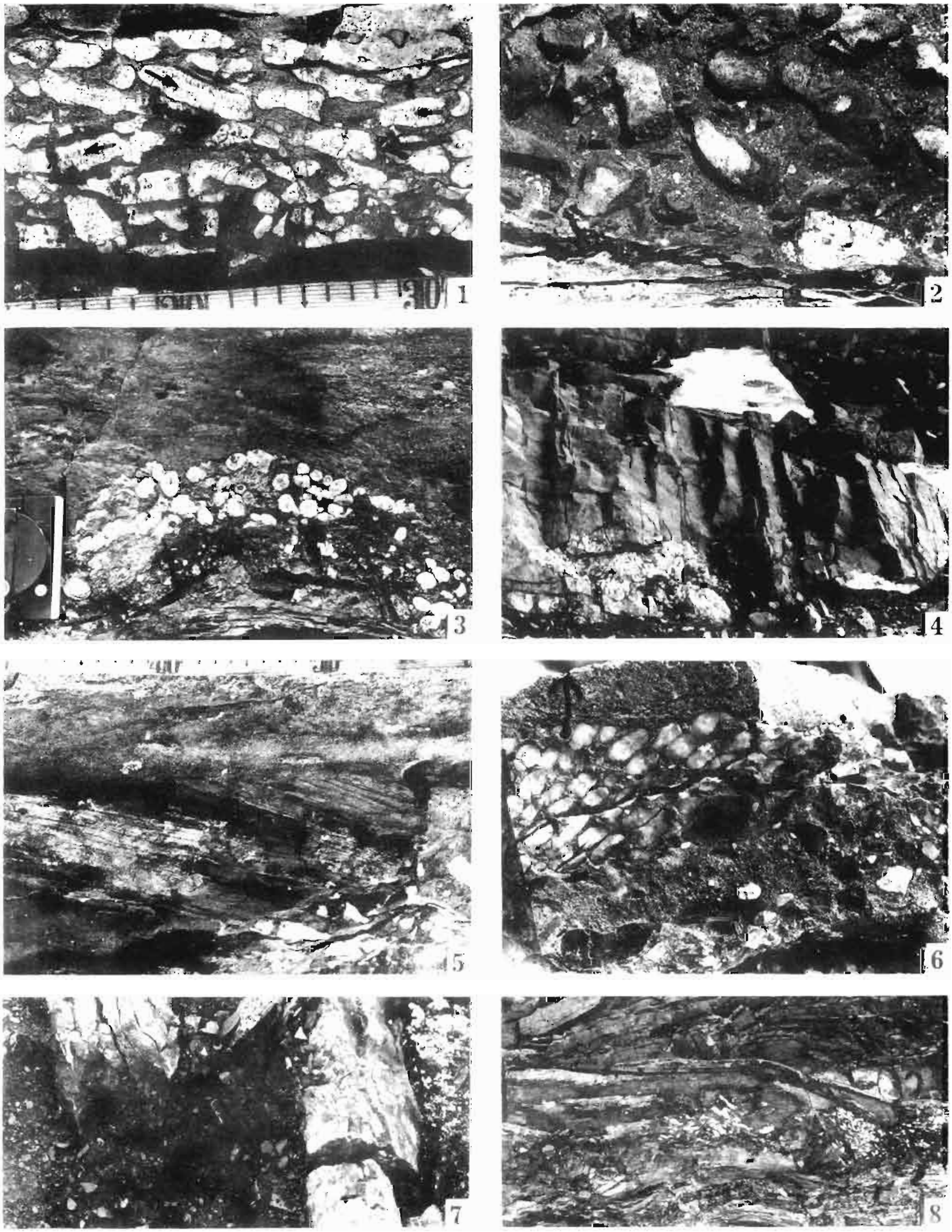

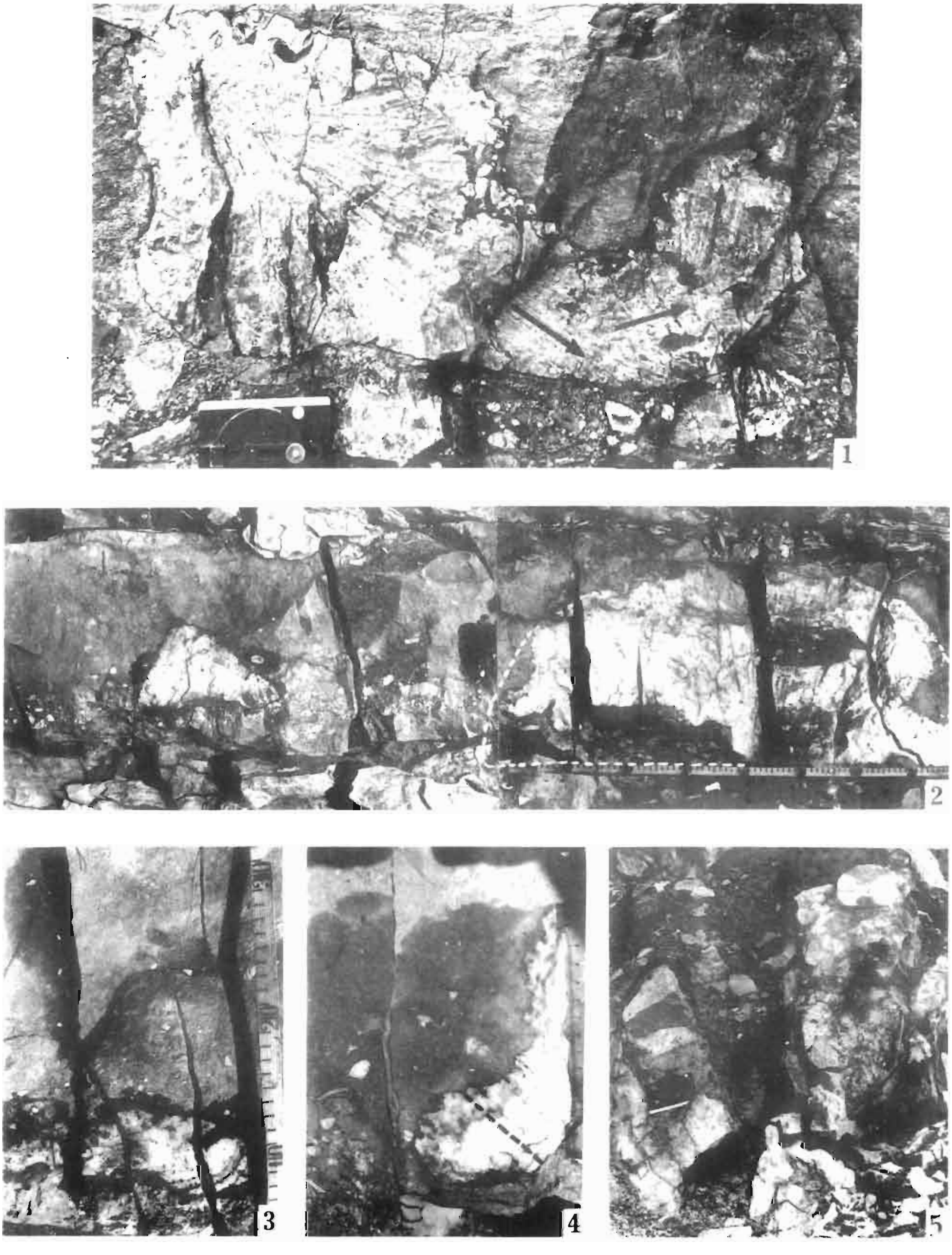
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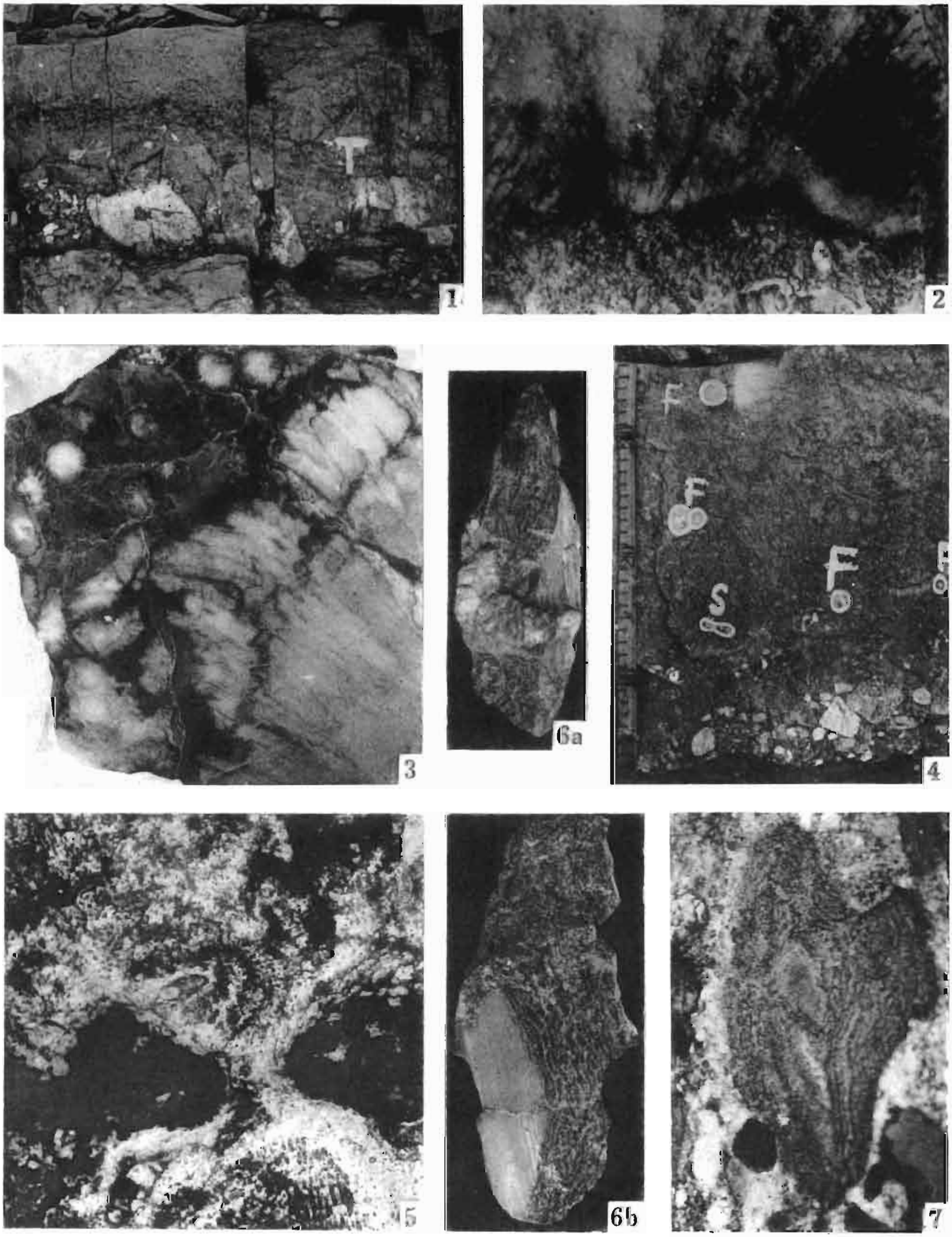
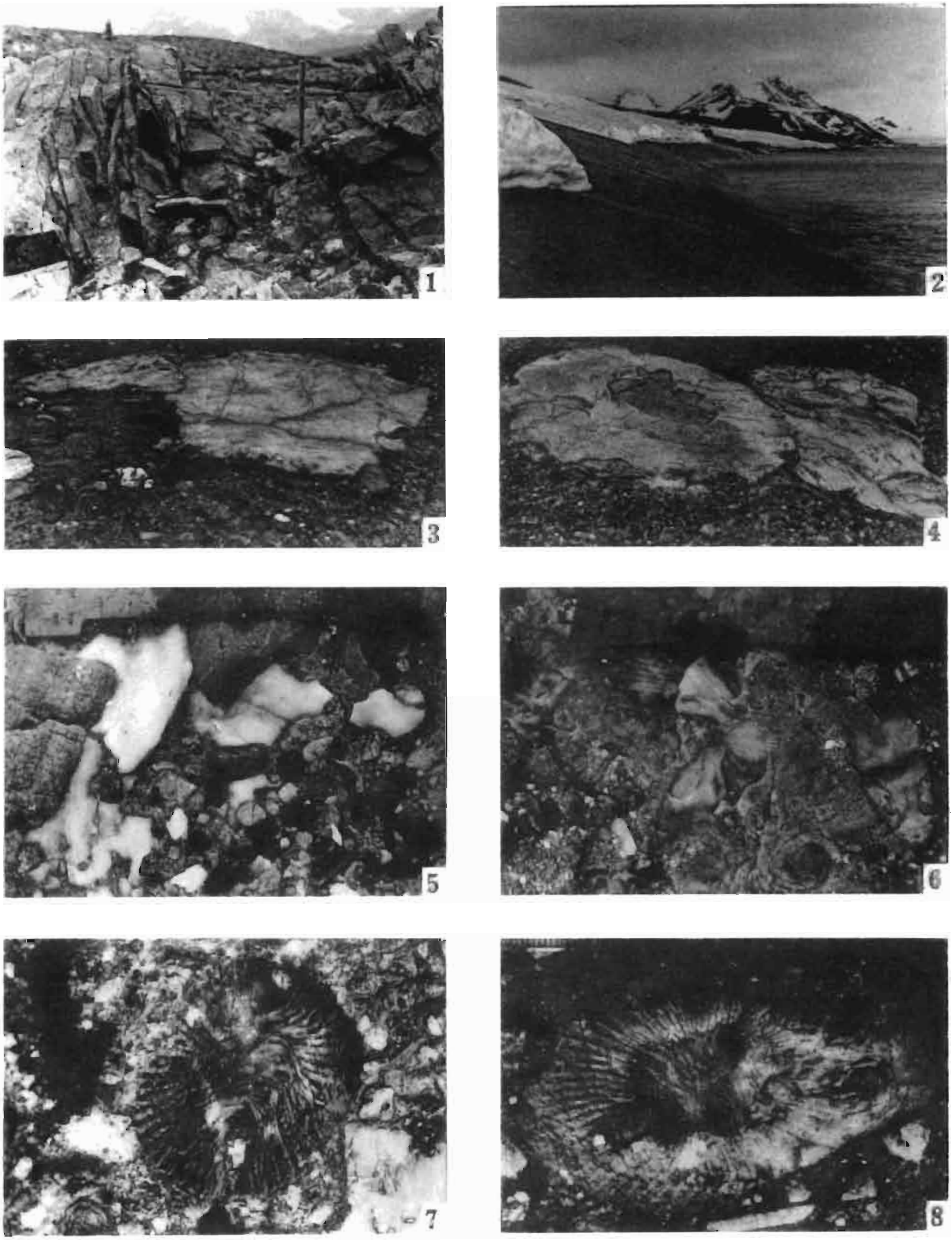
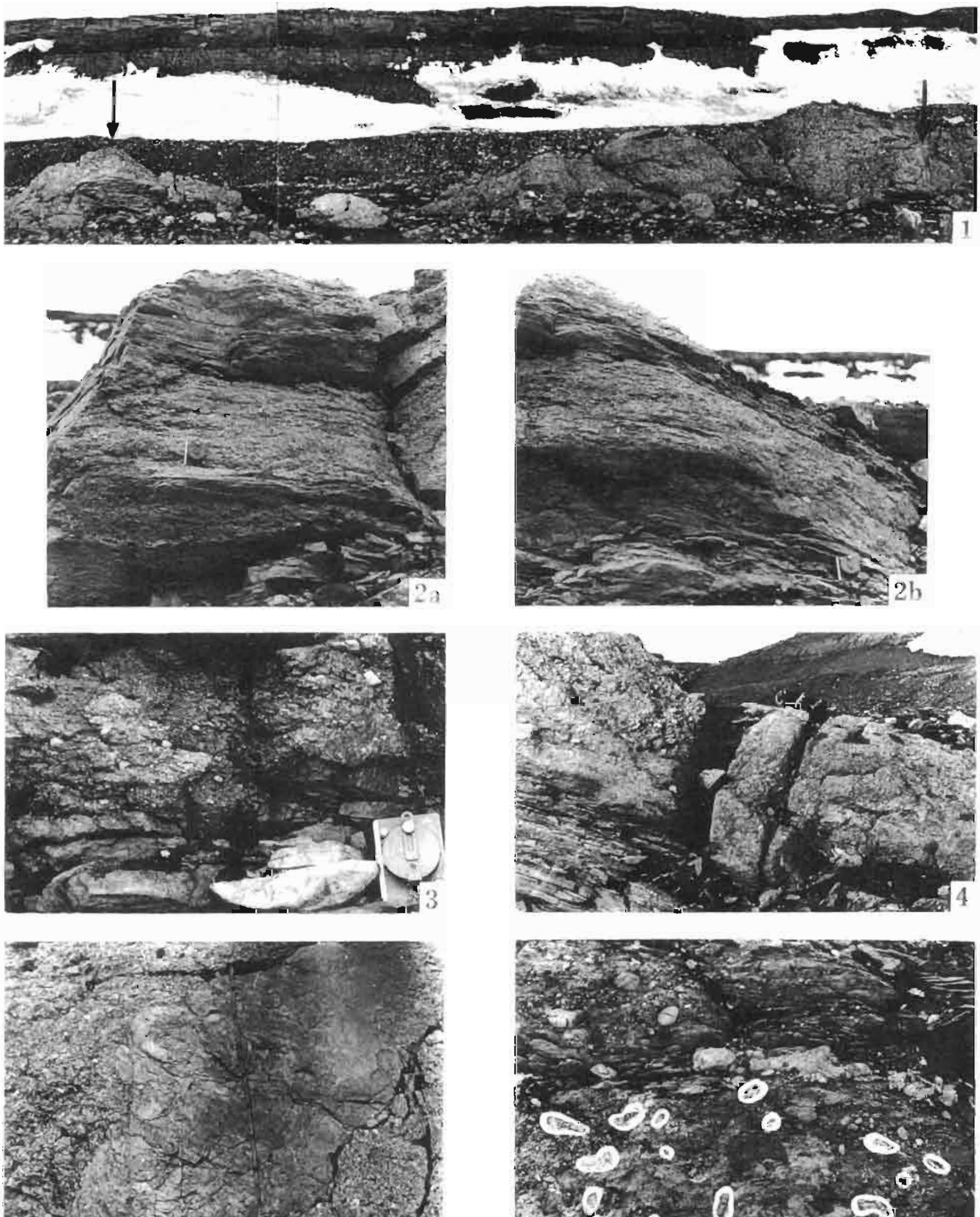
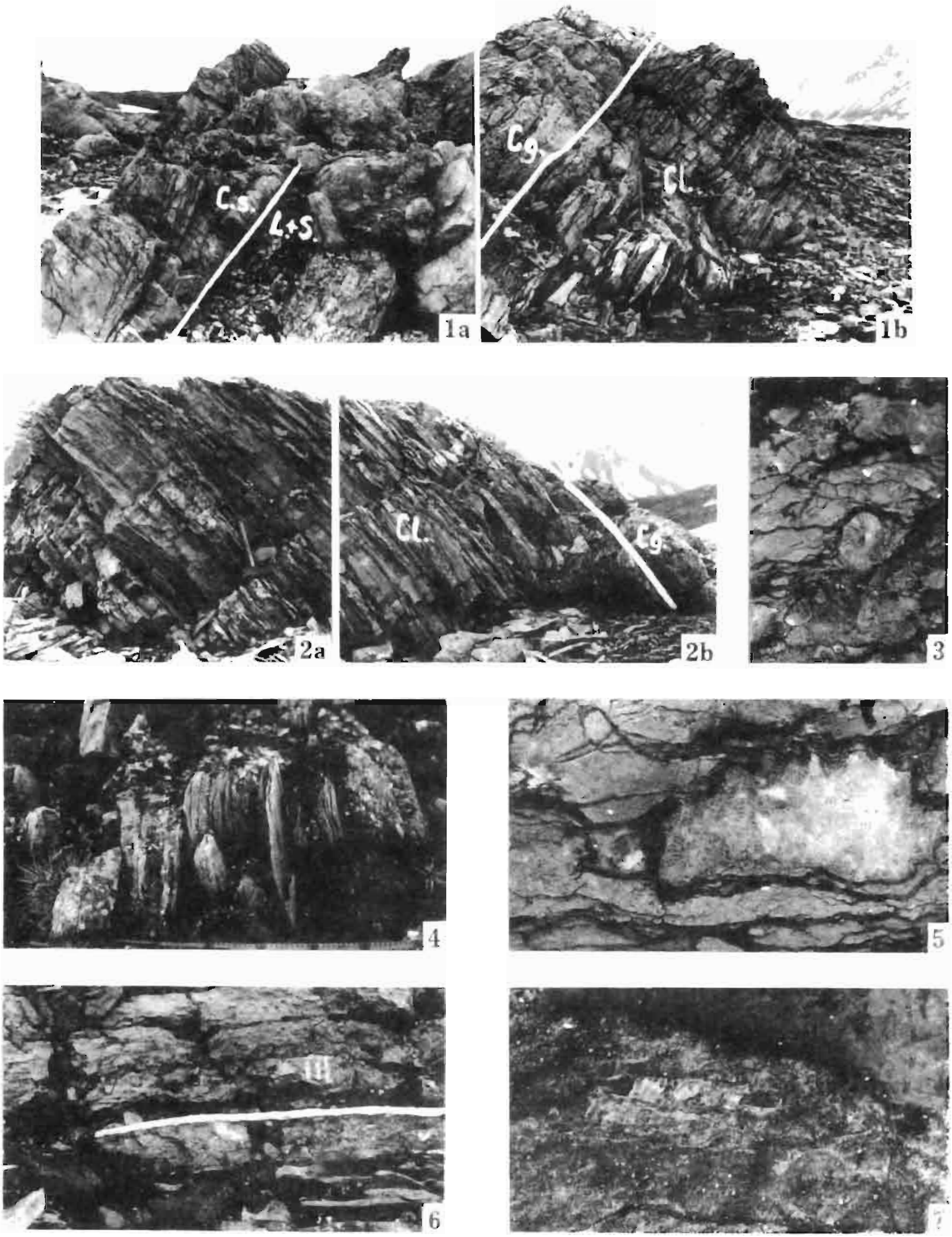
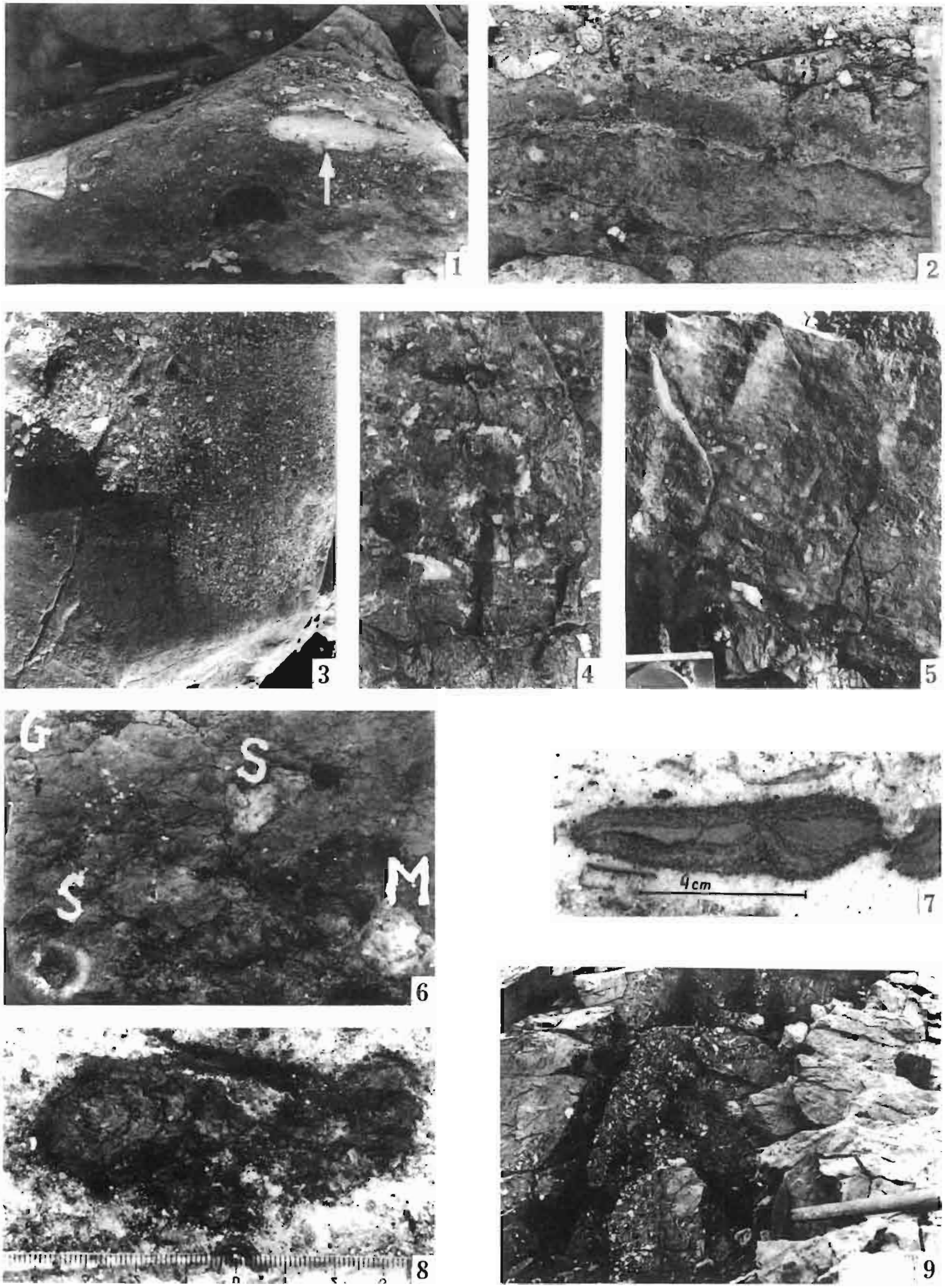
5


1
2
F
F
F
S
3
6a
4
5
6b
7






C.s.
L+S.
1a
Cg.
Cl.
1b
2a
Cl.
Cg
2b
3
4
5
6
7



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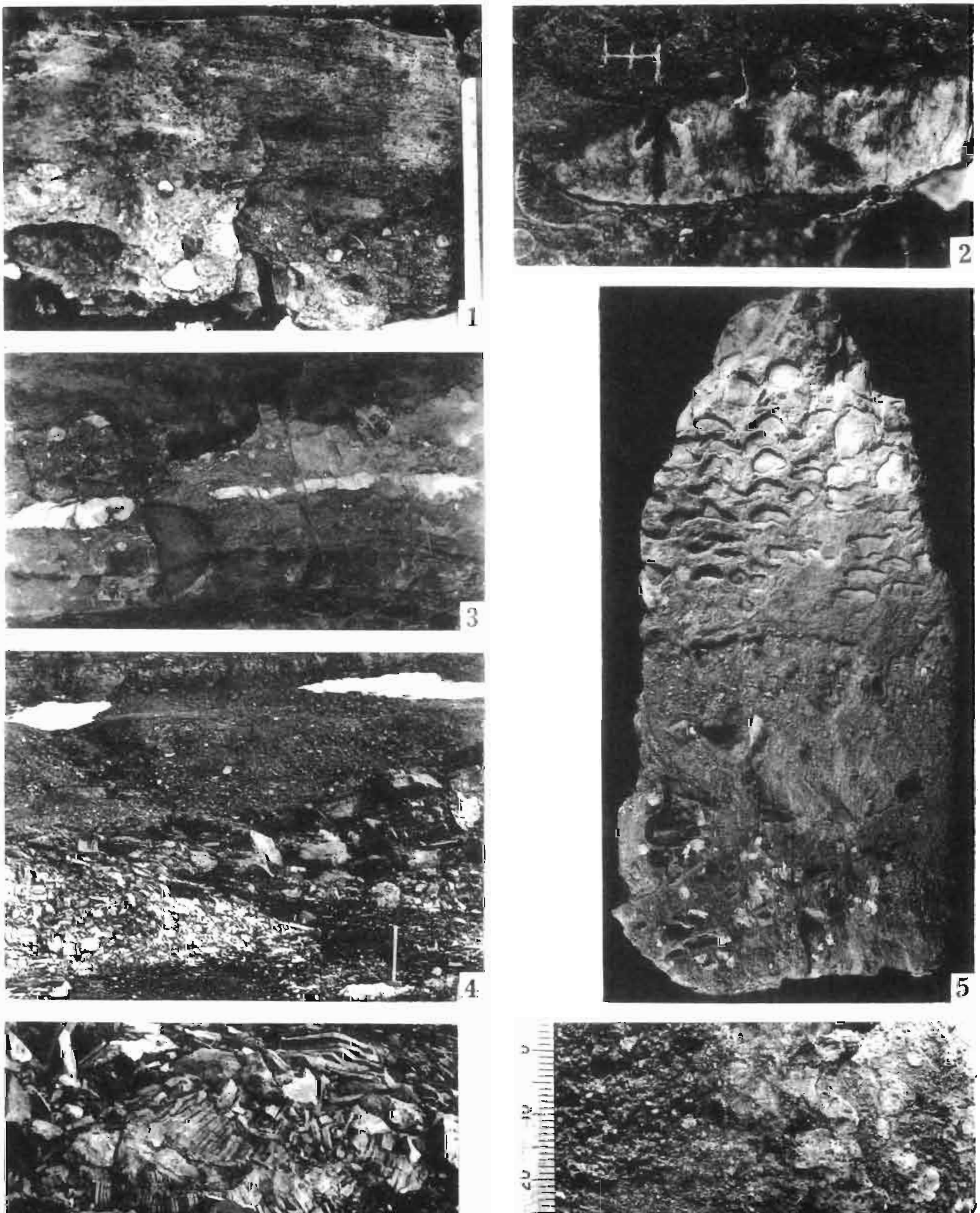


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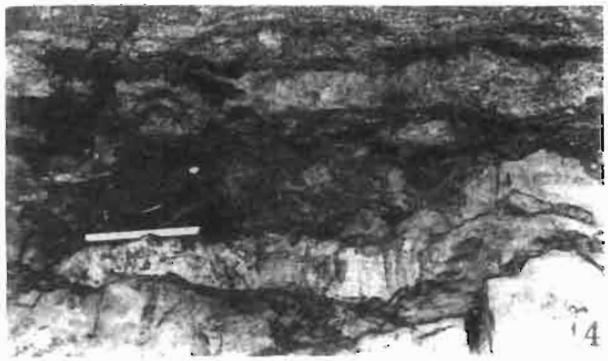
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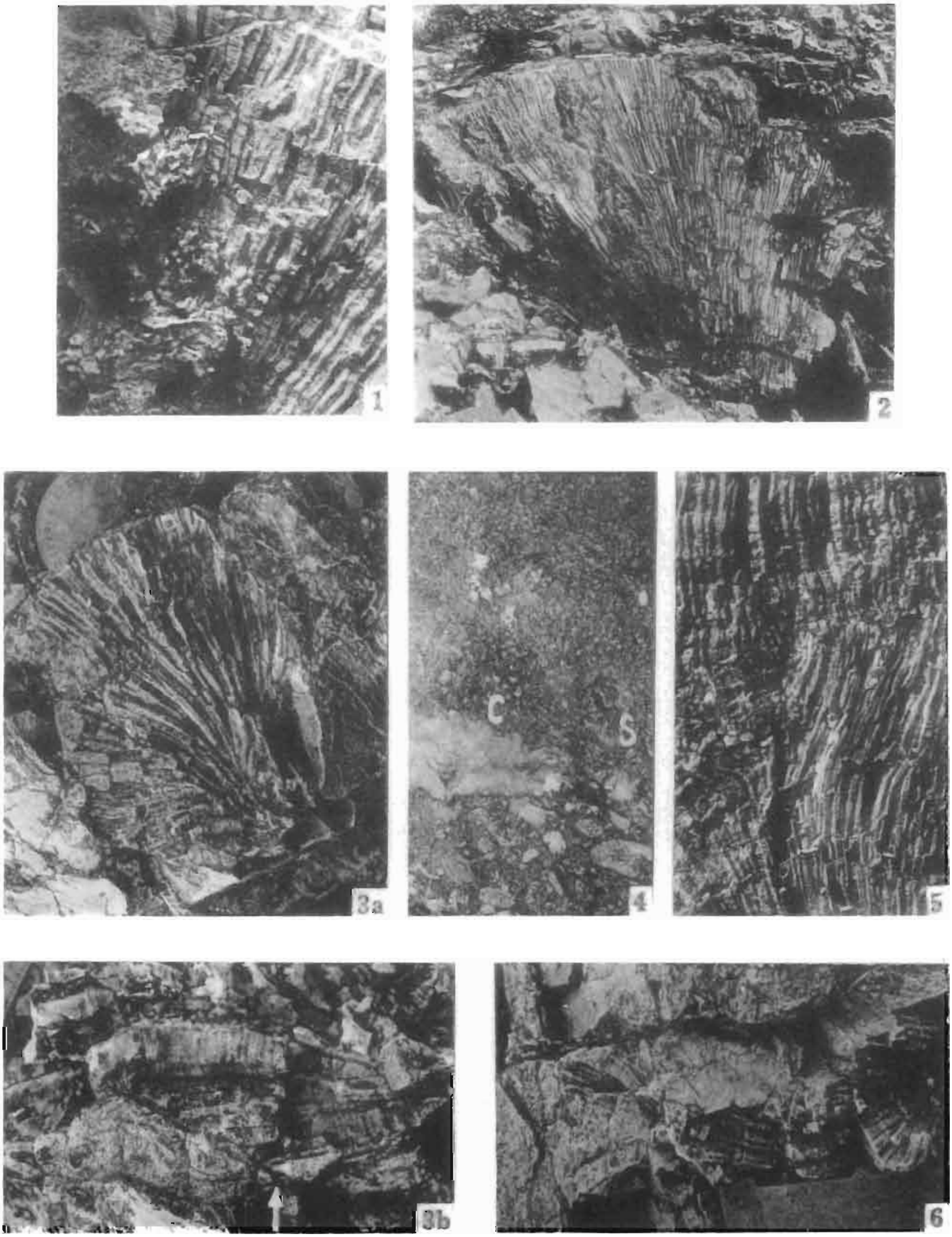
5


6


7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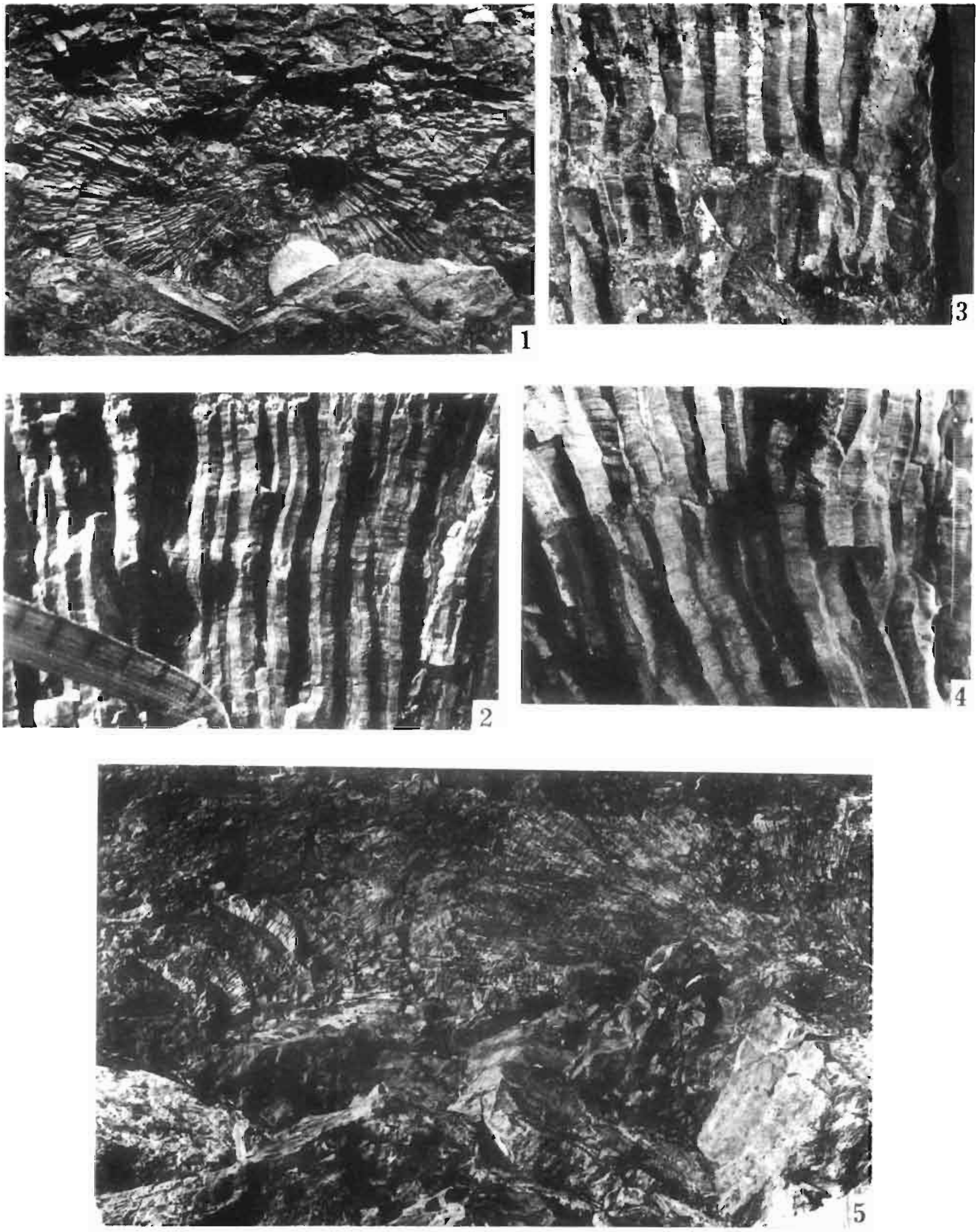
2
3a
C
S
4
5
3b
6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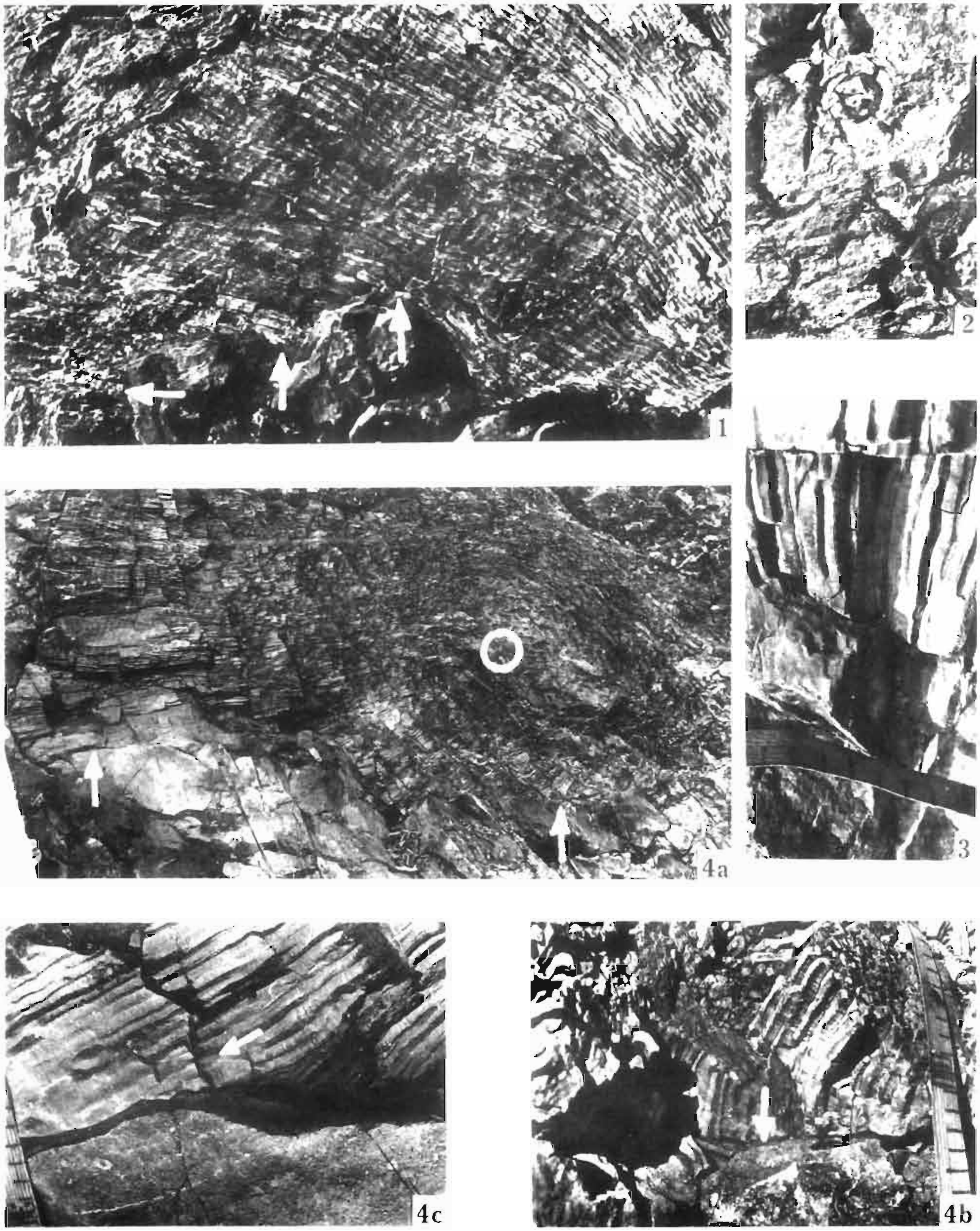
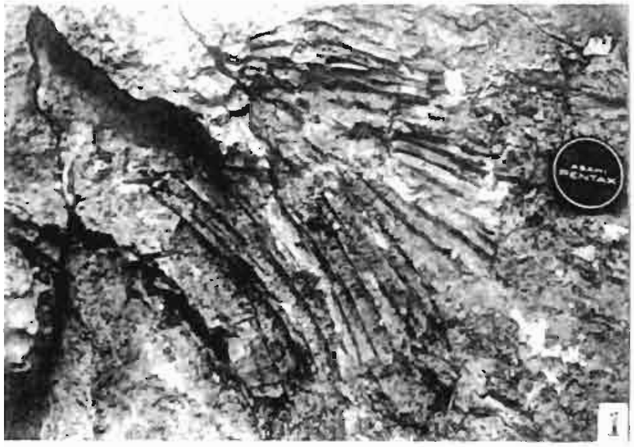
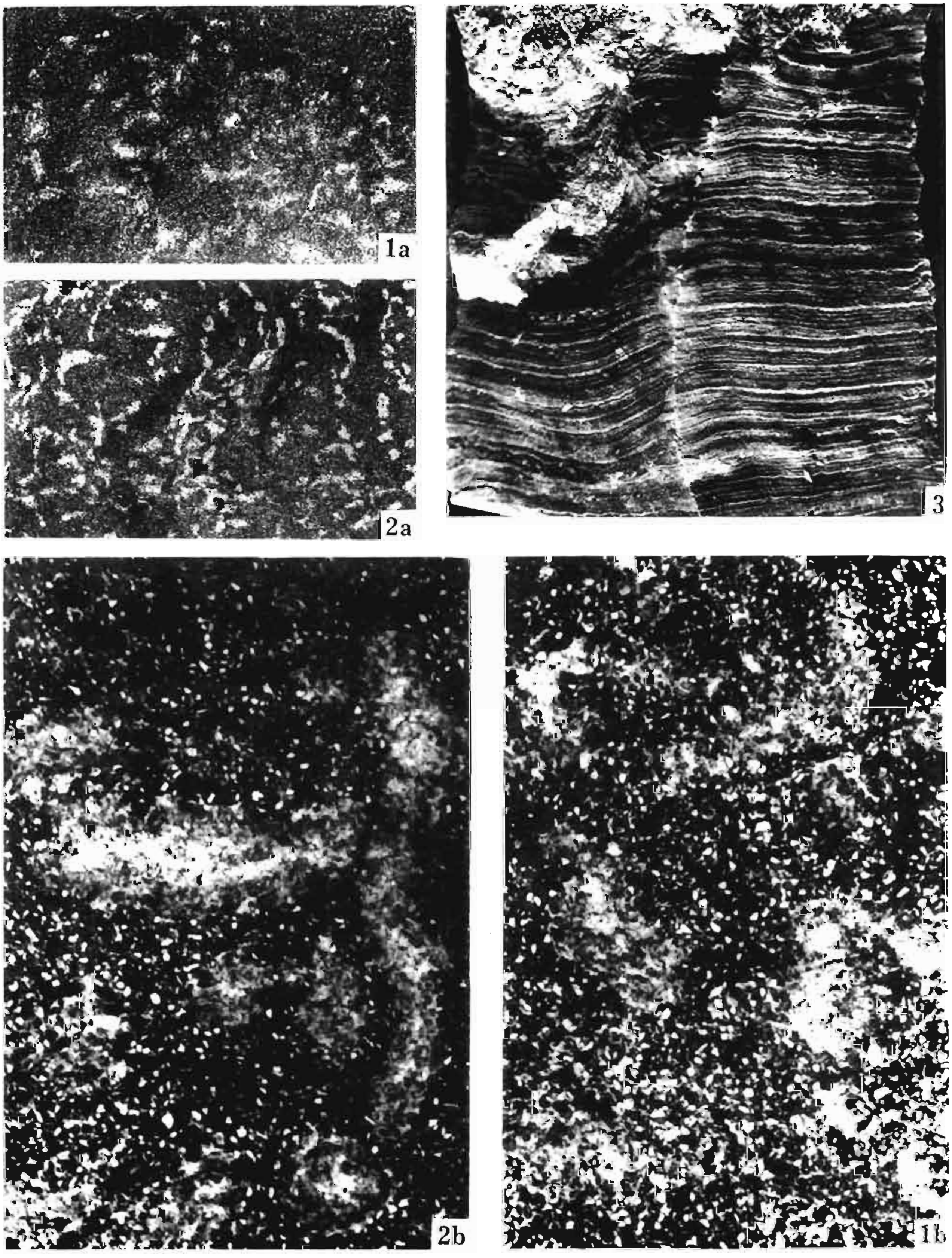


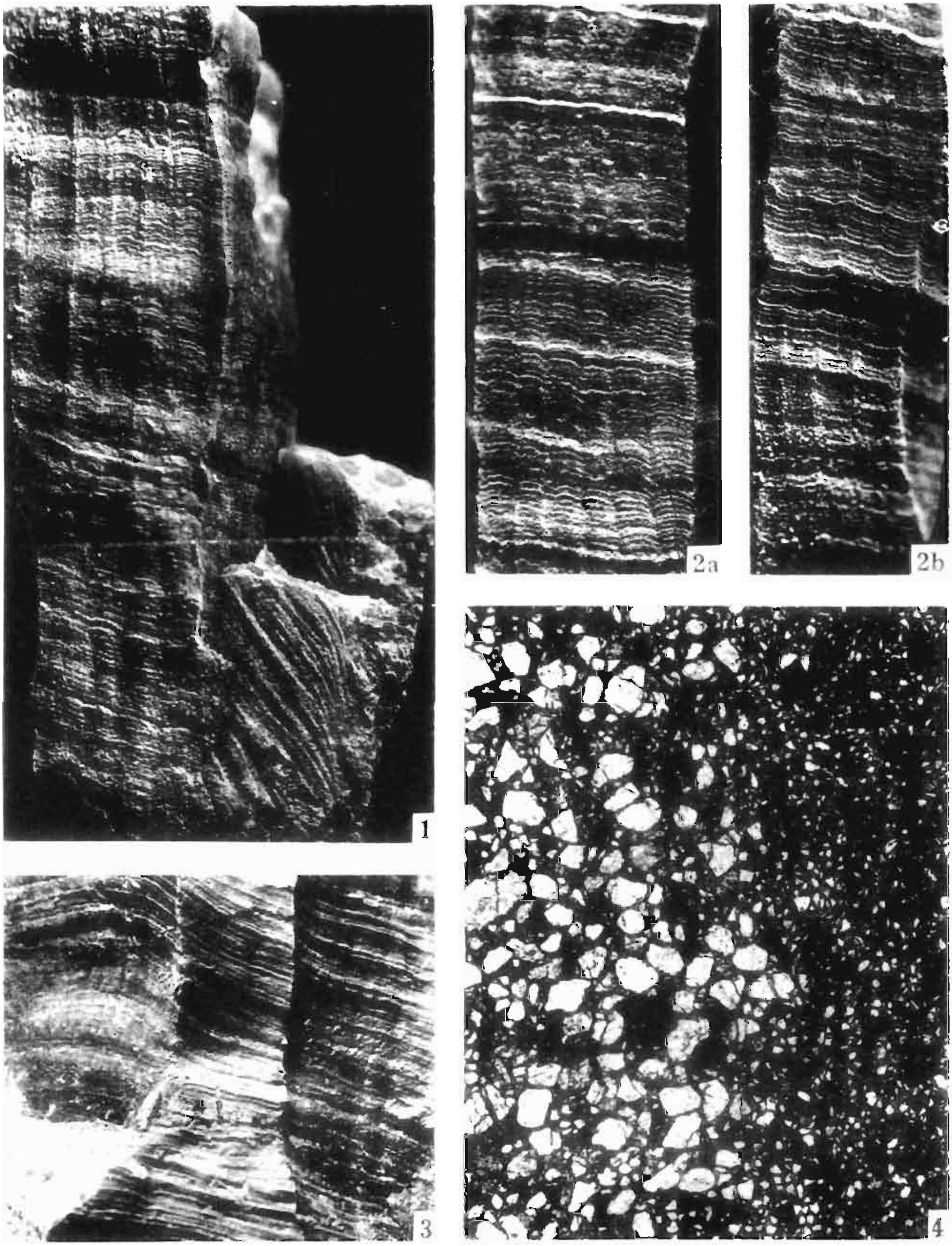

1


2


T.B.
H.B
3


T.
U.C
T.B
H.B.
4


1a
2a
3
2b
1b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2b
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4