GUIDE TO FAKSE LIMESTONE QUARRY

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The quarry is situated immediately to the east of the small town of Fakse in southern Sjælland, about 20 km from Stevns Klint and about 65 km SSW of Copenhagen. Earlier spellings of Fakse vary considerably. Limestone from quarries at Fakse was used for building churches in Mediaeval times and later on in secular buildings and for agricultural and other purposes.

The earliest mention of fossils from the limestone are from the second half of the 18th century. The locality was effectively brought to the attention of geologists by the papers of Steffens and Bedemar (see Garboe, 1959) and especially by Forchhammer (1825).

There were originally a number of small quarries in the hill Fakse Bakke, almost all traces of which have now been obliterated by the present extensive workings. Before he established the Danian Stage in 1847, Desor visited one or more of these small quarries and also considered Stevns Klint; Grönwall (1899) and Nielsen (1909) later placed the quarry within a subdivided Danian stratigraphy and Rosenkrantz (1938) described a borehole on Fakse Bakke that penetrated the underlying lower Danian and entered the Maastrichtian chalk. Rosenkrantz & Rasmussen (1960) gave a general account of the quarry and many of the lithofacies it exposes, and quarry sections have been published by Asgaard (1968) and Cheetham (1971). A description of the quarry was published in Danish by Floris (1971).

Today the large quarry covers 1 km^2 and is about 50 m deep. The present quarrying methods of blasting and harrowing are not favourable to the production of clean sections, and exposures *in situ* are limited. Large quantities of highly fossiliferous bryozoan limestone and coral limestone are available on the quarry floor, however, which yield extensive faunas. All the rocks exposed are of *Tylocidaris bruennichi* Zone, middle Danian (see Asgaard, this volume). All samples so far studied from the quarry and from a boring belong to nannoplankton zone NP 3 (Perch-Nielsen, this volume). The absence of typical *Prinsius martini* and *Neochiastozygus* also in a sample from the now totally worked out 'Næsekalk' chalk facies, which furnished the best preserved coccoliths at Fakse, indicates that only the lower part of NP 3 is represented at Fakse. *Chiasmolithus danicus* is well developed and the Prinsiaceae are dominated by *Prinsius rosenkrantzi*.

In earlier days it was seen that the bryozoan limestone largely occurred as a complex of mounds, intercalated by banks or lenses of coral limestone. This relationship can only locally be seen today (Fig. 2). In most places the material appears to be more or less autochthonous, but at some localities within the pit (Fig. 1, D,F), steep, intraformational submarine talus slopes of abraded intraclastic debris occur (Asgaard, 1968, Fig. 3).

The two major facies of limestone occur in a wide range of subfacies, owing in part to local depositional differences and in part to local variation in diagenesis.

Bryozoan limestone

This facies ranges from a mud-supported, chalk-like, uncemented rock containing sparse skeletal grains, through wackestones and packstones, variously cemented, and dominated by bryozoan skeletons, to grainstones with little or no micrite matrix. The latter commonly fills thalassinoid burrows in coral limestone, thereby presenting a spectacular and characteristic facies of Fakse bryozoan limestone (Fig.3).

Locally the bryozoan limestone contains greyish or brownish flint, developed as thin sheets or layers that follow and emphasize bedding. Ghosts of the replaced bryozoans remain visible within the silicified sediment to produce a very characteristic flint facies. In a few places dolomitization has produced well-developed cannon-ball concretions, commonly in association with flint layers.

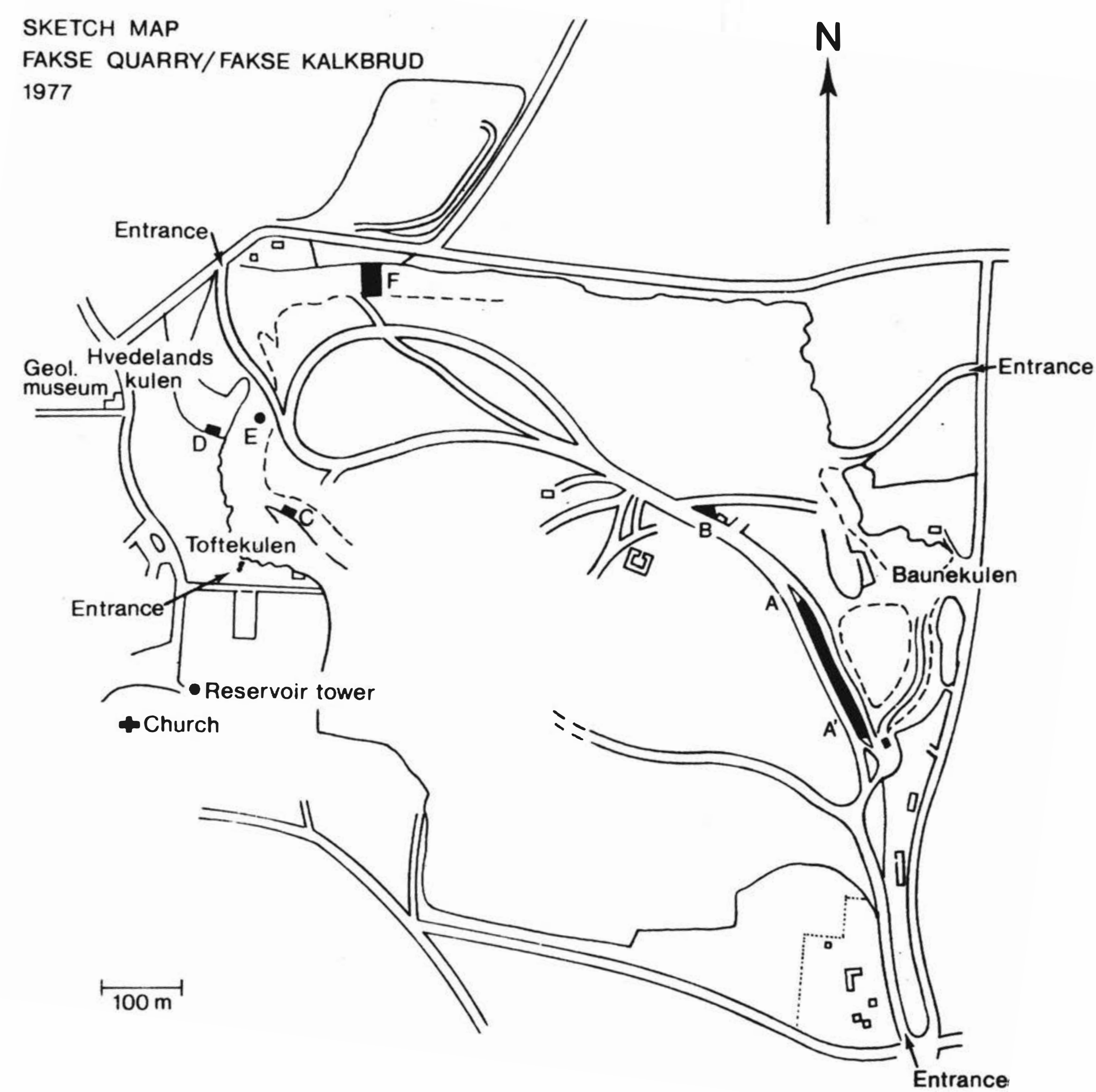
Coral limestone

The coral limestone facies is largely unbedded, flintless, and occurs as much larger banks or lenses than at Limhamn (Holland & Gabrielson, this volume). The rock has arisen through the extensive growth of coral, dominated by three slenderly branching scleratinian species, *Dendrophyllia candelabrum*, *Faksephyllia faxoensis* and *Oculina becki*. Micrite has filled the interstices within this coral frame to varying degrees, and sizeable regions to small patches have remained mud-free (Fig. 4). The corals are clearly autochthonous; however, they are never found actually in life position (Floris, 1967), but always show various degrees of tilting and fragmentation.

The main sub-lithofacies of coral limestone to be found at Fakse are: (1) uncemented chalk containing calcitized corals; (2) the same, but thoroughly cemented; (3) the same, thoroughly cemented micrite, but with the corals dissolved to leave a network of branching, empty voids ('piped limestone'); (4) corals standing free, without matrix except within the skeleton between the septa, the aragonite calcitized and normally overgrown by calcite cement crusts (Fig. 6). Among the more or less complete corals (Fig. 5), debris of corals is also common, probably largely the result of *in situ* fragmentation. In many cases the coral skeleton was riddled by boring sponges, which must have promoted such fragmentation.

Fig. 1. Sketch map of Fakse Quarry, 1977. Owing to the rate of exploitation, individual exposures are normally only temporary in nature. However, it is hope that the following localities within the quarry will be available. A-A'. Section described by P.C.Rasmussen, herein (Fig. 2). B. Bryozoan mound. Irregular flints indicate burrows in the biomicrite. C. Oyster-conglomerate with matrix of bryozoan fragments, coral fragments, and small amounts of micrite (as partial fillings of the oyster shells). Transport probably over a very limited distance. D. Conglomerate of pebbles of local coral limestone ('piped limestone') in a matrix of bryozoan fragments. At least some of the pebbles were rolled after dissolution of the coral skeletons. E. Dolomite concretions; bulbous masses of dolomite or of dolomite crystals in apparently concretionary calcite. Dolomite is rare in Fakse Quarry and has been found only in the bryozoan limestone. F. A coral bank core overlies bedded coral limestone and a large unit of bryozoan limestone. The boundary between the two latter is locally subvertical, sharp and uneven. The unit of bryozoan limestone contains large rounded boulders (20 - 30 cm in diameter) of 'piped limestone'. The bedded coral limestone probably represents the flank of a coral bank and consists of thin beds of 'piped limestone', of coral fragments, and of coarse bryozoan fragments. In places it is conglomeratic, with pebbles of 'piped limestone' in a matrix of bryozoan fragments (at least some of the pebbles were deposited, while the aragonitic skeletons were still present). Some blocks of bryozoan limestone have only been slightly displaced.

In the lower part of the bedded complex are 'dykes' of bryozoan limestone with sharply outlined lumps of bedded coral limestone and diffusely outlined lumps of 'piped limestone'. The 'dykes' may be interpreted as fillings of canals, which had been eroded in a bank slope.


SKETCH MAP
FAKSE QUARRY/FAKSE KALKBRUD
1977
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Entrance
F
Geol. museum
Hvedelands kulen
Entrance
D
E
C
B
Toftekulen
Baunekulen
Entrance
A
Reservoir tower
Church
A'
100 m
Entrance

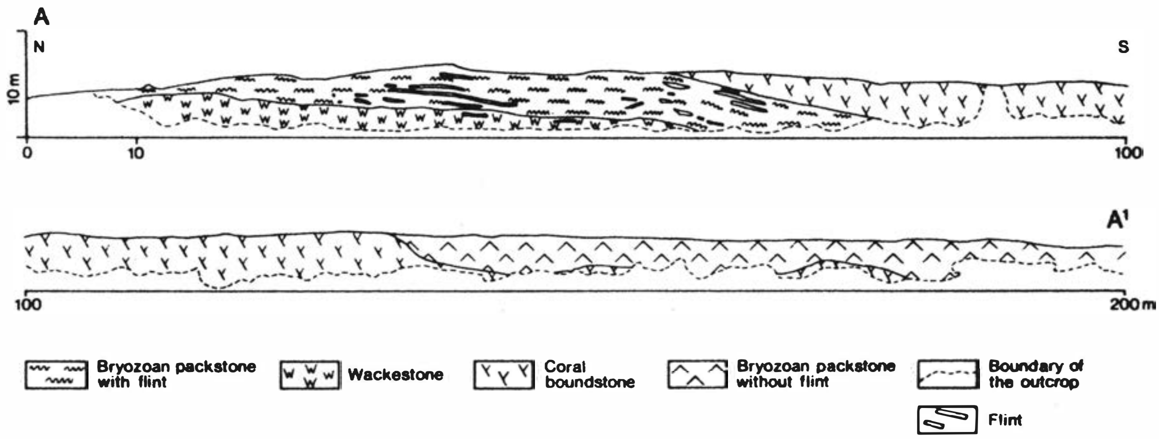


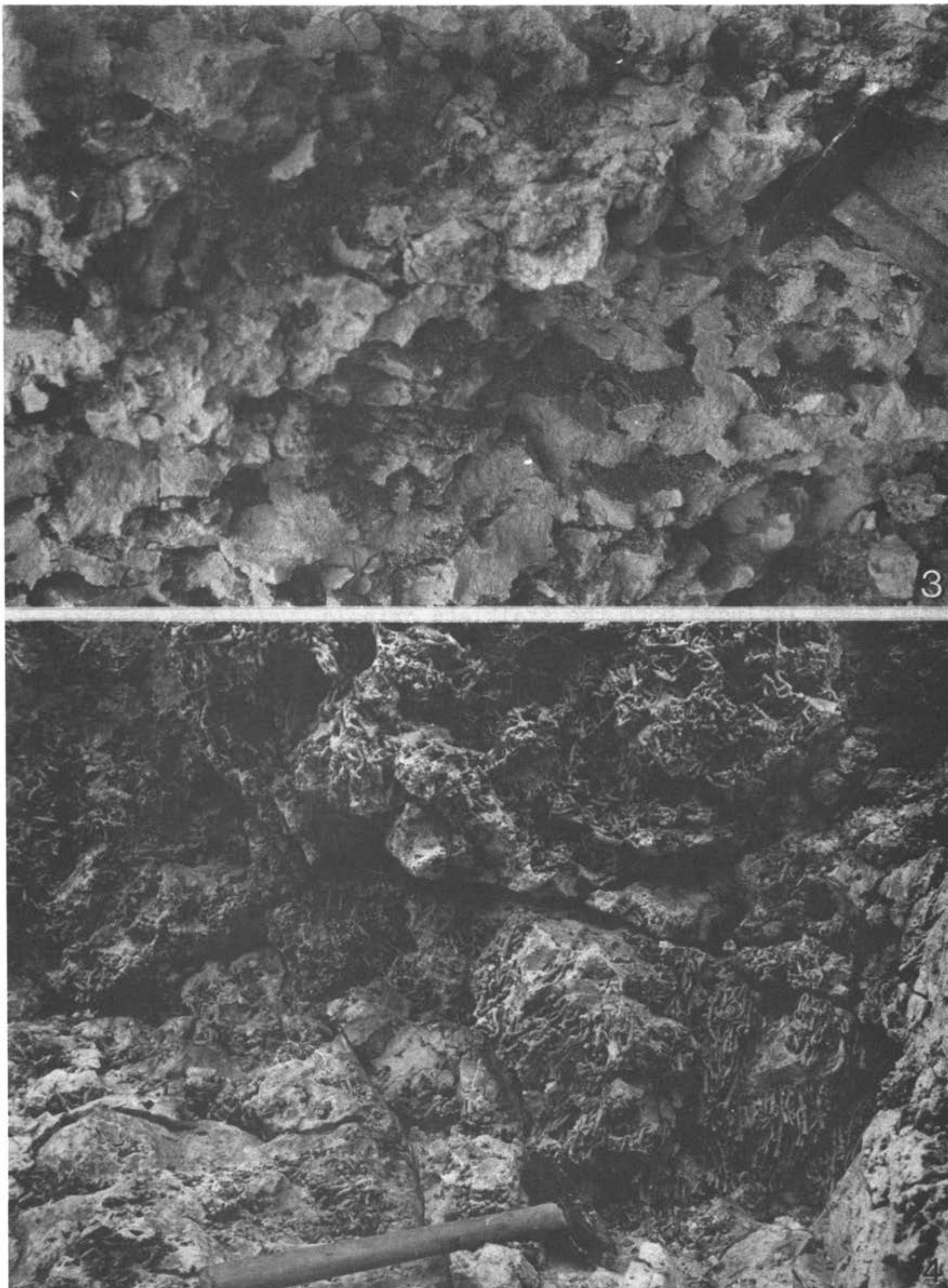
Fig. 2. Section A-A' (Fig. 1), described by P. C. Rasmussen in the text.

In contrast, skeleton debris has also been observed on 40^{o}-50^{o} slopes that had a topographic expression of over 20 m. These slopes carry material transported from the tops of densely populated coral banks. In contrast to the unbedded cores of the coral mounds, these talus slopes and mound flanks represent a bedded subfacies of coral limestone. In both bedded and unbedded varieties of coral limestone, the matrix fill between the skeletons can be either complete or incomplete, leading to the full range of rock facies described above, as seen at loc. F (Fig. 1).

Some of the cement of the coral limestone was very early, as is demonstrated by the presence of intraformational conglomerates of limestone blocks and fragments (locs D and F), in a bryozoan limestone matrix. Normally the coral skeletons are cut off flush with the matrix and are now empty voids, into which the bryozoan limestone sediment has not penetrated. Thus it is clear that aragonite dissolution post-dated lithification, break-up, transport and redeposition of the limestone fragments.

Fig. 3. Top of a coral limestone mound, penetrated by a network of voids, largely representing burrow systems, and filled with an open bryozoan grainstone.

Fig. 4. Core of coral limestone mound. Note the extensive areas and small patches within the coral frame that escaped mud filling. R.G. Bromley, photos.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Not unexpectedly, the faunas of the bryozoan limestone and coral limestone are widely different (e.g. Asgaard, 1968; Floris, this volume), owing to the extreme difference in substrate offered to the benthic community by the two sediments. The bryozoan limestone as a substrate is discussed by Håkansson & Thomsen, this volume, and Heinberg, this volume.

The coral limestone presented a very large area of hard substrate, well aerated and standing well proud of the depositional interface. Besides the remains of corals the sediment that accumulated on the coral banks was a mud. The fauna is thus a mixture of hard substrate epibenthos and mud-dwelling endobenthos, dominated by the former. Thus, a number of species of brachyuran crab and several cirripeds are common, several epibyssate bivalves and a large fauna of gastropods occur, together with diverse brachiopods adapted to several different niches among the branching corals (Asgaard, 1968), while boring sponges and microphytes (?) penetrated the skeletons.

The soft mud was burrowed by crustaceans, probably by nephropids, of which both skeletons and gastroliths have been recognized (Rasmussen, 1973). The mud was subsequently lithified, allowing an encrusting fauna to colonize the burrow walls and ceilings of larger cavities. This cryptic fauna included both the stalkless crinoid *Cyathidium holopus* and several sclerosponges (Rasmussen, 1973). Finally, the burrows were normally filled with bryozoan sand that filtered into the cavity system when the coral bank was buried by bryozoan limestone sediment (Fig. 3).

The coral limestone is particularly rich in well preserved fossils. Aragonitic forms are preserved as empty voids. Typical examples of the fauna are illustrated in Fig. 7.

The presence of light-dependant organisms (*Heliopora incrustans* and *Millepora parva*), together with the cryptic habit of light-shy forms (*Cyathidium holopus* and sclerosponges) demonstrates that the coral growth took place within the photic zone (Floris, 1962, 1971; Rasmussen, 1973). According to Floris (1975) the water depth probably averaged about 50 m.

Fig. 5. Core of a coral limestone mound, showing the unbroken nature of the corals.

Fig. 6. Close-up of part of Fig. 5, showing an area of coral thicket largely free of matrix. The corals are mainly calcitized and bear a thin epitaxial fringe of cement that partly obscures the encrusting fauna on the coral surfaces. Coin 2.5 cm. R. G. Bromley, photos.


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A special feature of Fakse Quarry is the close proximity of a great variety of carbonate rocks. We append here, therefore, a description of a section (Fig. 2, A-A' in Fig. 1) by P. C. Rasmussen. Four main rock types are demonstrated in the section:

(1) Bryozoan packstone with flint (Fig. 8) forms a bryozoan biomicrite mound. It is a weakly lithified rock with sheets and nodules of flint, depicting the bedding planes of the mound. The rock has a weak lamination and is partly bioturbated; e.g. in the upper, lithified part of the mound some *Thalassinoides* occur.

(2) Coral boundstone (Fig. 9) is an early lithified rock consisting mostly of spar and micrite. The corals are preserved as cement filled voids. Most of the spar is a radiaxial cement, but other types of spar also occur. The matrix of the rock is bioturbated. *Thalassinoides* is seen near the boundary to the bryozoan packstone without flint. Silicified fossils and minute cavities filled with quartz are common.

(3) The less widespread wackestone (Fig. 10) is a white, weakly lithified rock, with a random orientation of the few fossils (mostly bryozoans, corals and planktic foraminifera). No sedimentary or biogenic structures are evident, but the rock is probably thoroughly bioturbated.

(4) Bryozoan packstone without flint (Fig. 11) is a biomicrite or, in places, a biosparite. In addition to bryozoans, the rock contains some corals and a few echinoid fragments. It has a weak lamination and is only weakly bioturbated; typically it contains open burrows after crustaceans.

All these rock types are autochthonous or only a little transported, but in other parts of the quarry signs of substantial transport have been recorded. General lithification is early and probably has taken place in immediate vicinity to the sea bottom; later most of the components have recrystallized, probably in a subaerial environment. However, typical subaerial or vadose diagenetic features, such as gravity- and meniscus cement, have not been seen.

Fig. 7. Examples of the Danian macro-fauna in Fakse Quarry. 1. *'Rhynchonella' flustracea*. 2. *'Terebratula' fallax*. 3. *C. incisa*. 4. *Argyrotheca faxensis*. 5. *Calantica dorsata*. 6. *Dromiopsis rugosa*. 7. *D. elegans*. 8. *Notidanus dentatus*. 9. *Lamna appendiculata*. 10. *Scaphanorhynchus tenuis*. 11. *Orthacodus lundgreni*. 12. *Thoracosaurus* sp. 13. *Emarginula coralliorum*. 14. *Palaeocypraea spirata*. 15. *Fusinus faxensis*. 16. *Charonia subglabrum*. 17. *Pleurotomaria niloticiformis*. 18. *Campanile pseudotelescopium*. 19. *Voluta faxensis*. 20. *Barbatia forchhammeri*. 21. *Cucullaea crenulata*. 22. *Isoarca obliquedentata*. 23. *Crassatella faxensis* 24. *Protocardia vogeli*. 25. *Meiocardia faxensis*, (after Rasmussen, 1966).

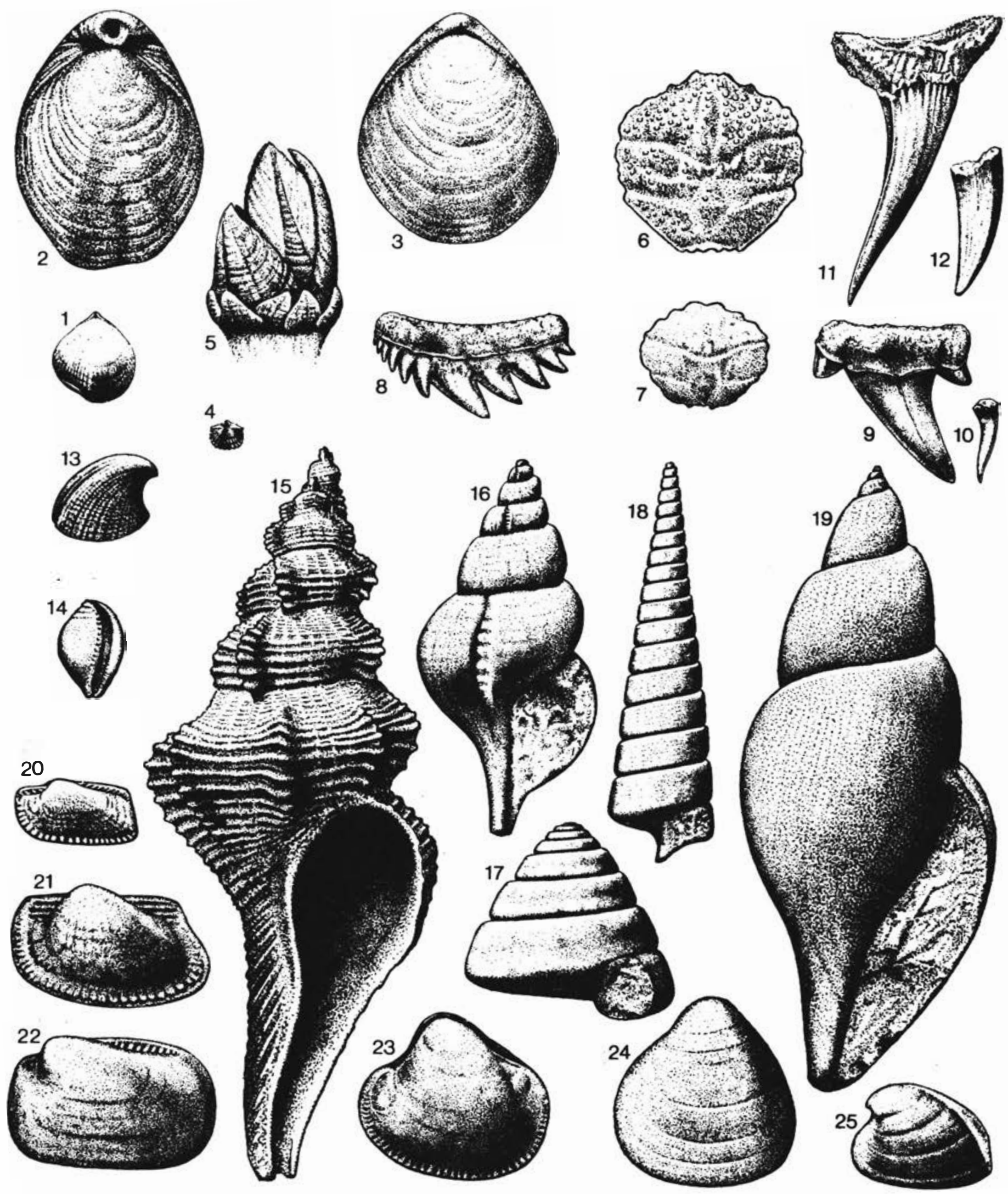

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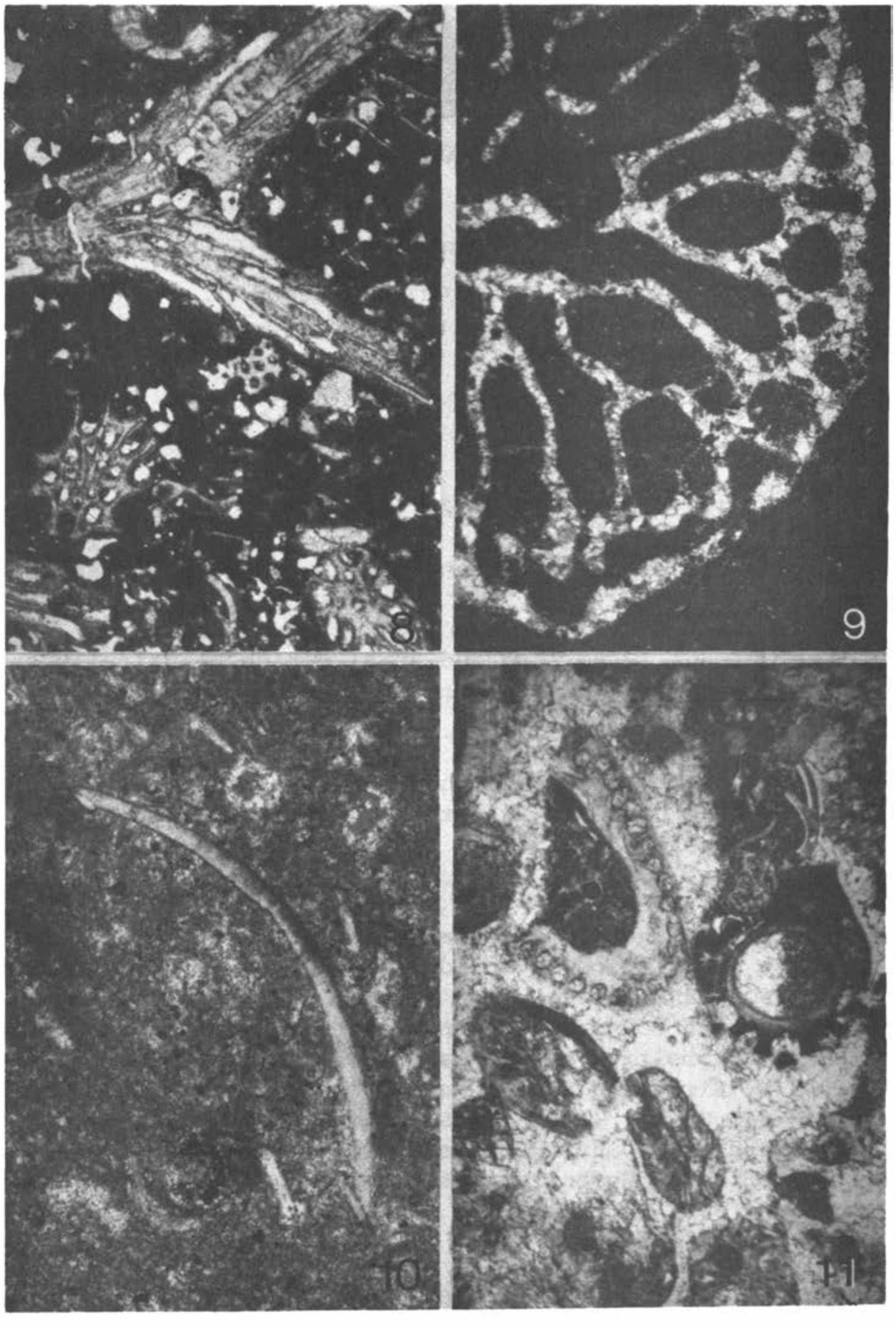
Fig. 8. Bryozoan packstone with flint. Ramose specimens of cyclostome bryozoans in transverse and longitudinal sections. Most colonies are broken and fragmented after imbedment.

Fig. 9. Coral boundstone (coral biomicrite). Transverse section of a coral showing well-developed septa in clear sparry calcite. Matrix is a very fine mud.

Fig. 10. Wackestone. Ostracode shell with preserved radiating prismatic structure and smaller recrystallized skeletal fragments in a mud matrix.

Fig. 11. Bryozoan packstone without flint. Transverse sections of bryozoans in a spar and mud matrix. Note the geopetal structures.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