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Conodont biostratigraphy of the Elbingerode Reef Complex, Harz Mountains

ABSTRACT: The stratigraphy and development of the Elbingerode Reef Complex (Harz Mountains) are presented in the light of conodont investigations. The Elbingerode Reef Complex, which developed on an isolated submarine volcanic rise within the Rhenish Trough, displays an atoll-like structure of facies pattern. Correlations based upon conodonts indicate the onset of reef growth in the Middle varcus Zone and ist diachronous termination up to the Upper *gigas* Zone. The younger, post-reef sediments ranging up to the *anchoralis-latus* Zone are recognized as the neptunian dykes and the pockets within the reef carbonates. The termination of reef formation in the Elbingerode Reef Complex is interpreted as result of the increasing subsidence of the sea floor. The conodont distribution within the reef carbonates is restricted to the fore-reef facies, but no clear depth segregation of conodonts is observed. Differentiation of CAI values within the Elbingerode Reef Complex is also discussed.

INTRODUCTION

The Elbingerode Reef Complex is situated on the flat upland area of the Middle Harz Mountains (German Democratic Republic), and it occupies an area of about 80 km² within the Blankenburg Fold Zone (*see* Text-fig. 1). The Elbingerode Reef Complex developed on an isolated submarine volcanic rise within the Rhenish Trough of the Variscan geosyncline (KREBS 1968, 1974). It holds a key position in the history of geological research of the Harz Mountains and in the interpretation of the paleogeographical development of the Central European Variscan belt, least of all the Rheno-Hercynian Zone.

The stratigraphical subdivision of the limestones of the Elbingerode Reef Complex is traditionally based on the distinction of the Middle Devonian *Stringocephalus* Limestone from the Upper Devonian Iberg-type limestone. The term *"Stringocephalenbildungen"* was used for the first time by ROEMER (1843) in the sense of a stratigraphically independent Middle Devonian unit. Later, KAYSER (1871) attributed it to the upper part of the Middle Devonian, positioned above the *Calceola* Beds of the Eifel Stufe, and compared it with the limestones of Givet in Belgium. It was also ROEMER (1843) who introduced the term "*Iberger Kalk*" with a stratigraphic understanding the same as that of the reef limestones at Bad Grund in the Upper Harz Mountains.

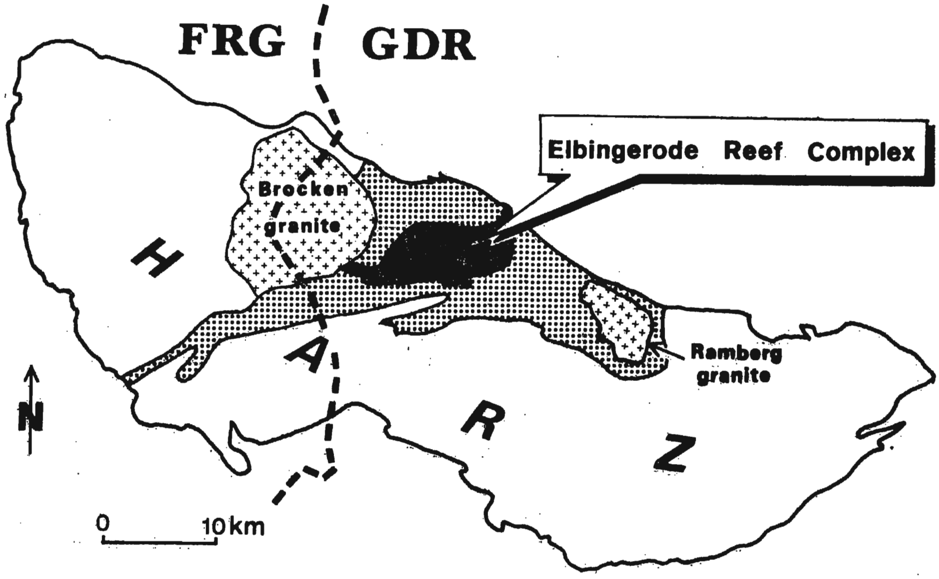

Fig. 1. Location of the Elbingerode Reef Complex within the Harz Mountains; the Blankenburg Fold Zone is stippled

ROEMER (1855) recognized the upper Middle Devonian *Stringocephalus* Limestone in the iron-ore bed only, and he regarded the whole reef limestone as the Upper Devonian. Further investigations (BEYRICH 1868; KAYSER 1880; LOSSEN 1881; KOCH 1895, 1898; ERDMANNSDÖRFER 1926; ERDMANNSDÖRFER & *al.* 1930; ZÖLLICH 1939) led to the restriction of the Upper Devonian area in the Elbingerode Reef Complex to a small area near Rübeland. Because of the problematical bases of their definitions, both paleontological and lithological, the terms

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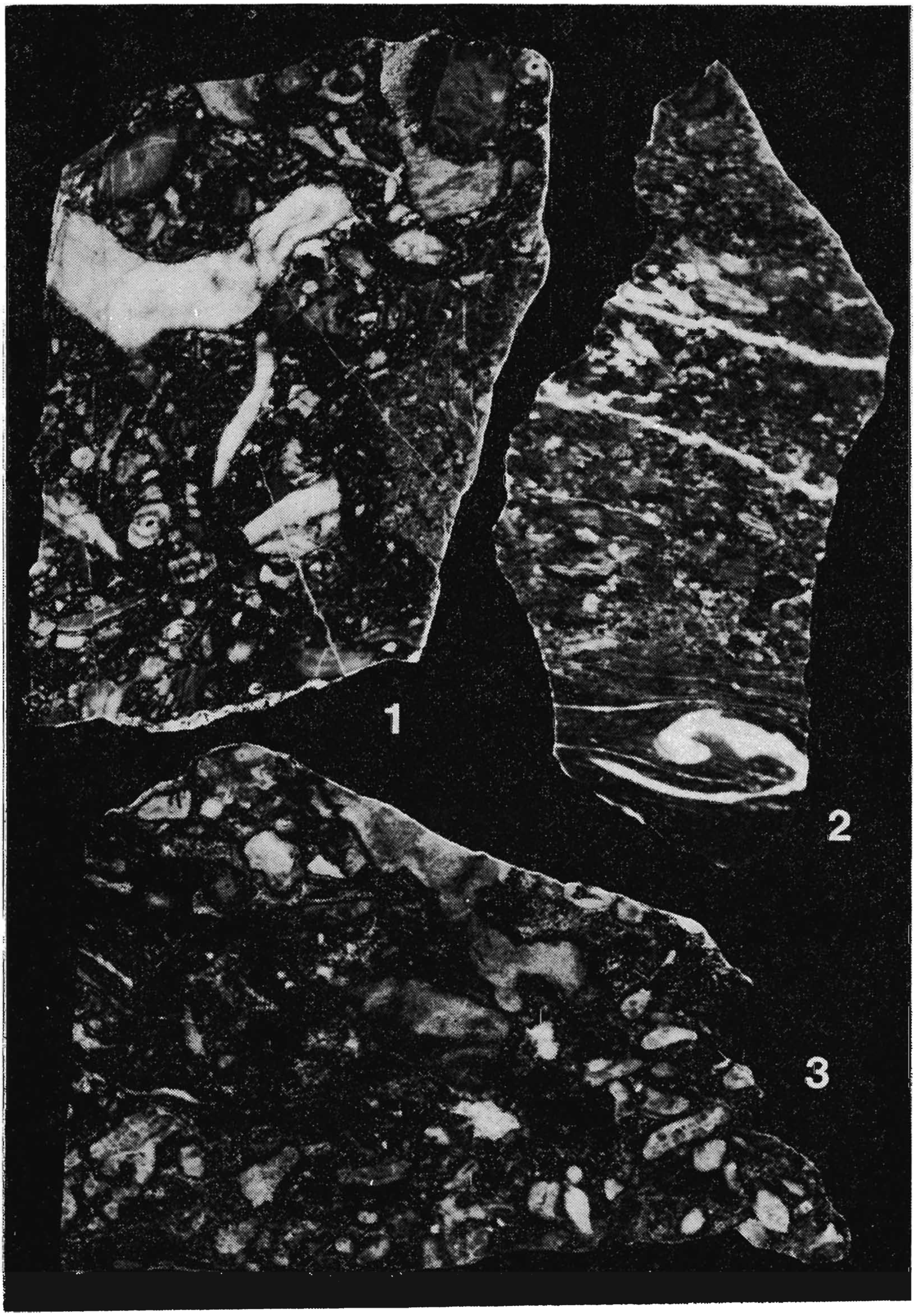
PLATE 1

1 — Poorly sorted bioclastic floatstone with abundant fragments of crinoids, receptaculitids, and stromatoporoids; iron-ore bed; Middle-Upper *varcus* Zone, Krockstein; polished section, × 0.8

2 — Graded bio-lithoclastic floatstone overlying peloidal wackestone; note the large shell of *Stringocephalus burtini*; back-reef (lagoonal) facies; pre-*rotundiloba* Interval, Schwefeltal, Elbingerode; polished section, × 0.7

3 — Bio-lithoclastic rudstone; the dominant skeletal fragments are pieces of tabulates; fore-reef facies; *Anc. triangularis* Zone, Rübeland; polished section, × 0.8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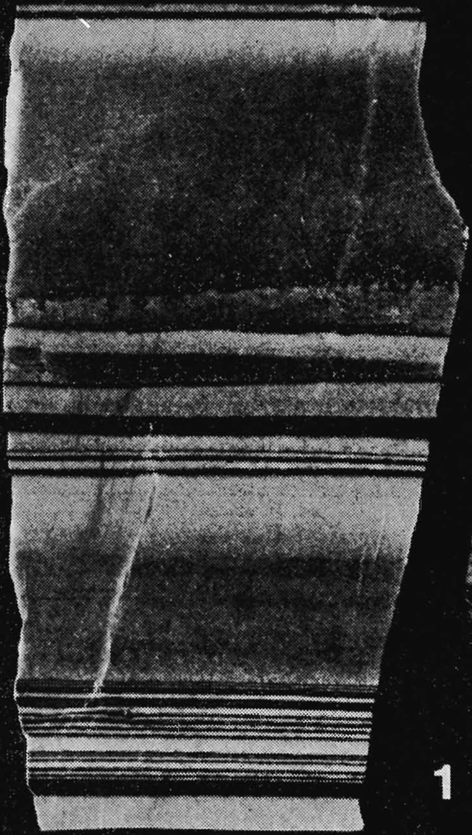

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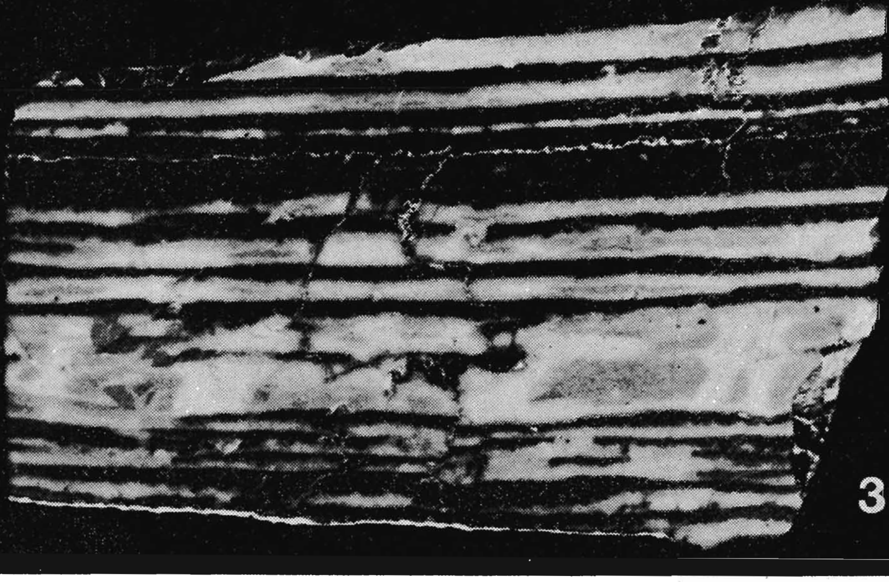

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the Middle Devonian *Stringocephalus* Limestone and the Upper Devonian Iberg Limestone in the Elbingerode Complex can be used today in a historical context only.

All conodont samples and figured specimens (Pls 3—22) are kept in the collection of the Department of Geological Sciences, Ernst-Moritz-Arndt University of Greifswald.

GENERAL LITHOLOGY

The Elbingerode Reef Complex is an atoll-like structure that has developed on a volcanic seamount. The substrate of the Elbingerode Reef Complex is composed of various volcanic and clastic rocks, *e. g.* keratophyres, spilites, and tuffs. This unit, Lower and/or Middle Devonian in age, was identified here by MUCKE (1973) as "*Schalsteinserie*". The oldest known sediments are the Wissenbach slates (Upper Emsian to Eifelian) cropping out within the central part of the Braunesumpf anticline (BORSDORF 1971).

An atoll-like structure of the Elbingerode Reef Complex is expressed by the carbonate facies pattern. Its two main parts can easy be distinguished: a central lagoon (back-reef environment) and a seaward exposed reef talus (fore-reef environment) that surrounds the lagoon (Text-fig. 2*A*). The reef core has hitherto not been recognized, but it was PALME (1968, 1977), who interpreted some parts of the fore-reef limestones as a reef core.

The fore-reef facies is characterized by the predominance of pack- and rudstones (Pl. 1, Fig. 3) in addition to float- and wackstones. These carbonates are unbedded and they contain various bioclasts, primarily of massive and dendroid stromatoporoids, tabulates, and rugose corals. They originated under high-energy conditions, as evidences of intensive matrix outwashing are commonly observed.

The lagoonal (back-reef) limestones are medium- to thick-bedded, laminated mudstones and grainstones with pellets in addition to wack- and packstones. Typical features are stromatactis, birdseyes, and laminar fenestral fabric. The mudstones often contain calcispheres, foraminifers, amphiporoids, and gastropods. Thick-bedded layers display often graded

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PLATE 2

1 — Allodapic, fine-grained lithoclastic packstone; neptunian dyke within the back-reef carbonates of the pre-*rotundiloba* Interval; Lower Carboniferous, Elbingerode; polished section, nat. size

2 — Fine-grained laminated mudstone with problematic tubiform structures and several cement generations; so-called "Höhlenrestaurant"-deposit; fore-reef facies; *Anc. triangularis* Zone, Rübeland; polished section, nat. size

3 — Laminated micrite; so-called "Bärenfelsen"-deposit occurring as a fissure infilling within the fore-reef limestones of the *Anc. triangularis* Zone; Famennian?, Rübeland; polished section, × 1.2

bedding and they probably represent tempestites (Pl. 1, Fig. 2). The back-reef limestones formed in a restricted and very shallow environment in which emersion events occasionally took place.

Due to the submarine exhalative or hydrothermal activity the basal part of carbonate complex has been transformed into iron-ore beds (Pl. 1, Fig. 1 and Text-fig. 2*A*) of the Lahn-Dill type on the flanks of Schalstein volcanic elevations, whereas in the central part of the Elbingerode area sulphide iron-ores occur.

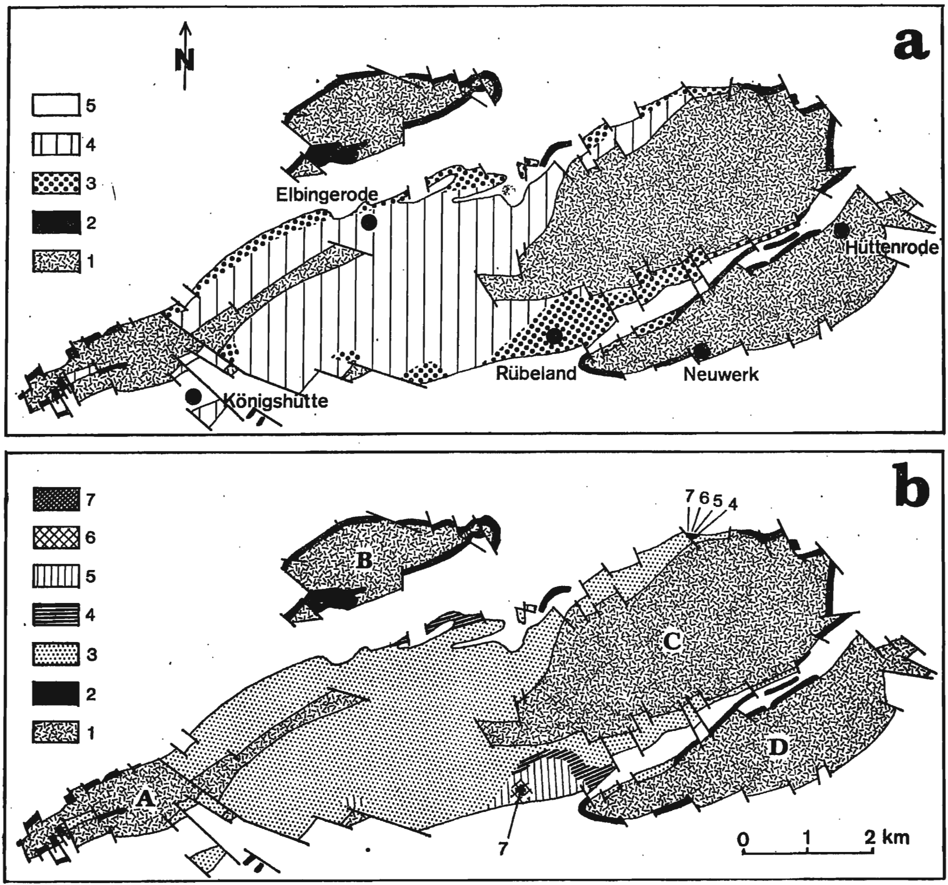


Fig. 2: **A** — Lithological units of the Elbingerode Reef Complex

1 — Schalstein series, 2 — iron-ore bed, 3 — conodont bearing fore-reef limestones, 4 — back-reef (lagoonal) limestones, 5 — clastic rocks (Culm and Blankenburg Fold Zone)

Note the presence of the central lagoon surrounded by fore-reef environment and Schalstein volcanic elevations

B — Biostratigraphy of the Elbingerode Reef Complex

1 — Lower-Middle Devonian (Schalstein series), 2 — Middle-Upper *varcus* Zone, 3 — pre-*rotundiloba* Interval, 4 — *asymmetricus* Zone, 5 — *Anc. triangularis* Zone, 6 — Lower *gigas* Zone, 7 — Upper *gigas* Zone

A — Elbingerode anticline, **B** — Büchenberg anticline, **C** — Braunesumpf anticline, **D** — Neuwerk anticline

CONODONT STRATIGRAPHY

Based on conodont fauna it was possible to date precisely the Elbingerode Reef Complex, the development of which lasted since the *varcus* Zone up to the *gigas* Zone. Moreover, younger sediments ranging up to the *anchoralis-latus* Zone were recognized as the neptunian dykes and the pockets within the reef complex. The conodont subdivision, however, is here more general (*cf.* Text-fig. 3) than the standard conodont zonation (ZIEGLER 1962, 1965, 1971; ZIEGLER & KLAPPER 1982a; KLAPPER & JOHNSON 1980; JOHNSON, KLAPPER & TROJAN 1980a; JOHNSON, KLAPPER & SANDBERG 1985) established for the pelagic facies, but it is more detailed than that given for the nearshore facies by SANDBERG & DREESEN (1984). The lower boundaries of the recognized conodont zones are placed always at the first observed appearance of the index forms. Other stratigraphically important elements are used to characterize the zones (*cf.* Text-fig. 4).

The *varcus* Zone

The *varcus* Zone, introduced by BISCHOFF & ZIEGLER (1957), has subsequently been precised by WITTEKINDT (1965); ZIEGLER, KLAPPER & JOHNSON (1976), KLAPPER & ZIEGLER (1979), and CLAUSEN, LEUTERITZ & ZIEGLER (1979). Accordingly, the base of the Lower *varcus* Zone is defined by the first occurrence of *Polygnathus timorensis*, because *Polygnathus varcus* occurs somewhat higher. The Middle *varcus* Zone starts with *Polgnathus ansatus* and the Upper *varcus* Zone with *Polygnathus latifossatus*.

PELAGIC FACIES		NEARSHORE FACIES	REEF FACIES		
ZIEGLER & KLAPPER (1982) KLAPPER & JOHNSON (1980) JOHNSON & al. (1980a,1985)		SANDBERG & DREESEN (1984)	Belgium MOURAVIEFF & BOUCKAERT (1973)	Elbingerode Reef Complex/Harz Mts Conodont Zones	Elbingerode Reef Complex/Harz Mts Lithostratigraphy
Pa. triangularis		Pelekys-gnathus planus O	Pa. triangularis	Pa. triangularis	post reef limestones
gigas	Um		Upper gigas s.l.	gigas U	reef limestones
	U				
	L	L	Anc. triangularis s.l.	gigas L	
Anc. triangularis		Icriodus symmetricus		Anc. triangularis	
asymmetricus	U		asymmetricus U	asymmetricus	
	M		asymmetricus M		
	L		asymmetricus L		
	Lm		(Lowermost) asymmetricus	pre-rotundiloba Interval	
dengleri U dengleri L	disparilis				
hermanni-cristatus	U				
	L				
varcus	U		varcus	varcus U	iron-ore bed
	M			varcus M	
	L			varcus L	volcanic rocks

Fig. 3. Comparison of the conodont zonations established for the pelagic and nearshore facies with the conodont subdivisions in the reef facies of Belgium and the Elbingerode Reef Complex

In the Elbingerode Reef Complex the Middle and Upper *varcus* Zones have only been proved conclusively in the iron-ore bed. These stratigraphic units are identified on the basis of *Polygnathus ansatus, Polygnathus linguiformis weddigei* and *Icriodus brevis*, the occurrence of which is limited to the Middle or Upper *varcus* Zone. Additionally, there are also *Polygnathus timorensis, P. linguiformis klapperi, P. linguiformis linguiformis, P. varcus, P. ovatinodosus* and *Ozarkodina sannemani*, which however, appear at still higher levels. A dating of the iron-ore bed was possible in nearly all places (Büchenberg anticline at Tännichen, Neuwerk anticline at Krockstein and Schöth, Elbingerode anticline at Mandelholz, Braunesumpf anticline at Garkenholz and Ibenklippen, *see* Text-fig. 2B).

The pre-*rotundiloba* Interval

In the Elbingerode Reef Complex the pre-*rotundiloba* Interval comprises the reef limestones lying above the iron-ore bed and before the first occurrence of *Ancyrodella rotundiloba* (base of the Lower *asymmetricus* Zone). Thus, there is no exact lower, but only a definite upper limit and this is why the recognized unit is termed as an interval, and not as a conodont zone. The lower part of the pre-*rotundiloba* Interval must be placed with certainty within the Upper *varcus* Zone, as indicated by the occurrence of *Polygnathus linguiformis linguiformis, P. varcus, P. ovatinodosus*, and *P. timorensis* (cf. Text-fig. 4). A subdivision of the pre-*rotundiloba* Interval is not possible. An increase of conodont frequency towards the top of this unit is usually noticeable. The presence of index conodonts of the *hermanni-cristatus* and *disparilis* Zones has not hitherto been proved. This deficiency may have primarily ecological causes, because the associated fauna (for example *Polygnathus limitaris*) was very often observed. The pre-*rotundiloba* Interval, therefore, certainly includes these zones, even though they could not be identified. Similar situation was mentioned by HUDDLE (1981), who desired a redefinition of the zones between appearance of *Polygnathus varcus* and *Ancyrodella rotundiloba*. A recognition of the *dengleri* Zone (KLAPPER & JOHNSON

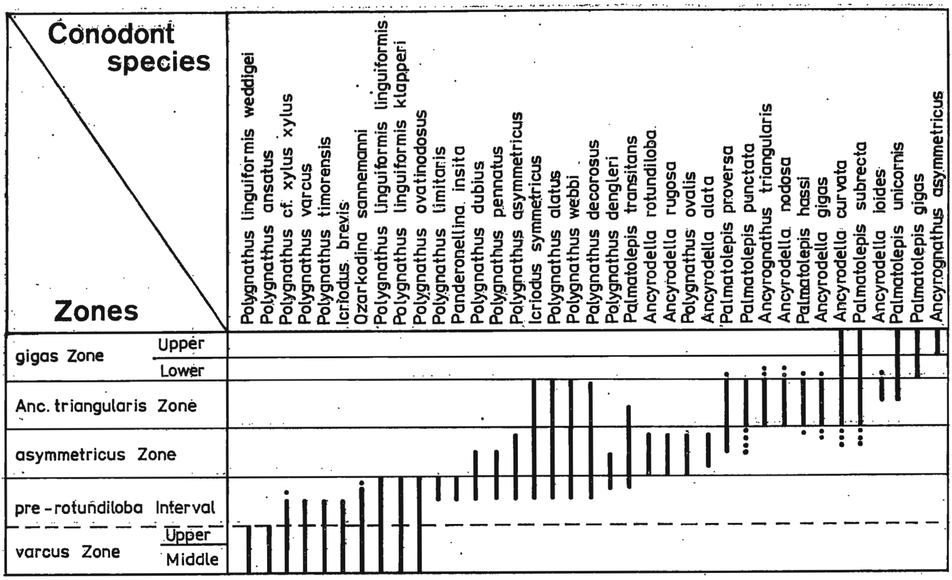
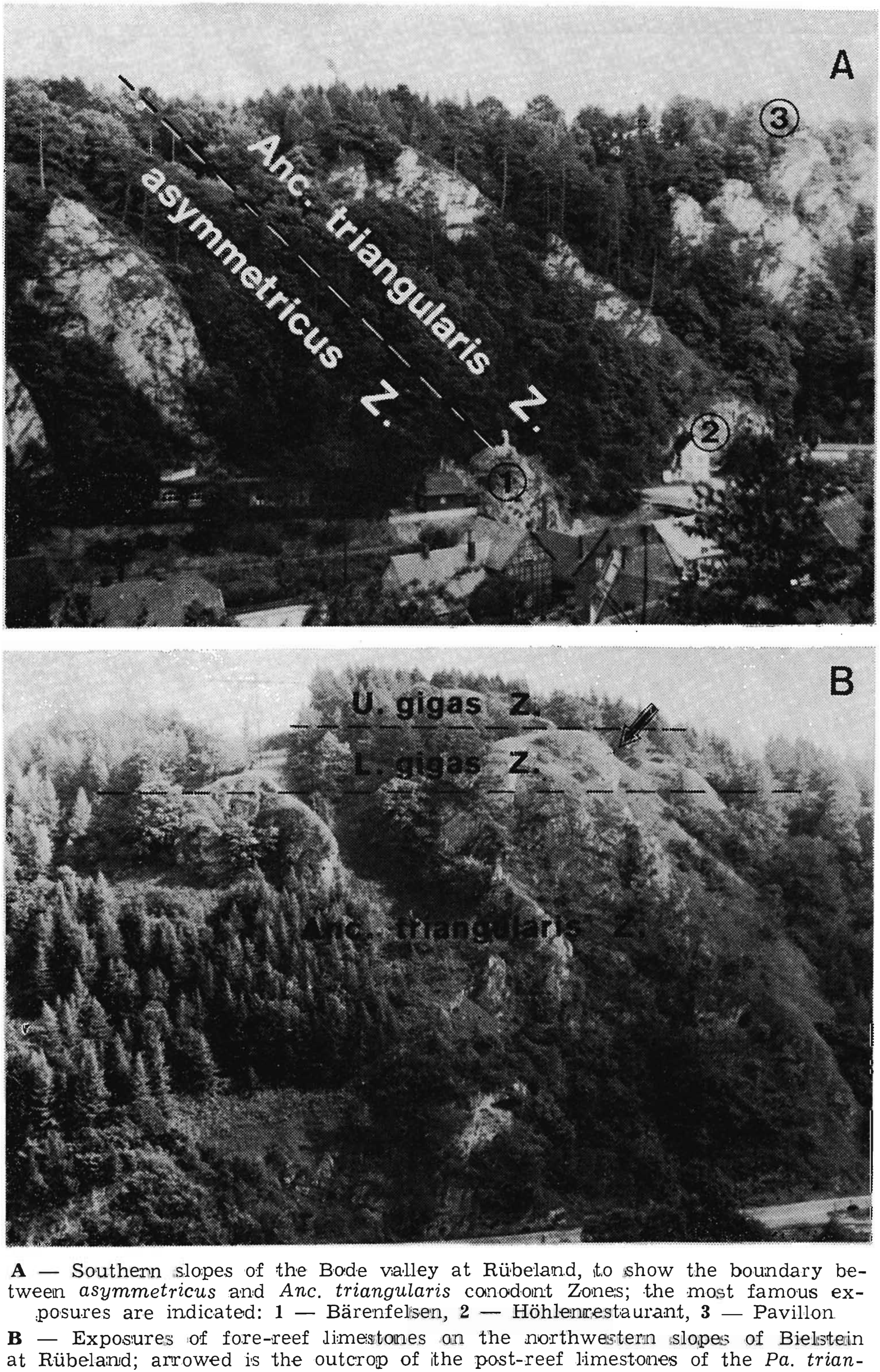


Fig. 4. Distribution of conodonts in the reef limestones of the Elbingerode Reef Complex



A — Southern slopes of the Bode valley at Rübeland, to show the boundary between *asymmetricus* and *Anc. triangularis* conodont Zones; the most famous exposures are indicated: **1** — Bärenfelsen, **2** — Höhlenrestaurant, **3** — Pavillon

B — Exposures of fore-reef limestones on the northwestern slopes of Bielstein at Rübeland; arrowed is the outcrop of the post-reef limestones of the *Pa. triangularis* and *crepida* Zones (brachiopod limestone of ROEMER, 1866; and "*Kellwasserkalk*" of BRANDES, 1869)

1980, JOHNSON, KLAPPER & TROJAN 1980a) has only local significance in the Elbingerode Reef Complex, because *Polygnathus dengleri* occurs together with *Ancyrodella rotundiloba*, i.e. much higher than the beginning of the stratigraphic range of this species.

Remarkable is the sparce occurrence of *Panderonellina* cf. *insita* in two samples of reef limestones of the Elbingerode Reef Complex. Additional characteristic conodonts of the pre-*rotundiloba* Interval, but with limited stratigraphic significance, are *Polygnathus dubius*, *P. alatus*, *P. webbi*, *P. decorsus*, *P. pennatus*, and *Icriodus symmetricus*. The pre-*rotundiloba* Interval corresponds to the *lunulicosta* Zone (*Pharciceras Stufe* of HOUSE, 1985) of the ammonoid chronology.

The *asymmetricus* Zone

The *asymmetriicus* Zone is not subdivided in the Elbingerode Reef Complex, because its deposits are exposed only in single outcrops. The lower boundary of the zone is defined by the first occurrence of *Ancyrodella rotundiloba*. Therefore, the lowermost *asymmetricus* Zone sensu ZIEGLER (1971) is included within the pre-*rotundiloba* Interval in the Elbingerode Reef Complex. The species *Ancyrodella rotundiloba* appears together with *Polygnathus ovalis* at nearly the same level. It is one of the most striking and evident guide fossils. The first occurrence of this species allows to divide the reef complex into an older part (without further subdivision), and a younger part where several conodont zones are recognized. The particular guide character of *Ancyrodella rotundiloba* was also pointed out by COEN & COEN-AUBERT (1971), COEN (1972), KLAPPER (1985) and FEIST & KLAPPER (1985).

The upper boundary of the zone is marked by the first occurrence of *Ancyrognathus triangularis*. Many species of the genus *Polygnathus* occurring within the pre-*rotundiloba* Interval range into this zone.

The *Anc. triangularis* Zone

The *Anc. triangularis* Zone can be traced unambiguously at Rübeland (Text-fig. 5*A*). This zone is defined by the appearance of *Ancyrognathus triangularis*, whilst its upper boundary is marked by the first occurrence of *Palmatolepis gigas*. The species *Palmatolepis subrecta* (Pl. 6, Figs 1—13) is an additional important and most frequent conodont element within this zone.

The *gigas* Zone

The youngest fore-reef limestones represent the *gigas* Zone. Thus, it seems that the termination of the reef growth in the Elbingerode Reef Complex took place in this very Zone. This zone was recognized at Rübeland (Bielstein) and on the northern flank of the Braunesumpf anticline (Volkmarskeller) and south of Elbingerode (Text-fig. 2*B*). At Rübeland (Text-fig. 5*B*) it can be divided into the Lower and Upper *gigas* Zones based on the appearance of *Palmatolepis gigas* and *Ancyrognathus asymmetricus*, respectively. The species *Palmatolepis linguiformis* has hitherto not been observed. It is supposed, however, that the Upper *gigas* Zone comprises the Uppermost *gigas* Zone sensu ZIEGLER (1971).

The post-*gigas* Interval

It seems that there is no significant stratigraphic gap between the reef and the post-reef sedimentation in the Elbingerode Reef Complex. Conodonts characteristic of all conodont zones proposed for pelagic realm since the *Pa. triangularis* Zone up to the *anchoralis-latus* Zone (cf. SANDBERG & *al.* 1978; LANE, SANDBERG & ZIEGLER 1980; ZIEGLER & SANDBERG 1984) were found in the post-reef limestones. None of these zones, however, can be traced separately because the conodonts occur as mixed faunas in the neptunian dykes and pockets within the reef body (Text-fig. 6).

POSITION OF THE MIDDLE/UPPER DEVONIAN BOUNDARY

The boundary was placed in the interval of the *lunulicosta* Zone or *Pharciceras* Stufe (HOUSE 1985) of the ammonoid chronology. There were no significant priorities for a decision about its position. The brachiopod *Stringocephalus burtini* was used as a guide fossil for the Middle Devonian already some decades before FRECH's (1888) definition of the base of *lunulicosta* Zone as the Middle/Upper Devonian boundary. Important contributions on this problem were presented by HOUSE & ZIEGLER (1977); ERRERA, MAMET & SARTENAER (1972); KIRCHGASSER (1970); KULLMANN & ZIEGLER (1970); BENSAID (1974); UYENO (1974); ORCHARD (1974); NORRIS & UYENO (1981), and FUCHS (1985b). ZIEGLER & KLAPPER (1982a) proposed the *disparilis* Zone as a boundary marker, whereas BULTYNCK (1982) considered the *Ancyrodella binodosa* — *Ancyrodella rotundiloba rotundiloba* transition as a datum-level for the correlation of the Givetian/Frasnian boundary. At last the IUGS Subcommission on Devonian Stratigraphy designated the base of the Lower *asymmetricus* Zone as the Middle/Upper Devonian boundary (ZIEGLER & KLAPPER 1982b, 1985).

In the Elbingerode Reef Complex the Middle/Upper Devonian boundary can only be recognized in the peripheral fore-reef limestones (*cf.* Text-fig. 2*B*) basing on the appearance of *Ancyrodella rotundiloba*. An additional guide for the recognition of this boundary here is the appearance of *Polygnathus ovalis*.

PALEOECOLOGY OF CONODONTS

In the Elbingerode Reef Complex visible is a relation between conodont distribution and particular facies. In fore-reef limestones the representatives of the genera *Palmatolepis, Ancyrodella, Ancyrognathus, Polygnathus,* and *Icriodus* occur together in nearly all samples. Their frequence is sporadic because the high rate of sedimentation caused a dispersal of conodont fauna. An average quantity of 6—8 kg fore-reef limestone per sample has yielded 1—10 conodont elements. Moreover, in almost all samples the platform elements outnumbered the ramiform ones. Contrary to the fore-reef limestones, the back-reef (lagoonal) carbonates yielded no conodonts, although more than 1000 kg of rocks were dissolved.

The general distinction between conodont-bearing and conodont-devoid parts of the Elbingerode Reef Complex demonstrates that conodont animals respond very sensitively to water energy processes as turbulence and wave agitation that occur in the passage between the peripheral fore-reef environment and the screened lagoon. The present study shows that the conodonts can be used, in the Devonian reef complexes, as indicators of the peripheral seaward open-marine reef flanks (fore-reef).

A series of discrete factors controls the conodont distribution (hydrodynamic differences, currents, variations of salinity, temperature, and bottom conditions) and may effect a depth segregation. SEDDON & SWEET (1971) proposed a biofacies model of conodont depth segregation (*cf.* *also* DRUCE 1973, 1976). It was recently tested by NICOLL (1984), who did not find any clear depth segregation of conodonts occurring in the Devonian reef complexes in Australia. Similar to that is the distribution of conodont fauna in the fore-reef limestones of the Elbingerode Reef Complex.

The lack of clear depth segregation in the Elbingerode Reef Complex was attributed by the author (FUCHS 1985a) to the different relief angles of reef located on the epicontinental areas, and those situated on isolated volcanic rises within the Rhenish Trough of the Variscan geosyncline. Steep angles of the reef flanks on isolated volcanic rises caused that the depth zones were much narrower than the sampling intervals.

CONODONT COLOR ALTERATION

EPSTEIN, EPSTEIN & HARRIS (1977) experimentally produced the color alteration of conodonts to prove dependance of conodont color upon the degree of metamorphism. An application of this method to the paleogeothermal studies was demonstrated for example by BEŁKA (1982), LÜTKE & KOCH (1983), and GAGIEV, GREVTSEV & IVANOV (1983).

In the Elbingerode Reef Complex the conodonts from the fore-reef limestones and from the most of post-reef carbonates have CAI values between 4 and 5. Some conodonts in the iron-ore bed, however, show CAI values as 5 up to 6. Higher values of CAI (5—6) are exhibited also by conodonts of mixed faunas from the Lower Carboniferous neptunian dykes containing elements from the asymmetricus Zone/?pre-rotundiloba Interval up to the anchoralis — latus Zone.

The CAI values of the fore-reef limestones (4—5) are considered as an effect of burial caused by the Variscan orogeny. The Elbingerode Reef Complex has been covered by flysch and early molasse sediments. Duration of burial can be declared of about 20 m.y., *i.e.* the period between the intense sedimentation of graywacke (*cu* III; see WEYER 1968) and the termination of molasse deposition (Grillenberg Beds of Westphalian *D*). The CAI values of 4 up to 5 were also observed by LÜTKE & KOCH (1983) in the western part of the Harz Mountains. They estimated temperature values of about 200°C. It seems that the fore-reef limestones of the Elbingerode Reef Complex have been heated to a temperature of about 200°C, and 300°C is considered as a maximum temperature.

A higher degree of metamorphism evidenced by CAI values of 5 up to 6 must be attributed to local thermal causes. This is because such small local anomalies in CAI values could not result from a higher geothermal gradient in such places. Thus, it seems that the higher CAI values yielded by some conodonts in the iron-ore bed are due to the thermal influence. These rocks have been heated over 300°C, but it is impossible to give a more precise temperature value. NICOLL (1981) stated high CAI values in Devonian carbonates in Australia of the narrow contact zone (1 m) of a volcanic plug and he determined a temperature of about 600°C.

The neptunian dykes and non-filled fissures within the Elbingerode Reef Complex may have served as ascent paths for aggressive hydrothermal solutions, comparable to those described by CLAUSEN, HATTON & STADLER (1985) from the Rhenish Mountains. The ascent of the thermal springs is thought to have occurred post-reefogenetically and pre-orogenetically. An initial moment happened immediately before the flysch stage, which can be compared to an orogenic act. During migration of hydrothermal solutions the fissure walls and external parts of neptunian dykes subjected to the greatest thermal influence, and in consequence the conodonts with different CAI values can occur together in one sample from these dykes. Such phenomena within the Elbingerode Reef Complex are recognizable exclusively in all neptunian dykes containing Lower Carboniferous mixed faunas (*cf.* Text-fig. 6), but they never occur in the older neptunian dykes of Famennian age.

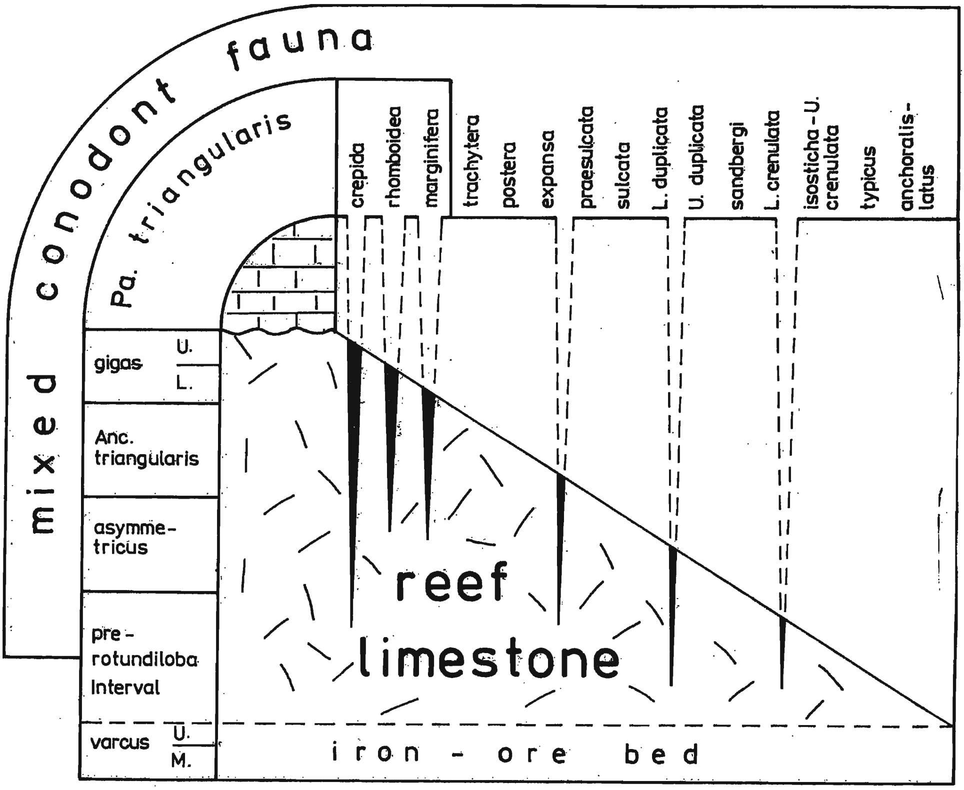


Fig. 6. Generalized stratigraphic scheme of the reef and post-reef deposits of the Elbingerode Reef Complex; note differentional distribution of neptunian dykes, different in age, within the reef carbonates

DEVELOPMENT OF REEF STRUCTURE

In the Elbingerode area, the intense initial volcanic activity started in the lower part of the Middle Devonian and it continued until the Givetian (MUCKE 1973). As a result, several submarine elevations have formed. Their bathymetrically exposed position was a prerequisite for the start of carbonate sedimentation and settling of reef builders. The reef growth in its first stage, however, was occasionally stopped due to repeated short-persisting volcanic events causing an increase of suspended matter. Moreover, the submarine-exhalative or hydrothermal activity transformed the detrital carbonates into iron-ore beds. All conodont-bearing samples of the iron-ore beds are nearly isochronous in age (Middle to Upper *varcus* Zone). The onset of the undisturbed reef growth took place in a later time of the Upper *varcus* Zone (Text-fig. 6).

The Elbingerode Reef Complex is developed as an atoll-like structure around the Braunesumpf and the Elbingerode anticlines (*see* Text-fig. 2). There is a distinct differentiation between fore-reef carbonates forming the flanks and the back-reef (lagoonal) limestones covering the central part of the structure. The thickness of limestones in the central lagoon is estimated as about 500 m. These very shallow carbonates fill up a depression surrounded by a rim of volcanic elevations. LANGE (1973) interpreted this structure as a collapsed caldera. Contrary to that, MUCKE (1973) explained the great thickness of carbonates as a result of compaction of volcanic tuffs and synsedimentary subsidence of the lagoon bottom, and this is supported, first of all, by only shallow-water character of carbonates. Although any conodonts have not been found, these back-reef limestones are regarded as not younger as the *asymmetricus* Zone. This is because that in some places the lagoonal carbonates are covered by fore-reef limestones (of the *asymmetricus* Zone) that allow to determine the decline of shallow-water deposition.

The thickness of the fore-reef limestones ranges from 200 to 300 m in the Rübeland area but to the east and to the west a tendency to a considerable decrease in thickness is noted. The conodont data indicate that the fore-reef limestones cover the time span from the pre-*rotundiloba* Interval up to the *gigas* Zone. Thus, they constitute an equivalent of the Iberg facies in other parts of the Rheno-Hercynian Zone. The stratigraphic results obtained in the Rübeland area demonstrate also a spatial nature of the fore-reef carbonates, as the carbonate bodies are lenticular in shape and they display on onion-peel structure (Text-fig. 2). According to GEISTER (1983), the onion-peel structure evidences an unambiguously transgressive character of the reef development which resulted from a rapid subsidence. This is a reason that such reefs are also called the "drowned reefs". The rapid subsidence of the sea floor or a sea-level rise surpassed the rate of reef-growth and led to the characteristic onion-peel structure, and in the final stage to the death of reef builders.

The reef growth has ceased not synchronically within the Elbingerode Reef Complex. At the Büchenberg and Neuwerk anticlines (Text-fig. 2*B*), the reef growth had already stopped in the pre-*rotundiloba* Interval and the lower Upper Devonian pelagic post-reef limestones followed the reef limestones or the iron-ore bed (*cf.* WEYER 1960; SCHIMANSKI 1960, 1969; REICHSTEIN 1960a, b). The reef development on the flanks of the atoll, however, carried on up to the Upper *gigas* Zone.

Time of termination of the reef growth in the Elbingerode Reef Complex corresponds to the worldwide death of the Devonian reefs in the *gigas* Zone (*cf.* BURCHETTE 1981; EDER & FRANKE 1982; JOHNSON, KLAPPER & SANDBERG 1985; HOUSE 1985). The transgressive character of the reef growth and the succession of pelagic post-reef limestones following the reef development indicate that the termination of reef formation in the Elbingerode Reef Complex was caused by an increased subsidence of the sea floor.

CARBONATE POST-REEF SEDIMENTATION

The post-reef deposits covering originally the Elbingerode Reef Complex have been removed during the post-Variscan erosion. They are only preserved as neptunian dykes and infillings of pockets within the reef carbonates (Text-fig. 6). The origin of fissures and cavity fillings is still not quite clear. Most probably, the opening of fissures was caused by pre-orogenic tectonic events or by a differential settlement of reef complex. But reef sediments must have already been early diagenetized, because post-reef deposits follow with little hiatus in cavities and fissures. For example, there are fissure fillings of the *asymmetricus* Zone in the limestones of the pre-*rotundiloba Interval* (at Garkenholz) and fissure fillings of the Upper *gigas* Zone within reef limestones of the *Anc. triangularis* Zone (at Rübeland).

Macrofauna, primarily brachiopods occur abundantly in the pockets but they are never found in the neptunian dykes and fissures. Commonly, there appears a layer of fibrous calcite at the margin of the fissure. There are several types of infillings of the pockets and neptunian dykes in respect to their age and lithology. The most significant are characterized as follows.

BRACHIOPOD LIMESTONE. This lithology contains a very rich brachiopod fauna and it occurs as cavity and pocket fillings in the fore-reef limestones of the *gigas* Zone at Rübeland (Text-fig. 5*B*). The brachiopod limestone represents the earliest known post-reef deposition. Conodont fauna is indicative of the *Pa. triangularis* Zone. Within these limestones the Frasnian/Famennian boundary as defined by HOUSE & ZIEGLER (1977) and DRESSEN, KASIG, PAPROTH & WILDER (1985) would be situated. Presumably, in this lithology are contained the brachiopod faunas with *Spirifer verneuili* last mentioned by ROEMER (1866) from the "Kalkplateau south of Rübeland".

LAMINATED RED AND GREY MICRITIC LIMESTONES. These are the so-called *"Bärenfelsen"* deposits (Pl. 2, Fig. 3) occurring within the fore-reef limestones of the pre-*rotundiloba* Interval up to the *gigas* Zone. They are comparable to the *"Rotpelite"* of the Rhenish Slate Mountains (*cf.* SCHNEIDER 1972, 1977; KREBS 1966, 1968, 1969) and to sediments of the neptunian dykes in the Holy Cross Mountains (*cf.* SZULCZEWSKI 1973). PALME (1968, 1977), however, used for them the term *"Milchkalke"*. Only a few samples contained rare conodonts of Famennian age, and the lack of conodonts can be explained by hydrodynamic sorting. The cavities and fissures were filled with calcareous mud transported by currents and the conodonts with a high specific weight were concentrated in the coarse fraction and are absent in the fine mud.

FINE-GRAINED AND MICRITIC LIMESTONES. This lithology fills the fissures within the pre-*rotundiloba* Interval up to the *gigas* Zone. Particular dykes belong either to the *crepida* Zone, or to *rhomboidea*, or even to the *marginifera* Zone. One lithofacies type is of special interest because of its locality (Bielstein) and lithology corresponding to the Kellwasser limestone of BRANDES (1869), who described such limestones from the plateau south of hte Bode valley at Rübeland. SCHRIEL (1954) believed that this outcrop was destroyed, because neither ERDMANNSDÖRFER (1930) nor ZÖLLICH (1939) mentioned it. These are black, marly shales with limestone nodules. The conodont investigations exhibit, however. that the marly matrix belongs to the *crepida* Zone whereas the limestone nodules are bodies of reef limestones of the *gigas* Zone. Thus, it is not a real equivalent to the Kellwasser limestone.

ALLODAPIC LIMESTONES AND MICROBRECCIAS. These lithologies are graded litho- and bioclastic packstones (Pl. 2, Fig. 1) occurring within the pre-*rotundiloba* Interval and the *asymmetricus* Zone. They contain very rich conodont mixed faunas covering the time span from the *asymmetricus* Zone/? pre-*rotundiloba* Interval to the *anchoralis-latus* Zone.

PALEOGEOGRAPHICAL REMARKS

The greater part of Devonian reefs was situated in shallow areas (Rhenish Slate Mountains, Holy Cross Mountains, Moravian Karst, Australia, North America). The paleogeographic position of the Elbingerode Reef Complex that developed on the volcanic elevation within the Rhenish Trough, is quite different. Therefore, the depositional history of the Elbingerode Reef Complex can only be compared with a few reefs of the Variscan belt (for example with the reef of Langenaubach in the Rhenish Slate Mountains; *see* KREBS 1966).

Within the Rhenish Trough, the reef development terminated by drowning due to increased epirogenetic subsidence of the sea floor (*cf.* FUCHS & RUCHHOLZ 1985). The volcanic rises topped by reef structures persisted there as submarine elevations still during the Early Carboniferous (*cf.* RABIEN 1956, WEYER 1981). The increasing subsidence of the Trough led to the relief steepening at flanks of the Trough and caused an increase of clastic sedimentation. The shelf reefs may have died due to water pollution (increased suspended matter) without any significant raising or lowering of the sea floor or sea level. The onset of clastic sedimentation (flysch stage) took place at the margins of the Variscan geosyncline in the Upper Devonian, whereas the inner Rhenish Trough was reached by flysch sediments not earlier than in the Lower Carboniferous.

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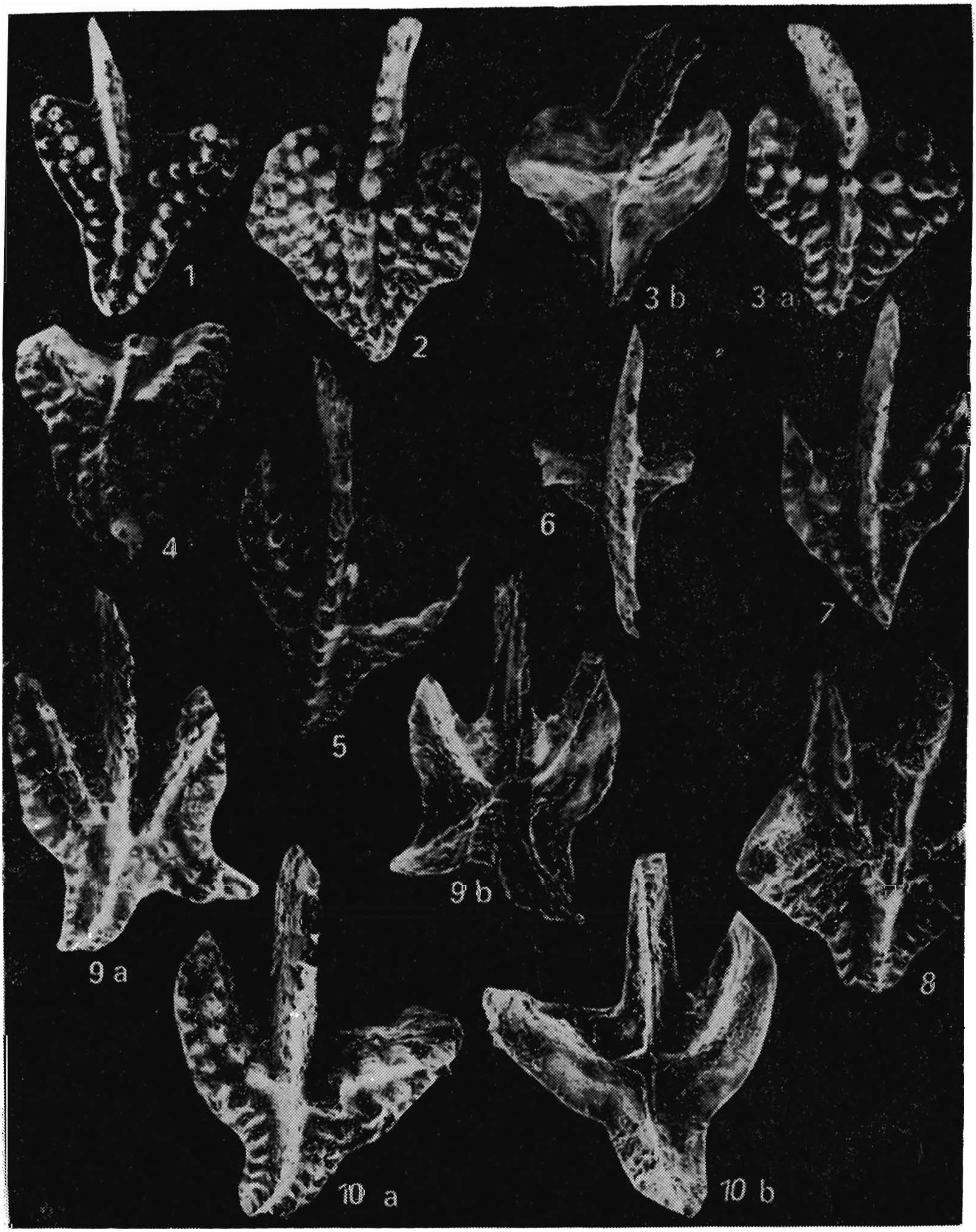


1, 3 — *Ancyrodella alata* GLENISTER & KLAPPER, 1966; from Rübeland, 1 — × 50; 3a — upper view, × 40; 3b — lower view, × 40

2 — *Ancyrodella rotundiloba* (BRYANT, 1921); from Rübeland, × 40

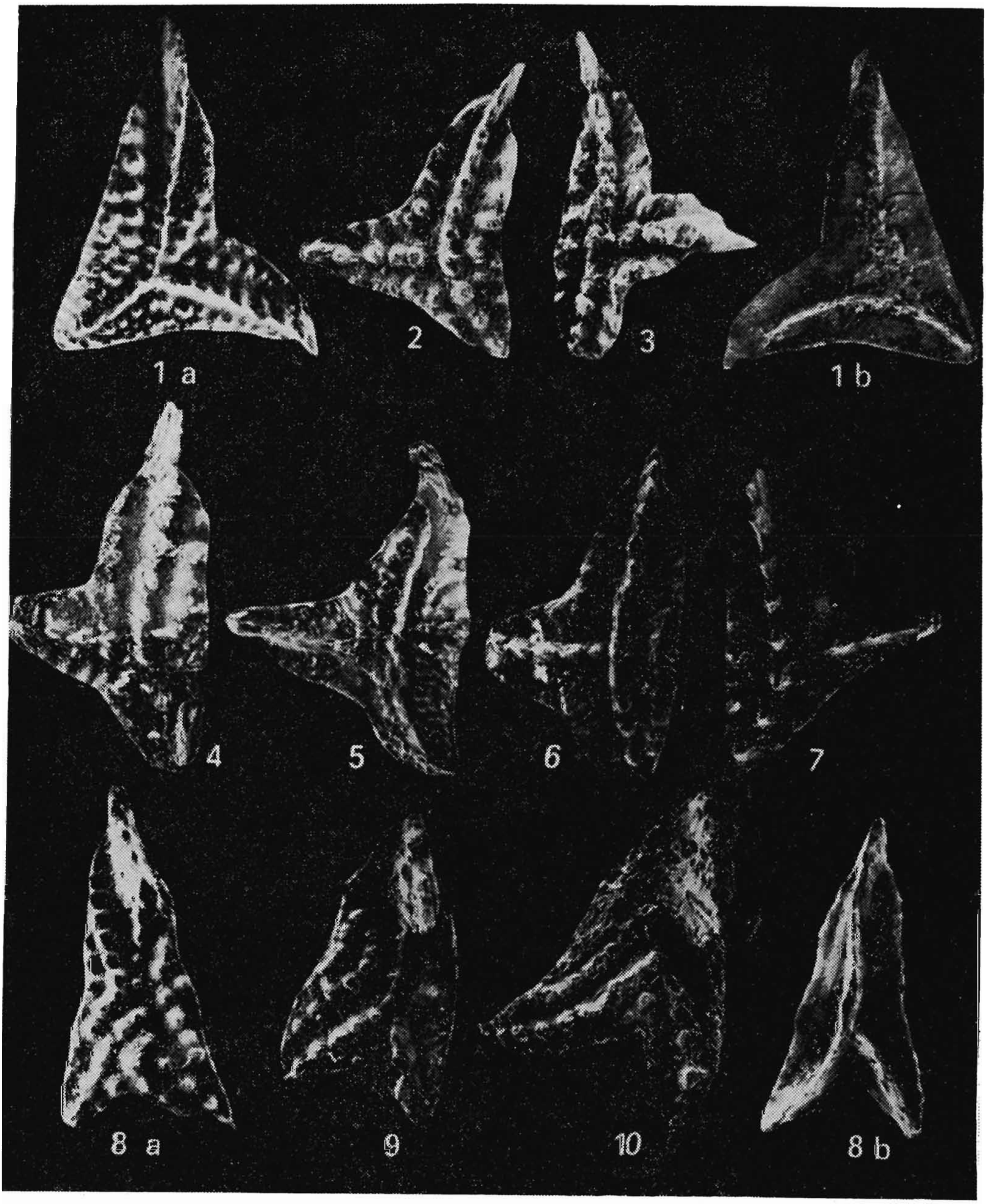
4 — *Ancyrodella rugosa* BRANSON & MEHL, 1934; from Rübeland, × 30

5, 7, 10 — *Ancyrodella nodosa* ULRICH & BASSLER, 1926; from Rübeland, 5 — × 35; 7 — × 55; 10a — upper view, × 40; 10b — lower view, × 40

6 — *Ancyrodella ioides* ZIEGLER, 1958; from Rübeland, × 70

8-9 — *Ancyrodella curvata* (BRANSON & MEHL, 1934); from Rübeland, 8 — × 70; 9a — upper view, × 50; 9b — lower view, × 50

All upper views, except as noted



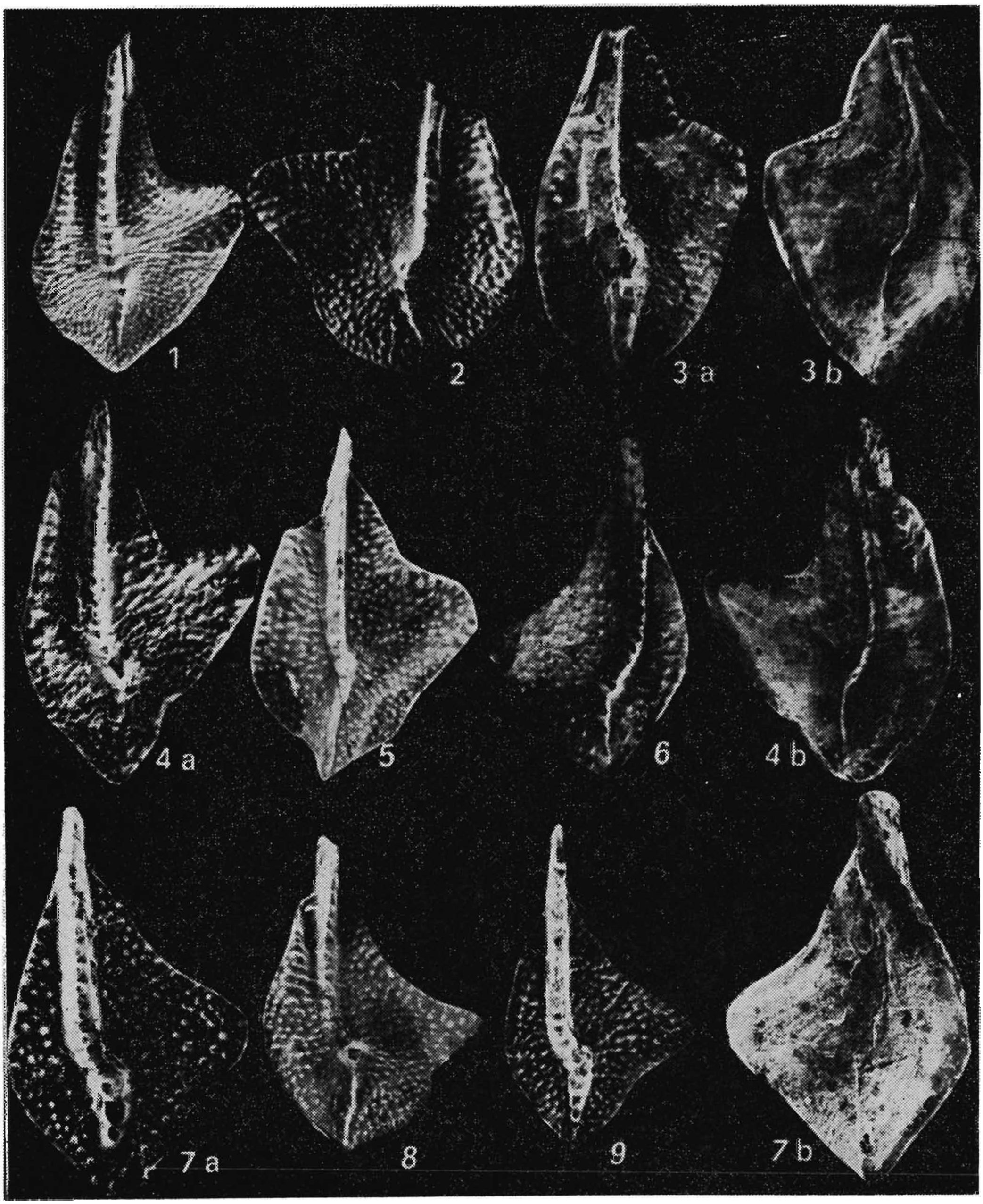
Ancyrognathus triangularis YOUNQUIST, 1945

1 — from Rübeland, in upper (1a) and lower (1b) views, × 35; **2-4** — from Rübeland, × 50; **5** — from Rübeland, × 40; **6-7** — from Rübeland, × 70

Ancyrognathus asymmetricus ULRICH & BASSLER, 1926

8 — from Rübeland, in upper (8a) and lower (8b) views; **9** — from Elbingerode, × 50; **10** — from Rübeland, × 30

All upper views, except as noted



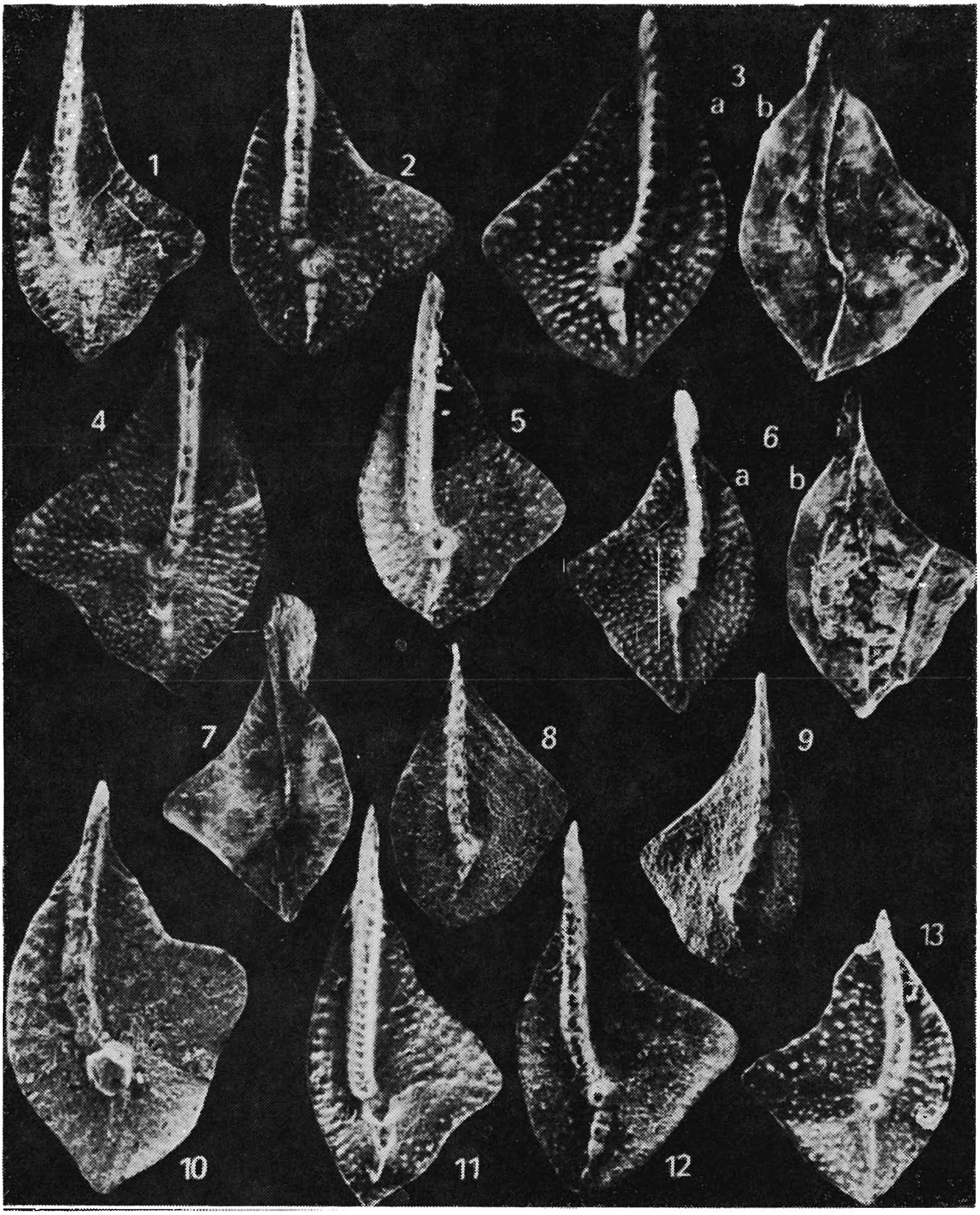
Palmatolepis proversa ZIEGLER, 1959

1 — from Rübeland, × 25; **2** — from Rübeland, × 40; **3** — from Rübeland, in upper (3a) and lower (3b) views, × 60; **4** — from Rübeland, in upper (4a) and lower (4b) views, × 60; **5** — from Rübeland, × 35

Palmatolepis subrecta MILLER & YOUNGQUIST, 1947

6 — from Rübeland, × 55; **7** — from Rübeland, in upper (7a) and lower (7b) views, × 55; **8** — from Rübeland, × 35; **9** — from Rübeland, × 40

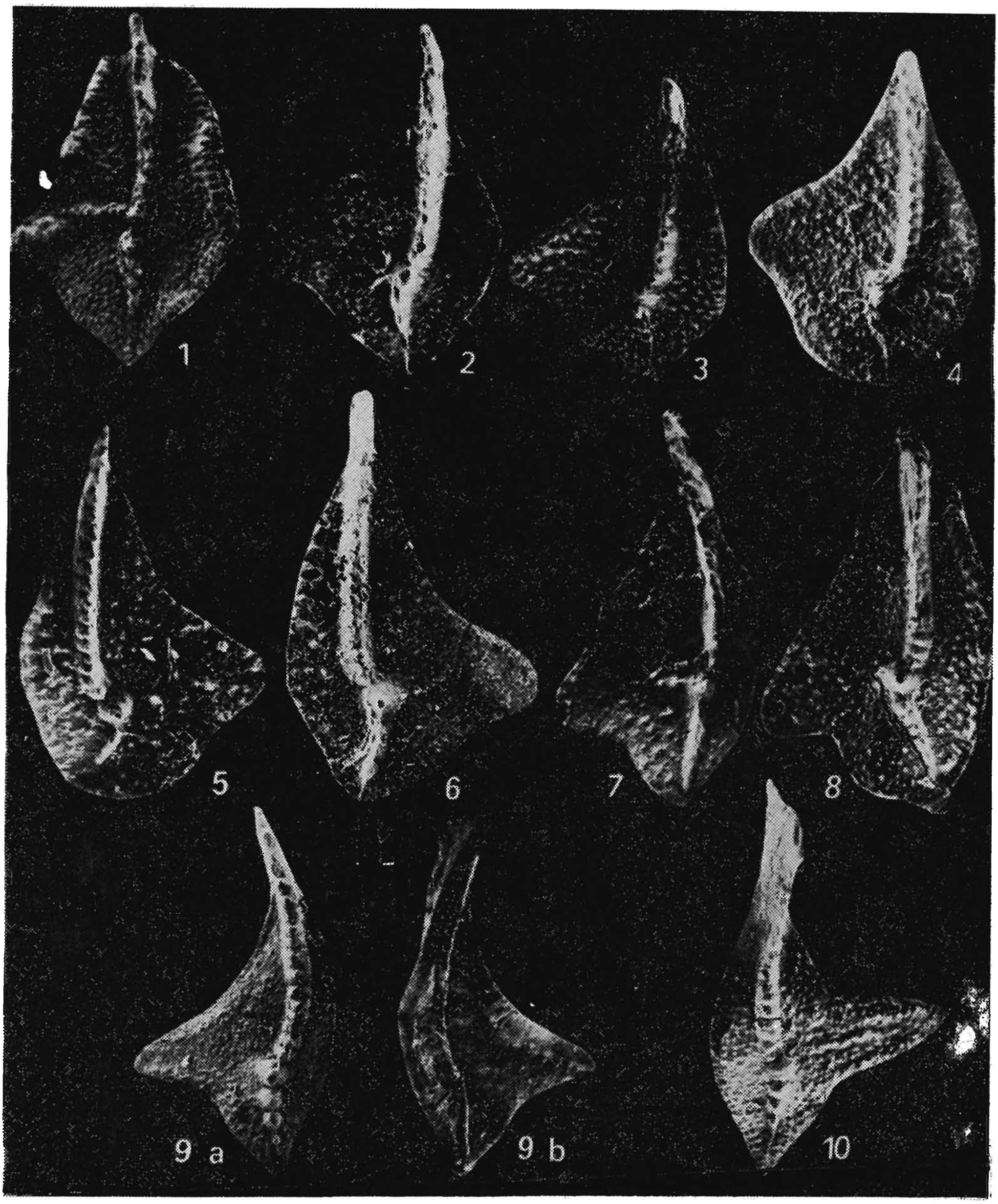
All upper views, except as noted



Palmatolepis subrecta MILLER & YOUNGQUIST, 1947

1-2, 5, 11 — from Rübeland, × 55; **3** — from Rübeland, in upper (3a) and lower (3b) views, × 55; **4** — from Rübeland, × 35; **6** — from Rübeland, in upper (6a) and lower (6b) views, × 35; **7, 13** — from Rübeland, × 40; **8-10, 12** — from Rübeland, × 65

All upper views, except as noted



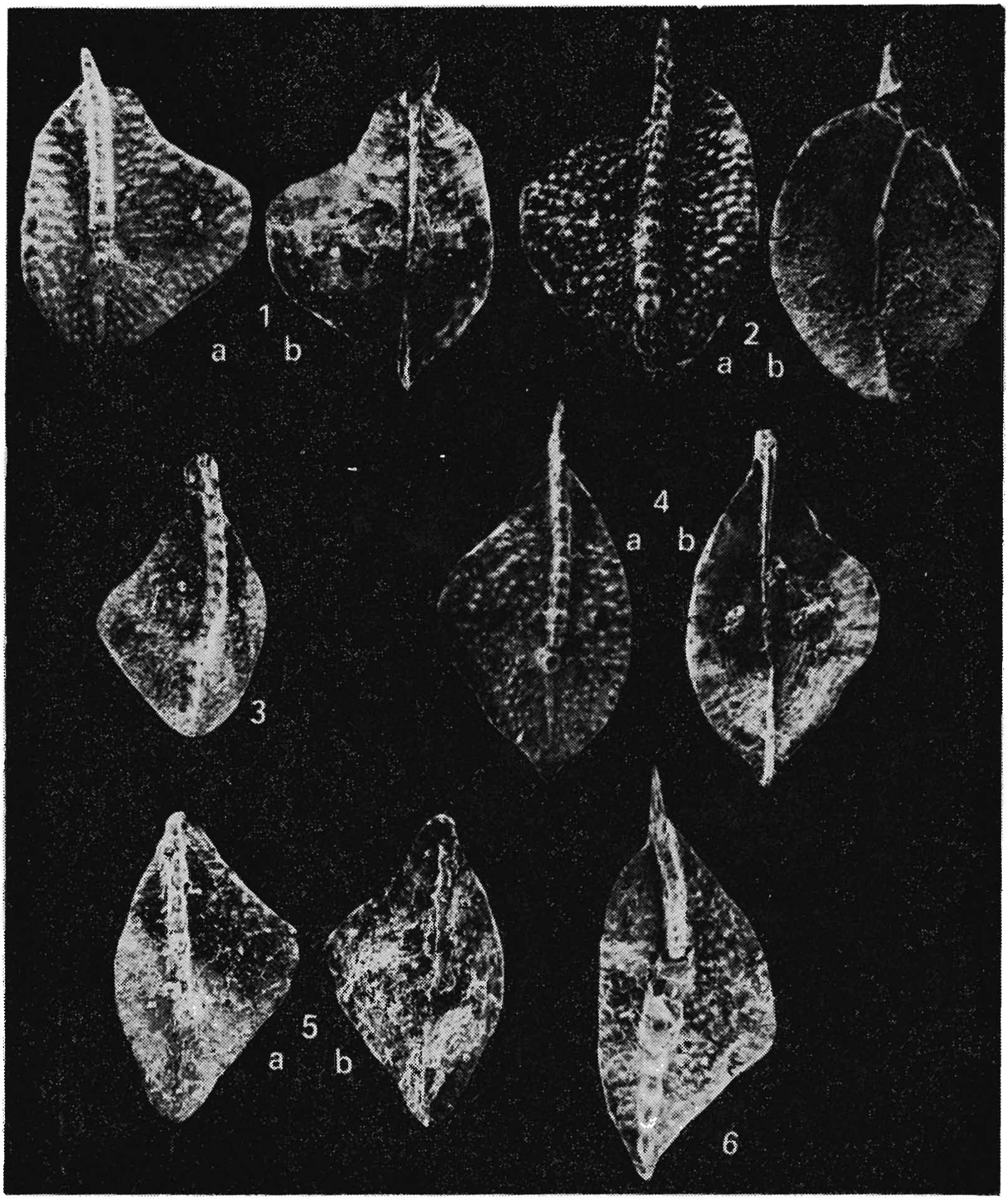
1 — *Palmatolepis punctata* HINDE, 1879; from Rübeland, × 25

2 — *Palmatolepis hassi* MÜLLER & MÜLLER, 1957; from Rübeland, × 55

3-9 — *Palmatolepis subrecta* MILLER & YOUNGQUIST, 1947 (*unicornis* trend); from Rübeland, 3 — × 40; 4-8 — × 65; 9 — in upper (9a) and lower (9b) views, × 40

10 — *Palmatolepis gigas* MILLER & YOUNGQUIST, 1947; from Rübeland, × 40

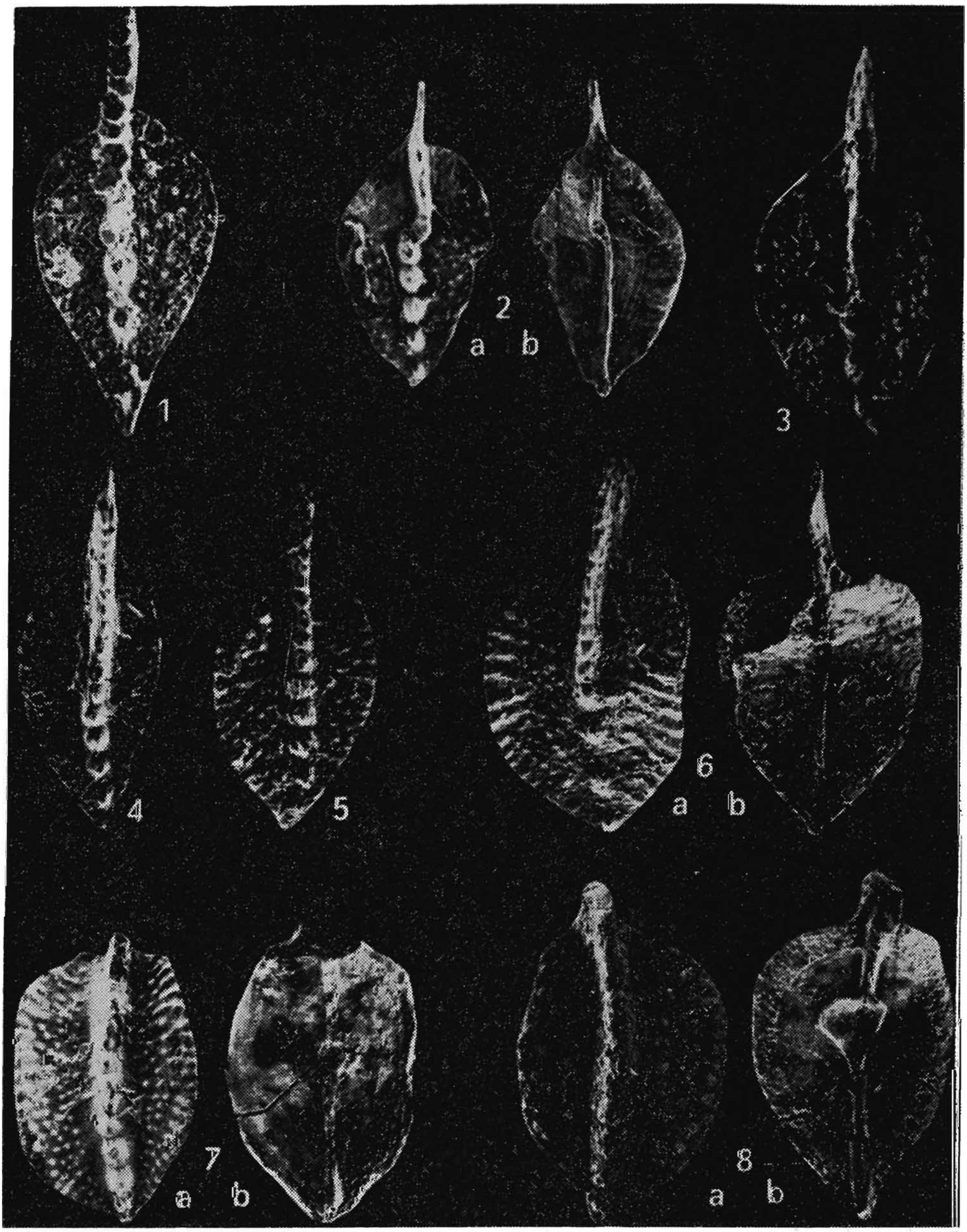
All upper views, except as noted



Palmatolepis transitans MÜLLER, 1956

1 — from Garkenholz, in upper (1a) and lower (1b) views, × 40; **2** — from Rübeland, in upper (2a) and lower (2b) views, × 55; **3** — from Elbingerode, × 70; **4** — from Eggerode, in upper (4a) and lower (4b) views, × 40; **5** — from Garkenholz, in upper (5a) and lower (5b) views, × 70; **6** — from Rübeland, × 55

All upper views, except as noted



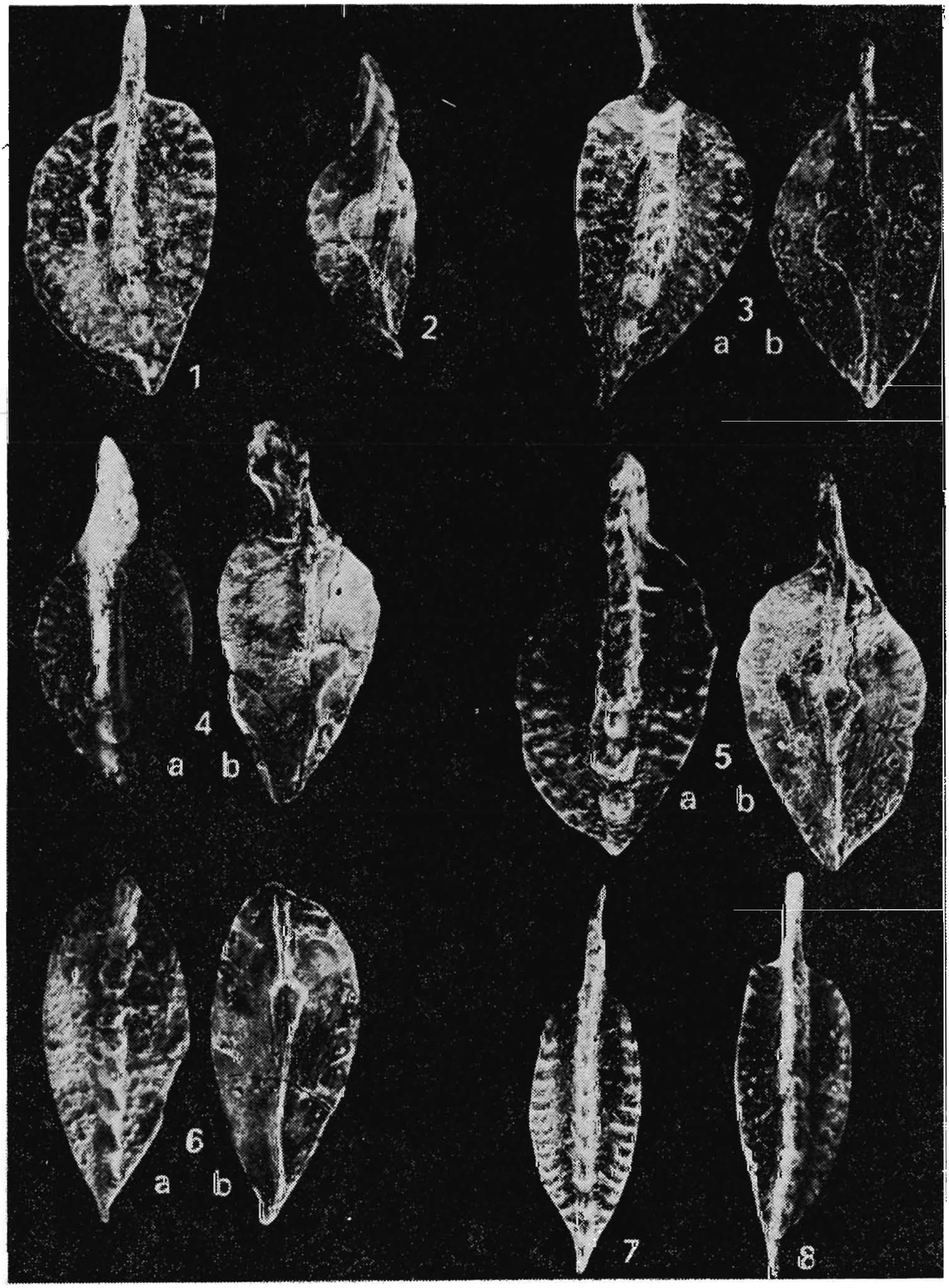
Polygnathus ovalis ZIEGLER & KLAPPER, 1964

1 — from Rübeland, juvenile specimen, × 115; **2** — from Rübeland, in upper (2a) and lower (2b) views, × 70; **8** — from Rübeland, in upper (8a) and lower (8b) views, × 70

Polygnathus asymmetricus BISCHOFF & ZIEGLER, 1957

3-4 — from Rübeland, × 70; **5** — from Eggerode, × 70; **6** — from Garkenholz, in upper (6a) and lower (6b) views, × 55; **7** — from Rübeland, × 40

All upper views, except as noted



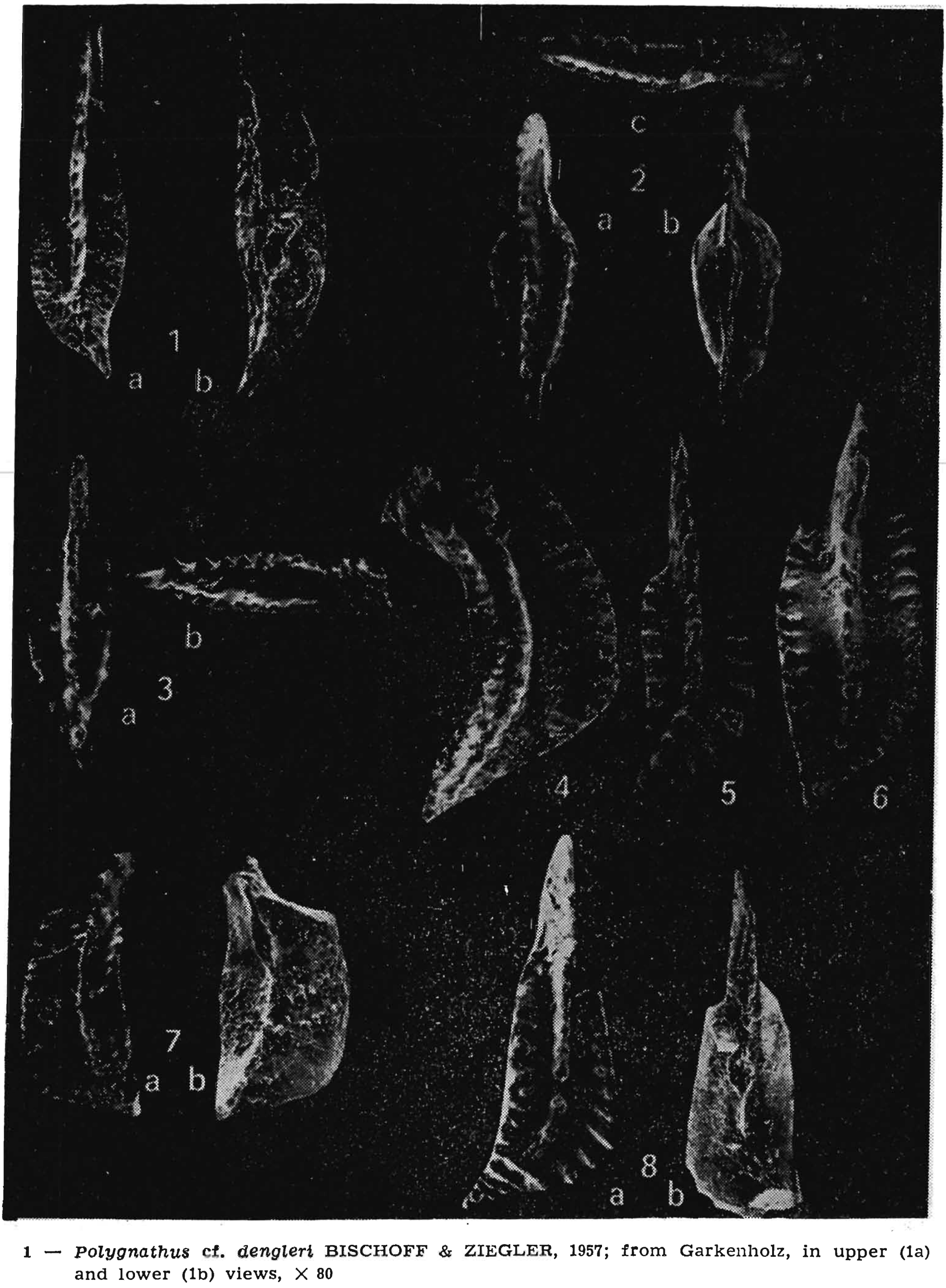
Polygnathus ovalis ZIEGLER & KLAPPER, 1964

1-3 — from Garkenholz, 1 — × 60; **2** — juvenile specimen, only lower view, × 90; **3** — in upper (3a) and lower (3b) views, × 80; **4** — from Rübeland, in upper (4a) and lower (4b) views, × 45; **5** — from Rübeland, in upper (5a) and lower (5b) views, × 80

Polygnathus dengleri BISCHOFF & ZIEGLER, 1957

6-8 — from Garkenholz, **6** — in upper (6a) and lower (6b) views, × 80; **7** — × 60; **8** — × 45

All upper views, except as noted



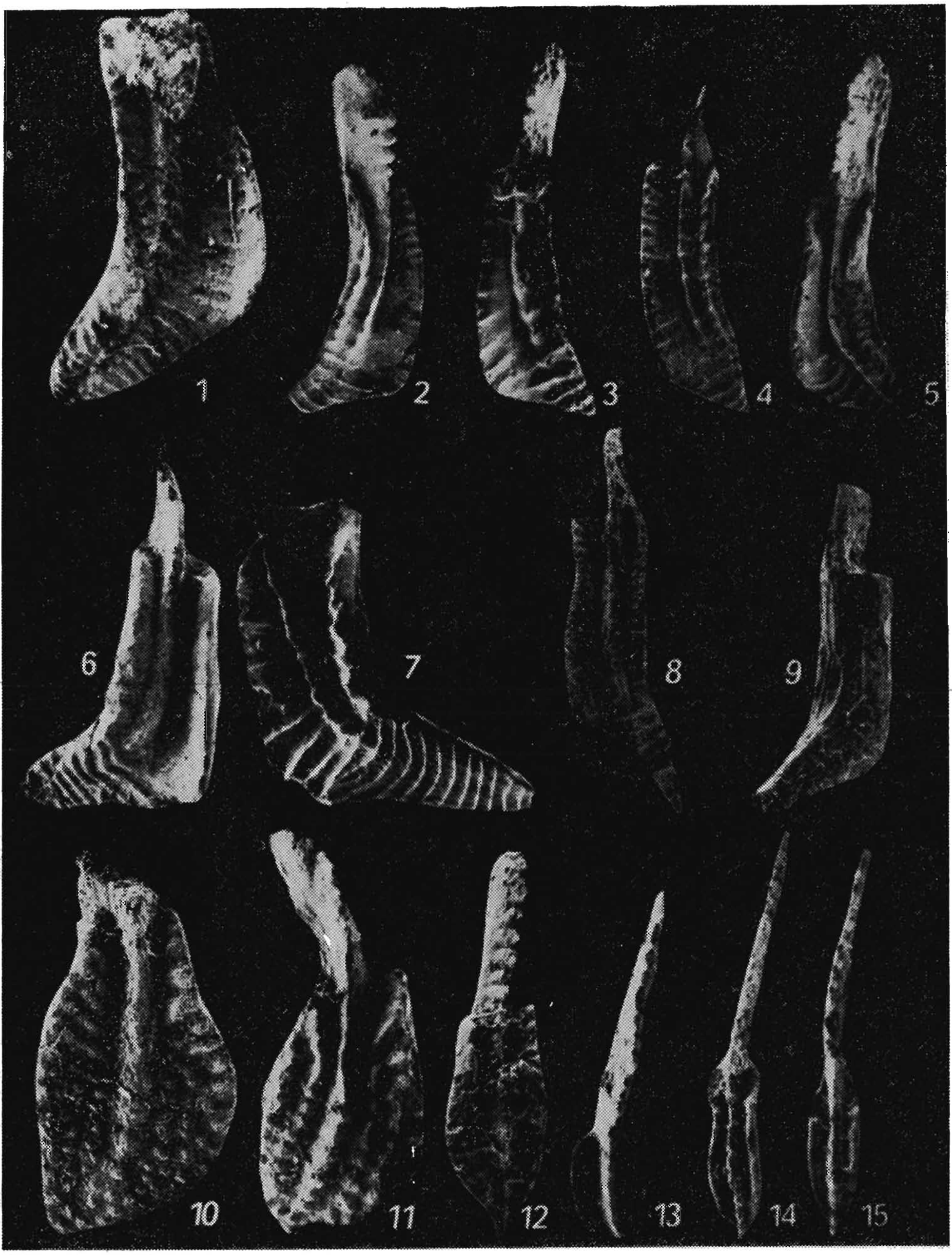
1 — *Polygnathus* cf. *dengleri* BISCHOFF & ZIEGLER, 1957; from Garkenholz, in upper (1a) and lower (1b) views, × 80

2-3 — *Polygnathus dengleri* BISCHOFF & ZIEGLER, 1957; from Rübeland, 2 — in upper (2a), lower (2b) and lateral (2c) views, × 60; 3 — in upper (3a) and lateral (3b) views, × 80

4-6 — *Polygnathus linguiformis weddigei* CLAUSEN, LEUTERITZ & ZIEGLER, 1979; 4 — from Neuwerk, × 60; 5 — from Büchenberg, × 45; 6 — Ibenklippen, × 60

7-8 — *Polygnathus linguiformis klapperi* CLAUSEN, LEUTERITZ & ZIEGLER, 1979; 7 — from Ibenklippen, in upper (7a) and lower (7b) views, × 60; 8 — from Neuwerk, in upper (8a) and lower (8b) views, × 45

All upper views, except as noted



1-9 — *Polygnathus linguiformis linguiformis* HINDE, 1879; 1-2 — from Neuwerk, × 35; 3 — from Neuwerk, × 60; 4 — from Volkmarskeller, × 45; 5 — from Mandelholz, × 30; 6-7 — from Ibenklippen, × 35; 8-9 — from Büchenberg, × 35

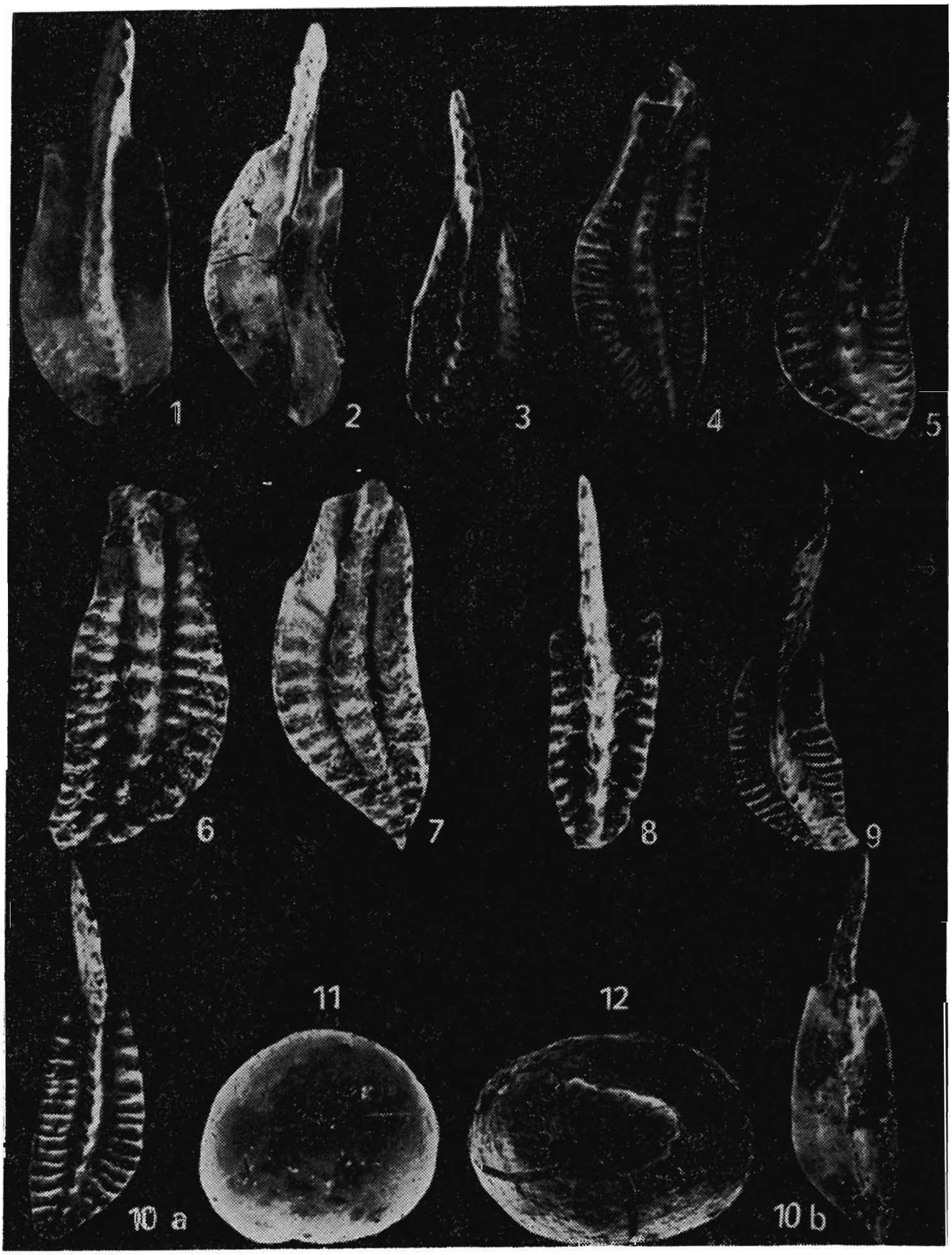
10-11 — *Polygnathus limitaris* ZIEGLER & KLAPPER, 1976; 10 — from Rübeland, × 60; 11 — from Hornberg, × 45

12 — *Polygnathus* cf. *xylus xylus* STAUFFER, 1940; from Büchenberg, × 75

13 — *Polygnathus varcus* STAUFFER, 1940; from Garkenholz, × 60

14-15 — *Polygnathus timorensis* KLAPPER, PHILIP & JACKSON, 1973; 14 — from Büchenberg, × 45; 15 — from Volkmarskeller, × 45

All upper views, except as noted



1-3 — *Polygnathus alatus* HUDDLE, 1934; 1-2 — from Garkenholz, × 60; 3 — from Rübeland, juvenile specimen, × 90

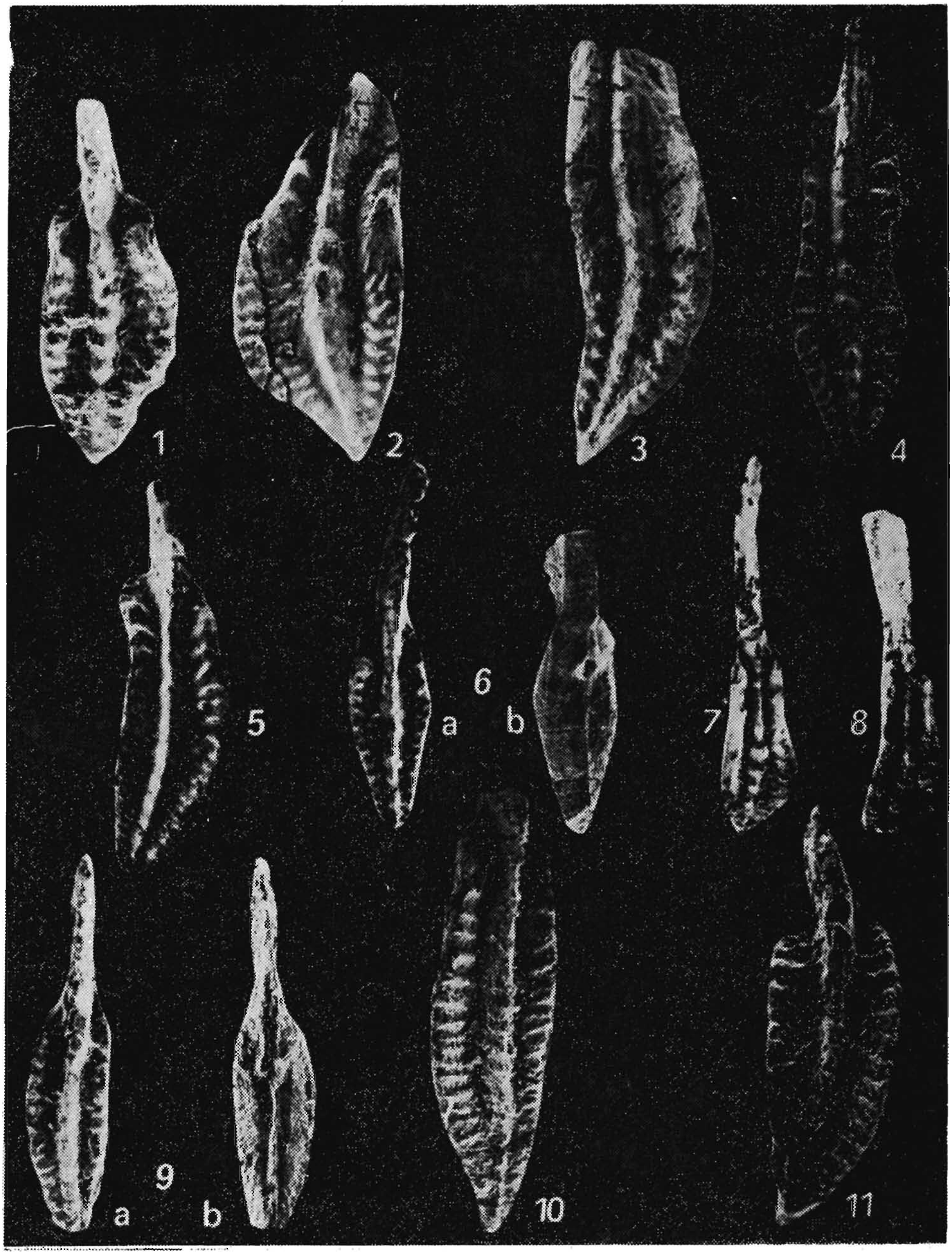
4-5 — *Polygnathus alatus* HUDDLE, 1934 (*webbi* trend); from Rübeland, × 60

6-7 — *Polygnathus webbi* STAUFFER, 1938; 6 — from Rübeland, × 60; 7 — from Elbingerode, × 60

8-10 — *Polygnathus pennatus* HINDE, 1879; 8 — from Rübeland, × 45; 9 — from Garkenholz, × 60; 10 — from Rübeland, in upper (10a) and lower (10b) views, × 45

11-12 — "conodont pearls"; from Rübeland, 11 — × 60; 12 — × 75

All upper views, except as noted



1-2 — *Polygnathus ovatinodosus* ZIEGLER & KLAPPER, 1976; from Hornberg, 1 — × 60

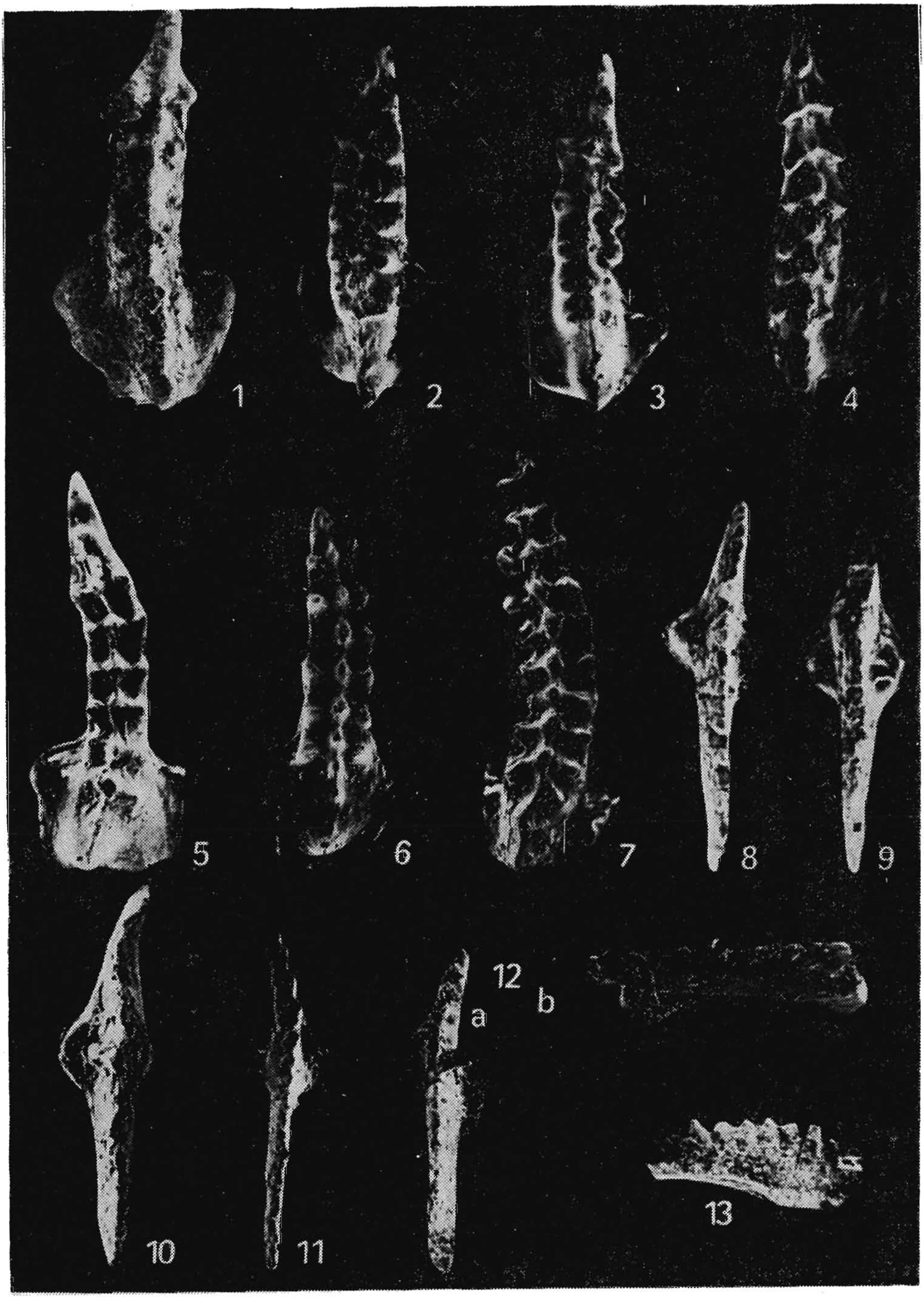
3-4 — *Polygnathus dubius* HINDE, 1879; 3 — from Hornberg, × 60; 4 — from Rübeland, × 40

5-6 — *Polygnathus dubius* HINDE, 1879 (*decorosus* trend); 5 — from Rübeland, × 45; 6 — from Hornberg, in upper (6a) and lower (6b) views, × 40

7-8 — *Polygnathus ansatus* ZIEGLER & KLAPPER, 1976; from Ibenklippen, 7 — × 30; 8 — × 45

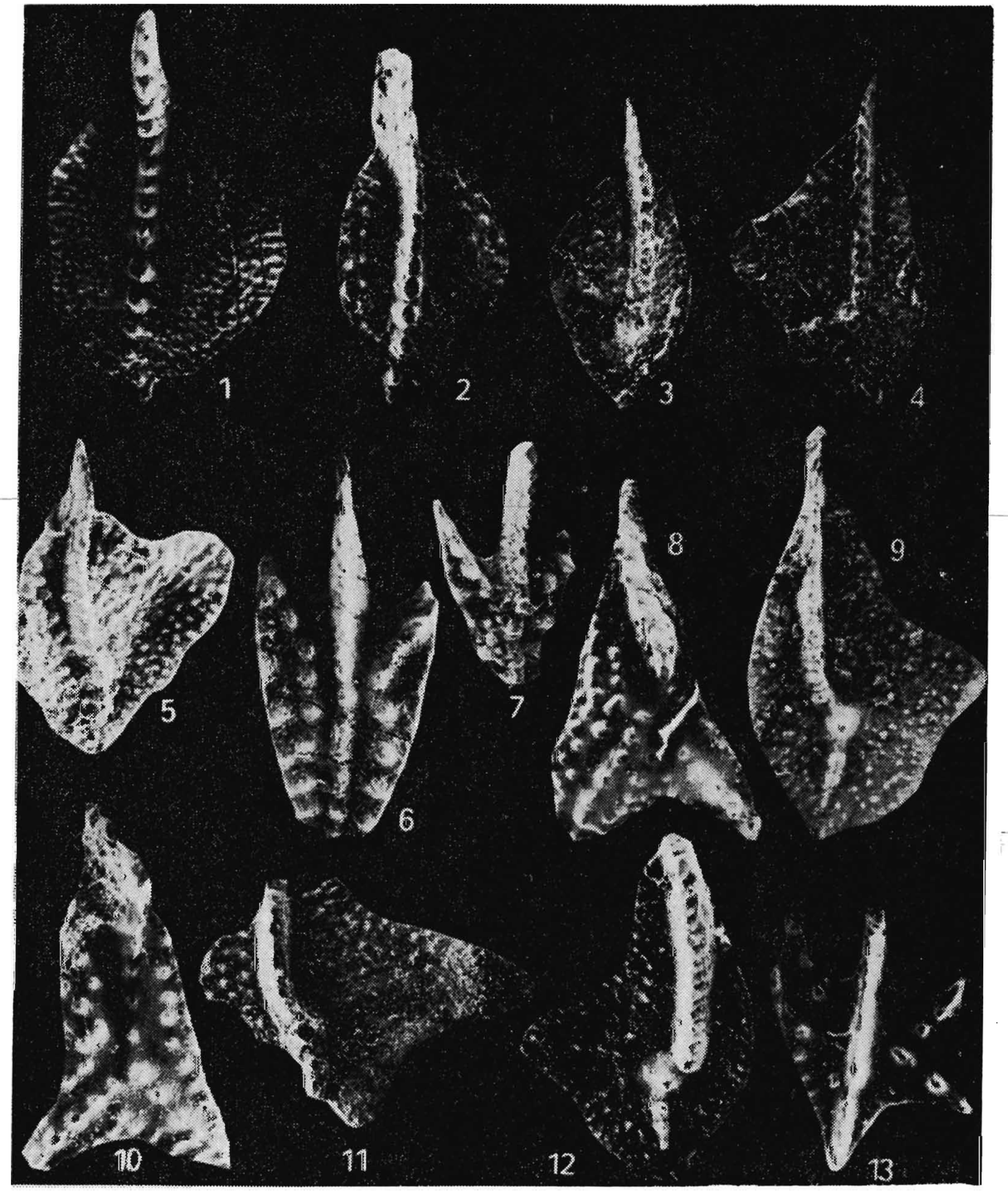
9-11 — *Polygnathus decorosus* STAUFFER, 1938; from Grakenholz, 9 — in upper (9a) and lower (9b) views, × 60; 10-11 — × 80

All upper views, except as noted



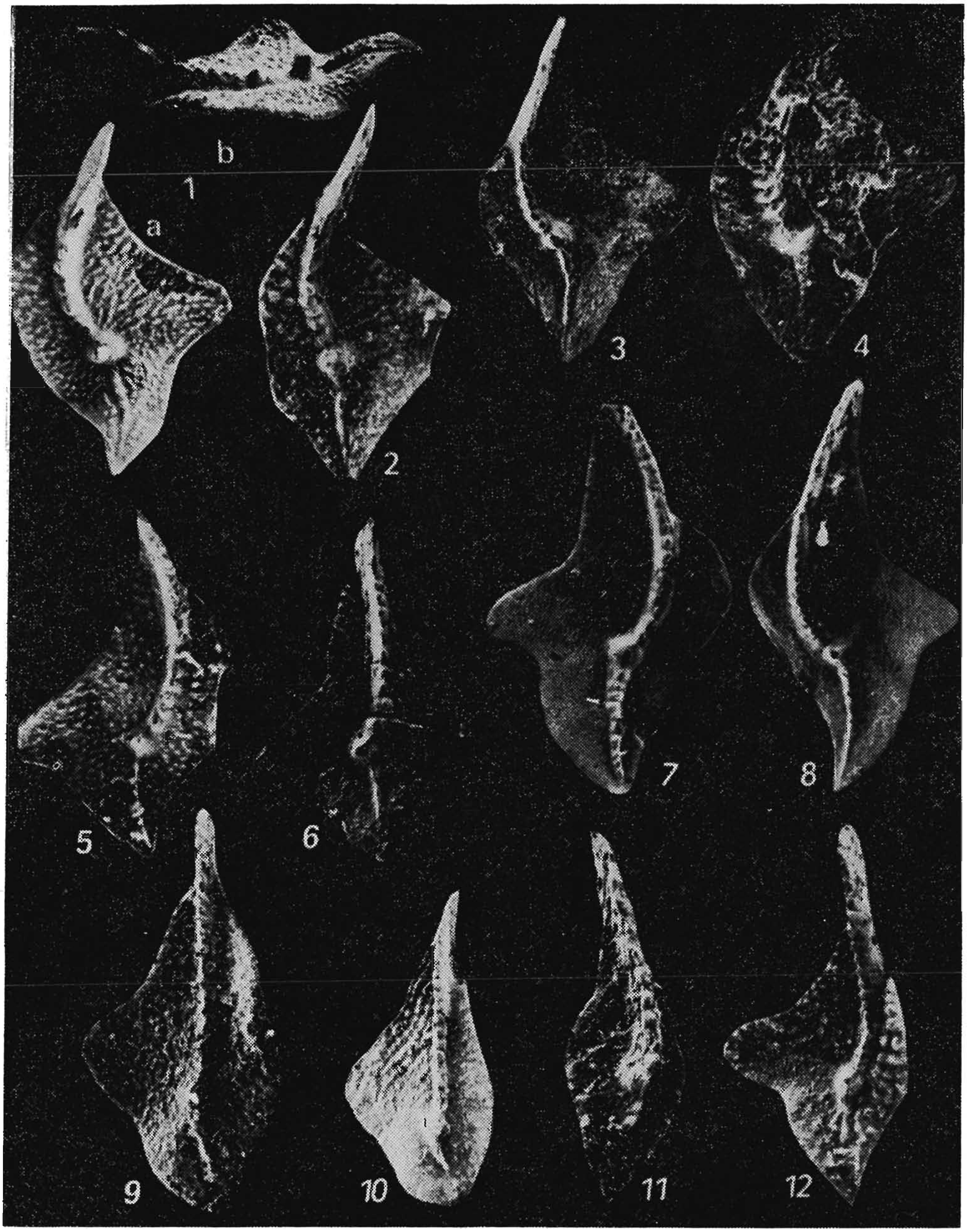
1-4 — *Icriodus brevis* STAUFFER, 1940; 1 — from Mandelholz, × 50; 2-4 — from Büchenberg, × 50
5-7 — *Icriodus symmetricus* BRANSON & MEHL, 1934; from Rübeland, × 80
8-12 — *Ozarkodina sannemanni* (BISCHOFF & ZIEGLER, 1957); 8-10 — from Rübeland, × 50; 11 — from Büchenberg, × 65; 12 — from Elbingerode, in upper (12a) and lower (12b) views, × 80
13 — *Panderonellina* cf. *insita* (STAUFFER, 1940); from Elbingerode, × 80

All



1-2 — *Polygnathus asymmetricus* BISCHOFF & ZIEGLER, 1947; from Garkenholz, 1 — × 40; 2 — × 65
3-4 — *Palmatolepis transitans* MÜLLER, 1956; from Garkenholz, × 65
5 — *Palmatolepis proversa* ZIEGLER, 1958; from Garkenholz, × 55
6-7 — *Ancyrodella gigas* YOUNGQUIST, 1947; from Garkenholz, × 65
8, 10 — *Ancyrognathus asymmetricus* (ULRICH & BASSLER, 1926); 8 — from Ibenklippen, × 40; 10 — from Rübeland, × 65
9, 12 — *Palmatolepis subrecta* MILLER & YOUNGQUIST, 1947; 9 — from Ibenklippen, × 65; 12 — from Rübeland, × 65
11 — *Palmatolepis gigas* MILLER & YOUNGQUIST, 1947; from Rübeland, × 55
13 — *Ancyrodella curvata* (BRANSON & MEHL, 1934); from Rübeland, × 65

All upper views



1-2, 5 — *Palmatolepis triangularis* SANNEMANN, 1955; from Rübeland, 1 — in upper (1a) and lateral (1b) views, × 35; 2 — specimen transitional to *Pa. quadrantinodosalobata*, × 70; 5 — × 45

3-4 — *Palmatolepis subperlobata* BRANSON & MEHL, 1934; from Rübeland, 3 — juvenile specimen, × 125; 4 — juvenile specimen, × 90

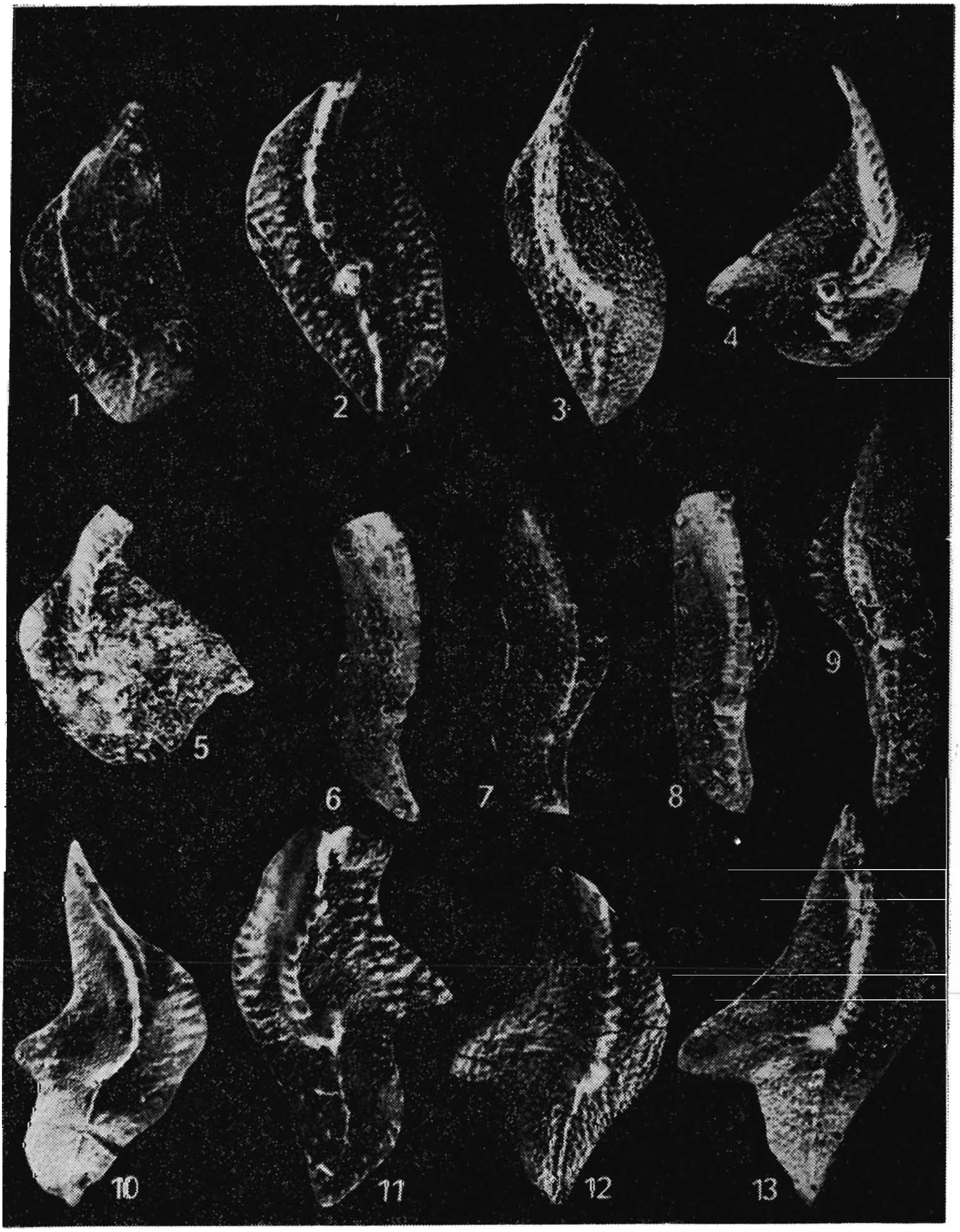
6 — *Palmatolepis delicatula clarki* ZIEGLER, 1962; from Rübeland, × 60

7-8 — *Palmatolepis tenuipunctata* SANNEMANN, 1955; 7 — from Elbingerode, × 35; 8 — from Ibenklippen, × 60

9-11 — *Palmatolepis minuta minuta* BRANSON & MEHL, 1934; 9—10 — from Garkenholz, 9 — × 60; 10 — × 45; 11 — from Elbingerode, × 60

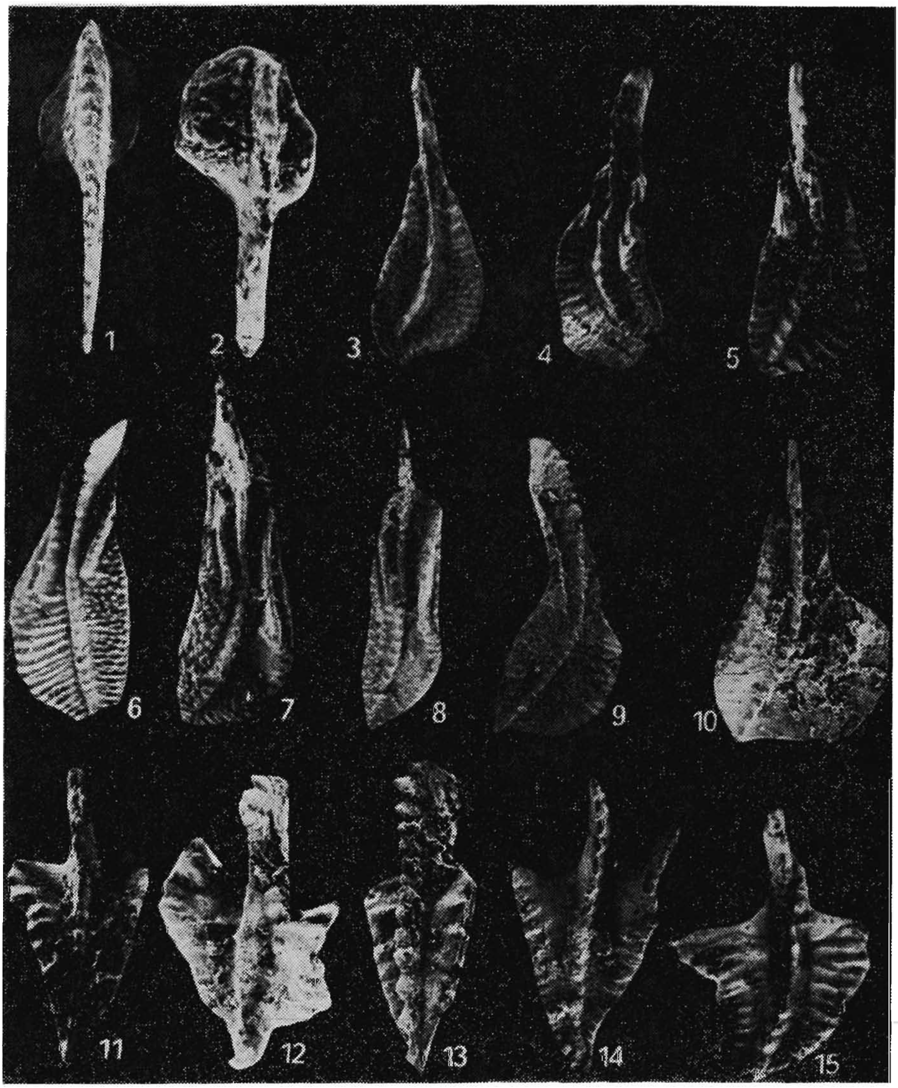
12 — *Palmatolepis quadrantinodosalobata* SANNEMANN, 1955; from Elbingerode, × 60

All upper views, except as noted



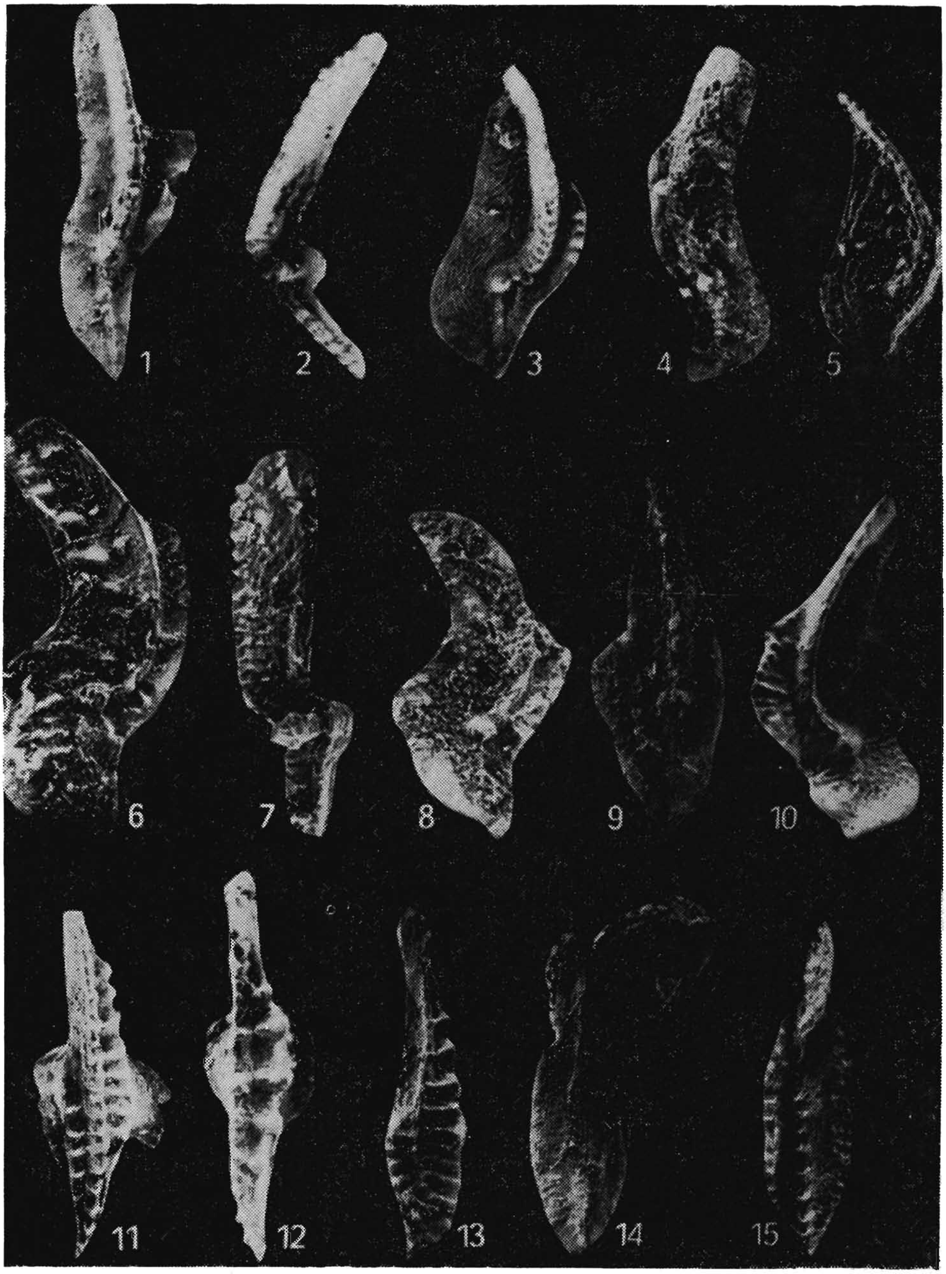
1-2 — *Palmatolepis crepida* SANNEMANN, 1955; from Rübeland, × 65
3 — *Palmatolepis regularis* COOPER, 1931; from Rübeland, × 80
4-5 — *Palmatolepis circularis* SZULCZEWSKI, 1971; 4 — from Rübeland, × 80; 5 — from Garkenholz, × 65
6-8 — *Palmatolepis glabra prima* ZIEGLER & HUDDLE, 1969; 6 — from Garkenholz, × 65; 7 — from Rübeland, × 45; 8 — from Zillier, × 80
9 — *Palmatolepis glabra lepta* ZIEGLER & HUDDLE, 1969; from Rübeland, × 80
10-11 — *Palmatolepis perlobata sigmoidea* ZIEGLER, 1962; from Elbingerode, × 45
12-13 — *Palmatolepis perlobata schindewolfi* MÜLLER, 1956; from Elbingerode, 12 — × 40; 13 — × 30

All upper views



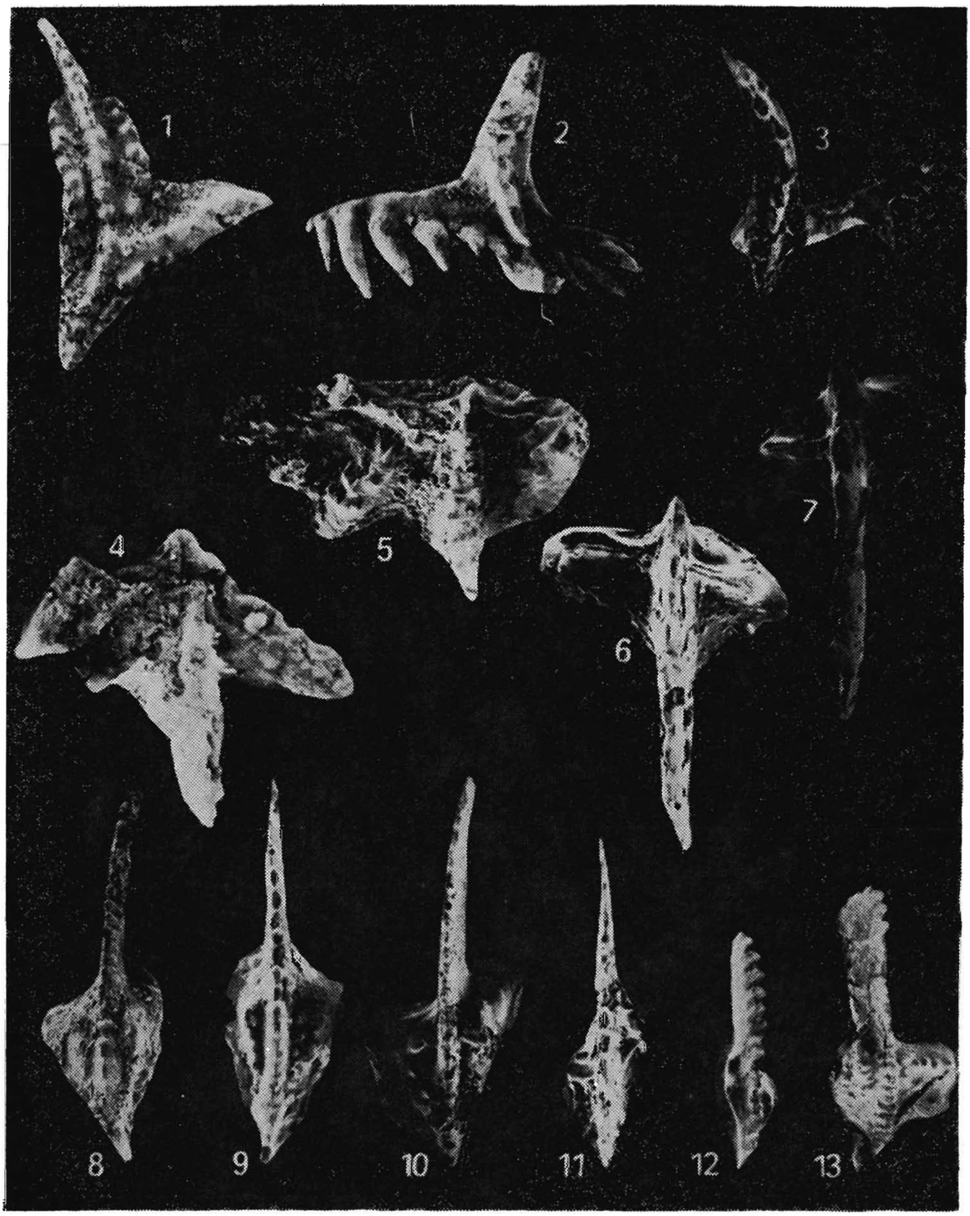
1 — *Protognathodus meischneri* ZIEGLER, 1969; from Zillier, × 60
2 — *Protognathodus kockeli* BISCHOFF, 1957; from Zillier, × 75
3-5 — *Siphonodella duplicata* (BRANSON & MEHL, 1934); 3-4 — from Rübeland, 3 — × 30; 4 — × 20; 5 — from Zillier, × 75
6 — *Siphonodella duplicata* sensu HASS (1959); from Zillier, × 30
7-8 — *Siphonodella obsoleta* HASS, 1959; from Rübeland, × 40
9-10 — *Siphonodella crenulata* (COOPER, 1939), morphotype 2; 9 — from Rübeland, × 35; 10 — from Zillier, × 60
11, 13 — *Pseudopolygnathus oxypageus* LANE, SANDBERG & ZIEGLER, 1980; from Rübeland, 11 — × 45; 13 — × 60
12, 14-15 — *Pseudopolygnathus pinnatus* VOGES, 1959; from Rübeland, × 35

All upper views



1 — *Palmatolepis glabra acuta* HELMS, 1963; from Zillier, × 30
2 — *Palmatolepis gracilis gracilis* BRANSON & MEHL, 1934; from Rübeland, × 45
3 — *Palmatolepis marginifera marginifera* HELMS, 1959; from Zillier, × 75
4 — *Palmatolepis glabra distorta* BRANSON & MEHL, 1934; from Rübeland, × 60
5 — *Palmatolepis marginifera utahensis* ZIEGLER & SANDBERG, 1984; from Zillier, × 90
6 — *Palmatolepis rugosa trachytera* ZIEGLER, 1960; from Zillier, × 60
7 — *Palmatolepis gracilis sigmoidalis* ZIEGLER, 1962; from Zillier, × 60
8 — *Palmatolepis perlobata postera* ZIEGLER, 1960; from Rübeland, × 60
9 — *Palmatolepis gracilis expansa* SANDBERG & ZIEGLER, 1979; from Rübeland, × 35
10 — *Palmatolepis rugosa* cf. *ampla* SANDBERG & ZIEGLER, 1979; from Zillier, × 35
11, 13 — *Bispathodus ultimus* (BISCHOFF, 1957); from Rübeland, × 45
12 — *Bispathodus aculeatus aculeatus* (BRANSON & MEHL, 1934); from Zillier, × 75
14-15 — *Siphonodella* cf. *praesulcata* SANDBERG, 1972; from Rübeland, × 45; 14 — in lower view with "conodont pearls"

All upper views, except Fig. 14



1 — *Ancyrognathus triangularis* YOUNGQUIST, 1945; from Rübeland, × 35

2-3 — *Scaliognathus praeanchoralis* LANE, SANDBERG & ZIEGLER, 1980; from Rübeland, 2 — × 35; 3 — × 60

4-5 — *Dollymae hassi* VOGES, 1959; from Rübeland, × 40

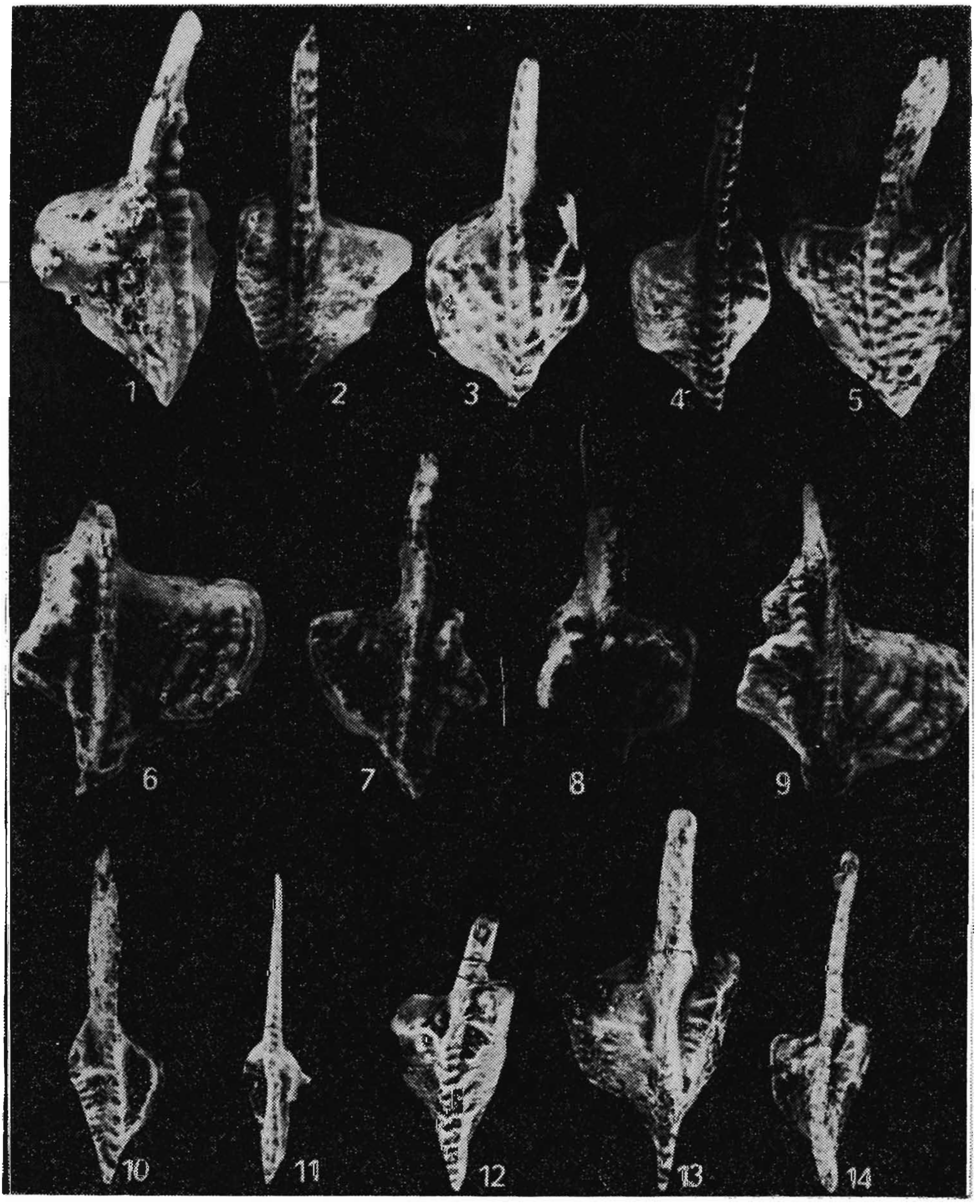
6-7 — *Dollymae bouckaerti* GROESSENS, 1971; from Zillier, × 90

8-10, 12 — *Gnathodus typicus* COOPER, 1939; 8 — from Rübeland, × 45; 9—10, 12 — from Zillier, × 75

11 — *Gnathodus texanus* ROUNDY, 1926; from Zillier, × 90

13 — *Gnathodus semiglaber* BISCHOFF, 1957; from Zillier, × 30

All upper views



1-2, 10 — *Gnathodus delicatus* BRANSON & MEHL, 1938; 1 — from Zillier, × 60; 2 — from Rübeland, × 45; 10 — from Rübeland, × 70

3-4, 6-9 — *Gnathodus punctatus* (COOPER, 1939); 3, 6 — from Zillier; 3 — × 60; 6 — × 45; 4, 7-9 — from Rübeland, × 40

5 — *Protognathodus praedelicatus* LANE, SANDBERG & ZIEGLER, 1980; from Zillier, × 60

11 — *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS, 1970; from Rübeland, × 30

12-14 — *Gnathodus semiglaber* BISCHOFF, 1957; from Rübeland, × 40

All upper views

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A. FUCHS

STRATYGRAFIA KONODONTOWA KOMPLEKSU OSADÓW RAFOWYCH Z OKOLIC ELBINGERODE W GÓRACH HARZU

(Streszczenie)

W pracy przedstawiono wyniki badań fauny konodontowej (*patrz* pl. 3—22) uzyskanej z osadów dewońskiego kompleksu rafowego występującego w okolicach Elbingerode w Górach Harzu (fig. 1). Struktura rafowa, mająca formę atolu, rozwinęła się tu na podmorskim wyniesieniu wulkanicznym (*patrz* fig. 2). Fauna konodontowa umożliwiła precyzyjne datowanie poszczególnych faz rozwoju tej struktury (*patrz* fig. 3—5). Początek sedymentacji węglanowej miał miejsce w środkowym poziomie *varcus*, zaś zamieranie rafy przebiegało diachronicznie, aż do górnego poziomu *gigas*. Obecność konodontów jest jednak wyłącznie ograniczona do facji osadów przedrafowych. Niemniej nie stwierdzono tam żadnej segregacji taksonów konodontowych ze względu na głębokość ich występowania.

W obrębie skał węglanowych kompleksu rafowego (*por.* pl. 1) stwierdzono ponadto występowanie żył neptunicznych i wtórnych wypełnień w formie kieszeni (*patrz* pl. 2), które swym wiekiem sięgają aż po dolnokarboński poziom *anchoralis-latus*, lecz zwykle zawierają wymieszaną faunę konodontową (*por.* fig. 6).

Konodonty pochodzące z osadów facji przedrafowych, jak i te z żył neptunicznych wykazują czasami duży przedział zmienności barw. Najprawdopodobniej zjawisko to wywołały krążące w skałach kompleksu rafowego roztwory hydrotermalne pochodzące z wulkanicznego podłoża.

Zamarcie struktury rafowej w okolicy Elbingerode jest interpretowane jako efekt gwałtownego wzrostu subsydencji dna morskiego.