

An octocoral from the Lower Ordovician of Sweden

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With 2 Plates and Appendix

Geochemische Untersuchungen an einem apatitischen Problematicum aus dem Ordoviciun von Schweden

by
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Mit 1 Tabelle

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An arborescent apatitic fossil with lateral branching and concentric laminar structure was found in a basal Volkhovian (Arenigian) limestone at Borghamn. Like the axes of certain recent gorgonians it has loculi and a hollow central core. The phosphate has ca. 0.1% J, rather evenly distributed. Al (non-silicate) is sporadically enriched. The fossil is described as *Nonnegorgonides zieglerei* n. gen. n. sp.. Gorgonians were previously unknown in beds older than Cretaceous.

In einem Kalkstein im tiefsten Volkhovium (Arenig) wurde bei Borghamn ein bäumchenförmiges apatitisches Fossil mit seitlichen Zweigen und einer konzentrischen Lagenstruktur gefunden. Es besitzt Lokuli und einen zentralen Hohlraum im Innern, wie die Achsen gewisser rezenter Gorgonien. Der Phosphat enthält etwa 0.1% Jod ziemlich gleichmäßig verteilt, Aluminium (nicht Si-gebunden) ist stellenweise angereichert. Das Fossil wird als *Nonnegorgonides zieglerei* gen. n. sp. beschrieben. Gorgonien waren bisher in präkretazischen Schichten unbekannt.

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Introduction

In 1968 I had the good luck to discover a previously unknown megafossil in the orthoceratite limestone quarry at Borghamn (UTM coordinates VE 815 713), Sweden. The fossil, a twig-like structure consisting of branching rods of a light greyish material, was found in a dump of limestone at the bottom of the quarry. Several pieces of it could be collected at the time. When the geology department of the Marburg University made an excursion to Sweden in the following year, a visit was paid to the Borghamn quarry, where further fragments were found. When all fragments were glued together, it turned out that the material collected in 1969 belonged to the same specimen as that found in 1968.

Geologic background

The Lower Ordovician orthoceratite limestone of Borghamn belongs to a facies that may once have been continuous over the Baltic Shield. It is a bedded to nodular limestone that formed at very slow rates of deposition during the Late Tremadocian to

Llandeilian. The fauna mainly consists of arthropods, unidentified echinoderms, small brachiopods, gastropod protoconchs, cephalopods, and conodonts. In the upper and lower parts of the succession, major brachiopods, bryozoans, and entire echinoderms are either rare or absent. The fossil discovered at Borghamn is an unexpected appearance in this association.

The Borghamn section has been described i. a. by ROSÉN (1916) and WESTERGARD (1940). The basal Ordovician consists of about 5 m of black shale with inclusions of black bituminous limestone. Small quartz pebbles may occur in the basalmost bed. Above the black shale that is of Tremadocian age there follows about 1.3 m of strongly glauconitic limestone with shale interlayers, and with small pebbles of quartz and phosphatized black limestone at the base. This is probably basal Arenigian. Like the underlying black shale it is no longer accessible at the finding place of the fossil. The glauconitic limestone is overlain by about 2.5 m of light greenish grey shale with lenses and layers of limestone of the same colour. This so-called Lower Didymograptus Shale is Arenigian (Latorpian). It is succeeded by several meters thick orthoceratite limestone of Arenigian-Llanvirnian age, which forms the top of the section.

The fossil was found in a slab quarried from the basal bed of the orthoceratite limestone. This bed contains conodonts of the *Baltotriodus triangularis* Zone, and hence belongs to the base of the Volkhovian Stage of the Baltoscandian Arenigian (LINDSTRÖM 1971 a).

As in other parts of the Baltic Shield where the base of the Volkhovian can be identified, this bed shows a complex and interesting sedimentology. Deposition of a ca. 0.12 m thick unit took place in several stages. At least the following events can be distinguished.

1. – Intensive burrowing and grazing of a surface of the mud that went into forming the uppermost portion of the shale.
2. – Deposition of coarsely arenitic limestone on the surface with abundant trace fossils. The limestone contains abundant glauconite and rounded to angular quartz grains. The fossil was found in this bed.
3. – Lithification of the limestone bed.
4. – Deposition of calcarenite and marl with abundant inarticulate brachiopods that may reach a size of about 5 mm.
5. – Gentle slumping, with displacement of the limestone formed under 2–3 (see LINDSTRÖM 1971 b, Abb. 4).
6. – Vertical burrowing.
7. – Deposition of fine calcareous mud.
8. – Lithification of the bed formed under 7.
9. – Formation of a smooth discontinuity surface with amphorashaped pits. The surface is brightly coloured in red, yellow, and light greyish green.
10. – Deposition of red calcareous mud.
11. – Gentle slumping, with fragmentation and displacement of the structures formed under 7–9.
12. – Lithification of the mud formed under 10.
13. – Formation of a slightly irregular discontinuity surface that cuts across structures 7–12.
14. – Deposition of red calcareous mud.
15. – Lithification.
16. – Formation of a surface like 13, with borings.
- 17–18. – Repetition of 14–15.
19. – Smooth discontinuity surface.
- 20–28. – Thrice repetition of 14–16.

Condensation as a result of very slow sedimentation, slumping, and occasional deposition of quartz grains, are obvious features of the Borghamn section. The section is situated at the foot of Mount Omberg, a tectonically raised block of Precambrian rocks. The characteristics of the section are explicable if Omberg formed a rise already during the time of deposition of the Lower Ordovician beds. Late Precambrian or Lower Cambrian Sandstone, once deposited over much of Sweden, if existent and exposed on the rise would have yielded the quartz grains; these were no doubt derived from a nearby source. If the calcareous sediments were deposited on the slope of the rise, this would explain the repeated slumping. The abundant inarticulates, as well as the fossil to be described as *Nonnegorgonides*, might have lived on the higher ground of the rise.

Description of the fossil

The fossil consists of fragments of several branches, presumably belonging to one individual. The longest fragment is 225 mm. It consists of an n^{th} order branch, called main stem, that is straight and gives off lateral $(n + 1)^{\text{th}}$ order branches to alternate sides at intervals varying from 12 mm to 45 mm. The angle of departure of the branches is commonly about 45° , but is $70\text{--}90^\circ$ in three cases occurring on the main slab. The preserved part of the main stem decreases from 2.7 mm to 1.2 mm thickness in a preserved length of 200 mm.

At their point of departure most branches are somewhat thinner than the main stem. They are either straight or curved so as gradually to become subparallel to the main stem. They give off $(n + 2)^{\text{th}}$ order branches at intervals of 10–35 mm, and these again give off $(n + 3)^{\text{th}}$ order branches, however, at longer intervals. The surface of the slab is strewn with shorter fragments that vary in thickness from 2.3 mm to 0.5 mm. The longest is 134 mm. It forms a gentle sine curve and decreases from 1.0 to 0.7 mm thickness. It is only seen to give off two branches, both laterally. Since these other fragments cannot be traced to the main stem, and the latter does not show any points of attachment of further branches, one must assume that only a part of the original structure is preserved.

Where preserved in full relief the cross section is subcircular. Where flattening occurs, this has been accomplished by caving in and partial rupturing of the outer surface. The proximal position of the fossil is rotated upwards from the bedding plane. This, again, has led to breakage.

The surface is ornamented by sharp-crested, longitudinal wrinkles with a wave-length of about 0.05 mm. Smooth portions are adorned with a much finer striation, suggesting a fibrous structure. The thinnest, distal parts of the branches (0.5 mm thick) have numerous, low and smooth protuberances, ca. 0.1–0.3 mm long and either adjacent to one another or with a variable spacing. In thin sections of thicker, more proximal fragments, it can be seen that protuberances formed at an early stage in these as well, to become overgrown later on.

The fossil consists of compact, continuous lamellae that are 1–6 μm thick. There are sequences of lamellae that are in close contact with one another, as well as lunulate interspaces. Some interspaces are relatively narrow intercalations in the lamellar sequences and comprise only a few degrees of the cross-section curvature. Though their filling is commonly gone, it appears not always to have been calcitic. The more important interspaces may extend round much of the branch and are filled with unusually perfect monocrystalline calcite. Lamellae are frequently interrupted at the margins of these interspaces, and the ends may be curled up. Whereas the outer border of such an interspace consists of a smooth lamella, the lamella at the inner margin is crinkled. The crinkling and breakage of lamellae could be taken as indication that the larger interspaces are secondary features. According to this interpretation the crinkled inner lamella was originally adjacent to the smooth lamella at the outer boundary of the interspace. When forced to retract by shrinkage of still more internal lamellae it had to respond by folding. Ruptures at some fold hinges show that the folded lamellae were occasionally brittle rather than flexible. The folding corresponds to the fine corrugations externally on the branches. The center of each branch is an open and continuous space, secondarily filled with monocrystalline calcite.

The calcite filling of the spaces within the fossil may be either clear or provided with a variable content of either small grains or floccules. Within each single space it is always the same. Some interspaces contain spherical brown bodies of apparently organic matter.

Chemistry and mineralogy

The lamellae consist homogeneously of a weakly birefringent mineral with optical axes evidently perpendicular to the lamellar surfaces. The size of the crystallites is below the range visible in thin section. Electron probe analysis (PIETZNER, Appendix) show concentrations of Ca and P, but not of C, at the sites of the lamellae, confirming the suspicion that the lamellae consist of calcium phosphate. F shows a spatial correlation with Ca and P. According to PIETZNER, the mineral is a high-F, high-pH francolite.

The abundance of trace elements suggests a replacement origin of the phosphate.

Whereas the large interspaces are filled with calcite, in some interspaces with uniformly distributed, small amounts of Fe and Mn, the smaller interspaces appear porous, possibly owing to organic material lost in preparation. They can contain phosphatic floccules and varying amounts of calcite and ferromanganese components.

Aluminium is a minor component but is concentrated in an interesting manner. In certain interspaces it occurs with Si, which speaks for clay minerals either diagenetic or intruded from without. Elsewhere it is concentrated, without Si, along certain lamellae and as a lining of interspaces. In the latter case the microscopic picture shows a thin sheet of radial crystallites. PIETZNER (Appendix) suggests that Al may either be built into the apatite or form a separate phosphate phase.

The fossil (but not the surrounding sediment) has a remarkable concentration of iodine (ca 0.1%). It occurs principally in the phosphatic lamellae (125–2230 ppm), not so much in the calcite (25–750 ppm). In the outermost lamellae there is a clear tendency for J to decrease outwards.

The organic chemistry was investigated by Dr. A. A. Prashnowsky, Würzburg. Because the sample was too small, not much could be definitely said. Of the carbohydrates, glucose and ribose were present in the sample, but xylose, galactose, mannose, and arabinose were missing. Of 16 amino acids that might be considered, only glycine, alanine, aspartic acid and histidine were present.

Discussion

The fossil was subjected the considerable shrinkage after death. The amount of deformability of the lamellae indicates that these did not originally consist of phosphate. However it would certainly have helped phosphatization if a mineral phase, like calcite or aragonite was present in the tissue from the beginning.

The enrichment in Al is a geochemical argument for an algal nature of the fossil, as noted by PIETZNER (Appendix). A further argument for an algal hypothesis could be seen in the iodine that is greatly concentrated in certain Phaeophyceae. However, the iodine disappears rapidly after death. The data on the organic chemistry are not conclusive.

Among the algae, only rhodophytes and phaeophytes have an organization that might remotely permit comparison with the Borghamn fossil. However, they do not have a concentric laminated structure but have either a cortex of smaller cells formed by outward splitting off from larger cells of the medulla, or a one to several layers thick cortex without distinct lamination and a medulla consisting of interwoven filaments. Even large-celled rhodophytes that grew by increments do not have continuous, distinct growth laminae of uniform thickness. In laminated rhodophytes, like *Hildenbrandia*, the radial filaments, densely compacted laterally to form the layers, would moreover appear as a radial structure. Because of the importance of specialist experience, I have shown the existing material of high-magnification photographs to Dr. Jacqueline Cabioch of the C. N. R. S. marine biological station at Roscoff, France, who also kindly conferred with other algal specialists. I was informed with some assurance that neither the morphology nor the structure of the fossil were algal.

A similar structure does, however, exist in the animal kingdom. Octocorals belonging to Order Gorgonacea (sea whips, sea feathers, and sea fans) have more or less branched colonies that are provided with an axial structure surrounded by a rind. The axial structure can be either a dense, horny or calcareous central cylinder, or a medullar zone of spicules bound together more tightly than those of the rind. The rind consists of coenenchyme

and houses the polyps as well as the solenia, or connecting tubes between the polyps. It also contains a great abundance of calcitic spicules of different shapes (DEICHMANN 1936, HYMAN 1940, BAYER 1961).

Whereas the rind tends to disintegrate rapidly after death, the axis is somewhat more resistant. It is secreted by an epithelium situated on the inner side of the rind. As the colony grows, the axial cortex grows thicker. It does not carry imprints of the individual polyps found in the rind. The Gorgonacea are mostly fastened to the substratum by a basal plate or root-like hold fast. The aspect of the colony is plant-like. It commonly branches in one plane.

Four gorgonacean families are characterized by a horny axis with a concentric lamellar structure. They are, the Acanthogorgiidae, the Gorgoniidae, the Plexauridae, and the Paramuriceidae. Unfortunately, these families are most easily differentiated by means of rind structure and, above all, the characteristics of the spicules. Such characters are evidently useless in the case of the Borghamn fossil. The core of the axis in the said families is divided into chambers by a close sequence of thin, transverse walls. In the Borghamn fossil the core is open. It is possible that this is an original feature, but walls, once present, might also have disintegrated. According to Dr. F. M. B a y e r, Smithsonian Institution, Washington, D. C. (written communication) the latter possibility is quite likely, because in many gorgonacean genera the transverse walls are extremely thin and delicate. Dry specimens of West Indian *Plexaura homomalla*, *Lophogorgia* sp., and *Lep-togorgia* sp. were available for thin sectioning of the axis. A compact structure of concentric laminae surrounded the empty core in all transverse sections. The longitudinal sections showed the laminae to be arranged in overlapping lenticular packets, with the orientations somewhat different from packet to packet, although generally subparallel to the length axis of the colony. At crossed Nicols the fibrous lenticles showed a migrating extinction. Although a fibrous structure can be discerned in the lamellae of the fossil as well, the later lamellae are continuous and parallel to the axis.

According to B a y e r (letter of Oct. 25, 1977), »The lamellae, and the lunulate interspaces between them, called 'loculi' by most writers on gorgonians, are very typical«. The following further remarks in the same letter are important, »I think that the interspaces in your fossil are for the most part quite normal, not the result of shrinkage. In *Plexaura homomalla* and many others, these spaces are mostly hollow but contain delicate calcified strands, whereas in others (e. g., *Plexaurella*) they are completely filled with calcite as shown by Kölliker, 1865, and Küenthal, 1919. The wrinkled surface can be seen in many Recent species«. Whereas the structural evidence of shrinkage had prevented the present author from identifying the interspaces with loculi – a further gorgonian feature – an expert on Recent gorgonians thus underscores the identity of the interspaces with gorgonian loculi, at the expense of the shrinkage evidence. Since the interpretation of the interspaces as loculi is accepted as compelling and the shrinkage evidence on the other hand is clear enough, the two interpretations probably must be combined with one another. Evidently the loculi were widened by postmortal shrinkage processes in the Ordovician material.

The presence of loculi eliminates the Gorgoniidae as a probable family for the fossil (B a y e r, letter cited above).

Interestingly enough, gorgonaceans are exceptionally rich in iodine, the horny material (gorgonin) of *Eunicella ctenocelloides* containing as much 8.9% J (ROCHE, FONTAINE & LELOUP 1963). Among the amino acids that constitute the gorgonin, glycine and alanine are the most important, with arginine, thyrrosine, and aspartic acid coming next. Arginine and thyrrosine were not found in the fossil, contrary to histidine that is a very subordinate component of gorgonin.

If the fossil is a gorgonian the enrichment in Al probably is post-mortual. The distribution of Al is much more irregular than that of J. It occurs along certain lamellae and in the linings of interspaces. In the outermost parts, Al is connected with Si, Fe, and Mg, which suggests either intrusion or neof ormation of clay minerals. Internally, it is enriched almost exclusively within purely phosphatic realms. Since these are connected either with interspaces or with the hollow core, Al probably came from without, either with or after the phosphate ions, and preceding the deposition of calcite. One might speculate that the early phase of fossilization was spent under a thin and possibly shifting, non-compacted cover of immature silicate sediment rich in Al, like for instance volcanic ash. Such is believed to have taken part in the formation of the non-calcareous fraction of the orthoceratite limestone (LINDSTRÖM, 1974). Lately, proof in this direction has turned up (LINDSTRÖM, 1978). The phosphatization, too, requires that the fossil stayed for a long time under quiet conditions either in direct contact with the sea-water or under a sediment cover that was thin and permeable enough to allow percolation of solution with the properties suggested by PIETZNER (Appendix).

Systematics

Order Gorgonacea LAMOUROUX, 1816
Family unknown
Genus **Nonnegorgonides** gen. nov.

Type species: *Nonnegorgonides ziegleri* n. sp.

Derivatio nominis: nonne, lat., = interrogative particle, with a positive reply anticipated.

Diagnosis: Axis with smooth, continuous, concentric lamellae of organic material susceptible to phosphatization, extensive axial core hollow, uncertain, if with or without chambers. Sequence of growth lamellae interrupted by frequent loculi. At least in early growth stages, the axis of twigs may carry small, wart-like protuberances.

Remarks: Since the mode of branching is not necessarily a genus-level characteristic, it is included under the species. The most convincing similarity is with certain *Eunicella* species (Bayer, written communication). However, it is impossible to suggest a generic affinity in the absence of spicules.

Nonnegorgonides ziegleri n. sp.
Pl. 1, figs. 1–5; Pl. 2, figs. 1–11

Derivatio nominis: Prof. Willi Ziegler, Marburg, for his friendly help and enthusiasm in connection with this and other research objects.

Holotype: Mbg 3503, pl. 1, figs. 1, 2, pl. 2, figs. 10, 11 (University of Marburg, geology and paleontology collection).

Locus typicus: Borghamn quarry, N flank of Mt Omberg, S of Motala, Sweden, VE 815 712.

Stratum typicum: Basal Volkhovian, »Flowery Sheet«, slumped bed at base of continuous limestone section.

Distribution: A further, small fragment of the aspect and morphology of the Borghamn fossil was found in the basal part of the *Amorphognathus variabilis* Zone, basal Kundan, uppermost Arenigian, 9.9 m above the base of the Ordovician limestone sequence at Gullhögen, Skövde, Sweden.

Diagnosis: Height of mature specimens reaching over 30 cm; branching lateral, in one plane, spacing ca. 10–100 mm; branches rapidly assume a vertical orientation; before reaching 1

mm thickness the axis of the branches carries small, wart-like protuberances.

Description: The diameter of the preserved axis has evidently been reduced by shrinkage. In the thicker fragments it is 2.5–2.7 mm. Distal branches taper to less than 0.6 mm. If the longest, straight branch is taken to be an n^{th} order branch, there are at least $(n + 3)^{\text{th}}$ order branches. Branching mostly takes place to alternate sides. Compared with most living gorgonians, the spacing of the branches is wide.

Before shrinkage even wrinkled lamellae may have been smooth. A fibrous structure is indicated by very fine striation on otherwise smooth lamellae.

The surface of young branches is rendered wavy or knobby by the presence of small protuberances. These form by thickening of lamellae and widening of interspaces and are overgrown before the branches reach a thickness of ca. 1 mm.

Summary and conclusions

An unusual fossil has been found in Arenigian limestone of pelagic type at two localities in south-central Sweden. It is arborescent, laterally branched, 225 mm long, and composed of calcium phosphate (francolite). Phosphatization probably was post-mortual. There is evidence of post-mortual shrinkage. The structure consists of concentric lamellae separated by lunulate interspaces (loculi). The shrinkage has contributed to formation of interspaces. These are filled with single-crystal perfect calcite. Concentration of Al without Si at certain lamellae might have been taken as a geochemical indication of algal affinity. The structure, however, is non-algal, and the Al concentration is likely to be post-mortual and roughly synchronous with phosphatization. A high concentration of J (0.1%) is rather evenly distributed throughout the lamellar structure. Hence, J is suggested to be primary. Although this is compatible with an algal affinity, in the present case it speaks for affinity with the Gorgonacea that are great concentrators of iodine.

The following points furthermore indicate that the fossil is a gorgonian axis: it was originally organic, it consists of thin, originally smooth, and concentric lamellae that are evidently composed of very fine fibres, the lamellae are separated by loculi, the axis has a hollow core, it is laterally branched in one plane, and it bears no impressions of individual zooids and hence (since it is not a plant) must have been surrounded by a rind by which it was secreted and that contained the zooids. The fossil apparently belongs to a group of families of which a chambered axial core may be expected. Since chamber walls must form as continuations of growth lamellae across the growing tips of branches, and there is no indication that the branches of the investigated fossil were open at the tip, it is probable that a chamber structure has existed in the fossil, although it was not found in the fragments sacrificed for sectioning.

The importance of *Nonnegorgonides ziegleri* is twofold. It is the oldest gorgonacean fossil found, since it extends the range of the Gorgonacea from the Cretaceous (Bayer 1956) to the lower Ordovician. Furthermore, it sheds some further light on oceanographic and sedimentary conditions in the Early Ordovician sea of the Baltic Shield. Gorgonacea live at greatly different depths, so that the fossil cannot be taken as a depth indicator. However, as a relatively tall colonial animal, it depended on well aerated bottom conditions and a flow of suspension food. It is probable that Mt. Omberg, adjacent to the Borghamn locality, existed as a rise on the Ordovician sea-floor. Possibly, *Nonnegorgonides* thrived on this rise which is likely to have caused upwelling of relatively nutrient rich bottom water. The conditions of fossilization speak

for a sea-bed with a very quiet water regime and extremely slow sedimentation. The Al trace component of the fossil may come from the alteration of volcanic ashes on the sea-bed.

If the Early Ordovician sea-bed contained greater numbers of octocorals than suggested by chance fossilization, these might have contributed to the formation of calcite mud by their abundant spicules.

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Appendix

Geochemische Untersuchung an einem apatitischen Problematicum aus dem Ordovicium von Schweden

Horst PIETZNER

Ziel der Untersuchung ist der Nachweis und die quantitative Bestimmung von Jod. Für die Untersuchung standen 350 mg Substanz zur Verfügung. Mit der Röntgenfluoreszenzanalyse (RFA 4495) wurde auf Elemente mit $Z > 20$ (Ca) geprüft, Anregung Mo-Anode 50 kV/40mA. Folgende Elemente wurden nachgewiesen: Ca (Hauptbestandteil); J 0, 1% (quantitativ bestimmt); Y, Sr (Nebenbestandteile, Größenordnung geschätzt O, X%); Fe, Cu, Mn, Ti, Th, Rb, Ba, Ce, La, Pr, Nd, Sm, Gd, Dy (Spuren < 0, X%). Das Fehlen der übrigen SE erklärt sich durch Verdeckung infolge von Linienkoinzidenzen und Konzentrationen unterhalb der Nachweisgrenze.

Da die Probe 40 – 45% Calcit enthält, wurden die Jodgehalte im Apatit und im Calcit mit der Mikrosonde bestimmt. Die Lage der Meßpunkte ist im Probenstrombild (ae^+) (Pl. 2, fig. 5) vermerkt. Im Apatit wurden J-Gehalte zwischen 125 ppm und 2230 ppm gefunden. Das arithmetische Mittel ergibt 1080 ppm. Wenn man die Analysendaten der mehr oder weniger deutlich unterscheidbaren Apatitlagen zusammenfaßt, wird die zweifellos vorhandene Rhythmik auch im Jod-Gehalt erkennbar:

Meßpunkte	1 bis 15	1200 ppm Jod
Meßpunkte	16 bis 30	1370 ppm Jod
Meßpunkte	31 bis 45	1080 ppm Jod
Meßpunkte	46 bis 60	850 ppm Jod
Meßpunkte	61 bis 75	1190 ppm Jod
Meßpunkte	76 bis 90	760 ppm Jod

Bemerkenswert ist, daß die kleinsten Jod-Gehalte am Außenrand (rechte Bildhälfte, Meßpunkte 76 bis 90) gefunden wurden. In den porigen Bereichen zwischen den Apatitlagen sinkt der Jodgehalt unter 100 ppm und schwankt sehr stark. Die Ursache für die Streuung ist sicherlich in der schlechten narbigen Oberfläche dieser Probenstücke zu suchen.

Da der Jod-Gehalt des Calcites mit durchschnittlich 320 ppm ungewöhnlich hoch ist, wurde das Nebengestein auf Jod untersucht. Der Befund ist negativ, wobei die Nachweisgrenze bei 30 ppm liegt.

Neben Fluor, Jod, Schwefel und Kalium wird im Apatit immer wieder Aluminium beobachtet (s. Elementverteilungsbilder). Der Gehalt ist gering. Das Element ist fein verteilt sowohl im dichten Apatit als auch auf Grenzflächen der rhythmischen Apatitausscheidungen zu beobachten. Da der entsprechende Silizium-Gehalt fehlt, kann es sich nicht um Tonmineralbeimengungen handeln. Das Aluminium kann im Apatit-Gitter deponiert sein oder aber auch eine eigene Phosphat-Phase bilden. Eine typische Tonmineralanreicherung zeigt die etwa 20 μ m breite Zone in unmittelbarer Nachbarschaft des schmalen Außenrandes, erkenntlich an den Al-, Si-, K- und Fe-Anreicherungen.

Aus einer Diffraktometeraufnahme der apatitischen Substanz wurden die Gitterkonstanten ermittelt. In Tabelle 1 sind die gefundenen d-Werte mit ihren Intensitäten und die Gitterkonstanten zusammen mit Literaturwerten aufgeführt. Danach ist der Apatit als Francolith (Carbonat-Apatit), $Ca_5 F (PO_4, CO_3OH)_3$, zu bezeichnen. Aus Valenzgründen ist nach dieser Formel ein einwertiges Kation erforderlich. Mit der Mikrosonde konnte Kalium nachgewiesen werden. Nach Syntheseversuchen

von D. R. SIMPSON (1968) verkürzt sich der Gitterparameter a_0 mit steigendem Fluorgehalt. Im vorliegenden Falle sollte er demnach bei $\geq 2,9\%$ F liegen. Die ionensensitive Fluor-Bestimmung an 200 mg Substanz ergab 3,7% F. (Die Bestimmung verdanke ich Herrn Dr. A. SCHIFFERS, RWE, Betriebsverwaltung Fortuna). Die Größe von c_0 zeigt dagegen eine eindeutige Abhängigkeit von den pH-Bedingungen. Danach sollte der Francolith bei $pH > 12$ gebildet worden sein.

Zur Frage der Signifikanz der Jod-Gehalte für eine bestimmte Tiergruppe sollen einige Bemerkungen den vorliegenden Untersuchungsergebnissen angefügt werden.

Der Jodgehalt in magmatisch gebildeten Apatiten ist gering. Er liegt bei o. x. ppm (DOELTER, 1929, S. 1001). Größere Gehalte (bis 280 ppm J) sind dagegen in organogen gebildeten Phosphaten zu finden (WILKE – DÖRFURT, 1927). Anreicherungen von Jod sind bekannt geworden in Algen, Korallen, Hornschwämmen, Austern, Fröschen, Krebsen und Seesternen. Die Algen gelten nach

$d_{(hkl)}$ (Å)	I/I ₁	Gitterkonstanten	a_0 (Å)	c_0 Å	co/a_0
8.14	9	1. Problematicum	9.36 ₈ ± 0.008	6.89 ₆ ± 0.029	0.736 ₁
7.24	2				
5.24	3				
4.05	11	2. Hydroxyl-Apatit (synth.) mit 1.8% CO ₂ und 1.1% F	9.385	6.88	0.7330
3.45	26				
2.794	92				
2.779	47				
2.699	100	3. Hydroxyl-Apatit	9.410	6.867	0.7298
2.623	18				
2.509	6	4. Fluor-Apatit	9.37	6.87	0.7332
2.247	31				
2.219	4	2. bis 4. nach NEWSELY (1964)			
2.139	8				
2.064	4				
2.025	3	5. Hydroxyl-Apatit Ca ₅ OH (PO ₄) ₃	9.44	6.95	0.736
2.000	3				
1.882	16	6. Carbonat-Apatit (Francolith) Ca ₅ F (PO ₄ , CO ₃ OH) ₃	9.36	6.90	0.737
1.861	2				
1.839	23	5. und 6. nach STRUNZ (1957, S. 235)			
1.794	13				
1.768	18				
1.748	10				
1.742	9	7. Hydroxyl-Apatit (9 - 432)	9.418	6.884	0.731
1.647	5				
1.637	5	8. Fluor-Apatit (12 - 261)	9.424	6.888	0.7309
1.576	2				
1.526	10	9. Fluor-Apatit (15 - 876)	9.3684	6.8841	0.73482
1.504	4				
1.454	6	10. Francolith (21 - 141)	9.346	6.887	0.7369
1.441	8				
1.422	9	7. bis 10. nach ASTM			
1.400	2				
1.357	2				
1.338	4				

Tabelle 1: Röntgenbeugungsanalyse Cu_{Kα}-Strahlung 1.54178 Å

LINSTOW (1929) als Jodpflanzen. Besonders Braunalgen können bis zu 5,35% Jod in der Asche enthalten.

Rezente Schwämme sind von E. M. LOW (1949) besonders sorgfältig auf Jod und Brom untersucht worden (Fundpunkte: Bahamas, Bermuda, Florida). Sie fand bei Hornschwämmen im Mittel 4900 ppm, bei nicht keratinösen Schwämmen 3500 ppm. Von besonderer Bedeutung ist ihre Feststellung, daß das Jod an das Protein gebunden ist. Die Menge ist nicht artspezifisch, jedoch fundortabhängig, was durch unterschiedliche Lebens- und damit Wachstumsbedingungen erklärt wird.

Es besteht kein Zweifel, daß der Jodgehalt keine artspezifische Zuordnung des Problematicums gestattet. Der Aluminium-Gehalt könnte als Kriterium für eine Zuordnung zur Pflanzenwelt herangezogen werden, da Pflanzen dieses Element nicht selten zu speichern vermögen.

Aus der Spurenelementassoziation und der Struktur sowie Textur des Francoliths sollte geschlossen werden, daß die Phosphatbildung postmortal erfolgt ist. Bemerkenswert ist das Fehlen von

Uran; es weist auf oxidierende Bildungsbedingungen hin. Der Apatit kann als echtes chemisches Präzipitat aus einer übersättigten Lösung durch Anstieg des pH-Wertes bei der Zersetzung von Protein entstanden sein. Die rhythmischen Phosphatausscheidungen zeichnen verschiedene Gewebe- bzw. Protein-Lagen nach. Damit finden die verschiedenen Jod-Gehalte der einzelnen Lagen zwangsläufig eine Erklärung.

Es verdient weiterhin erwähnt zu werden, daß Francolith durch Verdrängung aus Calcit entstehen kann. L. L. AMES (1959) hat die Vorgänge dabei im System $\text{CaCO}_3 - \text{Na}_3\text{PO}_4 - \text{H}_2\text{O}$ bei niedrigen Temperaturen untersucht. Wesentliche Voraussetzungen für die Bildung von Carbonat-Apatit sind danach 1. pH-Werte $> 7,2$. Calciumbicarbonat gesättigtes System, 3. PO_4^{-3} -Konzentrationen $> 0,1$ ppm und 4. schwache oder fehlende Sedimentation. Die mit der metasomatischen Umwandlung von Calcit in Carbonat-Apatit verbundene Volumenschumpfung könnte die Porigkeit der apatitischen Lagen erklären. Möglicherweise sind auch beide Bildungsvorgänge beteiligt. Die Jodreichen Lagen sind durch Ausfällung entstanden, während die porigen Jod-armen Bereich Verdrängungsbildungen darstellen.

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Plate 1

Nonnegorgonides zieglerei n. gen., n. sp.

Fig. 1 – Lateral branching. Part of holotype.

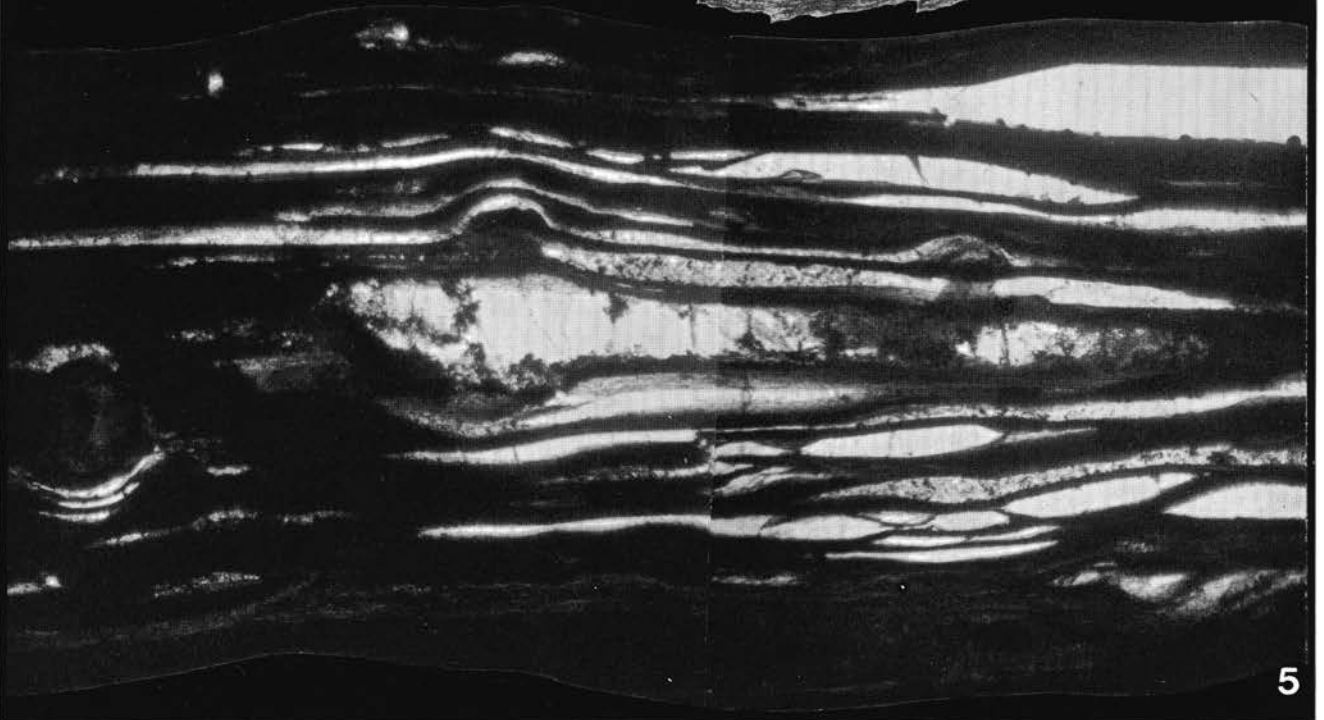
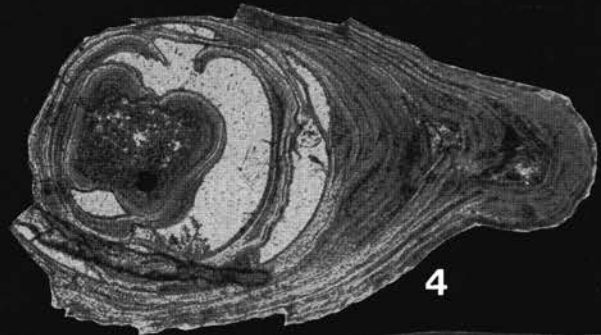
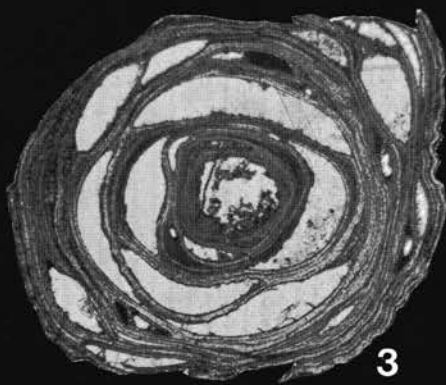
Fig. 2 – Distal portion. X 0.85. Holotype, Mbg. 3503.

Fig. 3 – Thin section, showing calcite filled interspaces, and wrinkling of inner wall of interspaces. Note axial void. Mbg. 3504. X 50.

Fig. 4 – Thin section near point of branching. Note curled ruptured ends of growth lamellae, and brittle style of wrinkling of outermost lamellae. Mbg. 3505.

Fig. 5 – Lengthwise section, showing calcite filled interspaces; wart-like protuberances on the earlier growth lamellae; small spherules at lower wall of calcite filled interspace. upper right. Mbg. 3506. X 45.

Photo: Petrat.



1

2

3

4

5

Plate 2

Nonnegorgonides zieglerei n. gen., n. sp.

1–9 by H. Pietzner

Figs. 1–4 – Al, Ca, P and Si distribution of same portion of cross section. Note partial lack of correlation between Al and Si; Ca occurs as phosphate and calcite. X 195.

Fig. 4 – Test current image, pol. +, 15 kV/10nA. The points numbered 1 – 133 were analysed for iodine. X 195.

Figs. 5 – 9 – Same portion of cross section as Fig. 4, distribution of Ca, P, Al, Si. Note Al & Si enrichment in outermost lamellae. X 195.

Fig. 10 – Lateral branching. Note lengthwise corrugations and isolated, oblique, fiber-like wrinkles. X 6. Part of holotype.

Fig. 11 – Older, relatively smooth, and young, warty branch. X 8.5. Part of holotype.

