GONIATITES STRIATUS AND RELATED FORMS FROM THE VISÉAN OF IRELAND

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ABSTRACT. Five goniatite species, of which two are new, are described from the P_{1b} subzone of the Upper Viséan shales of Dough Mountain, Co. Leitrim, Ireland. These species are diagnosed mainly on the test ornamentation which is claimed to be continuously variable and is arbitrarily divided into stages. Goniatites, the mature ornament of which belongs to a particular stage, are named as separate morphological species. The succession of ornament stages constitutes a trend which has operated upon a primitive stock both in B_2 and P_{1b} times. This has led to the production of homeomorphs the separation of which is important in stratigraphical studies.

INTRODUCTION

IN the P_{1b} subzone of the Bollandian occurs a closely related group of goniatites including the subzonal index fossil *Goniatites falcatus* Roemer and also *G. striatus* (J. Sowerby). Collecting from the Leitrim Shales in the Dough Mountain area, between Manorhamilton and Kiltyclogher, Co. Leitrim, Ireland, has provided an abundant suite of well-preserved goniatites from this subzone, which is about 50 feet thick. Scattered goniatites are to be found throughout this thickness, but by far the most prolific horizon occurs about 6 feet above a thin sandstone at the base. When making the collection, specimens from different stratigraphical levels were not separately labelled but it can be definitely stated that examples of all the species described in this paper occur in this thin prolific bed.

It may be that if all levels provided such an abundance of specimens that the numerical proportions of the different species would vary in a systematic manner according to the stratigraphic level. Since, however, only single specimens are known from most levels, we have not sufficient data to establish this. Kobold (1933, p. 471) collecting from successive thin beds within this subzone in Germany claimed a stratigraphical succession of species of this group of goniatites which we have not been able to corroborate.

Registration numbers preceded by the letters G.S.M. or B.M. are, respectively, those of specimens in the Geological Survey Museum, London, and the British Museum (Natural History).

SHELL ORNAMENTATION

In the *Goniatites striatus* group the succession of shell ornament stages, when complete, is as follows:

1. In individual development the earliest type consists of roughened to crenulate transversals only. In the young these are forwardly bowed over the venter. This is the *crenistria*-stage.

2. Increase in the crenulation of the transversals gives rise to spirals which increase in strength until they equal the transversals. This reticulate pattern is the *concentricus*-stage.

3. Then the transversals weaken whilst the spirals retain their strength so that they become the dominant feature of the ornament over the entire shell. This domination may be achieved at different diameters on different regions of the shell, i.e. near the

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umbilical border, on the flanks, and over the venter. When the spirals are dominant this is called the *striatus*-stage.

4. Then follows a stage in which transverse elements reappear. This is a result of periodic appearance of thin grooves, fairly distantly spaced, dividing the surface of the shell into 'straps' upon which up to twelve faint transverse growth-lines may be accommodated. This is the *spirifer*-stage.

5. The grooves deepen and widen and the 'straps' become ribs of the 'dip escarpment' type with the steep slope facing forwards. This is the *radiatus*-stage.

6. The development of a bow, convex forward, near to the umbilical edge leads to the final *falcatus*-stage.

Each of the stages 2 to 6 may constitute the adult ornament of a particular form of the *striatus* group and in such cases the form is here named as a species.

DESCRIPTIONS OF SPECIES

Goniatites concentricus sp. nov.

Plate 64, figs. 1–3, 5–8; Plate 65, fig. 6

Glyphioceras intermedium Kobold MS., Haubold 1930, p. 78.
Glyphioceras intermedium Kobold 1933, p. 487, pl. 22, figs. 2–4.
Goniatites cf. *intermedium* Moore 1936, p. 187, pl. 3, fig. 3.
Non *Goniatites intermedium* Brown 1841, p. 215; 1849, p. 248.

Holotype. G.S.M. 87221 (Pl. 64, fig. 7), Dough Mountain, Co. Leitrim, Ireland.

Horizon. Viséan, P_{1b} subzone of the English goniatite zonal scheme; subzone IIIα/β to IIIβ_2 of the German scheme (*fide* Kobold 1933).

Discussion of the name. The name *Goniatites intermedius* Kobold could be used for this species if it were not preoccupied by *G. intermedium* Brown. Since Kobold's original material was indifferently preserved we have preferred to erect a new species based on well-preserved Irish material rather than simply to rename Kobold's species.

Dimensions (in mm.)

Diameter	*Thickness*	*T/D%*	*Umbilicus plus inner area*	*U/D%*
28·7	18·2	63	5·5	19·0
33·5	21·0	63	6·0	18
36·1	26·0	72	6·0	17
42·3	25·1	60	6·5	15·5
28·2	20·6	73	6·5	23
49·0	28·3	58	7·0	14
26·6	18·8	70	..	..

Description. In his description of *Glyphioceras intermedium*, Kobold emphasized the intermediate character of his species, especially as regards the ornament, between *G. crenistria* on the one hand and *G. striatus* on the other. In the former the ornament consisted of crenulate transversals only whereas in the latter spirals were the dominant

element of the shell ornament. The stratigraphical position claimed by Kobold for his species on the basis of his own collecting was not inconsistent with his hypothesis.

A specimen (G.S.M. 87225), presumed to be the young of this species, is shown on Pl. 64, figs. 1 and 2. At 10 mm. shell diameter the thickness is 85 per cent. The ornament consists dominantly of crenulate transversals spaced at $4\frac{1}{2}$ per mm. on the centre of the venter. These leave the umbilicus with a forward direction and describe a shallow, forwardly directed bow on the lower parts of the flanks from which they bend backward to make a slight sinus in the middle of the flanks. From this they pass into a very slight lingual bow at the site of the future latero-ventral shoulder. Over the venter, even at this diameter, a faint hyponomic sinus may be seen (Pl. 64, fig. 2). One faint constriction is visible through the test. Faint spirals are present. Pl. 64, fig. 1 shows these appearing around the umbilical edge about half a whorl behind the aperture. They can be seen to result from the strengthening and alignment of the 'teeth' of the crenulations on the transverse striae. Faint, incipient distant spirals can be detected on the site of the latero-venter.

The holotype shows the mature test ornament. The same elements of the transversals already recognized in the above-described nucleus are recognizable, but the sinus in the middle of the flanks is almost obliterated and the transversals are straight in this region. Moreover, the lingual bow has not developed and is a minor feature of the swinging course of the transversals. On the other hand, the hyponomic sinus is now an appreciable feature. Spirals are distributed all over the shell but remain stronger around the umbilicus and on the latero-venter and the venter.

The suture line (text-fig. 1) shows a high median saddle and a ventral lobe with divergent sides. The first lateral lobe has an asymmetric, narrowly rounded top. The lateral lobe is not as narrow as that of *G. falcatus* but less wide than that of *G. striatus* and is slightly deeper than the ventral lobe and with slightly accuminate tip.

Internal characters. A specimen sectioned at right angles to the plane of bilateral symmetry passed slightly in front of the protoconch so that the nucleus of Pl. 64, fig. 6 is the first whorl. Although not quite median, the section was measured at half-whorl intervals since the errors in dimensions of such a section would be very small in the outer whorls. Since the section is figured it is not necessary to do more than mention the salient features. The ratio of thickness to shell diameter shows that the shell is almost spherical until the end of the fifth whorl. After that the whorl height increases slowly at first and, at the commencement of the sixth whorl, much more rapidly, so that the ratio decreases from 92 per cent. at the fifth whorl to 61·5 per cent. at $8\frac{1}{2}$ whorls when the diameter is 38·8 mm.

The umbilicus is about 16 per cent. of the diameter between the fifth and seventh whorls, but although the absolute size continues to increase, the ratio of umbilicus to diameter decreases slowly to 13·5 per cent. at 38·8 mm. diameter. The umbilical edge is sharply rounded and there is no inner area, the umbilical slopes being undercut. The greatest width is near the umbilical edge at the line of involution.

A section nearly along the plane of symmetry of a completely septate specimen shows $8\frac{3}{4}$ whorls (Pl. 64, fig. 5). There are 7 septa in the first and 6 in the second whorl. At $2\frac{1}{2}$ whorls the density of septation increases so that there are 13 septa in the third and 15 in the fourth whorls. In the next four whorls the septa number between 15 and 17 per

whorl and there are 17 in the last three-quarters of a whorl, which probably indicates the usual more closely-spaced septa which occur immediately behind the body chamber. At the greatest diameter seen, the siphuncle is about 0·5 mm. in diameter. The siphuncle increases in diameter very slowly, so that although it occupies about 17 per cent. of the whorl height in the fifth and sixth whorls, it occupies only about 9 per cent. in the seventh

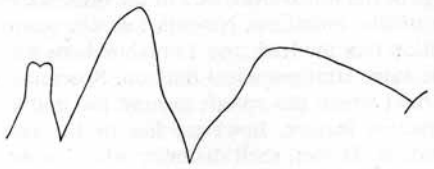

FIG. 1

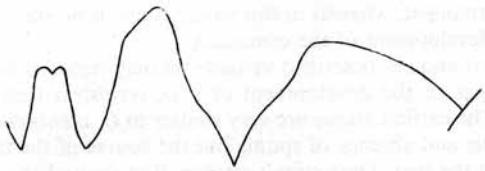

FIG. 2

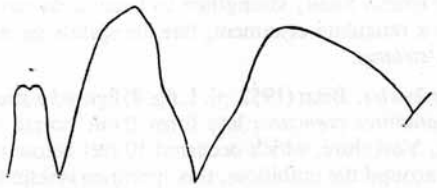

FIG. 3

TEXT-FIGS. 1–3. Suture lines magnified 100/diameter in mm. 1, *Goniatites concentricus* sp. nov., G.S.M. ZI 7315 at 26 mm. diameter, ×3·85. 2, *G. falcatus* Roemer, G.S.M. ZI 3762 at 30 mm. diameter, ×3·33. 3, *G. falcatus*, G.S.M. ZI 4033 at 46 mm. diameter, ×2·18.

and eighth whorls. The septal necks are retrosiphonate to the maximum diameter seen. This is usual in Lower Carboniferous goniatites. Details of the very early behaviour of the siphuncle are unfortunately not seen in this section.

Variation. Specimen G.S.M. 87224 (Pl. 64, fig. 3) is a variety with much finer transversals than the type. Specimens are known in which the spirals are absent and in this respect resemble the presumed ancestral *G. crenistria* but differ in the more sinuous course of the transversals and particularly in the deeper hyponomic sinus. They are also thinner than typical *G. crenistria* at the same diameter. Variants also occur in which the spirals are present around the umbilicus but lacking at the latero-venter. Such is typified by G.S.M. 87222 figured in Pl. 64, fig. 8. On the other hand, variants are seen in which

the spirals are stronger and more evenly distributed than in the type. A typical example of this variant is shown on Pl. 64, fig. 4. This might be regarded as transitional to *G. striatus* but is also strongly resembled by the specimen G.S.M. 85641 figured by Bisat (1952, pl. 1, fig. 4) from 10 feet below the *G. falcatus* band at Cowdale Clough, Barnoldswick, Yorks., and referred to '*G. crenistria* late form'. Our variant differs in the more sinuous course of the transversals and in the presence of an appreciable hyponomic sinus and in the smaller umbilicus. Nevertheless, the resemblance is close enough to warrant the supposition that the Irish and Yorkshire beds which yielded these specimens are nearly on the same stratigraphical horizon. Specimen G.S.M. 87223 (Pl. 64, fig. 9) is a peculiar variant which has spirals around the umbilicus but absent on the latero-venter. Its distinctive feature, however, lies in the periodic development of strengthened transversals at 22 mm. shell diameter which persist up to the maximum diameter of the specimen (25·5 mm.). This is the type of ornament characteristic of *G. radiatus* sp. nov. but in that species the periodically strengthened transversals succeed a dominant spiral ornament, whereas in this variety there is no stage of dominant spirals in the ontogenetic development of the ornament.

Apart from the first and last described variants we may regard these varieties as marking transitional stages in the development of a *G. crenistria* type of ornament into a *G. striatus* type. The earliest stages are very similar to *G. crenistria* in the presence of crenulate transversals and absence of spirals but the course of the transverse ornament serves to distinguish the two. Then spirals appear, first around the umbilicus and then on the latero-venter and venter. Finally they occur weakly on the flanks. This is the typical condition. The spirals finally strengthen to become as strong as the transversals when the test assumes a reticulate ornament, but the spirals never dominate the transversals as in typical *G. striatus*.

Comparisons with other species. Bisat (1952, pl. 1, fig. 4) figured a specimen (G.S.M.85641) under the name of *Goniatites crenistria* late form from horizon Co5 from Cowdale Clough, Barnoldswick, Yorkshire, which occurred 10 feet below the *G. falcatus* bed. In the presence of spirals around the umbilicus, this specimen resembles *G. concentricus* but differs in the straightness of the transversals as they cross the flanks, there being neither umbilical bow nor any sign of a lingua at a shell diameter of 30 mm. In this respect Bisat's specimen might be expected to be an earlier form than *G. concentricus*. Moreover, the size of the umbilicus, about 25 per cent. of the shell diameter, is greater than that of *G. concentricus*.

Bisat (1957, pp. 16–19, pl. 3, figs. 1–3, 5–7; text-figs. 1–6) described *Goniatites warslowensis* from beds presumed to be above the horizon of *G. falcatus* and commented on the similarity between the ornament of this species and Kobold's *G. intermedium*. But the spirals seem to be stronger in *G. concentricus* and a notable difference lies in the hyponomic sinus which is absent at 25 mm. diameter in *G. warslowensis* but already developing at 10 mm. in *G. concentricus*.

Goniatites striatus (J. Sowerby)

Plate 65, figs. 1–3

Ammonites striatus Sowerby 1814, p. 115, pl. 53, fig. 1.
Paraglyphioceras striatus Brüning 1923, p. 265.

Goniatites striatus Bisat 1924, p. 74.
Glyphioceras striatum striatum Schmidt 1925, p. 568.
Goniatites striatus Bisat 1934, p. 301, pl. 18, fig. 1; pl. 19, figs. 1, 2; pl. 21, fig. 1.
Goniatites striatus Delépine 1940, pp. 79–80, pl. 5, figs. 16–17.
Goniatites striatus Delépine 1941, p. 67, pl. 4, fig. 69; pl. 5, figs. 1, 2.

Holotype. B.M. 43870 (figured Bisat 1934, pl. 19, fig. 1). From 'Derbyshire'; exact location and horizon not known.

Horizon. Viséan, P_{1b} in England and Ireland. $III\beta_{1-5}$ in Germany (*fide* Kobold 1933).

Diagnosis. Goniatites in which dominant transverse striae in young give place to dominant spirals. Transverse elements of shell ornamentation reappear only at diameters greater than 60 mm. Suture line with wide lateral lobe and median saddle 50 per cent. of depth of ventral lobe.

Description of holotype. Dimensions: diameter 41 mm., thickness 25 mm. (T/D % = 63), umbilicus plus inner area 5 mm. (U/D % = 13). The holotype is incomplete terminating across a septum. Some seven-eights of the outer whorl is testiferous and shows spirals spaced at intervals of 0·3 mm. in the middle of the flanks at 30 mm. shell diameter. The transversals are very weak and the shell at 39 mm. diameter is ornamented by spiral striae almost exclusively. There appear to be no constrictions. The suture line, figured by Bisat (1934, pl. 19, fig. 2), is characterized by having a very wide lateral lobe. The course of the transversals departs very slightly from the radial direction across the flanks.

At 33 mm. a very shallow lingua (less than 1 mm.) appears.

Ontogeny. A series of specimens from Co. Leitrim and Derbyshire enable the ontogenetic development to be investigated. G.S.M. Zl 4055 (Pl. 65, fig. 3) shows the dominant transversals spaced at about 7 per mm. at a shell diameter of 10 mm. in the centre of the venter. These are almost radial on the flanks bending forward at the latero-venter into a slightly dented, forwardly directed bow over the venter. There are faint spirals around the umbilicus. On specimen Zl 3832 (Pl. 65, fig. 2) the crenulate transversals are still dominant at 21 mm. shell diameter being spaced at 2 per mm. in the centre of the venter. The spirals have strengthened but are still confined to the vicinity of the umbilicus. The transversals bend slightly forward on leaving the umbilicus, passing radially up the flanks and swinging back gently to form a very shallow hyponomic sinus. Specimen Zl 3133 shows that at 26 mm. shell diameter the spiral ornament has become dominant and extends all over the shell. G.S.M. 53552 from Jack Bank Quarry, Derbyshire, has a few transversals slightly accentuated and their course at 24 mm. diameter is almost radial on the flanks without a lingua and with a hyponomic sinus of 2½ mm. depth. The spirals remain dominant up to diameters between 60 and 70 mm. Thus G.S.M. 53553 shows only faint traces of transversals even at 67 mm. diameter. In G.S.M. 57922, also from Jack Bank Quarry, however, the transversals reappear at about a diameter of 64 mm. and gradually strengthen until at 81 mm. they are again the dominant element in the shell ornament. These large specimens show that the length of the body chamber is about 380°. Constrictions are not common and have been seen on one specimen only, namely Zl 4053 which shows a constriction on the internal mould at 27 mm. diameter.

Discussion. According to Bisat (1934) the species differs from *G. maximus* Bisat in that the latter is generally stouter. T/D% averages 63 in *G. striatus* and 75 in *G. maximus*.

Moreover, the median saddle of the suture line is less elevated in *G. maximus* being 40 per cent. of the depth of the ventral lobe as against 50 per cent. in *G. striatus*. The ornament is closely similar.

Goniatites spirifer Roemer

Plate 66, figs. 1, 3, 4

Goniatites spirifer Roemer 1850, p. 51, pl. 8, fig. 16.
Goniatites striatus Phillips 1836, pl. 19, fig. 1.
Goniatites striatus Smith 1903, pl. 10, fig. 11.
Glyphioceras crenistria var. *praestriata* Schmidt 1925, p. 566, pl. 21, fig. 2.
Glyphioceras spirifer Haubold 1930, p. 79.
Glyphioceras striatum spirifer Kobold 1933, pp. 489–90, pl. 22, figs. 5, 6.
Goniatites spirifer Hudson and Cotton 1945, p. 265, text-fig. 2.

Holotype. Mining Institute, Clausthal No. 389, figured by Kobold 1933, pl. 22, fig. 6: from 'Posidonomyenschiefer', near Lautenthal, Harz Mountains, Germany.

Horizon. Lower Lautenthal Shales, IIIα/β to IIIβ_3, in Germany (*fide* Kobold 1933). Viséan, P_{1b} in England and Ireland.

Diagnosis. *Goniatites* of the *G. striatus* stock developing a persistent stage of ornamentation characterized by thin, widely-spaced grooves following the direction of the peristome.

Description. The species agrees with the general description of *G. striatus* except for the appearance of widely-spaced transverse grooves cutting across the spirals and forming strap-like bands of test between. This type of ornamentation (*spirifer*-stage) is seen to succeed the *striatus*-stage of ornamentation at various diameters and in varying degrees of perfection in different specimens. Moreover, it normally precedes the typical *radiatus*-stage ornament in the ontogeny of *G. radiatus* (Pl. 67). In order to make more precise a species which until now has been very poorly known and figured from poor shale impressions, we restrict it to shells in which the characteristic ornament appears before 50 mm. shell diameter and persists until fully grown. Large specimens of *G. striatus* with a terminal short, feeble *spirifer*-stage will still be called *G. striatus*. Specimens in which the *spirifer*-stage is followed by a *radiatus*-stage which occupies a considerable portion of the termination of the shell will be called *G. radiatus*. For examples in which the *spirifer*-stage is followed by a short, poorly developed *radiatus*-stage the best name would seem to be *G. spirifer* mut. towards *radiatus*.

Remarks. Information is to hand that German palaeontologists are now inclined to place the range of *G. spirifer* entirely *below* the *G. crenistria* zone, P_{1a}. This seems to us very doubtful since Roemer gave the horizon of the holotype as the 'Posidonomyenschiefer near Lautenthal', and Kobold has found comparable material with the same state of preservation near Lauthenthal in this formation and dates the beds as IIIβ_1. It seems that confusion exists between the true *G. spirifer* (from above P_{1a}) and homoeomorphs belonging to the *G. maximus* stock (such as *G. struppus* sp. nov. [see p. 395]; Bisat 1934, pl. 22, figs. 3 and 4) which occur below P_{1a} in England.

On the basis of the figures given by Phillips (1836) and J. P. Smith (1903) their specimens ought to be referred to *G. spirifer* rather than *G. striatus*. The constrictions mentioned by Phillips and shown in his figure are, in our experience, unusual in members of the *G. striatus* stock. Foord and Crick (1897, p. 168) mention ornament of the type here referred to as the *spirifer*-stage in certain specimens identified by them as *G. striatus*, but such ornament is absent from the holotype of *G. striatus* (see Bisat 1934, pl. 19, fig. 1).

Goniatites radiatus sp. nov.

Plate 67, fig. 1; Plate 68, figs. 1, 2, 4, 5

Goniatites falcatus Delépine 1940, pl. 5, figs. 13, 14.

Holotype. G.S.M. Zl 3129 (Pl. 68, fig. 5), Dough Mountain, Co. Leitrim, Ireland.

Horizon. Viséan, P_{1b}.

Diagnosis. *Goniatites* of the *G. striatus* stock in which test ornament of the *G. striatus* type is succeeded by a transient stage of *G. spirifer* type and finally by ribs and grooves which interrupt the spiral ornament as in *G. falcatus* but which lack the marked forward umbilical bowing of that species.

Dimensions (in mm.)

	Diameter	*Thickness*	*T/D%*	*Umbilicus plus inner area*	*U/D%*
Zl 3129	71·1	38·0	49	8	11
	70·0	35·0	50	7½	11
	56·0	35·0	63	6½	12
	40·2	28·2	70	4½	11

Description. The ontogenetic development of the test ornament is well shown in the specimen (G.S.M. Zl 7330) figured on Pl. 67. In the earliest portion of the ornament seen on the last whorl the strength of the spirals and the transversals is equal and the reticulate ornament characteristic of *G. concentricus* in evidence. The transversals gradually lose strength and the spirals become dominant. Then for about a quarter of a whorl the ornament is in the *striatus* condition. Marked grooves, distantly spaced, then appear and for a short distance the *spirifer* type of ornament is assumed. Between these distant grooves appear others which at first do not extend down to the umbilical edge. Finally, relatively closely-spaced ribs interrupting the continuity of the spirals as in the *falcatus* ornament (but with a more rectilinear course over the flanks) constitute the adult ornament.

The changes in whorl shape can be seen in the sectioned specimen (Pl. 68, fig. 4) where the cadicone stage is seen to end at the 6th whorl, after which the whorl height rapidly increases relative to the thickness. This contrasts with *G. falcatus* where the cadicone stage persists up to the 8th whorl. The umbilicus slowly decreases from 15 per cent. of the diameter at the end of the 6th whorl to 10 per cent. of the diameter at the 10th whorl. In these particulars it resembles *G. concentricus* or *G. striatus* rather than *G. falcatus*.

Discussion. Although the essential continuity of the *concentricus*, *striatus*, *spirifer*, and *radiatus* ornamentation patterns can be easily demonstrated, the transition from the last to *falcatus* is not so commonly seen. In the specimen figured on Pl. 68, fig. 2, the course of the transversals shows an approach to those of *G. falcatus* in the later part of the last whorl.

Goniatites falcatus Roemer

Plate 65, fig. 5; Plate 68, fig. 3; Plate 69, figs. 1–6

Goniatites falcatus Roemer 1850, p. 50, pl. 80, figs. 11, 12.
Glyphioceras subreticulatum Frech 1899, pl. 46*a*, fig. 6.
Glyphioceras striatum falcatum Schmidt 1925, p. 569, pl. 21, fig. 7; *non* pl. 23, fig. 18.
Glyphioceras striatum falcatum Haubold 1930, p. 90.
Glyphioceras striatum falcatum Kobold 1933, pp. 420–1.
Goniatites falcatus Moore 1936, p. 180.

Holotype. Mining Institute, Clausthal No. 392 (Pl. 68, fig. 3), from 'Posidonomyenschiefer', Lautenthal, Harz Mountains, Germany.

Horizon. Viséan, P_{1b} in England and Ireland. $III\beta_{3-4}$ in Germany (*fide* Kobold 1933).

Diagnosis. Goniatites with strong doubly-bowed transversals and hyponomic sinus. Transversals rib-like and interrupting spiral ornament. Relatively narrow first lateral lobe and tall, pointed first lateral saddle.

Dimensions (in mm.)

	Diameter	*Thickness*	*T/D%*	*Umbilicus plus inner area*	*U/D%*
ZI 4033	49·0	30·6	63	9·5	19
	48·1	32·0	67	8·7	18
	47·3	29·6	63	8·1	17
ZI 3881	43·6	29·3	67	8·5	20
	37·0	24·5	67	5·3	14
ZI 3882	33·7	25·2	75	6·3	19
ZI 3762	31·3	23·1	74	6·2	20

Description of holotype. The holotype (Pl. 68, fig. 3) is an imperfect specimen of which only the right side is preserved and the suture line is not visible. The estimated diameter is 51 mm. with an umbilical width of 18 per cent. In the strength and direction of the transverse ornament it agrees perfectly with the Irish specimens described below.

Description of Irish specimens. Typically the species has a relatively stout shell but, as can be seen from the above dimensions, there is some variation. Thus, between 30 and 50 mm. shell diameter, the ratio T/D% ranges between 62 and 74. The umbilicus is fairly wide but again variable, being 14–20 per cent. of the shell diameter.

The most distinctive feature of the species is the ornament consisting of strong transversals, of rib-like strength, with a typical cross-section in the line of the plane of symmetry. There is a steep forward rise to the point of inflexion and a gentle backward slope to the next 'rib'. The transversals interrupt the spiral ornament which is impressed only on the 'dip slope' of the rib except that in the region around the umbilicus the spirals

are more continuous (Pl. 69, fig. 5). On some well-preserved examples the spirals may dent the forward edge of the rib, producing a crimped effect. On leaving the umbilicus, the transversals bend markedly forward and then swing gently but decidedly backwards to form a sinus situated well up the flanks. Thence they proceed to describe a very small lingual bow before passing over the venter to form a hyponomic sinus which is 1 mm. deep at 30 mm. shell diameter and between 4½ and 6½ mm. deep at 45–49 mm. shell diameter.

The suture line is shown in text-figs. 2, 3. The narrowness of the first lateral lobe is in contrast to that of *G. striatus* (q.v.).

Internal characters. A specimen (Pl. 65, fig. 5) sectioned along the median plane is entirely septate and shows 8⅞ whorls. The density of septation is as follows: whorl no. 1 contains 5 septa; whorl 2 has 8 septa; whorl 3 has 9 septa; whorl 4 has 13 septa; whorl 5 has 16 septa; whorl 6 has 20 septa; whorl 7 has 17 septa; whorl 8 has 17 septa; whorl 9 has 20 septa (estimated). The septal necks are all retrosiphonate to the end. The main feature shown by a section at right angles to the plane of symmetry (Pl. 69, fig. 1) is the relative persistence of the cadicone stage. Thus it is only in the last visible whorl (the 9th) that the whorl height begins to increase relative to the width. As compared with other members of the *G. striatus* stock, there is a persistence of a whorl shape characteristic of the young of the *striatus* group into the adult of *G. falcatus.*

Discussion. The specimen figured by Delépine (1941, pl. 4, fig. 10) and attributed to *G. falcatus* has much weaker ornament than typical *G. falcatus* and would be attributable to *G. spirifer* were it not for the presence of a decided umbilical bow on the transversals. The two Belgian specimens figured by Delépine (1940, pl. 5, figs. 13–15) are also not typical of *G. falcatus.* The original of the specimen shown in figs. 13 and 14 seems to be *G. radiatus* sp. nov., and that of fig. 15 to be near to *G. spirifer.* The specimen figured by Schmidt (1925, pl. 23, fig. 18 reproduced here as Pl. 65, fig. 4), which is 42 mm. in diameter, is unusual, as Schmidt pointed out, in showing the early part of the last whorl bearing typical *striatus* ornament succeeded abruptly (with ⅛ whorl) by typical *falcatus* ornament.

GENERAL DISCUSSION

As previously indicated we have not found the species just described succeeding each other in any definite stratigraphical order, although the possibility of different species forming the modal type at successive horizons is mentioned. Thus although ontogenetically the sequence *concentricus—striatus—spirifer—radiatus—falcatus* can be demonstrated we are not able to claim that the group evolved palingenetically in this way. It would appear from the succession given by Kobold, together with his estimates of the relative abundance of the three species recognized by him, that *G. spirifer* preceded *G. striatus.* We have not been able to repeat the bed-by-bed collecting done by Kobold and until this is done it might be thought presumptuous to challenge his conclusions; nevertheless, on the basis of our ontogenetic studies we would be surprised if in fact the maximum of *G. spirifer* did precede that of *G. striatus.* It is, however, to be admitted that Hudson and Cotton (1945) recorded a succession of members of this group in the Alport borehole and identified the lowest members of it as *G. spirifer.* But they (contrary to Kobold) found forms identified as *G. falcatus* succeeding it and preceding the appearance

EXPLANATION OF PLATE 64

Figs. 1–3, 5–8. *Goniatites concentricus* sp. nov., Dough Mountain, Co. Leitrim, Ireland. 1, Nucleus of a striatoid goniatite attributed to this species showing appearance of spirals round the umbilical edge, G.S.M. 87225, ×5. 2, Same specimen, ventral view with incipient spirals at the latero-venter and commencement of hyponomic sinus, ×5. 3, Variant with fine transverse ornament, G.S.M. 87224, ×2. 5, Section almost in the median plane (the portion above the line is almost exactly median), G.S.M. Zl 7337, ×2. 6, Transverse section, the plane of section passes slightly in front of the protoconch and the innermost circle is the first whorl, not the protoconch. 7, Holotype, G.S.M. 87221, ×2. 8, Variant lacking spirals on latero-venter, G.S.M. 87222, ×2.

Fig. 4. *Goniatites* sp., Dough Mountain, Co. Leitrim, Ireland. Transitional from *G. concentricus* to *G. striatus*, G.S.M. 87220, ×2.

Fig. 9. *Goniatites* aff. *concentricus* sp. nov., Dough Mountain, Co. Leitrim, Ireland. Accentuation of transversals near peristome as in *G. radiatus* sp. nov., G.S.M. 87223, ×2.

EXPLANATION OF PLATE 65

Figs. 1–3. *Goniatites striatus* (J. Sowerby), Dough Mountain, Co. Leitrim, Ireland. 1, Faint transversals visible in early part of last whorl but later dominated by spirals, G.S.M. Zl 7316, ×2. 2, Note dominant transverse ornament but spirals appearing round umbilicus, G.S.M. Zl 3832, ×2. 3, Young specimen showing transverse ornament on venter, spirals absent, G.S.M. Zl 4055, ×2.

Fig. 4. *Goniatites falcatus* Roemer var., copy of Schmidt 1925, pl. 23, fig. 18. Typical *striatus* ornament rapidly succeeded by typical *falcatus* ornament, ×1½.

Fig. 5. *Goniatites falcatus* Roemer, Dough Mountain, Co. Leitrim, Ireland, median section.

Fig. 6. *Goniatites concentricus* sp. nov., River Ribble, Dinckley, Lancashire. Manchester Museum LL 256, ×2½, figured Moore 1936, pl. 3, fig. 3.

EXPLANATION OF PLATE 66

Figs. 1, 3, 4. *Goniatites spirifer* Roemer, Dough Mountain, Co. Leitrim, Ireland. 1, Note the appearance of widely-spaced transverse grooves at 48 mm. shell diameter, G.S.M. Zl 7325, ×2. 3, G.S.M. Zl 7328, ×2. 4, G.S.M. Zl 7327, ×2.

Fig. 2. *Goniatites sp.*, Dough Mountain, Co. Leitrim, Ireland. Note *striatus* ornament succeeded by a short *spirifer* stage and finally *radiatus* ornament. G.S.M. Zl 7326, ×2.

EXPLANATION OF PLATE 67

Fig. 1. *Goniatites radiatus* sp. nov., Dough Mountain, Co. Leitrim, Ireland. Showing succession of test ornamentation in which the *concentricus*, *striatus*, *spirifer*, and *radiatus* types are seen in that order in the last whorl. G.S.M. Zl 7330, ×4·2.

EXPLANATION OF PLATE 68

Figs. 1, 2, 4, 5. *Goniatites radiatus* sp. nov., Dough Mountain, Co. Leitrim, Ireland. 1, G.S.M. Zl 7331, ×1. 2, Showing development of umbilical bow in transverse ornament near aperture, G.S.M. Zl 7329, ×1. 4, Median section, G.S.M. Zl 7332, ×1. 5, Holotype, G.S.M. Zl 3129, ×1.

Fig. 3. *Goniatites falcatus* Roemer, holotype, Mining Institute of Clausthal collection No. 392, ×1½, Posidonomyenschiefer, Lautenthal, Harz Mountains, Germany.

EXPLANATION OF PLATE 69

Figs. 1–6. *Goniatites falcatus* Roemer, Dough Mountain, Co. Leitrim, Ireland. 1, Median section, G.S.M. Zl 7333, ×2. 2, Note strong sinuous transversals and spirals continuous round the umbilicus but interrupted higher on the flanks; also narrow lateral lobe of the suture line, G.S.M. Zl 3762, ×2 (see also fig. 6). 3, G.S.M. Zl 3881, ×2. 4, Same specimen as fig. 3, venter, note depth of hyponomic sinus, ×2. 5, Details of spiral ornament of specimen figured in fig. 3, note shape of transverse ribs and interrupted spirals, ×6·7. 6, Ventral view of same specimen as fig. 2, note tall external saddle of the suture line with pointed tip, ×2·4.

of *G. striatus*, although ultimately overlapping it. It must then be admitted that the ontogenetic appearance of the different ornaments characterizing the species here described cannot be shown to be paralleled by their stratigraphical order and indeed such evidence as exists is contrary to the idea.

From a stratigraphical point of view it is also important to describe what appears to be the operation of a similiar trend in the ornament stages upon an earlier goniatite stock in the B_2 zone, producing forms which are, so far as the test ornament is concerned, homeomorphic with some of the species described above. These earlier forms belong to the *Goniatites hudsoni—maximus* stock. Bisat (1934) described this group and derived the interrelationships of the forms known to him at the time. Apparently the earliest species is *G. antiquatus* Bisat with faintly crenulate transversals. *G. hudsoni* has strongly crenulate transversals with a few spirals round the umbilical margin. Both these species may be regarded as in the *crenistria*-stage when adult. *G. wedberense* Bisat is also in this stage up to a shell diameter of 25 mm., but at a greater size becomes reticulate, i.e. features the *concentricus*-stage. *G. maximus* Bisat persists in the *crenistria*-stage up to 18 mm. diameter. Between 18 and 25 mm. the ornament is in the *concentricus*-stage. Above this diameter the spirals become dominant, at first around the umbilicus, then on the flanks, and finally at 32 mm. diameter they cover the complete shell. In the typical form this, the *striatus*-stage, persists for the rest of its growth, but in *G. maximus* var. c. Bisat (1934) at 45 mm. diameter the thin grooves characteristic of the *spirifer*-stage appear. It is here proposed to name this variety *Goniatites struppus* sp. nov. (holotype G.S.M. 53549, figured Bisat 1934, pl. 22, figs. 3, 4, p. 299, from Black Hole, Malham, Yorkshire, B_2 zone). There appear to be no homeomorphs of *G. radiatus* and *G. falcatus* in the B_2 zone. The discrimination between the known homeomorphs from the B_2 and P_1 zones is very difficult and would require well-preserved material. It is a subject of future investigation.

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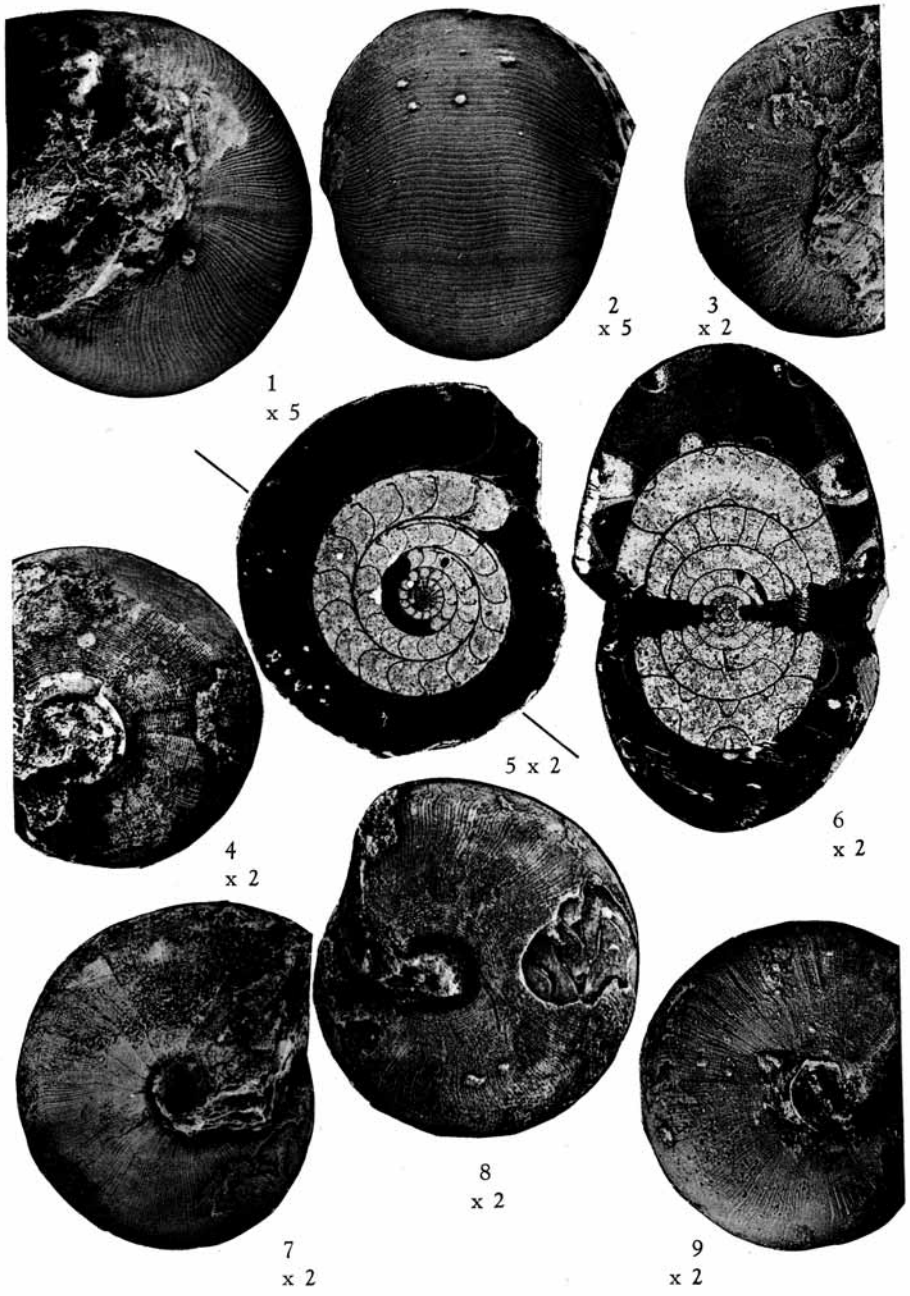

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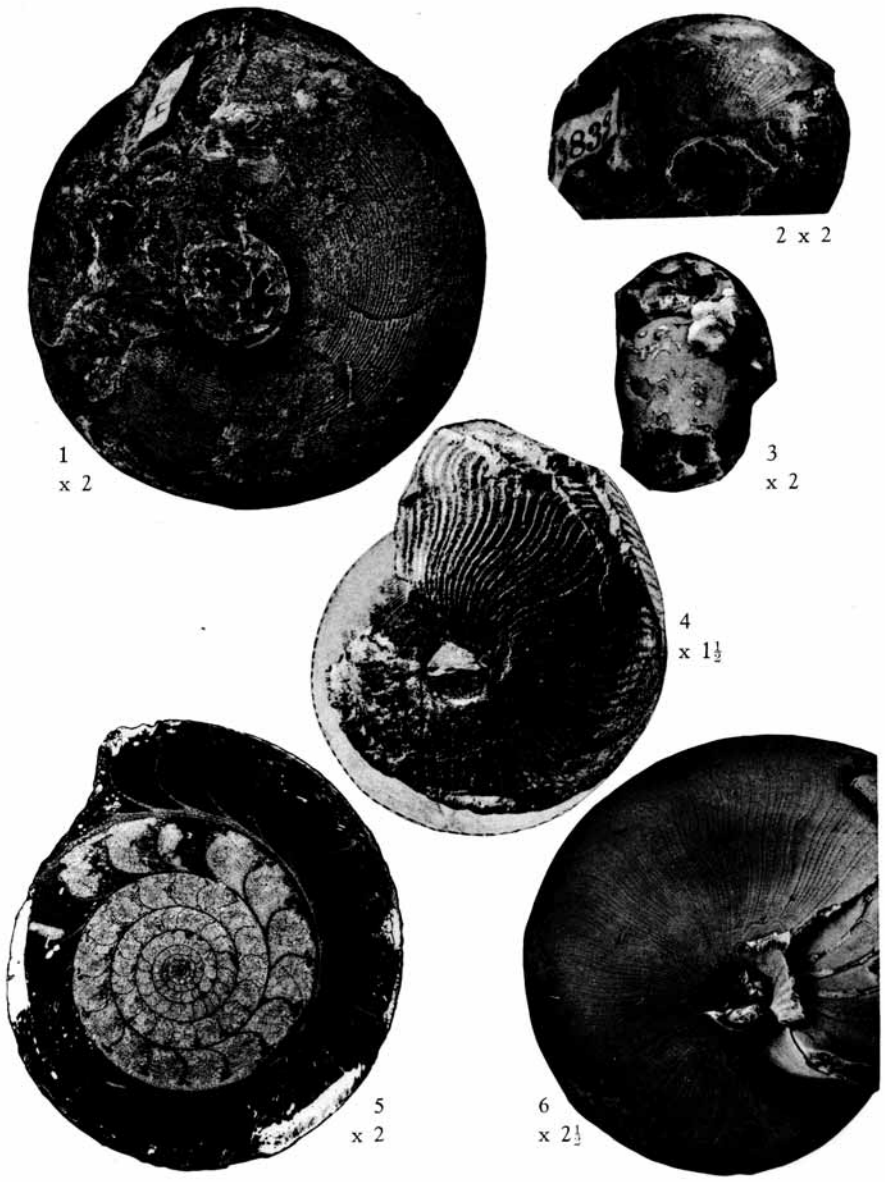

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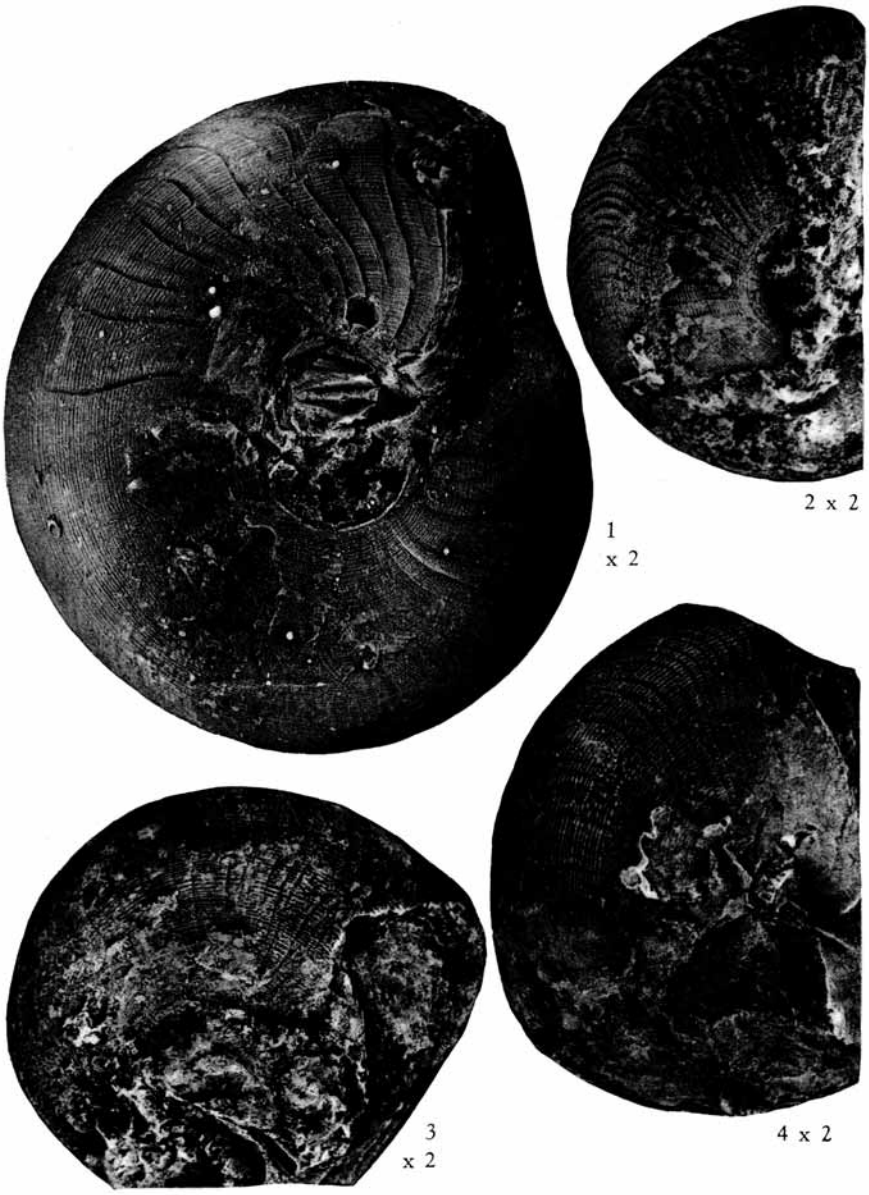

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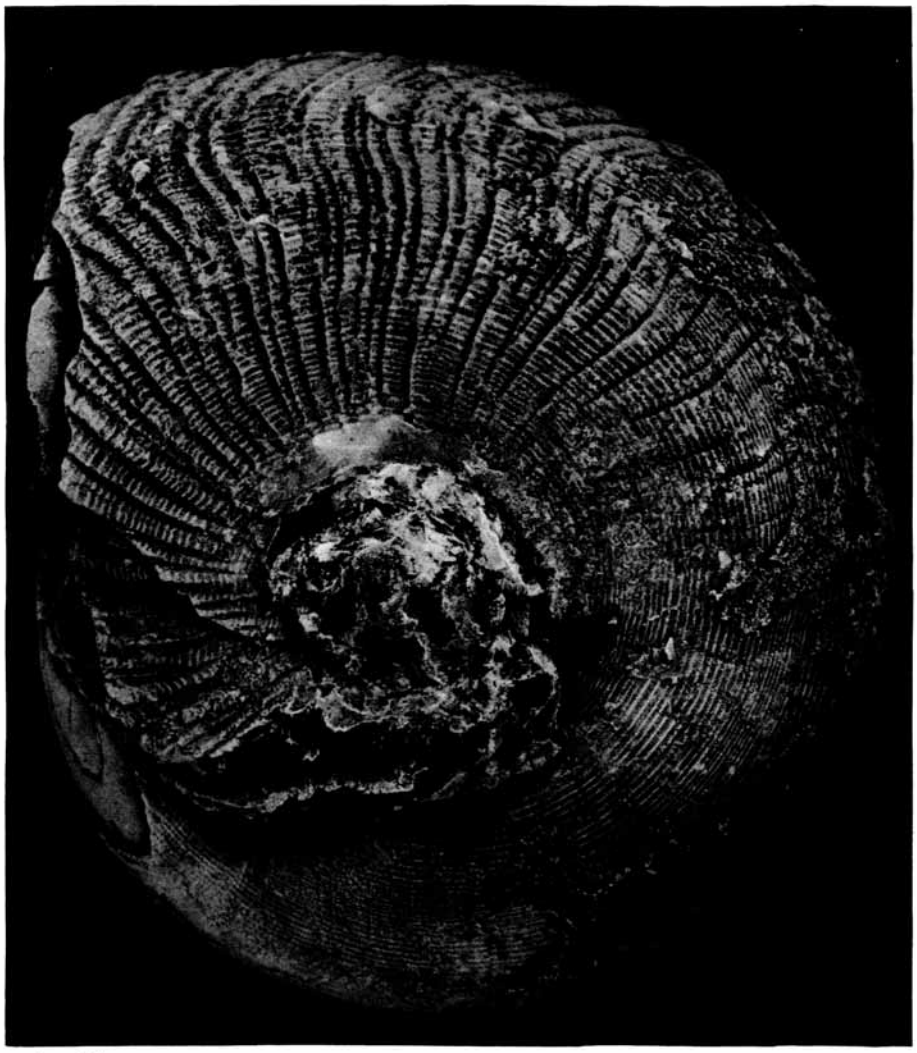

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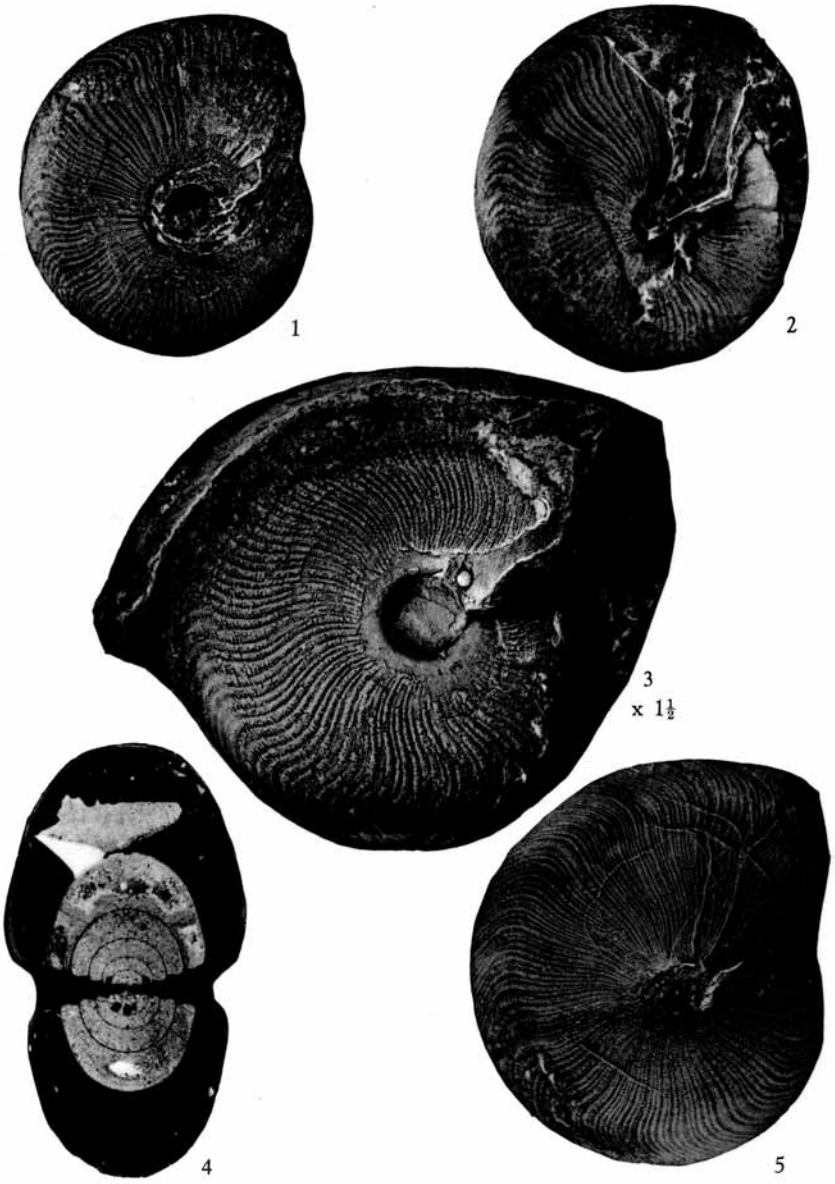

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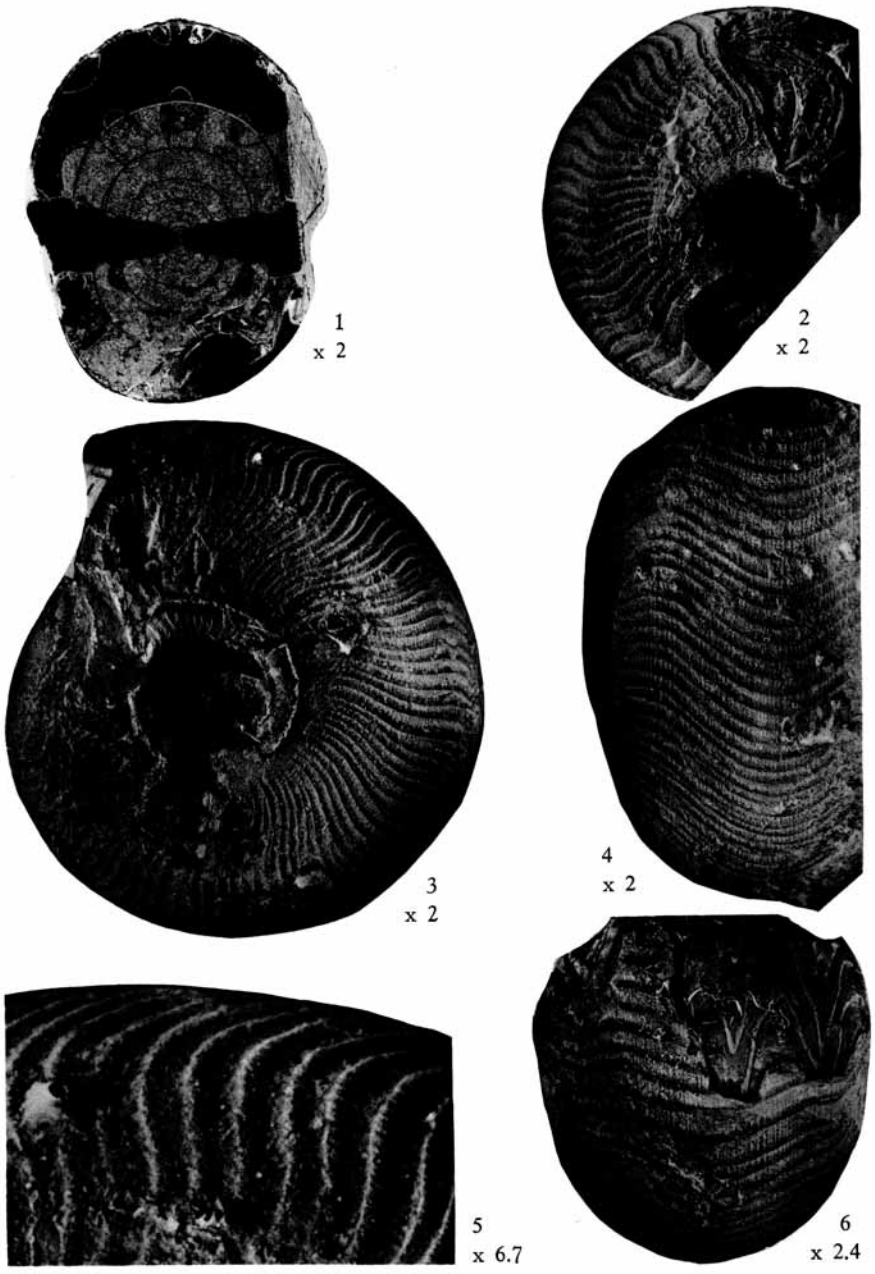

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