Middle Cretaceous deposits and biostratigraphy of the Annopol section, Central Polish Uplands

Mittelkretazische Ablagerungen und Biostratigraphie des Profils von Annopol, Zentrales Polnisches Hochland

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Mit 2 Textfiguren und 4 Tafeln

Zusammenfassung. In der transgressiven mittelkretazischen Folge der Antiklinale von Annopol, Zentrales Polnisches Hochland, wurde mit Ammoniten, Inoceramen und planktischen Foraminiferen eine Kondensation nachgewiesen. Diese stratigraphische Kondensation ist in einigen Abschnitten der Folge mit einer Resedimentation der Ablagerungen und Fossilien verbunden. Die stärkste Kondensation betraf den Zeitabschnitt von der Hoplites dentatus-Zone (Lyelli- und Spathi-Subzonen) bis zur Mortoniceras inflatum-Zone und ist durch eine Phosphorit-Schicht gekennzeichnet. Auch Bioturbationen und Hardgrounds treten in Zusammenhang mit der Kondensation auf. Planktische Foraminiferen des oberen Albien in Sedimenten des mittleren Albien sind auf die Aktivität grabender Organismen zurückzuführen, welche Spuren vom Typus des Chondrites angelegt haben. Eine ähnliche Aktivität mittelcenomaner Dekapoden, die an den Grabgängen vom Thalassinoides-Typ erkennbar sind, hatte die Umlagerung mittelcenomaner planktischer Foraminiferen in untercenomane Ablagerungen zur Folge. Die Analyse der gesamten Ammonitenfaunen aus der Folge von Annopol zeigt deren typisch borealen Charakter, sowohl im Albien als auch im Cenomanien. Dies ist auch an gleichalten Faunen des gesamten übrigen Zentralen Polnischen Hochlandes festzustellen.

Abstract. The mid-Cretaceous transgressive sequence the Annopol anticline, Central Polish Uplands, displays a condensed nature as evidenced by the occurrence ranges of ammonites, inoceramids and planktic foraminifera. The stratigraphic condensation in some parts of the sequence is associated with redeposition of both deposits and fossils. The strongest condensation is featured by the greatest frequency of phosphatic nodules (making up a phosphorite bed), and ranges from a part of the *Hoplites dentatus* zone (*lyelli* and *spathi* Subzones) to the *Mortoniceras inflatum* zone. The condensation is also correlated with bioturbations and the develop-

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ment of hardgrounds. The post-deposition activity of burrowers (evidenced by bioturbations of the *Chondrites* type) resulted in an introduction of Upper Albian planktic foraminifera into Middle Albian deposits. A similar activity of Middle Cenomanian decapods (recognizable through burrows of the *Thalassinoides* type) resulted in the introduction of Middle Cenomanian planktic foraminifera into Lower Cenomanian deposits. An analysis of all ammonite faunas of the Annopol sequence shows their typical Boreal character, both in the Albian and in the Cenomanian. This character is expressed to the same extent as through the entire Central Polish Uplands.

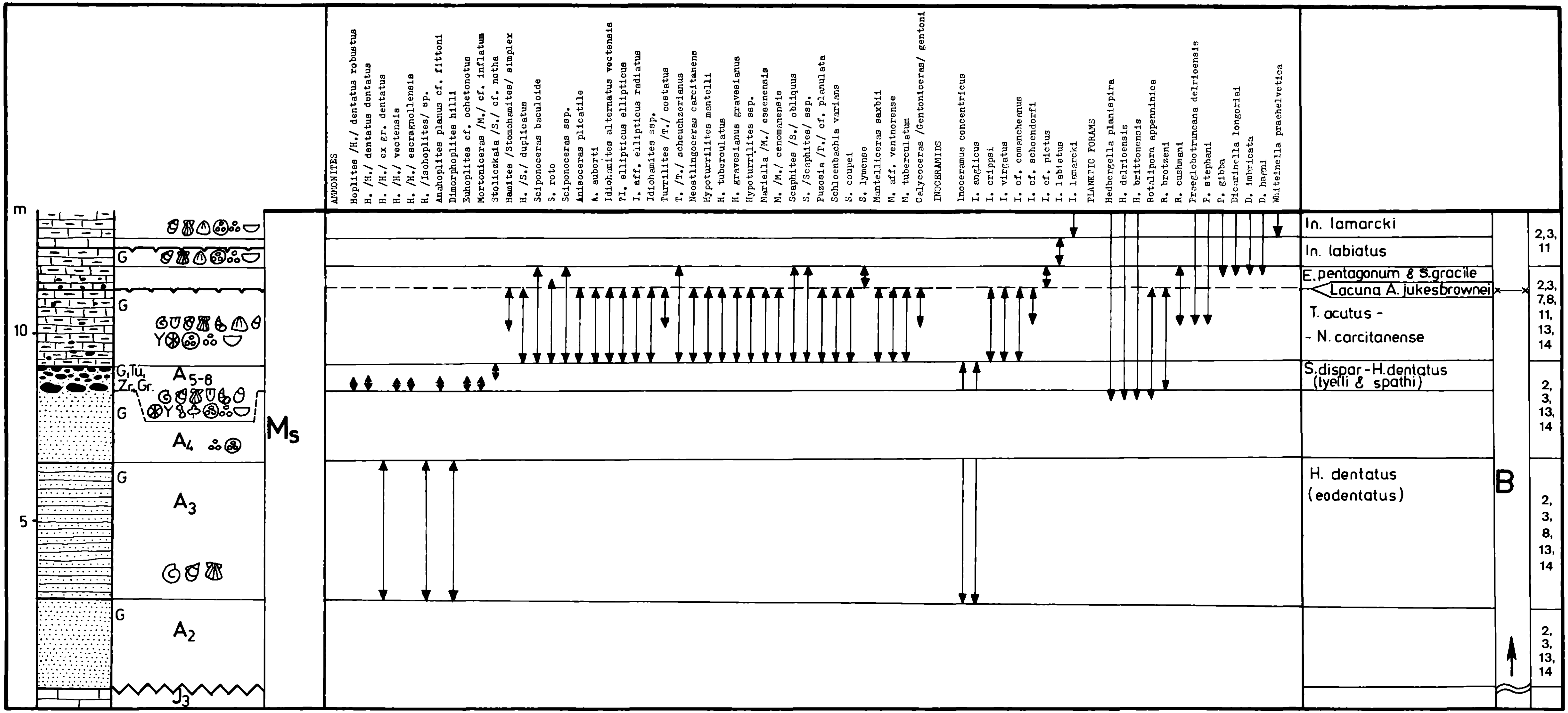
1. Introduction

Sections of the well-studied locality Annopol-on-Vistula are exposed along the Vistula embankments, on the surface and in an abandoned phosphorite mine (SAMSONOWICZ, 1925, 1934). Exposed at Annopol-on-Vistula are mid-Albian through Lower Turonian sandy or marly-sandy deposits (Text-Fig. 1), evidently condensed in relation to those outside the Annopol anticline (CIESLINSKI, 1959, 1976). The biostratigraphic subdivision of those deposits is based on ammonites (Pls. 1 – 3) and inoceramids (SAMSONOWICZ, 1925, 1934; POZARYSKI, 1947; CIESLINSKI, 1959, 1976; MARCINOWSKI, 1980; MARCINOWSKI & RADWANSKI, 1983).

2. Lithology and Stratigraphy

2.1. Albian

In the Albian, poorly glauconitic sands rest upon the Kimmeridgian limestones and are themselves overlain by sandstones, locally quartzitic (unit A_3 in Text-Fig. 1), with *Hoplites (Isoplites)* sp. (=*Anahoplites* cf. *praecox* SPATH, of CIESLINSKI, 1959) indicative of the *eodentatus* Subzone of the *Hoplites dentatus* zone (MARCINOWSKI & RADWANSKI, 1983). Capping the sand is the phosphorite bed, averaging 40 cm in thickness. The lower part of this bed contains irregular phosphatic lumps, which are usually oblong and cemented into coke-like bodies. The nature of the phosphorite from the lower part of the phosphatic bed (units 5 – 7 in MARCINOWSKI & RADWANSKI, 1983; Text-Fig. 6) is most likely similar to that of intraformational breccias: a laminated phosphatic sediment, possibly concretionary in parts, has been crushed into pieces or lumps and reworked by hydrodynamic agent. It has also been mixed with abundant organic remains such as pieces of wood (commonly bored by wood-borers) and diverse invertebrates associated with bony material of fishes and reptiles (cf. MARCINOWSKI & RADWANSKI, 1983, and the literature cited therein). All organic remains are more or less phosphatized; some are worn, glauconitized or encrusted by various epizoans, mostly serpulids. These remains occur either within the phosphatic lumps or between them. The reworking and redeposition within the lower part of the phosphorite bed, recognizable also in ammonite moulds (SAMSONOWICZ, 1925), provide evidence that condensation comprises several ammonite zones across almost the entire middle and the lower part of the Upper Albian, i. e. including the



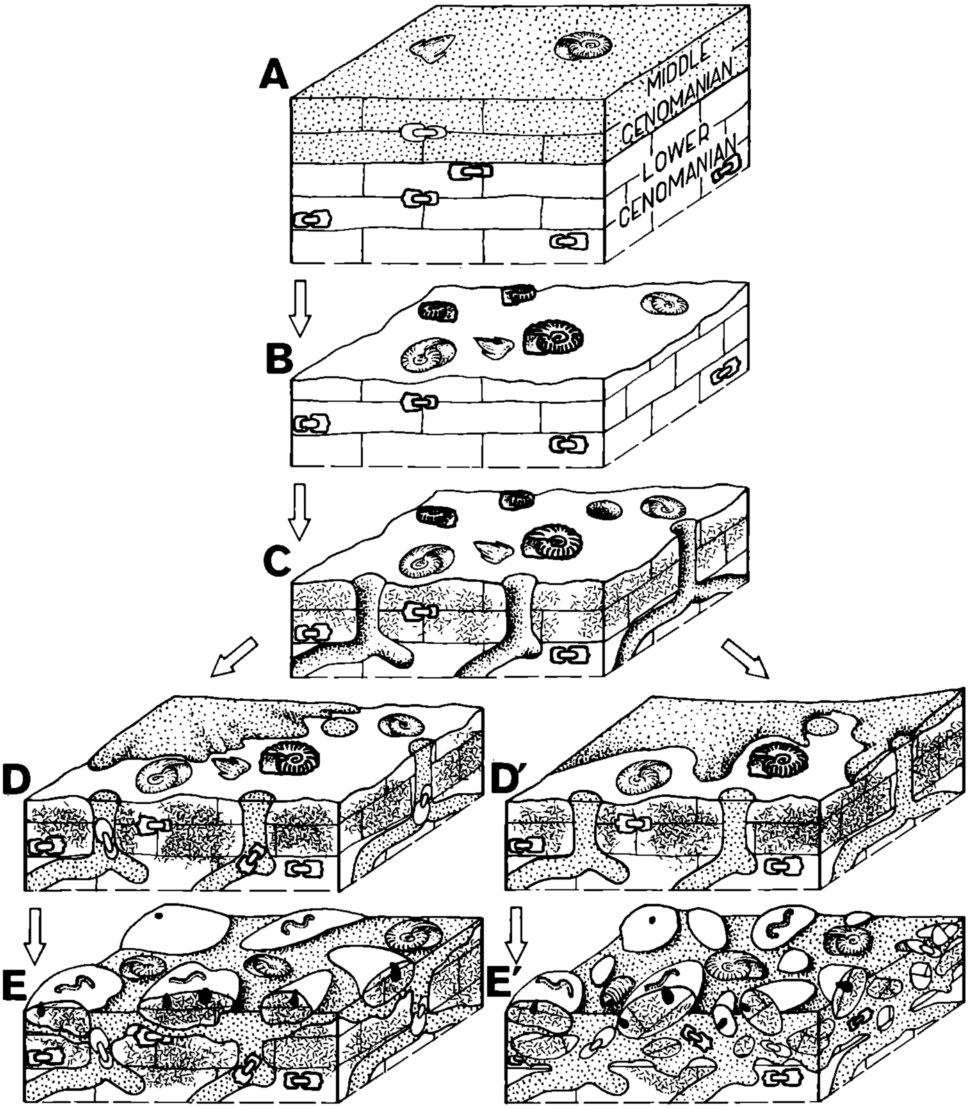
Text-Fig. 1. Detailed geological profile and distribution of the stratigraphically important fossils at Annopol-on-Vistula, Central Polish Uplands.

Mortoniceras inflatum zone (see occurrer e of ammonites presented in Text-Fig. 1). The species *Stoliczkaia* cf. *notha* (SEELE), reported by CIESLINSKI (1959, unit 8) from the upper part of the phosphorite bed, corresponds to the topmost zone of the Upper Albian, i. e. the *Stoliczkaia dispar* zone. Here, the matrix is more marly and glauconitic than in the lower part of the bed and small phosphatic nodules form larger, more or less regular phosphatic aggregates (5 – 10 cm in diameter). In the topmost part of the phosphorite bed stratigraphical (distribution of ammonites) and sedimentological evidence indicates a fragmentary redeposition of both fossils and phosphatic aggregates. These phenomena are confined only to the *Stoliczkaia dispar* zone. Bioturbations of the *Chondrites*- type are present not only in the entire phosphorite bed (part of the *Hoplites dentatus* to *Stoliczkaia dispar* zones), but a few centimetres beneath it as well. These bioturbations are responsible for a post-depositional introduction of Upper Albian foraminifera *(Hedbergella brittonensis, Rotalipora appenninica, R. brotzeni)* into Middle Albian deposits (see occurrence of planktic foraminifera presented in Text-Fig. 1). A synsedimentary redeposition of the entire phosphorite bed, as expressed by PERYT (1983) can therefore not be accepted. Furthermore, PERYT's (1983) belief that a very slow sedimentation caused co-occurrence of Middle and Upper Albian fossils does not appear to be correct because this process, contrary to redeposition, could not disturb the stratification of both the sediments and the fossils.

2.2. Cenomanian

Overlying the Middle to Upper Albian phosphorite bed are Cenomanian sandy glauconitic marls still containing phosphatized fossils, most of which are fragmentarily preserved. These deposits represent the entire Lower and parts of the Middle Cenomanian, i. e. the *Neostlingoceras carcitanense* to *Turrilites acutus* zones (see Text-Fig. 1). In their upper part, approx. 1.7 – 1.8 m above the Albian/Cenomanian boundary a bank of larger phosphatic nodules (flattened and glauconitized) displaying the nature of a hardground appears. The partly cemented sediment below the hardground is riddled by *Thalassinoides*-type burrows. A stratigraphic gap at the hardground probably comprises the entire *Acanthoceras jukesbrownei* zone (MARCINOWSKI, 1980). It is interesting that *Rotalipora cushmani,* a species appearing first in the Middle Cenomanian (cf. ROBASZYNSKI, 1980), occurs about 1 m below hardground along with Lower and Middle Cenomanian ammonites (cf. Text-Fig. 1; see also PERYT, 1983, Text-Fig. 2). Evidence that stratigraphic condensation and reworking of deposits is limited only to this interval exists. As a consequence, the previous opinion on the condensed nature of the entire Cenomanian deposit below the hardground (MARCINOWSKI, 1980, MARCINOWSKI & RADWANSKI, 1983) must be modified. The sedimentological and micropaleontological data (Pl. 4), especially the composition of assemblages of the planktic foraminifera coming from both infillings of the burrows and from their surroundings, allow several developmental stages of the hardground to be recognized (see Text-Fig. 2):

A. Sedimentation period up to a part of the Middle Cenomanian (including the *Turrilites acutus* zone).



Text-Fig. 2. History of the Middle Cenomanian hardground at Annopol-on-Vistula, Central Polish Uplands; explanation in the text.

B. Break in sedimentation (most probably *Acanthoceras jukesbrownei* zone) with erosion down to Lower Cenomanian deposits; phosphatization of moulds, sometimes also of shells; formation of the "residual lag".

C. Non-deposition period; settling of the burrowing fauna; incipient substrate cementation.

D. Very slow sedimentation; infilling of burrows with new sediment as well as with small particles (up to 3—4 cm in diameter) of the "residual lag".

D′ (alternative). Like D. but without filling of burrows by the "residual lag".

E. Erosional episode; boring, encrusting of phosphatic nodules, and impregnation with phosphates and glauconite of the eroded hard substratal fragments (formation of hiatus concretions).

E′ (alternative). Like E. but with more extensive erosion and reworking; for the first time the Middle Cenomanian ammonites are introduced into the Lower Cenomanian deposits.

A stratigraphic gap comprising the upper part of the *Mantelliceras dixoni* zone and the lower part of the *Acanthoceras rhotomagense* zone, as postulated by PERYT (1983), is not acceptable due to the contrary evidence provided by the stratigraphic ranges of the ammonites (see Text-Fig. 1, and MARCINOWSKI, 1980). Overlying the hardground are heavily glauconitic marls approx. 0,5 m thick of Upper Cenomanian age, containing *Schloenbachia lymensis* SPATH, *Actinocamax plenus* (BLAINVILLE) and *Inoceramus* cf. *pictus* SOWERBY and continuing into the Lower Turonian. In the Upper Cenomanian the assemblage of the planktic foraminifera changes (just below a non-depositional surface) and representatives of the genus *Dicarinella* appear (see Text-Fig. 1). According to POZARYSKI (1947, p. 31), the Upper Cenomanian at Annopol is represented not only by the hardground but most probably also by a part of the underlying deposits, i. e. those representing a part of the Lower and a part of the Middle Cenomanian in the tripartite subdivision of this stage accepted by the authors (cf. KENNEDY, HANCOCK & CHRISTENSEN, 1981). CIESLINSKI (1959) used a bipartite subdivision of the Cenomanian, and his Upper Cenomanian therefore also corresponds to the upper part of the Middle Cenomanian in the tripartite subdivision (see MARCINOWSKI, 1974, Table 6).

2.3. Turonian

The Lower Turonian (*Inoceramus labiatus* zone) with its lower part consist of marls having a much lower content of glauconite and phosphatic nodules than the Upper Cenomanian. These marls are truncated by another hardground and, thereafter, the facies changes abruptly into the limestones just above the hardground. The Lower Turonian deposits are also condensed (thickness 0.6 m), with *Inoceramus labiatus* (SCHLOTHEIM) occurring both in marls and limestones. The Middle Turonian (*Inoceramus lamarcki* zone) marls and siliceous marls (opokas) with flints (several dozen metres in thickness) quite frequently contain the index species. Abundant inoceramids allow the recognition of only two zones sensu lato; a more detailed subdivision requires further investigation.

The more precise stratigraphic subdivision of the Turonian based on the planktic foraminifera (PERYT, 1983) appears to be unrealistic. PERYT's opinion that *Dicarinella biconvexa biconvexa* and *D. biconvexa gigantea* are limited to the uppermost Cenomanian and lowermost Turonian is in contrast to her former data which showed these foraminifera also occurring above the hardground along with *Praeglobotruncana helvetica* (compare PERYT, 1983, Fig. 2 with PERYT, 1980, pp. 66–67, 70 and Tables 3–4). Besides, in the profile at Karsy (12 km from Annopol) these foraminifera co-occur with *Inoceramus hercynicus* PETRASCHECK. This indicates the uppermost part of the *Inoceramus labiatus* zone in its broad sense as used in Poland (cf. TRÖGER, 1981). These observations demonstrate that the definition of the *Whiteinella archaeocretacea* and *Praeglobotruncana helvetica* subzones by PERYT (1983) is invalid; moreover, the foraminifera were sampled from fragmentary profiles which were then placed into a single specially constructed biostratigraphical zone (compare PERYT, 1980, Fig. 2 with PERYT's recapitulation presented 1983 in Fig. 2).

3. Ammonite Biogeography

The ammonite fauna of the Annopol-on-Vistula section shows that any significant transportation of shells can be excluded by their preservation state and that reworking is the only phenomenon which took place here. A relative poor Middle and Upper Albian ammonite assemblage is dominated by representatives of the family Hoplitidae, and thus their affinity to the Boreal Hoplitid Faunal Province is obvious. The entire investigated Lower to Middle Cenomanian ammonite assemblage is more or less uniform and dominated by representatives of the Boreal genus *Schloenbachia* associated with heteromorphs. Assemblages of such composition are indicative of nearshore to offshore environments of moderate depth; the life habitats here are comparable to those occupied by the ammonite groups A and B of TANABE et al. (1978, Text-Fig. 10; cf. also MARCINOWSKI, 1980, pp. 311–312). The Boreal nature of the Albian-Cenomanian ammonite fauna at Annopol is well documented and a similar situation is noted in the whole epicontinental area of Poland (cf. MARCINOWSKI, 1970, 1974, 1980; CHLEBOWSKI, HAKENBERG & MARCINOWSKI, 1978).

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References

[1] Chlebowski, R., Hakenberg, M., & Marcinowski, R. (1978): Albian ammonite fauna from Mt. Chelmowa near Przedborz (Central Poland). – Bull. Acad. Polon. Sci. Terre, *25* (2): 91–97; Warsaw.

[2] Cieslinski, S. (1959): The Albian and Cenomanian in the northern margin of the Holy Cross Mts. – Trav. Inst. Geol., *28:* 1–95; Warsaw.

[3] – (1976): Development of the Danish-Polish Trough in the Holy Cross region in the Albian, Cenomanian and Lower Turonian. – Bull. Inst. Geol., *295:* 249–271; Warsaw.

[4] Kennedy, W. J., Hancock, J. M., & Christensen, W. K. (1981): Albian and Cenomanian ammonites from the island of Bornholm (Denmark). – Bull. Geol. Soc. Denmark, *29:* 203–244; Copenhagen.

[5] Marcinowski, R. (1970): The Cretaceous transgressive deposits east of Czestochowa (Polish Jura Chain). – Acta Geol. Polon., *20* (3): 413–449; Warsaw.

[6] – (1974): The transgressive Cretaceous (Upper Albian through Turonian) deposits of the Polish Jura Chain. – Acta Geol. Polon., *24* (1): 117–217; Warsaw.

[7] – (1980): Cenomanian ammonites from German Democratic Republic, Poland, and the Soviet Union. – Acta Geol. Polon., *30* (3): 215–325; Warsaw.

[8] – & Radwanski, A. (1983): Mid-Cretaceous transgression onto the Central Polish Uplands (marginal part of the Central European Basin). – Zitteliana, *10:* 65–95; München.

[9] Peryt, D. (1980): Planktic foraminifera zonation of the Upper Cretaceous in the middle Vistula river valley, Poland. – Palaeont. Polon., *41:* 3–101; Warsaw–Cracow.

[10] – (1983): Planctonic foraminiferal zonation of Mid-Cretaceous of the Annopol anticline (Central Poland). – Zitteliana, *10:* 575–583; München.

[11] Pozaryski, W. (1947): A phosphate deposits of the north-eastern margin of the Holy Cross Mountains. – Bull. Serv. Géol. Polon., *27:* 1–56; Warsaw.

[12] Robaszynski, F. (1980): *In:* Robaszynski et al (Foraminifères): Synthèse biostratigraphique de l'Aptien au Santonien du Boulonnais a partir de sept groupes paléontologiques: Foraminifères, Nannoplancton, Dinoflagellés et macrofaunes. – Rev. Micropaléont., *22* (4): 195–321; Paris.

[13] Samsonowicz, J. (1925): Esquisse géologique des environs de Rachow sur la Vistule et les transgressions de l'Albien et du Cénomanien dans le sillon nord-européen. – Bull. Serv. Géol. Pologne, *3* (1–2): 45–118; Warsaw.

[14] – (1934): Explication de la feuille Opatow, pp. 1–117. – Serv. Géol. Pologne; Warsaw.

[15] Tanabe, K., Obata, I., & Futukami, M. (1978): Analysis of ammonoid assemblages in the Upper Turonian of the Manji area, Central Hokkaido. – Bull. Nat. Sci. Mus., Ser. C (Geol. & Paleont.), *4* (2): 37–60; Tokyo.

[16] Tröger, K. A. (1981): Zu Problemen der Biostratigraphie der Inoceramen und der Untergliederung des Cenomans und Turons in Mittel- und Osteuropa. – Newsl. Stratigr., *9* (3): 139–156; Berlin-Stuttgart.

Plate 1

1. *Turrilites (Turrilites) costatus* LAMARCK, Middle Cenomanian, from the hardground.
2. *Neostlingoceras carcitanense* (MATHERON), Lower Cenomanian.
3. *Sciponoceras baculoide* (MANTELL), Lower/Middle Cenomanian, from the condensed part of the profile.
4. *Hamites (Stomohamites) duplicatus* PICTET & CAMPICHE, Cenomanian, from the part of the profile below the hardground.
5. *Idiohamites* aff. *ellipticus radiatus* SPATH, Cenomanian, from the part of the profile below the hardground.
6. *Idiohamites alternatus vectensis* SPATH, Cenomanian, from the part of the profile below the hardground.
7. *Anisoceras auberti* (PERVINQUIÈRE), Cenomanian, from the part of the profile below the hardground.
8. *Hamites (Stomohamites) simplex* d'ORBIGNY, Middle Cenomanian, from the hardground.
9. *Sciponoceras roto* CIESLINSKI, Upper Cenomanian, a few centimetres above the hardground.
   a—lateral, *b*—ventral, *c*—dorsal views; for turrilids: *a*—outer face of the whorl, *b*—lower face of the whorl, *c*—upper face of the whorl; arrow indicates the end of the phragmocone.

All figures are magnified × 1.5, except Figs. 1.8 which are of natural size.

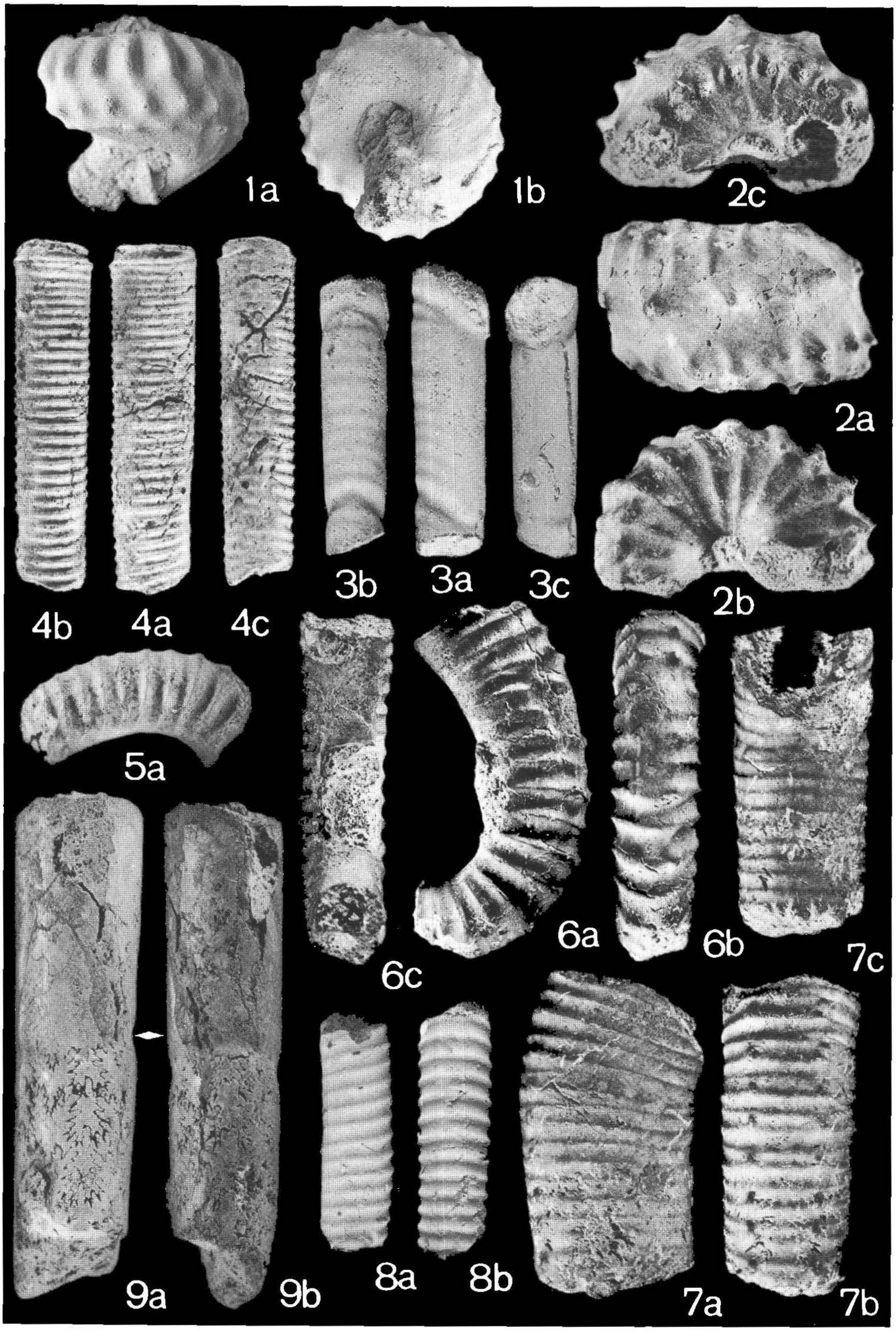
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Plate 2

1. *Schloenbachia varians* (Sowerby) *subplana* (Mantell), Cenomanian, from the part of the profile below the hardground.
2. *Schloenbachia coupei* (Brongniart) *costata* (Sharpe), Cenomanian, from the part of the profile below the hardground.
3. *Schloenbachia varians varians* (Sowerby), Cenomanian, from the part of the profile below the hardground.
4. *Schloenbachia varians* (Sowerby) *subtuberculata* (Sharpe), Cenomanian, from the part of the profile below the hardground.
5. *Mantelliceras* aff. *ventnorense* Diener, Lower Cenomanian.
6. *Hoplites (Hoplites) escragnollensis* Spath, Middle Albian, from the lower part of the phosphorite bed (units 5–8 in the Text-Fig. 1).
   a—lateral, *b*—ventral, *c*—dorsal views; arrow indicates the end of the phragmocone.

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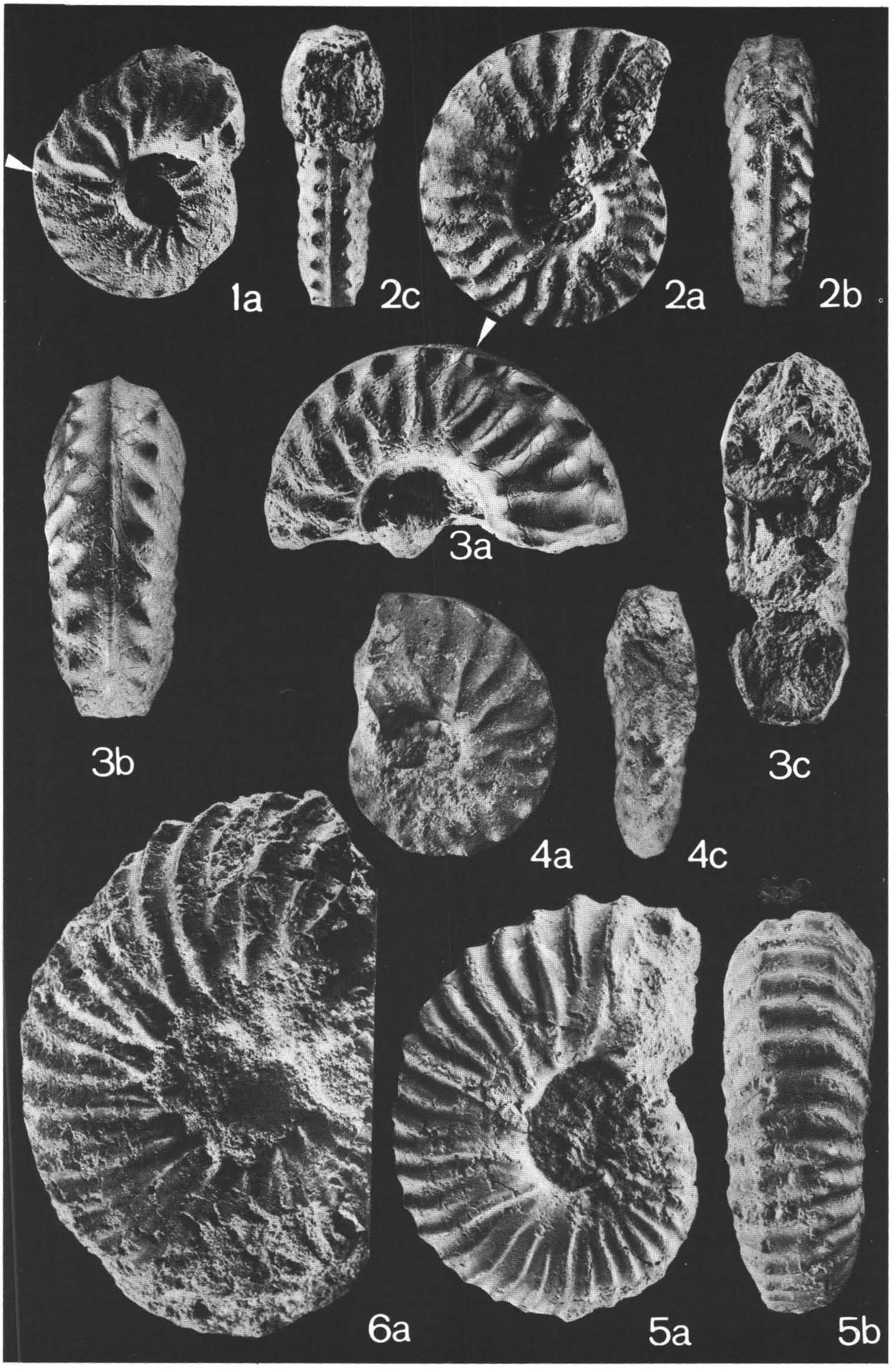
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Plate 3

1. *Hoplites (Hoplites) dentatus* (SOWERBY), Middle Albian, from the lower part of the phosphorite bed (units 5–8 in the Text-Fig. 1).
2. *Dimorphoplites* sp., Middle Albian, from the quartzitic sandstones (unit 3 in the Text-Fig. 1). *a*—lateral, *b*—ventral views.

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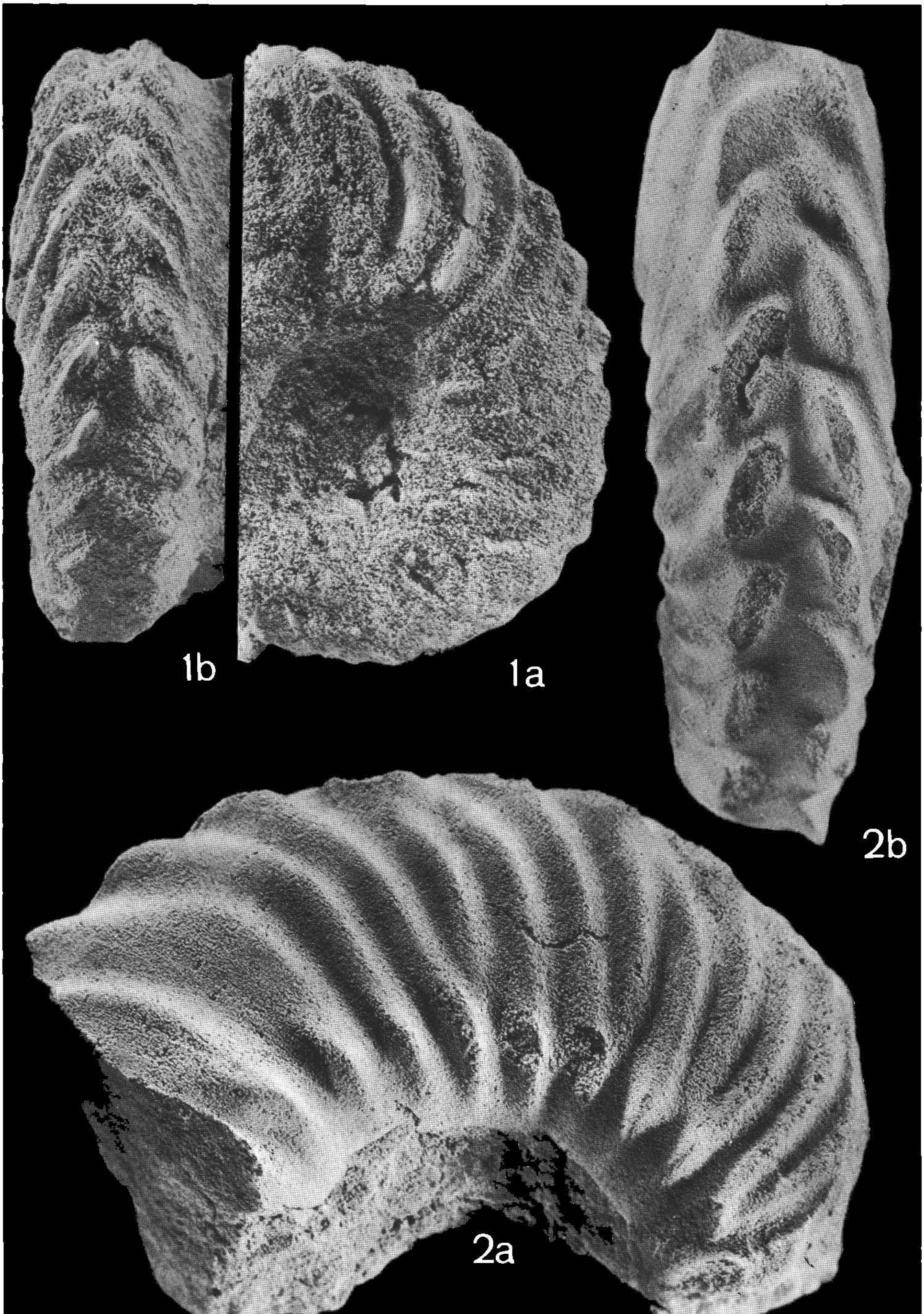
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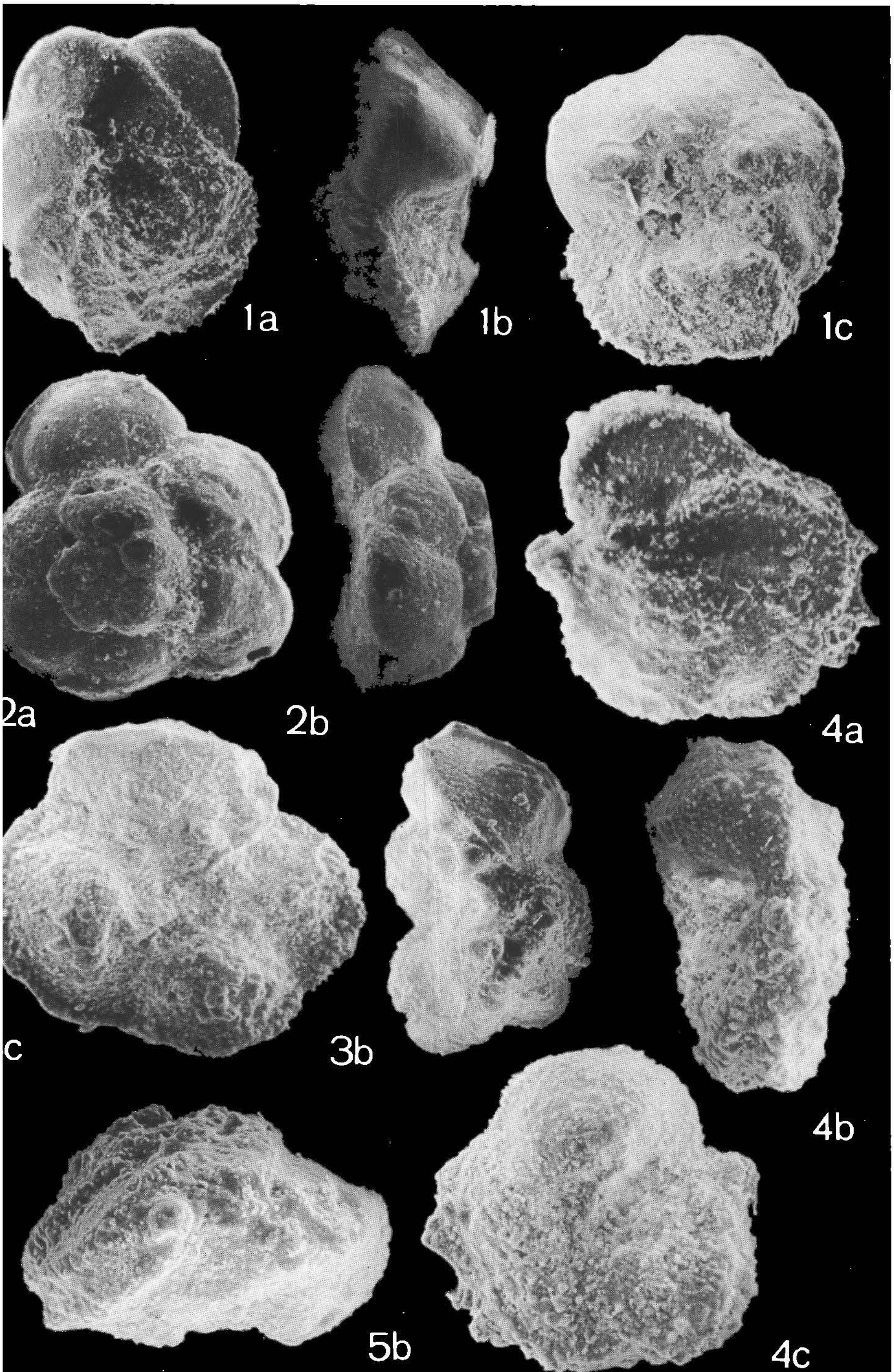
Plate 4

1. *Rotalipora brotzeni* (SIGAL), Lower/Middle Cenomanian, from the condensed part of the profile, 50 cm below the hardground, × 90.
2. *Rotalipora cushmani* (MORROW), Middle Cenomanian, infillings of the burrows, 50 cm below the hardground, × 110.
3. *Rotalipora cushmani* (MORROW), Middle Cenomanian, the hardground (material from the surroundings of the hiatus concretions), × 96.
4. *Dicarinella longoriai* PERYT, Lower Turonian (*Inoceramus labiatus* zone), 20 cm above the next hardground (*compare* the Text-Fig. 1), × 110.
5. *Dicarinella imbricata* (MORNOD), Lower Turonian (*Inoceramus labiatus* zone), the same place as above, × 90.

   a—dorsal, *b*—lateral, *c*—ventral views.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