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# The Scythicus Zone (Middle Volgian) in Poland: its ammonites and biostratigraphic subdivision

ABSTRACT: New paleontological material comprising Middle Volgian ammonites from the classical region of Tomaszów Mazowiecki in Central Poland, chiefly from the section at Brzostówka, is presented. A new species, *Zaraiskites regularis* sp.n., is established. Four new horizons are established in the Scythicus Zone of Poland: the Quenstedti and Scythicus Horizons in the Scythicus Subzone, followed by the Regularis and Zarajskensis Horizones in the Zarajskensis Subzone. These horizones are based on four successive assemblages of *Zaraiskites*, interpreted as biospecies. The new horizons allow to establish some more precise interregional stratigraphic correlations; *e.g.*, the Regularis Horizon has its age equivalent at some level in the Calpionellid Zone *A* in the Upper Tithonian Substage.

## INTRODUCTION

The Volgian deposits of cratonic Poland are nearly everywhere covered by Cretaceous, Tertiary and/or Quaternary sediments, so that some Volgian strata come to the surface only in a few regions. The most important region is that of Tomaszów Mazowiecki, *c.* 100 km south west of Warsaw (Text-fig. 1), where Volgian deposits were first recognized to occur in Poland by MICHALSKI in 1883. Subsequently, several papers concerned with general biostratigraphic problems of the Polish Volgian (*e.g.*, LEWIŃSKI 1923; KUTEK 1926a, b, 1967; KUTEK & ZEISS 1974, 1975, 1988, 1994) were largely, or even exclusively, based on data obtained in the region of Tomaszów Mazowiecki.

In that region, the best section of the Volgian Stage was provided by the locality of Brzostówka. Here, several exposures of Volgian deposits were discontinuously aligned along the upper edge of the northern slope of the Pilica

River. Because of a veneer of Quaternary sediments, these deposits were accessible only in a clay-pit and several quarries. At present, next to nothing is left from these exposures at Brzostówka, a village now included within the administrative boundaries of the town of Tomaszów Mazowiecki. As most probably no further important biostratigraphic data will be provided by the section of Brzostówka, it seems to be the right time to summarize the data hitherto obtained. The paper by KUTEK & ZEISS (1974) includes descriptions and figures of ammonites collected in the lower part of the Brzostówka section, in the topmost Lower Volgian and in the Scythicus Subzone of the Middle Volgian Scythicus Zone, so that the new paleontological material presented in this paper chiefly concerns the higher part of the section, corresponding to the Zarajskensis Subzone of the Scythicus Zone (Text-fig. 2). Some additional data obtained from patchy exposures and boreholes in the region of Tomaszów Mazowiecki will also be taken into account, and some general problems related to the Polish Volgian will be discussed in several sections of this paper.

The new paleontological material presented in this paper is housed in the Museum of the Faculty of Geology, University of Warsaw, as the collection IGPUW/A/29.

The Volgian deposits of the region of Tomaszów Mazowiecki, which gently dip beneath Cretaceous deposits, belong to the Tomaszów Syncline (Text-fig. 1*B*), a structure developed within the south-western margin of the Mid-Polish Anticlinorium. In Mesozoic time, this region was included in the Central (Northwest) European Basin, and also in the Polish Rift Basin (the Polish Trough), which Laramide inversion gave rise to the Mid-Polish Anticlinorium (KUTEK & GŁAZEK 1972, POŻARYSKI & BROCHWICZ-LEWIŃSKI 1978). The

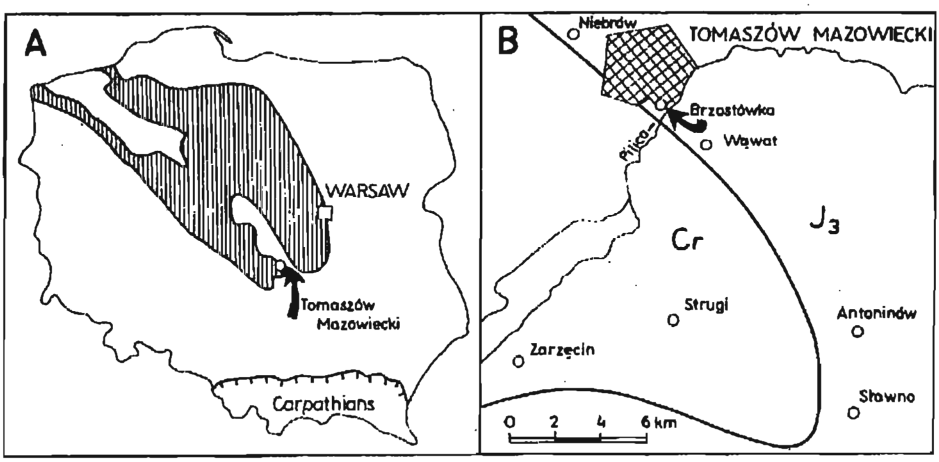



Fig. 1

A — Distribution of Volgian deposits in cratonic Poland (*after* DĄBROWSKA 1976); B — Location map of the studied area, with outline of the Tomaszów Syncline indicated by the junction of Upper Jurassic (Volgian) and Cretaceous (Neocomian) deposits limits of the present-day occurrences of the Volgian deposits of cratonic Poland (Text-fig. 1*A*) are the result of pre-Neocomian, pre-Albian and post-Cretaceous erosion, so that their restricted distribution does not preclude the existence in Volgian time of marine connections of the Polish Basin with, to the east, basins of the Russian Platform, to the south with Tethyan domains, and possibly to the west and north-west with regions of north-western Europe.

## LITHOLOGICAL SUCCESSION

The Volgian deposits cropping out at Brzostówka belong to the uppermost part of the Pałuki Formation and some lower part of the Kcynia Formation, which is here disconformably overlain by Neocomian sediments. The Pałuki and Kcynia Formations are developed over fairly large areas in Central Poland, and in a part of northern Poland (DEMBOWSKA 1979). To the north of Tomaszów Mazowiecki less and less deposits of latest Jurassic age are cut off by the base-Neocomian disconformity, and in some regions of Central Poland there is a sedimentary continuity across the Jurassic/Cretaceous boundary. A succession ranging from the latest Jurassic (Middle Volgian) into the Lower Berriasian, that embraces evaporitic, brackish and other non-marine sediments, and is more or less completely preserved in particular regions, can be referred to as belonging to the Purbeckian facies. This succession is overlain by Upper Berriasian marine sediments (DEMBOWSKA & MAREK 1975, MAREK & *al.* 1989).

In the region of Tomaszów Mazowiecki, as revealed by boreholes, the Pałuki Formation encompasses a part of the Eudoxus Zone and the Autissiodorensis Zone of the Upper Kimmeridgian, and the whole Lower Volgian (the Klimovi, Sokolovi, Pseudoscythica and Tenuicostata Zones), extending up into the Middle Volgian (Text-fig. 2; KUTEK & ZEISS 1994). Both the Upper Kimmeridgian and Lower Volgian portions of the Pałuki Formation are about 60 m thick. This Formation is built up of calcarous shales with intercalations of argillaceous limestone, being lithologically somewhat reminiscent of the British Kimmeridge Clay. The bands of harder rock that occur within the Pałuki Formation may form good marker horizons in exposures, but are difficult to identify over larger distances, especially in boreholes. Limestone intercalations are shown in the detailed section of the Brzostówka clay-pit (Text-fig. 3), but are not indicated in the more generalized section of Brzostówka (Text-fig. 2).

The deposits of the Pałuki Formation that were exposed at Brzostówka in the clay-pit were distinguished by LEWIŃSKI (1923) as the interval *I* (niveau *I* in French), and subdivided into beds *A* — *F* (see Text-figs 2 and 3). During the investigations carried out at a later time by KUTEK & ZEISS (1974) in this clay-pit, then disused, it was possible to extend the succession of Volgian deposits accessible to observation into the topmost Lower Volgian

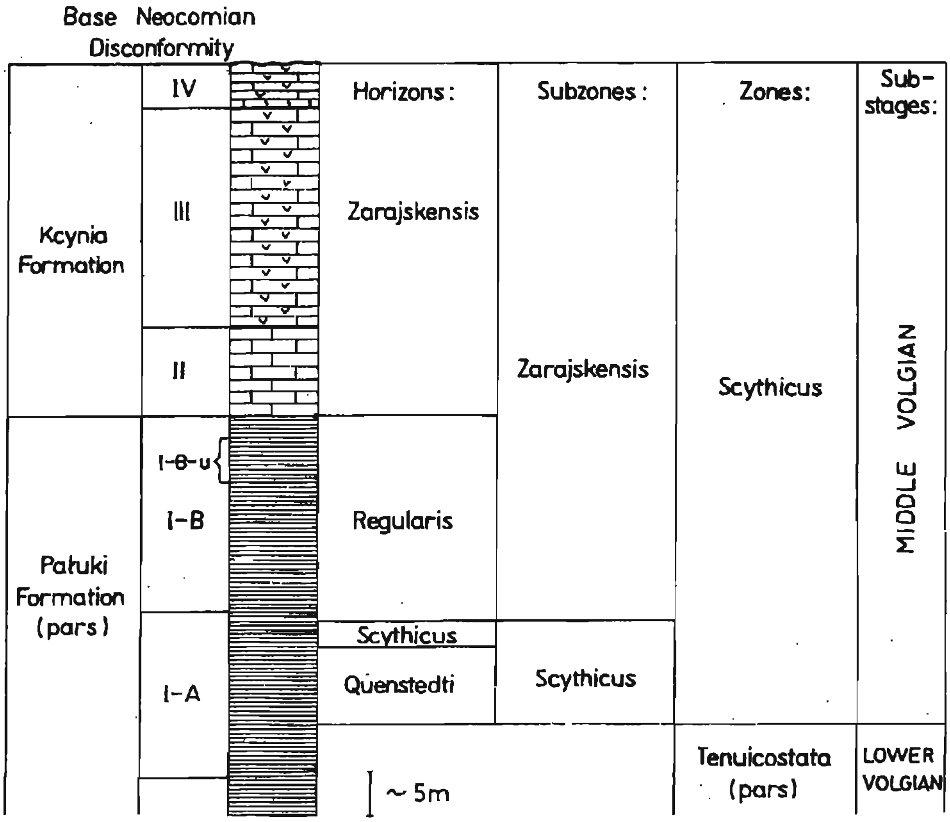



**Fig. 2. Lithostratigraphic and biostratigraphic subdivision of the Volgian section of Brzostówka**

(Text-fig. 3). On the other hand, it was not possible to make accessible the bulk of LEWIŃSKI's bed *F*; only the basal part of this bed with a total thickness of *c.* 5m can be equated with the beds ("layers") *b-1* and *b-2* of KUTEK & ZEISS (1974). The Volgian deposits that were exposed in the Brzostówka clay-pit will be referred to as the interval *I-A* (Text-fig. 2).

Still higher deposits of the Pałuki Formation, that overlie those exposed in the clay-pit, have never been well exposed at Brzostówka, and were not labelled by LEWIŃSKI (1923). These younger deposits, which estimated thickness is about 20m, will be referred to as the interval *I-B* (Text-fig. 2). Some new paleontological material was collecteed by Dr. M. GIŻEJEWSKA and the present Author at Brzostówka from debris excavated during construction work. The material came from an interval *c.* 5m thick, situated a few metres (2–3m?) below the top of the Pałuki Formation. This narrow interval, forming part of interval *I-B*, will be referred to as the interval *I-B-u* (u – upper).

The preserved thickness of the Kcynia Formation at Brzostówka is about 40m (*see* Text-fig. 2). This formation consists of white limestones (yellowish when weathered), which were assigned by LEWIŃSKI (1923) to his successive intervals (niveaux) *II*, *III* and *IV*. The interval *II*, about 10m thick, embraces limestones with a diversified fauna. The exposures of this interval vanished some 50 years ago, but comprehensive information on the faunal content of interval *II* can be found in the papers of MICHALSKI (1890) and LEWIŃSKI (1923).

The next-higher interval *III*, the thickness of which can be estimated as about 25m, consists of limestones that contain characteristic *Corbula* plasters and yield a low-diversity fauna, thus heralding the Purbeckian facies.

The interval *IV* was separated out by LEWIŃSKI (1923) because a distinctive bed, called by him "*The serpulite*", is developed at the base of this interval. This bed is a limestone, *c.* 1.5m thick, crowded with serpulids. It is followed by limestones with *Corbula*, a few (at least 2–3) meters thick. The highest Volgian deposits that occur at Brzostówka beneath the Neocomian disconformity have

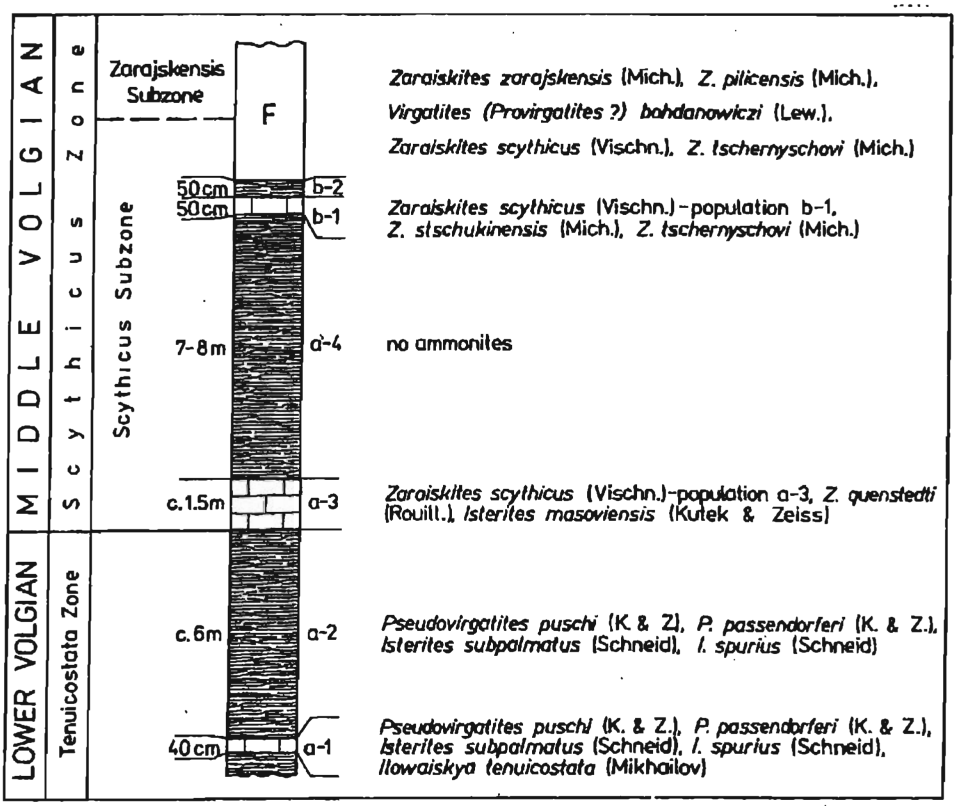



Fig. 3. Lithological sequence and distribution of ammonites in the section of the clay-pit at Brzostówka (*see* interval *I-A* in Text-fig. 2)

never been exposed, but indirect evidence suggests that these are limestones only a few metres thick.

In the region of Tomaszow Mazowiecki, the junction of Volgian and Neocomian deposits was exposed in the Wąwał clay-pit, *c.* 3 km south-east of Brzostówka (Text-fig. 1*B*), and has been recorded in numerous boreholes. In particular sections, the Neocomian sediments transgressive onto the Volgian are of Late Berriasian, Early Valanginian or Late Valanginian age (KUTEK & *al.* 1989).

At Sławno, 17 km south east of Brzostówka (*see* Text-fig. 1*B*), limestones of the Kcynia Formation displaying a combined thickness of about 10m have been exposed intermittently in small quarries. This limestones contain *Corbula* plasters, and also some occurrences of serpulids, but no distinctive bed of a "serpulite" could be recognized. The limestones exposed at Sławno correspond to some part of the combined intervals *III* and *IV* of Brzostówka, and will be referred to as interval *III*/*IV*. It is of interest that a characteristic coquina composed of *Septaliphoria* and terebratulaceans was recognized in the section provided by the quarries at Sławno (PSZCZÓŁKOWSKA 1962). Similar brachiopod coquinas were reported by DEMBOWSKA (1973, 1979) to occur in borehole sections in several regions of the Polsih Lowland, in the lower part of the Kcynia Formation.

It is also worth of note that all the Volgian ammonites found in the region of Tomaszów Mazowiecki and described in the comprehensive papers of MICHALSKI (1890) and LEWIŃSKI (1923) came from the intervals *I* and *II*. The first information on rare occurrences of ammonites at higher levels, in intervals *III* and *IV*, is that found in papers published by the present Author (KUTEK 1962a, b).

## TAXONOMY OF *ZARAISKITES*

The taxonomy of the genus *Zaraiskites* SEMONOV, 1898 (junior synonym: *Provirgatites* LEWIŃSKI, 1923), at its subgeneric level still in current use, is essentially that established by MICHALSKI (1890) in its comprehensive monograph on the ammonites of the Lower (now: Middle) Volgian Substage. Astonishingly, his publication reveals some very modern aspects: dimorphism was implicitly recognized in some species of Virgatitinae, and a very broad concept of species was applied.

MICHALSKI (1890) demonstrated that specimens of *Virgatites virgatus* (BUCH) and *Zaraiskites zarajskensis* (MICHALSKI) fall into two size categories. Adult forms of *V. virgatus* (see MICHALSKI 1890, pp. 20-22, 352-353, Pl. 1, Fig. 1) and *Z. zarajskensis* (see MICHALSKI 1890, pp. 103-104, 420, Pl. 6, Fig. 1) of medium size, with diameters up to about 100 mm, retain virgatotome ribbing up to the last whorl; such forms can now be interpreted with confidence as microconchs. MICHALSKI (1890) also pointed out that *V. virgatus*, and probably also *Z. zarajskensis*, include much larger forms, with diameters ranging up to about 300 mm, in which virgatotome ribbing reverts to bifurcate one on the outermost whorls (MICHALSKI 1890, pp. 20-22, 103-104, 420); these forms are clearly macroconchs. Large forms of *V. virgatus* were illustrated by MICHALSKI (1890, Pl. 2, Fig. 1 and Pl. 3, Fig. 1), and a large form of *Z. zarajskensis*, that also reveals the replacement of virgatotome ribbing by bifurcate ribbing, by LEWIŃSKI (1923, Pl. 11, Fig. 1).

In contrast with published sections from the Russian Platform, the Volgian of Poland provides a possibility to trace the succession of ammonite faunas in expanded and continuous sections, with no indications of stratigraphic condensation. On the other hand, again with contrast to Russia, the preservation state of the ammonites of the Polish Volgian is poor: with but a few exceptions, septal sutures are not preserved, and specimens found in shales are invariably (and sometimes obliquely) crushed. This usually precludes an interpetation of specimens of *Zaraiskites* of moderate size in terms of dimorphism, so more as microconchs of *Zaraiskites* have not a distinctive aperture (*e.g.* with lappets or horns), and as most specimens of this genus in Polish collections are incomplete. Nevertheless, large specimens of *Zaraiskites* with bifurcate ribbing on outer whorls can be interpreted with confidence as macroconchs. In addition to information on dimorphism in *Zaraiskites* provided by MICHALSKI's monograph, it can be taken into account that also the earlier ammonite assemblages that represent the lineage leading from *Virgataxioceres* via *Ilowaiskya* and *Pseudovirgatites* to *Zaraiskites* and *Virgatites* include large forms, in which polyploke, polygyrate or virgatotome ribbing reverts to bifurcate one on outer whorls (KUTEK & ZEISS 1994).

MICHALSKI's monograph also provides examples of a high degree of morphological variability in several species. For instance, in forms of *Zaraiskites stschukinensis* (MICHALSKI, 1890) the spectrum of variability extends from forms with up to six secondaries in virgatotome ribs, to forms in which at the same whorl diameter the ribbing is composed of bifurcate ribs associated with but a few trifurcate ribs (MICHALSKI 1890, Pl. 6, Figs 8-9). Another example is provided by *Z. scythicus* (VISCHNIAKOFF, 1882) in which the replacement of the bifurcate ribbing of the inner whorls by virgatotome ribbing can be observed at distinctly different diameters of whorls (MICHALSKI 1890, Pl. 7, Figs 1-2, 7).

However, when interpreting the paleontological material published by MICHALSKI (1890) it should be borne in mind that this material was interpreted by him collectively as representing the Lower (now: Middle) Volgian Substage, with little more precise knowledge on the stratigraphic distribution of particular forms. Hence, the morphological variability of forms assigned by MICHALSKI to particular species may be an expression of intraspecific variability of assemblages from restricted strigraphic horizons, but also of changes of morphological characters displayed vertically by successive assemblages. As discussed below, biostratigraphic data from Poland substantiate both these assumptions.

A broad, horizontal concept of species, as put forward by CALLOMON (1985), will be applied in this paper: ammonites revealing a continuous spectrum of morphological variability, and found in restricted horizons, will be interpreted as representing one biospacies. The same philosophy of taxonomy was applied, yet in an extreme fashion, by DZIK (1985) to the section of Brzostówka, all the Volgian ammonites from any one level having been treated tentatively as representing only one species. DZIK's interpretation heavily depended on a few biometrical criteria, such as involutness of shell and the ratio of secondary to primary ribs, which criteria, however, are of limited value, or even misleading, in the groups of ammonites concerned.

On the one hand, as already suggested by KUTEK & ZEISS (1974), all or nearly all forms of *Zaraiskites* from the Scythicus Zone at Brzostówka may represent but one species in any one horizon; and the three subspecies of *Pseudovirgatites puschi* (*P. puschi puschi*, *P. puschi simplicior*, and *P. puschi zaraiskoides*) established by KUTEK & ZEISS (1974) to accomodate forms from the topmost Lower Volgian of Brzostówka can be treated as mere labels for morphological variants. It can also be a matter of discussion whether the contemporaneous forms assigned to *Pseudovirgatites puschi* and *P. passendorferi* by KUTEK & ZEISS (1974) do represent different biospecies. Moreover, an application of a morphological, vertical concept of taxonomy, coupled w h an unfortunate selection of distinctive morphological characters, did produce artefacts of tax nomy of the kind pointed out by DZIK (1985), suggesting stratigraphic overlap of several species of *Zaraiskites*. It should be borne in mind, however, that morphological overlap is to some extent a subjective matter: a marked overlap suggested by one selected morphological character may decrease or vanish, if other characters are also taken into account.

On the other hand, however, there have not been found in bed *a-3* of Brzostówka any forms bridging the morphological gap between the forms assigned to *Zaraiskites* and the much less densely ribbed, particularly in inner whorls, forms of *Isterites masoviensis* (KUTEK & ZEISS, 1974). In the topmost Lower Volgian a still greater contrast in style, density and development of ribbing is displayed between forms of *Pseudovirgatites* and those attributed by KUTEK & ZEISS (1974) to *Isterites subpalmatus* (SCHNEID) and *I. spurius* (SCHNEID). Moreover, a difference in geographic distribution should also be taken into account, *I. subpalmatus* and *I. spurius* being known from Central Poland and Franconia, whereas Early Volgian representatives of *Pseudovirgatites* from Poland and the Russian Platform (KUTEK & ZEISS 1974, 1975, 1988, 1994). A species accomodating *Pseudovirgatites*- and *Isterites*-like forms in Poland, but only *Isterites*-like forms in Franconia, would be suggestive of existence of two geographic subspecies, and there is little doubt that this would also be an artefact of taxonomy.

All the species described by MICHALSKI (1890) that are now assigned to *Zaraiskites* were included by him in his group of *Perisphinctes zarajskensis*, but he also distinguished within this group a sub-group of *P. zarajskensis*, *P. pilicensis* and *P. stschukinensis* from a sub-group of *P. quenstedti*, *P. scythicus*, *P. tschernyschovi* and *P. apertus*. These are the groups of *Zaraiskites zarajskensis* and of *Z. scythicus* as defined by COPE (1978, p. 517). The Polish paleontological material allows to assign the species *Z. quenstedti* (ROUILLIER, 1849) and *Z. scythicus* (VISCHNIAKOFF, 1882) to the group of *Z. scythicus*, and *Z.*

*zarajskensis* (MICHALSKI, 1890) as well as *Z. regularis* sp.n. to the group of *Z. zarajskensis*.

The forms belonging to the group of *Zaraiskites zarajskensis* differ from those of the group of *Z. scythicus* in that the dense bifurcate ribbing of inner whorls is replaced at smaller whorl diameters by a more prolonged virgatotome stage of ribbing. In forms of the latter group the virgatotome ribbing is less regular, including a significant proportion of intercalatory ribs; moreover, the virgatotome ribs usually branch at a wider angle, thus producing sheaves with less densely spaced secondary ribs, as can be seen in representatives of the group of *Z. zarajskensis*.

## DATA FROM THE BRZOSTÓWKA CLAY-PIT

The succession of ammonites in the Volgian deposits exposed in the clay-pit of Brzostówka was comprehensively described by KUTEK & ZEISS (1974). The data presented in that paper are summarized in Text-figure 3, with paleontological nomenclature left unchanged. The species shown to occur in bed *F* are those reported by LEWIŃSKI (1923).

The beds *a-1* and *a-2* of the clay-pit section belong to the Tenuicostata Zone of the Lower Volgian, and the beds *a-3*, *a-4*, *b-1* and *b-2* to the Scythicus Subzone of the Middle Volgian Scythicus Zone. The Lower Volgian strata have yielded specimens of *Pseudovirgatites, Isterites*, and *Ilowaiskya tenuicostata* (MIKHAILOV). Two different assemblages of *Zaraiskites* have been recognized in the Scythicus Subzone (in bed *a-3* and in beds *b-1*, *b-2*), that from the basal part of this zone (bed *a-3*) being associated with *Isterites masoviensis* (KUTEK & ZEISS).

After the publication of the paper by KUTEK & ZEISS (1974) the same succession of ammonites was recognized in some boreholes in the region of Tomaszów Mazowiecki (KUTEK & ZEISS 1994), and some new paleontological material was offered to the present Author by Dr. J. WIECZOREK; the latter material was collected from debris provided by a farmer's well at Sławno (*see* Text-fig. *1B*). One set of specimens of ammonites comes from shales and, in some cases, from a somewhat harder rock. These specimens accord with forms from Brzostówka assgned by KUTEK & ZEISS (1974) to *Ilowaiskya tenuicostata, Pseudovirgatites puschi, P. passendorferi* and *Isterites*. Hence, it can be concluded that these specimens represent strata equivalent to the beds *a-1* and *a-2* of the Brzostówka section. Another set of specimens comes from an argillaceous limestone and mostly includes forms of *Zaraiskites* comparable with forms found in bed *a-3* at Brzostówka; a few specimens may belong to *Isterites masoviensis*. This indicates that this limestone corresponds to the bed *a-3* of the Brzostówka section.

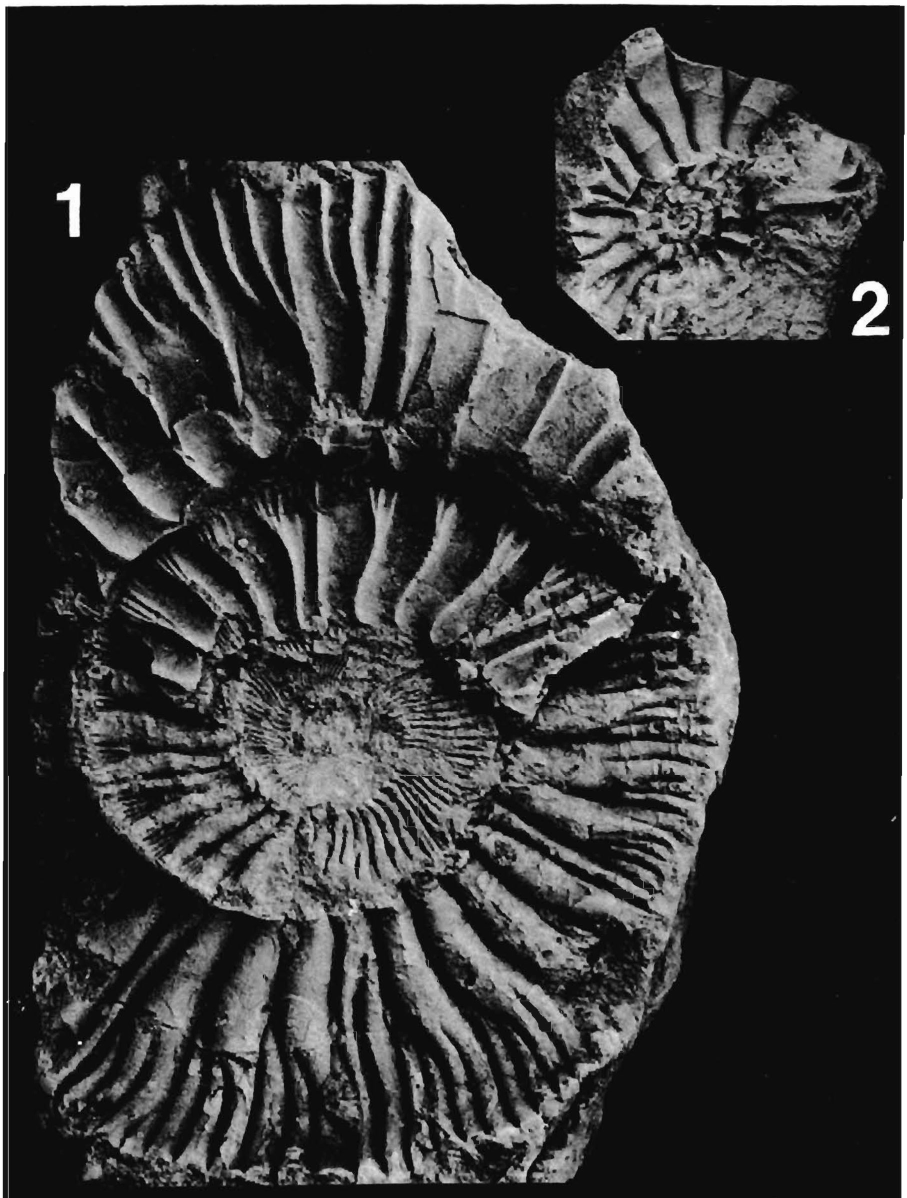
The new paleontological material from Sławno is mostly of poor preservation. Nevertheless, it is of interest because it reveals in another section the succession of ammonites recognized across the base of the Middle Volgian at Brzostówka, and provides additional evidence relevant to the morphological variability of the assemblage of *Zaraiskites* from the basal portion of the Scythicus Zone.

## THE BASE OF THE MIDDLE VOLGIAN AND THE TENUICOSTATA ZONE

In Central Poland the base of the Middle Volgian Substage is marked by the evolutionary transformation of *Pseudovirgatites* into *Zaraiskites*. As recognized at Brzostówka, the most progressive morphological variants of *Pseudovirgatites* from the topmost Lower Volgian (beds *a-1* and *a-2*), referred to by KUTEK & ZEISS (1974) as *P. puschi zaraiskoides*, and the most conservative variants of *Zaraiskites* from the basal Middle Volgian (bed *a-3*) assigned to *Z. quenstedti* (ROUILLIER), are morphologically so close that no doubt is left about the evolutionary link between the genera *Pseudovirgatites* and *Zaraiskites*. On the other hand, all the reasonably complete specimens found above the base of the Middle Volgian can be kept distinct on morphological grounds from those collected from below this base. So the base of the Middle Volgian appears to be a sharp boundary both from a stratigraphic and paleontological point of view.

The assemblage of ammonites consisting of *Pseudovirgatites*, *Isterites* and *Ilowaiskya tenuicostata* (MIKHAILOV), which was recognized by KUTEK & ZEISS at Brzostówka in the topmost Volgian (beds *a-1* and *a-2*) in 1974, had no known counterpart in Russian sections. Hence, a zone or subzone of *Pseudovirgatites puschi*, a subzone of *Ilowaiskya tenuicostata* within the *Pseudoscythica* Zone, or a zone of *I. tenuicostata* were tentitively proposed by KUTEK & ZEISS (1974, 1975, 1988) to accomodate strata containing this assemblage of ammonites, the base of such strata being then unknown. Later on, additional data from boreholes allowed to recognize that *I. tenuciostata* appears, earlier than forms of *Pseudovirgatites*, 20–25m below the top of the Lower Volgian in sections of the region of Tomaszów Mazowiecki (KUTEK & ZEISS 1994). Specimens of *Ilowaiskya pseudoscythica* (ILOVAISKY, 1941) were found in boreholes at still lower levels, and no stratigraphic overlap of *I. pseudoscythica* with *I. tenuicostata* was observed. So there is good evidence substantiating the establishment in Poland of a distinct Tenuicostata Zone above the Pseudoscythica Zone (KUTEK & ZEISS 1994), with *Ilowaiskya tenuicostata* (MIKHAILOV, 1964) as the zonal index. The lower boundary of the Tenuicostata Zone is defined as the level of first appearance of *I. tenuicostata*, its upper boundary coinciding by definition with the base of the scythicus Zone.

As the Pseudoscythica zone is distinguished in sections of the Russian Platform, above the Klimovi and Sokolovi Zones, as the highest zone of the Lower Volgian, the concept of establishing an additional zone for the topmost Lower Volgian was challenged by MESEZHNIKOV (1982, 1988). However, it can be argued that the fact that no counterpart of the Polish Tenuicostata Zone has been recognized in Russian sections may be due to stratigraphic discontinuities and condensation and, in some cases, perhaps to limited knowledge on the vertical distribution of ammonites, or to artefacts of taxonomy.

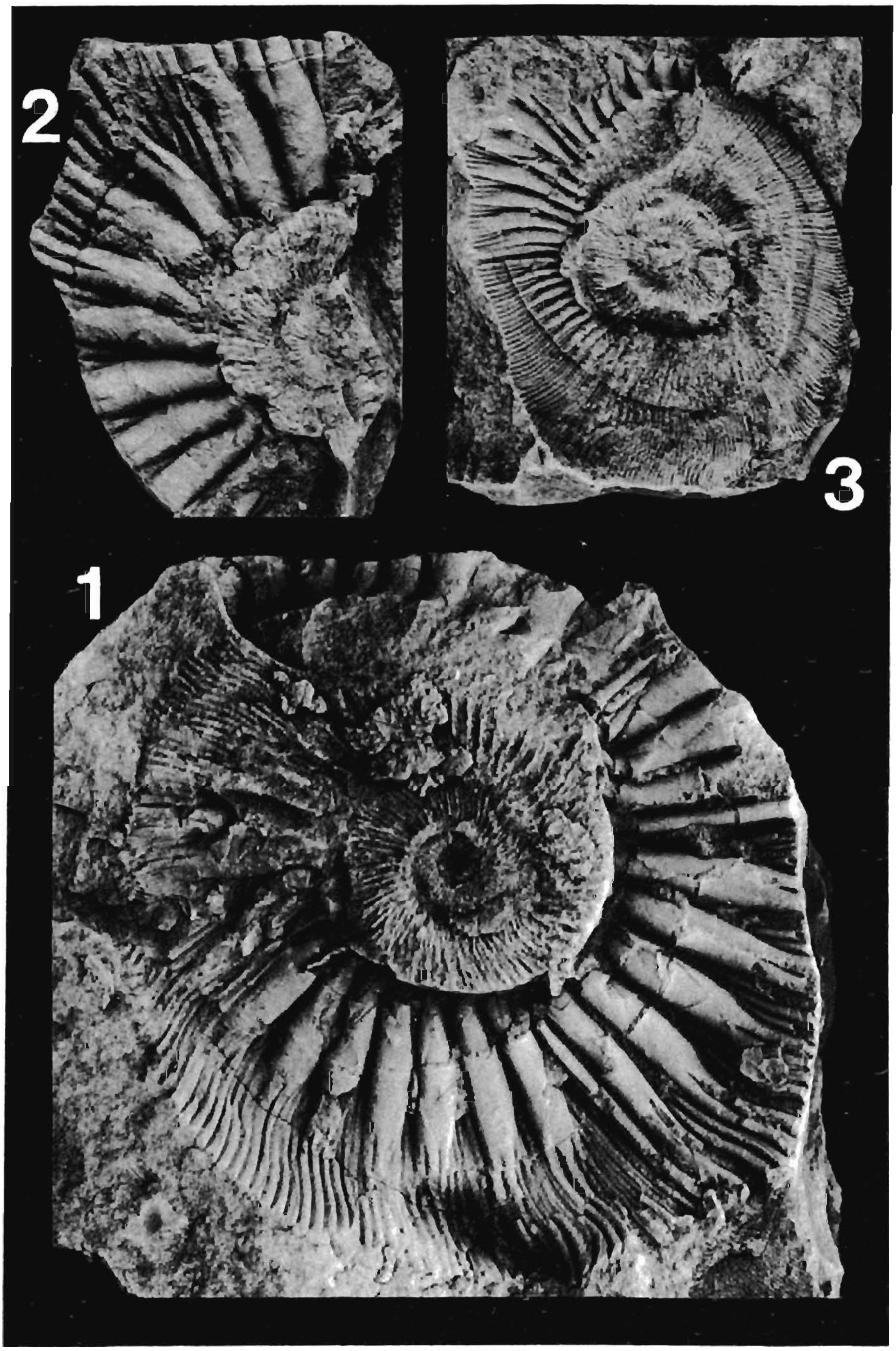



Ammonites from the Quenstedti Horizon; well at Sławno

1 — *Zaraiskites quenstedti* (ROUILLIER); specimen IGPUW/A/29/50

2 — *Zaraiskites tschernyschovi* (MICHALSKI) or *Isterites masoviensis* (KUTEK & ZEISS); specimen IGPUW/A/29/54

All figures of natural size




*Zaraiskites quenstedti* (ROUILLIER); Quenstedti Horizon, well at Sławno

1 – Specimen IGPUW/A/29/51; 2 – Specimen IGPUW/A/29/52; 3 – Specimen IGPUW/A/29/53

All figures of natural size

As also pointed out by KUTEK & ZEISS (1994), in the type section of the Volgian Stage at Gorodishche on the Middle Volga, the Pseudoscythica Zone, which yields specimens of *I. pseudoscythica,* but none of *I. tenuicostata,* is overlain by the Middle Volgian Panderi Zone (a zone equivalent to the Polish Scythicus Zone). At Gorodishche, the total thickness of the Lower Volgian is about 6m. In the section at Kashpirovka in the same region, the Panderi Zone rests directly on deposits of the Sokolovi Zone, and in the region of Moscow on pre-Volgian rocks (MIKHAILOV 1957, 1964; GERASSIMOV & MIKHAILOV 1966). This suggests that the disconformity developed in parts of the Russian Platform at the base of the Middle Volgian may also exist in the section of Gorodishche.

The ammonites of the Polish Tenuicostata Zone have some counterparts in Russia in the region of Orenburg (the region of the Ural and Ilek Rivers). The Lower Volgian sediments of this region, as described by MIKHAILOV (1964), are variable lithologically, rich in glauconite and phosphatic deposits, and usually very thin. For instance, except for a section on the Vetlanka River, the sediments ascribed by MIKHAILOV to the Pseudoscythica Zone are *c.* 1 m or less, in some sections only 25-35 cm thick. These features are suggestive of stratigraphic condensation and discontinuity. Specimens of *I. tenuicostata* were found in a relatively well-precised stratigraphic position only in the Vetlanka section, where they were collected by MIKHAILOV from a sandstone 3.6m thick, together with specimens of *I. pseudoscythica* and forms referred to as *Pectinatites (Wheatleyites)* aff. *eastlecottensis* (SALFELD), *P. (W.) arkelli* (MIKHAILOV), and *P. (W.) spathi* (MIKHAILOV); the two latter forms can be reinterpreted (KUTEK & ZEISS 1994) as forms of *Pseudovirgatites* and *Isterites*. These ammonites were not collected more precisely from narrower horizons, so that it cannot be excluded that the stratigraphic ranges of particular taxa are not the same.

In the publications of MESEZHNIKOV (1982, 1988) on the zonal subsivisions of the Tithonian (Volgian) Stage in the USSR the information can be found that "in none of the sections of the Pseudoscythica Zone studied, including the most complete section near Lake Inder (20m), is *P. (?) tenuicostatus* Michlv. isolated from the rest of the zonal assemblage". It would be difficult to comment on this brief statement which seems to have not been supplemented by any further published data concerning the vertical distribution of ammonites in the section near Lake Inder (in the peri-Caspian region).

In any case, the Tenuicostata Zone is a stratigraphic reality in Poland. In the region of Tomaszów Mazowiecki this zone attains a considerable thickness of 20-25m as compared with the thickness of the rest of the Lower Volgian (35-40m), all its zones (the Klimovi, Sokolovi, Pseudoscythica, and Tenuicostata Zones) being developed in the same lithofacies of the Pałuki Formation (KUTEK & ZEISS 1994). Thus, a considerable span of time may correspond to the Tenuicostata Zone, which should be taken into account when establishing correlations between the Volgian and Tithonian Stages.

## *ZARAISKITES QUENSTEDTI* (ROUILLIER, 1849) BIOSPECIES

The forms of *Zaraiskites* from the basal Middle Volgian of Brzostówka (bed *a-3*) were described in detail by KUTEK & ZEISS (1974). They were referred to as *Z. quenstedti* (ROUILLIER) and *Z. scythicus* (VISCHNIAKOFF), "population from layer *a-3*". Some of these forms were assigned to *Z. scythicus* to match the range of morphological variability of this species as represented by the descriptions and figures by VISCHNIAKOFF (1882) and MICHALSKI (1890), but it was pointed out that these forms differ morphologically from the younger forms of *Z. scythicus* found at Brzostówka in beds *b-1* and *b-2*. It was also suggested by KUTEK & ZEISS (1974) that all the forms of *Zaraiskites* from bed *a-3*, which reveal a morphological continuity, represent but one biological species.

As remarked above, *Z. quenstedti* as interpreted by KUTEK & ZEISS (1974) includes forms displaying most close morphological affinities with *Pseudovirgatites*. The inner whorls of these forms show a very fine dense ribbing to a considerable whorl-diameter; this ribbing consists of bifurcate ribs that often join at the umbilical edge, forming bidichotomous and polydichotomous rib-units. This ribbing is replaced on middle whorls by distant virgatotome ribbing, the distances between ribs increasing several times abruptly after constrictions. The virgatotome ribbing is very irregular, with a large proportion of intercalatory ribs. Up to six secondary ribs correspond to one primary rib.

The forms referred to as *Z. scythicus*, "population from layer *a-3*", differ from those ascribed to *Z. quenstedti* in that the ribbing of inner whorls is less fine (but still fairly dense), including bidichotomous, but no polydichotomous rib-units; this ribbing persists to a smaller whorl-diameter. The virgatotome ribbing of the middle whorls is less irregular, with a smaller proportion of intercalatory ribs. There are up to five secondaries in virgatotome ribs. However, there is no distinct morphological gap between the forms from bed *a-3* that were ascribed to *Z. quenstedti* and *Z. scythicus*; this precluded the assignation of some specimens to any one of these species (*e.g.* KUTEK & ZEISS 1974, Pl. 25, Fig. 2).

All the forms of *Zaraiskites*, that display the continuous spectrum of morphological variability revealed by the specimens from bed *a-3* at Brzostówka, and that occur in the lowest horizon of the Scythicus Zone (the Quenstedti Horizon, *see below*), will be interpreted as one biospecies and referred to as *Zaraiskites quenstedti* (ROUILLIER, 1849) biospecies. This name is chosen because it is an earlier name than that of *Z. scythicus* (VISCHNIAKOFF, 1882), and because the occurrences of forms referable to *Z. quenstedti* as interpreted by ROUILLIER (1849), VISCHNIAKOFF (1882), and MICHALSKI (1890) are restricted to the basal part of the Scythicus zone (the Quenstedti Horizon), as revealed by sections of the region of Tomaszów Mazowiecki.

It is also proposed to reinterpret the formal species *Zaraiskites quenstedti* (ROUILLIER, 1849) in morphological terms, and to include in this species, in addition to the forms hitherto assigned to *Z. quenstedti*, those mophological variants of *Zaraiskites* that show close morphological affinity with the former forms, but were hitherto accommodated in *Z. scythicus* (VISCHNIAKOFF). The morphological range of the reinterpreted *Z. quenstedti* (ROUILLIER) can be defined as corresponding to the morphological range revealed by the specimens referred to by KUTEK & ZEISS (1974) as *Z. quenstedti* (ROUILLIER) and *Z. scythicus* (VISCHNIAKOFF), "population from layer *a-3*", and by the additional paleontological material presented below.

Additional material concerning *Zaraiskites quenstedti* (ROUILLIER) biospecies and (reinterpreted) morphospecies has been provided by the well at Sławno; four specimens from the level corresponding to bed *a-3* of Brzostówka are figured in this paper (Pl. 1, Fig. 1 and Pl. 2, Figs 1-3). All the specimens show the characteristic long-persisting ribbing of the inner whorls, and the highly irregular virgatotome ribbing of the middle whorls. On the other hand, the specimens display some variation in rib density and development at comparable whorl-diameters. One large specimen (Pl. 1, Fig. 1), which is clearly a macroconch, shows the reversal of virgatotome ribbing to trifurcate and bifurcate ribs on an outer whorl.

A specimen (Pl. 3, Fig. 1) from the borehole Antoninów-Skorkówka (*see* Text-fig. 1*B*) also reveals the morphological features typical of *Zaraiskites quenstedti* (ROUILLIER), biospecies and morphospecies.

## THE QUENSTEDTI HORIZON

It is proposed to establish the Quenstedti Horizon as the lower horizon of the Scythicus Subzone (Text-fig. 2).

The lower boundary of the Quenstedti Horizon is defined as the level of first appearance of *Zaraiskites quenstedti* (ROUILLIER) bsp. and, more generally, of the genus *Zaraiskites*. This boundary coincides with the base of the Scythicus Subzone, the Scythicus Zone and the Middle Volgian Substage and, in the section of Brzostówka, with the base of bed *a-3*. The upper boundary of the Quenstedti Horizon coincides by defintion with the lower boundary of the next-higher Scythicus Horizon, the level of the first appearance of *Z. scythicus* (VISCHNIAKOFF) bsp. (*see below*).

The index of the Quenstedti Horizon is provided by *Zaraiskites quenstedti* (ROUILLIER, 1849) biospecies. The stratigraphic range of *Isterites masoviensis* (KUTEK & ZEISS) also appears to be restricted to the Quenstedti horizon (Text-fig. 3).

The limestone corresponding to bed *a-3* of Brzostówka yielded in the well at Sławno a peculiar incomplete specimen (Pl.1, Fig. 2). The last whorl preserved shows bifurcate ribs with a variable, but wide angle of furcation; these ribs are supplemented by some simple (and trifurcate?) ribs. Characteristic is the distant ribbing of inner whorls seen in the umbilicus. This specimen, standing morphologically well apart from *Z. quenstedti*, is hard to interpret unequivocally. One possibility is its inclusion in the poorly known species *Zaraiskites*(?) *tschernyschovi* (MICHALSKI) (*comp.* MICHALSKI 1890, Pl. 8, Fig. 3*b*), another one is in its interpretation as an extreme variant (*comp.* KUTEK & ZEISS 1974, Pl. 14, Fig. 3) of *Isterites masoviensis* (KUTEK & ZEISS).

## *ZARAISKITES SCHYTHICUS* (VISCHNIAKOFF, 1882) BIOSPECIES

The forms of *Zaraiskites* referred to by KUTEK & ZEISS (1974) as *Z. scythicus* (VISCHNIAKOFF), "population from layers *b-1* and *b-2*", differ from the earlier forms that were referred to by KUTEK & ZEISS (1974) as *Z. scythicus* (VISCHNIAKOFF), "population from layer *a-3*", and are now included in *Z. quenstedti* (ROUILLIER), biospecies and morphospecies, in that the bifurcate ribbing of the inner whorls is less dense, and persists to smaller diameters of whorls, whereas bidichotomus rib-units are rare. The distant virgatotome ribbing of the middle whorls is more regular, with less numerous intercalatory ribs, and with virgatotome ribs in which the number of secondaries amounts only to four. A reversal to trifurcate, and finally to bifurcate ribbing is displayed by outer whorls of large specimens (macroconchs). On the other hand, the discussed forms from the beds *b-1* and *b*-2 of Brzostówka (Text-fig. 3) display much morphological variation with respect to density of ribbing and persistence of successive ribbing stages. It was suggested by KUTEK & ZEISS (1974) that also the two specimens from bed *b-1* that were referred to as *Z. stschukinensis* (MICHALSKI), in which the bifurcate ribbing of the inner whorls is still less dense, or pushed back, can be interpreted as belonging to the same biological species as the contemporaneous forms ascribed to *Z. scythicus*, "population from layers *b-1* and *b-2*".

The forms of *Zaraiskites* referred to by KUTEK & ZEISS (1974) as *Z. scythicus* VISCHNIAKOFF), "population from layers *b-1* and *b-2*", and to *Z. stschukinensis* (MICHALSKI) display a continous range of morphological variability, and occur in a distinct horizon of the Scythicus Subzone (Text-figs 2–3). Therefore they will be interpreted as belonging to one biospecies, and referred to as *Zaraiskites scythicus* (VISCHNIAKOFF, 1882) biospecies. This name is adopted because the lectotype of *Z. scythicus* (the specimen figured by VISCHNIAKOFF 1882, Pl. 3, Fig. 1; designated by ARKELL 1956, Pl. 45) clearly falls within the range of morphological variability of *Z. scythicus* (VISCHNIAKOFF) bsp., as here defined. It is also proposed to reinterpret the formal species *Zaraiskites scythicus* (VISCHNIAKOFF, 1882) by exclusion of the morphological variants that are accomodated in the reinterpreted species *Z. quenstedti* (ROUILLIER, 1849).

## THE SCYTHICUS HORIZON

It is proposed to establish the Scythicus Horizon as the upper horizon of the Scythicus Subzone (Text-fig. 2). The lower boundary of the Scythicus Horizon is defined by the level of first appearance of *Zaraiskites scythicus* (VISCHNIAKOFF) biospecies; at Brzostówka it is drawn at the base of bed *b-1* (Text-fig. 3). The upper boundary of the Scythicus Horizon is equated by definition with the lower boundary of the next-higher Regularis Horizon (*see below*). It can be concluded (Text-fig. 3) that the latter boundary is situated within the bed *F* of LEWIŃSKI. From this it follows that the Scythicus Horizon occupies a relatively small portion of the Scythicus zone (Text-fig. 2).

Nearly all the ammonites hitherto found in the region of Tomaszów Mazowiecki in the Scythicus Horizon, and identified with certainty, can be assigned to the index species of this horizon, *i.e.* to *Zaraiskites scythicus* (VISCHNIAKOFF) biospecies. An exception is provided by a specimen from the bed *b-1* of Brzostówka, ascribed to *Z. tschernyschovi* (MICHALSKI) by KUTEK & ZEISS (1974).

## *ZARAISKITES REGULARIS* (SP. N.) BIOSPECIES

### *Zaraiskites regularis* sp.n.
### (Pl. 3, Fig. 2 and Pls 4–10)

?1890. *Per. Stschukinensis* n.sp.; A. MICHALSKI, pp. 110, 423 (*pars*).
1961b. *Virgatites virgatus* (BUCH); J. KUTEK, p. 663, Text-figure.
1965. *Zaraiskites zarajskensis* (MICH.); J. DEMBOWSKA, p. 298, Pl. 1, Fig. 3.
1965. *Virgatites virgatus* (BUCH); J. DEMBOWSKA, p. 299, Pl. 1, Fig. 2.
1973. *Zaraiskites pilicensis* (MICHALSKI); J. DEMBOWSKA, p 66 (*pars?*), Pl. 6, Figs 1-2.
1973. *Zaraiskites* cf. *zarajskensis* (MICHALSKI); J. DEMBOWSKA, p. 65 (*pars*), Pl. 6, Fig. 3.
1973. *Zaraiskites* sp. (*f*); J. DEMBOWSKA, p. 68, Pl. 6, Fig. 6.
1985. *Virgatites ("Zaraiskites")* sp.n.; J. DZIK, p. 82, Pl. 9; Pl. 10, Figs 1-2.

HOLOTYPE: The specimen IGPUW/A/29/1, presented in Pl. 5, Fig. 1.

TYPE LOCALITIES: Brzostówka, and the boreholes Strugi-*1*, Zarzęcin-*1* and Zarzęcin-*3*, in the region of Tomaszów Mazowiecki.

TYPE HORIZON: Regularis Horizon, Scythicus Subzone, Scythicus Zone, Middle Volgian; topmost part of the Pałuki Formation, chiefly interval *I-B-u* at Brzostówka.

DERIVATION OF THE NAME: Latin *regularis* – regular, pointing to the regular virgatotome ribbing of the species.

DIAGNOSIS: Dimorphic; bifurcate ribbing of inner whorls is replaced at relatively small whorl-diameter by very regular virgatotome ribbing; interspaces between sheaves of neighboring virgatotome ribs are not, or but slightly broader than interstices between secondary ribs in the sheaves; trifurcate and bifurcate ribbing reappears on outer whorls of macroconchs.

MATERIAL: 29 labelled specimens, and fragmentary material.

DESCRIPTION: All the ammonites hitherto found in the interval *I-B* of Brzostówka, together with some specimens from boreholes, can be accomodated in the new species *Zaraiskites regularis* sp.n. Best paleontological material has been provided by the interval *I-B-u* at Brzostówka.

All the specimens available are strongly crushed, with the effect that the diameter and height of whorls have been increased, and the furcation points of ribs lowered on the whorl side.

The measurements of some specimens given below bear no attempt to restore the primary dimensions. The following abbrevations are used: D — diameter of whorl; U — diameter of umbilicus; P/2 — number of primary ribs per half a whorl; S/P — ratio of secondary to primary ribs (usually with respect to 5 primary ribs counted back from points at which whorl-diameter is measured).

| Coll. numbers | D | U | P/2 | S/P | Figured in: |
|---|---|---|---|---|---|
| IGPUW/A/29/1 | 106 mm | 36 mm | | | Pl. 5, Fig. 1 |
| | 98 mm | 32 mm | 25 | 4.8 | |
| | 89 mm | 25 mm | 24 | 4.8 | |
| IGPUW/A/29/2 | 88 mm | 27 mm | 23 | 3.6 | Pl. 4, Fig. 2 |
| | 69 mm | 18 mm | | 2.6 | |
| IGPUW/A/29/3 | 84 mm | 26 mm | 16 | 2.8 | Pl. 3, Fig. 2 |
| | 66 mm | 20 mm | 16 | 2.6 | |
| IGPUW/A/29/22 | *c.*75 mm | *c.*20 mm | *c.*21 | 4.6 | Pl. 9, Fig. 1 |
| IGPUW/A/29/23a | *c.*60 mm | | | 3.6 | Pl. 9, Fig. 2a |
| IGPUW/A/29/25 | *c.*60 mm | | | *c.*2.5 | Pl. 9, Fig. 4 |

The ammonites assigned to *Zaraiskites regularis* often form plasters but, unfortunately, usually are found broken in the rock (Pl. 7 and Pl. 9, Fig. 3). Hence, in an arbitrary way only can some labelled specimens been separated from what can be called a fragmentary material.

The new species *Zaraiskites regularis* sp.n. includes forms in which the dense bifurcate ribbing of inner whorls persists to small diameters of whorls, and a long-lasting virgatotome stage of ribbing is characterized by very regular developments of virgatotome ribs. Hence, this species can be included in the group of *Z. zarajskensis*.

In some specimens (Pl. 5, Figs 2*a*, 3; Pl. 6, Fig. 3; Pl. 9, Fig. 2*c*) it can be recognized that the dense bifurcate ribbing of the innermost whorls is replaced at an estimated whorl-diameter of 35mm or less by still dense ribbing consisting of trifurcate ribs. In most specimens (*e.g.* Pl. 4, Fig. 2; Pl. 5, Fig. 1; Pl. 7, Fig. 3; Pl. 9, Figs 1-2*a*) this is followed by a stage of moderately distant virgatotome ribbing, comprising virgatotome ribs with four or five secondaries. In some other specimens (*e.g.* Pl. 3, fig. 2; Pl. 9, Figs 3-4) fairly distant ribbing appears at small whorl diameter, and the ribbing of middle whorls consists of ribs branching into up to three secondaries. These trifurcate ribs will also be termed virgatotome ribs, and the corresponding stage of ribbing a virgatotome stage, because the rib-style of trifurcate ribs does not differ from that of ribs with four or five secondaries (*comp.* Pl. 3, Fig. 1; Pl. 4, Fig. 2; *and* Pl. 5, Fig. 1).

In the collection there is also a peculiar form (Pl. 6, Fig. 1) in which distant ribbing developed at a whorl-diameter of about 40 mm is followed at a larger diameter by ribbing consisting of ribs branching into at least four secondaries.

In all the forms included in *Zaraiskites regularis* the virgatotome ribbing is very regular, comprising virgatotome ribs with well-shaped sheaves. These ribs branch at a narrow angle, so that the secondary ribs are densely spaced in sheaves, following a parallel or subparallel course. This feature is best marked in forms with virgatotome ribs branching into four or five secondary ribs, less so in forms with virgatotome ribbing composed of trifurcate ribs (Pl. 3, Fig. 2; Pl. 4, Fig. 2; Pl. 5, Fig. 1). Distinct intercalatory ribs are virtually absent.

The ribbing at the virgatotome stage is complicated by constrictions, which are invariably followed by simple ribs but are preceded by various rib developments, *e.g.* more or less regular virgatotome ribs, polyploke ribs or two ribs joined at the umbilical edge (Pl. 3, Fig. 2; Pl. 4, Fig. 2; Pl. 5, Fig. 1; Pl. 9, Fig. 4; Pl. 10, Fig. 1). Irregular ribs not connected with constrictions are extremely rare (Pl. 9, Figs 1, 3).

A distinctive feature of all the forms included in Zaraiskites regularis is that at the virgatotome stage of ribbing the interspaces between sheaves of neighboring virgatotome ribs are not, or but a little, broader than the interstices between secondary ribs within the sheaves (Pl. 3, Fig. 2; Pl. 4, Figs 1-2; Pl. 5, Figs 1, 2*b*, 3; Pl. 7, Figs 2-3; Pl. 9, Figs 1-4; Pl. 10, Fig. 2).

On the other hand, much morphological variation can be observed at the virgatotome stage of ribbing with respect to the ratio of secondary to primary ribs. Forms with virgatotome ribbing comprising ribs with four or five secondaries are quite common (*e.g.* Pl. 4, Fig. 2; Pl. 5, Fig. 1; Pl. 7, Figs 2-3; Pl. 10, Fig. 2). In other forms, however, the number of secondaries in virgatotome ribs appears to have not amounted to more than three (Pl. 3, Fig. 2; Pl. 5, Fig. 2*b*). A continuous range of variability of the ratio of secondary to primary ribs is revealed by the five specimens shown in Plate 9 (Figs 1, 2*a*, *b*, 3 and 4). All these specimens come from the borehole Strugi-*1*, from an interval only 1m thick.

The material collected at Brzostówka indicates that virgatotome ribbing with ribs with four secondaries may persists to a (crushed) whorl-diameter of about 100mm (Pl. 5, Fig. 1; Pl. 7, Fig. 3). Here the interval *I-B-u* also yielded fragments of large whorls (45 – 60mm high) that display bifurcate ribbing (Pl. 6, Fig. 2; Pl. 7, Fig. 1; Pl. 8). These whorls, which may correspond to estimated (crushed) whorl-diameters of about 140 – 200mm, are interpreted as belonging to macroconchs. A specimen from the borehole Zarzęcin-*3* (Pl. 10, Fig. 1) allows to estimate that in this case the replacement of virgatotome ribbing by bifurcate ribbing took place at a diameter of the order of 100mm.

A large specimen from Pomerania figured by DZIK (1985, Pl. 9, Pl. 10, Figs 1-2) as *Virgatites ("Zaraiskites")* sp.n. agrees very well with the forms from Brzostówka included in *Zaraiskites regularis*. This specimens is septated at least to a diameter of 198mm, and its end-size has been estimated by DZIK to have been of the order of 240 – 300mm. The specimen figured by DZIK does also allow to trace the gradual reversal of virgatotome ribbing with quadrifurcate ribs to bifurcate ribbing through an intermediate stage of predominantly trifurcate ribbing. In this case trifurcate ribs persist, in association with bifurcate ribs and occasional simple ribs bounding constrictions, to a diameter of about 190mm.

The data discussed above indicate that the bifurcate ribbing characteristic of the outer whorls of macroconch may appear in forms of *Zaraiskites regularis* at different whorl-diameters. This may be suggestive of a considerable variation in end-size of macroconchs of *Z. regularis*.

The new species *Zaraiskites regularis* sp.n. reveals a continous spectrum of morphological variability, as defined by the specimens discussed above, and is interpreted as a morphospecies. The forms included in *Z. regularis* have been found in a restricted stratigraphic interval (the Regularis Horizon, *see below*), in which no systematic vertical morphological changes have as yet been revealed by these forms. Hence, they can also be interpreted as a biospecies.

REMARKS: The forms included in *Zaraiskites regularis* sp.n. differ from the earlier forms from Brzostówka assigned to *Z. scythicus* (VISCHNIAKOFF, 1882) bsp. in that the bifurcate ribbing of inner whorls persists to smaller whorl-diameters, and by the much more regular development of the virgatotome stage of ribbing. Moreover, some forms of *Z. regularis* have virgatotome ribs with five secondaries, a feature never found in *Z. scythicus* bsp. Most of the forms included in *Z. regularis* could be distinguished from those of *Z. scythicus* bsp. on purely morphological grounds, even if their exact stratigraphic position were not known. Some problems might only arise with incomplete specimens displaying a suppressed virgatotome stage of ribbing, *i.e.* with forms with a very low ratio of secondary to primary ribs (*see e.g.* Pl. 29, Fig. 3 and Pl. 32, Figs 1-2 *in* KUTEK & ZEISS 1974; *and* Pl. 6, Fig. 1 and Pl. 9, Figs 3-4 in this paper).

Forms of *Zaraiskites regularis* sp.n. distinctly differ from those included in *Zaraiskites zarajskensis* (MICHALSKI, 1890) bsp. in having narrower interspaces between sheaves of neighbouring virgatotome ribs. Moreover, the number of secondaries in virgatotome ribs amounts to five in *Z. regularis* and to nine in *Z. zarajskensis* bsp. (*see* Pl. 6, Fig. 5 *in* MICHALSKI 1890; *and* Pl. 11, Fig. 1 in this paper).

Several Polish specimens, now referrable to *Zaraiskites regularis* sp.n., have hitherto been classified as *Z. zarajskensis* (MICHALSKI), *Z. pilicensis* (MICHALSKI), and even as *Virgatites virgatus* (BUCH) (comp. the synonymy of *Z. regularis*, which refers only to figured specimens from Poland). Moreover, some non-illustrated specimens (*see below*) were also assigned to *Z. quenstedti* (ROUILLIER) and *Z. scythicus* (VISCHNIAKOFF).

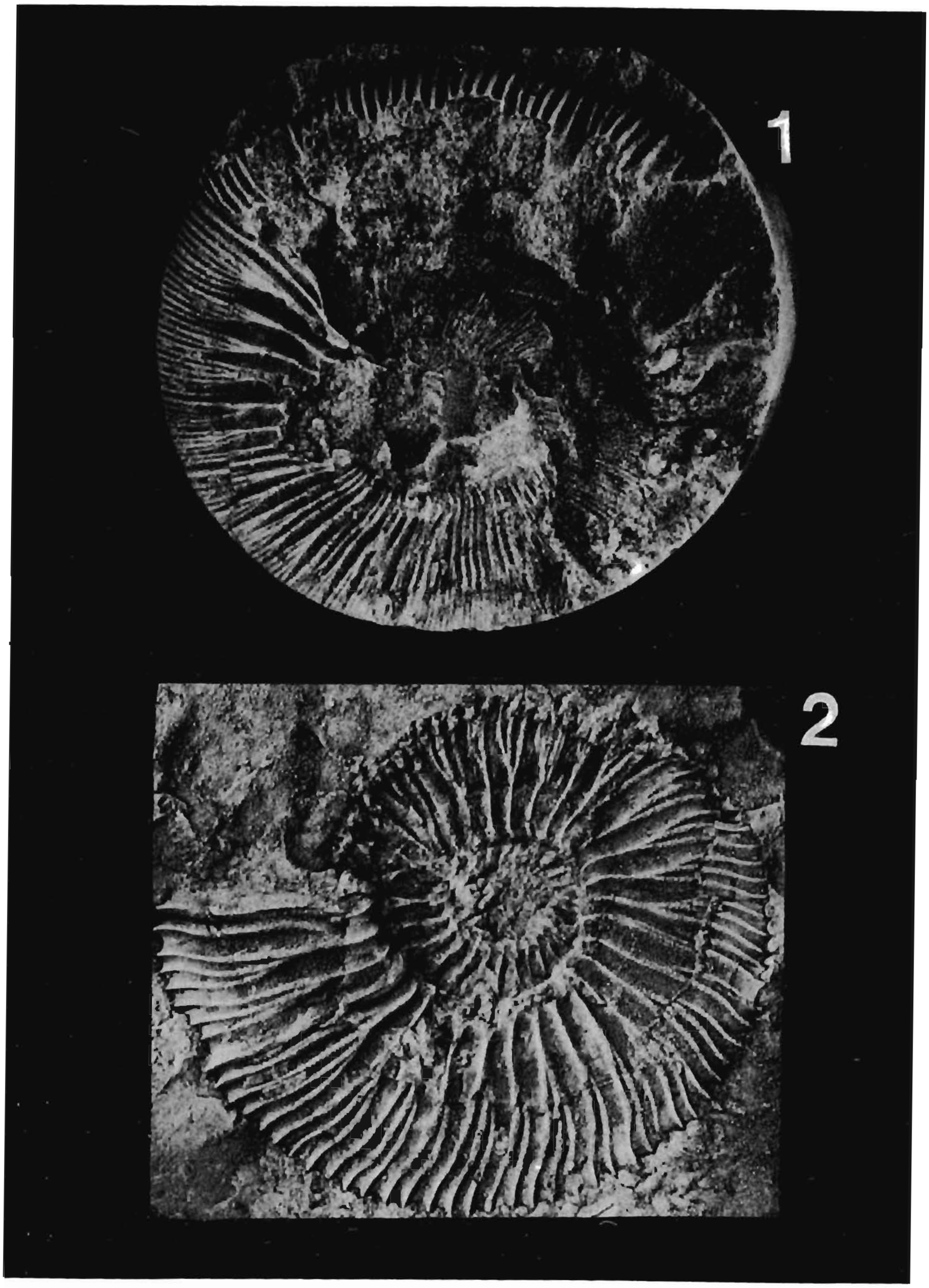
Some forms of *Zaraiskites regularis* sp.n. seem to be closely comparable morphologically with some forms of the species *Zaraiskites stschukinensis* (MICHALSKI, 1890) which also displays much morphological variation (*see* MICHALSKI 1890, Pl. 6, Figs 8-9). Unfortunately, the stratigraphic range of *Z. stschukinensis* has not yet been established with desirable precision; this species was based by MICHALSKI (1890) exclusively on specimens from Russia, but no forms of *Zaraiskites* have been referred to as *Z. stschukinensis* in recent Russian papers (*e.g.* MIKHAILOV 1964; GERASSIMOV & MIKHAILOV 1966; MESEZHNIKOV 1982, 1988). Hence, this stratigraphic range can only be estimated on indirect evidence. One of the specimens of *Z. stschukinensis* figured by MICHALSKI (1890, Pl. 13, Fig. 9) has its morphological counterpart in the Scythicus Horizon of Brzostówka (KUTEK & ZEISS 1974, Pl. 32, Fig. 1), whilst a Russian specimen of *Z. stschukinensis* figured by ARKELL (1956, Pl. 45, Fig. 2), which shows fairly large interspaces between sheaves of virgatotome ribs, corresponds morphologically to *Z. zarajskensis* bsp. Thus, the forms hitherto assigned to *Z. stschukinensis* incorporate a stratigraphic range extending from the Scythicus Horizon to the Zarajskensis Horizon, whereas the forms included in *Z. regularis* sp.n. are restricted to the intervening Regularis Horizon (*see* Text-fig. 2).

The species *Zaraiskites stschukinensis* was based by MICHALSKI (1890) on a collection which did not include large specimens; hence the interpretation of the lectotype of *Z. stschukinensis* (MICHALSKI 1890, Pl. 6, Fig. 8; designated by ARKELL 1956, Pl. 45, Fig. 2) raises difficulties. This is a small incomplete specimen, with a diameter of about 45mm. It shows regular virgatotome ribbing comparable with that found in *Z. regularis* sp.n., with interspaces between sheaves of virgatotome ribs but indistinctly broader than those found in most forms of *Z. regularis*. However, forms of *Zaraiskites* are known in which the virgatotome ribbing does not differ at the same whorl-diameter from that shown by the lectotype of *Z. stschukinensis*, but which display very broad interspaces between sheaves at greater diameters. A spectacular example is provided by a specimen of *Z. pilicensis* figured by MICHALSKI (1890, Pl. 6, Fig. 10); the latter specimen clearly reveals the diagnostic characters of *Z. zarajskensis* bsp. Moreover, the lectotype of *Z. stschukinensis* has virgatotome ribs with six secondaries, a feature commonly found in forms assigned to *Z. zarajskensis* bsp., but not observed in *Z. regularis* sp.n., in regular virgatotome ribs.

It is still possible that some of the Russian specimens assigned to *Zaraiskites stschukinensis* (MICHALSKI) fall in the range of morphological variability of *Z. regularis* sp.n., and represent the same stratigraphic interval. However, as uncertainties would remain, and much confusion arise, if the concerned forms from Poland were ascribed to *Z. stschukinensis*, it appears to be justified to accomodate these forms in *Zaraiskites regularis* sp.n., a species with a well-established stratigraphic and morphological range.

## THE REGULARIS HORIZON

It is proposed to establish the Regularis Horizon as the lower horizon of the Zarajskensis Subzone (Text-fig. 2), with *Zaraiskites regularis* sp.n., interpreted as biospecies, as the index species. The lower boundary of this horizon is

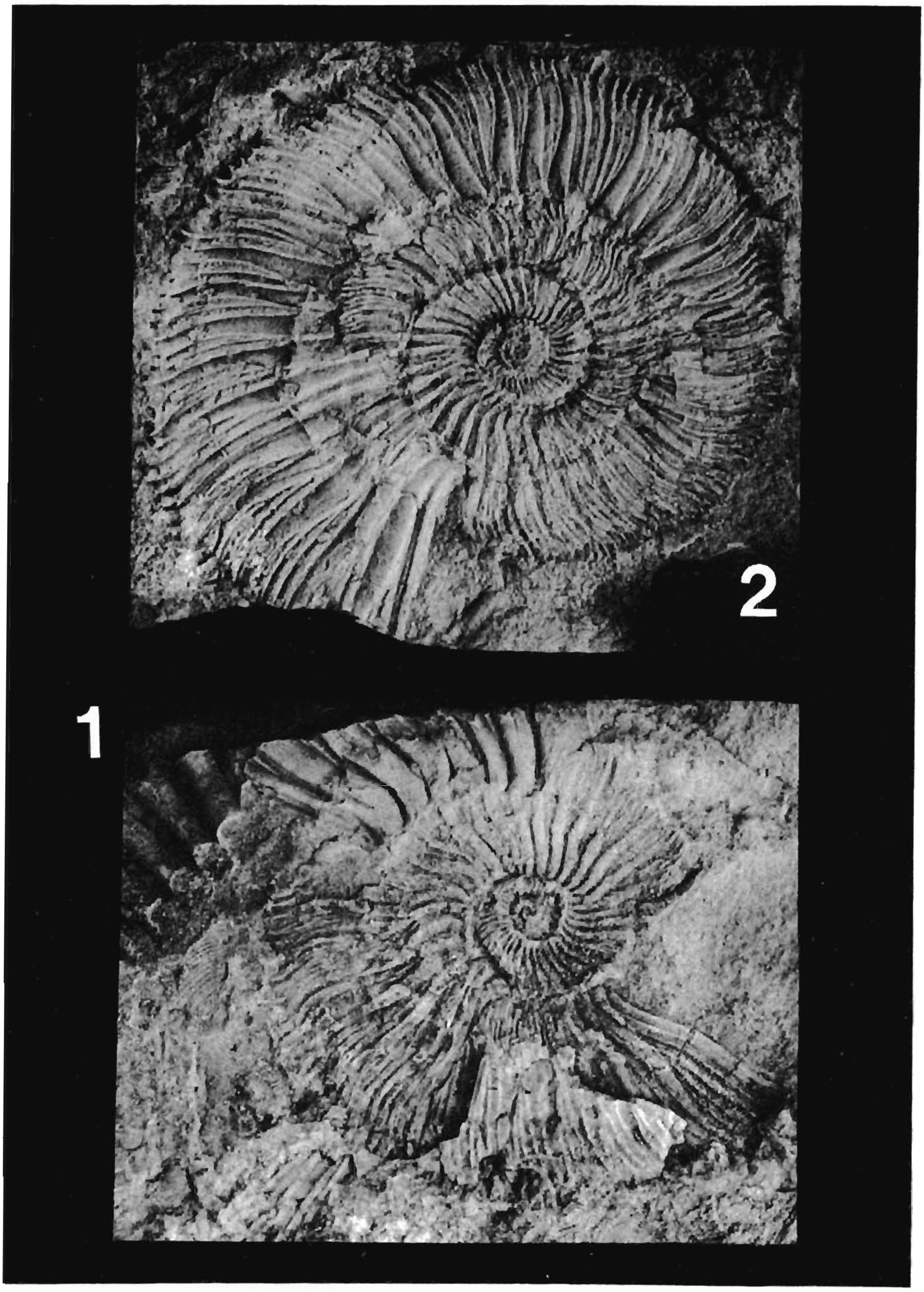



Ammonites from the Quenstedti and Regularis Horizons

1 — *Zaraiskites quenstedti* (ROUILLIER); Quenstedti Horizon; specimen IGPUW/A/29/55; borehole Antoninów-Skorkówka (depth 54.7m)

2 — *Zaraiskites regularis* sp.n., paratype, Regularis Horizon; specimen IGPUW/A/29/3; Brzostówka, interval *I-B-u*

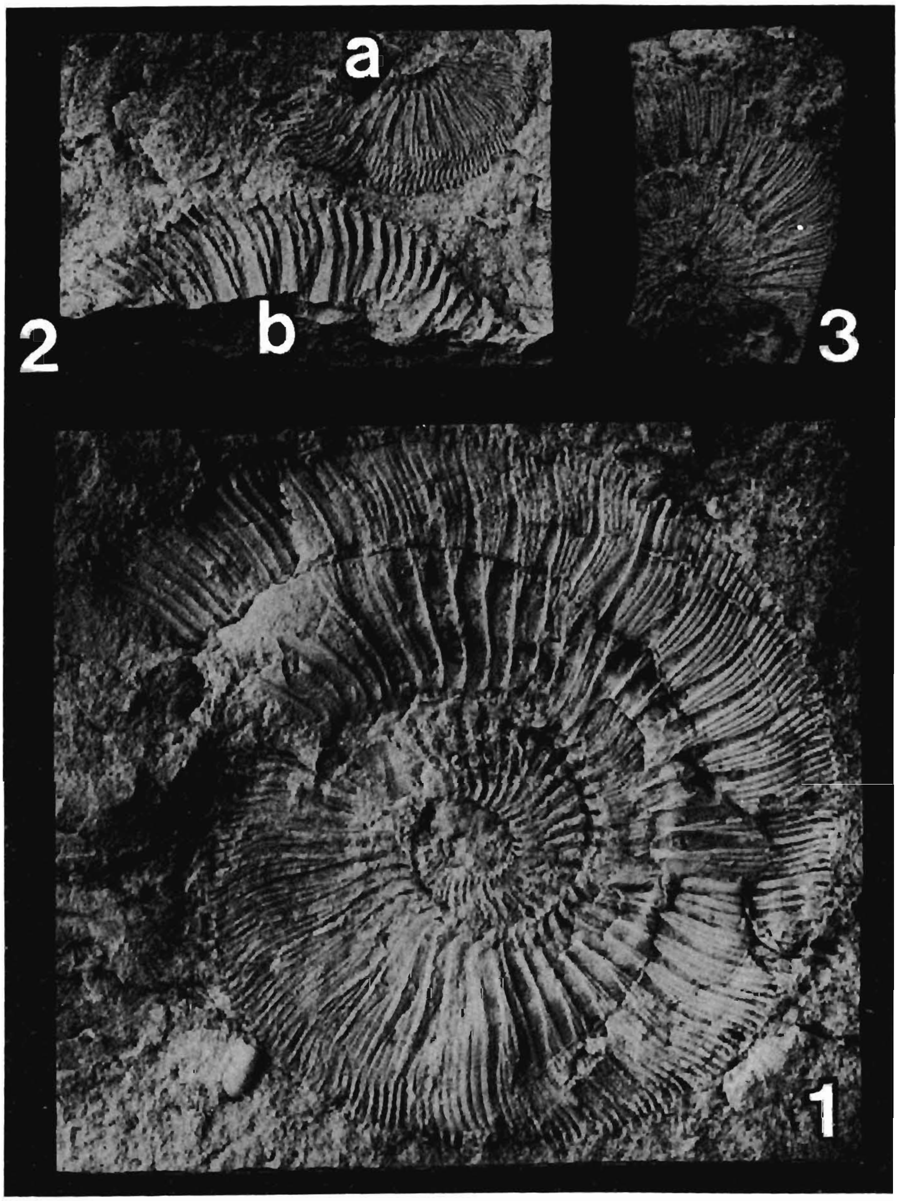
All figures of natural size




*Zaraiskites regularis* sp.n.; Regularis Horizon, Brzostówka, interval *I-B-u*

1 – Paratype; specimen IGPUW/A/29/4; 2 – Paratype; specimen IGPUW/A/29/2

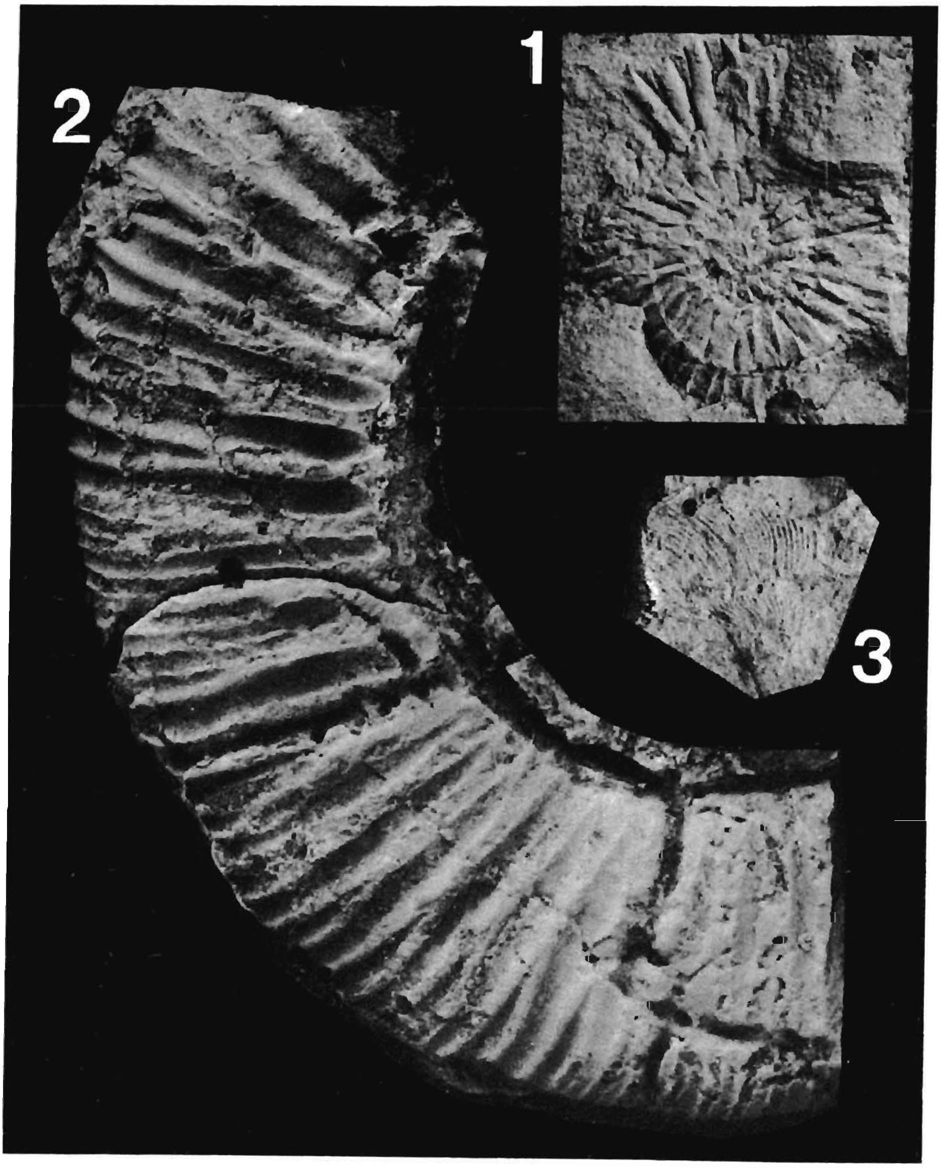
All figures of natural size




*Zaraiskites regularis* sp.n.; Regularis Horizon; Brzostówka, interval *I-B-u*

**1** – **Holotype**; specimen IGPUW/A/29/1; **2 a, b** – Paratypes; specimens IGPUW/A/29/8a, b;
**3** – Paratype; specimen IGPUW/A/29/7

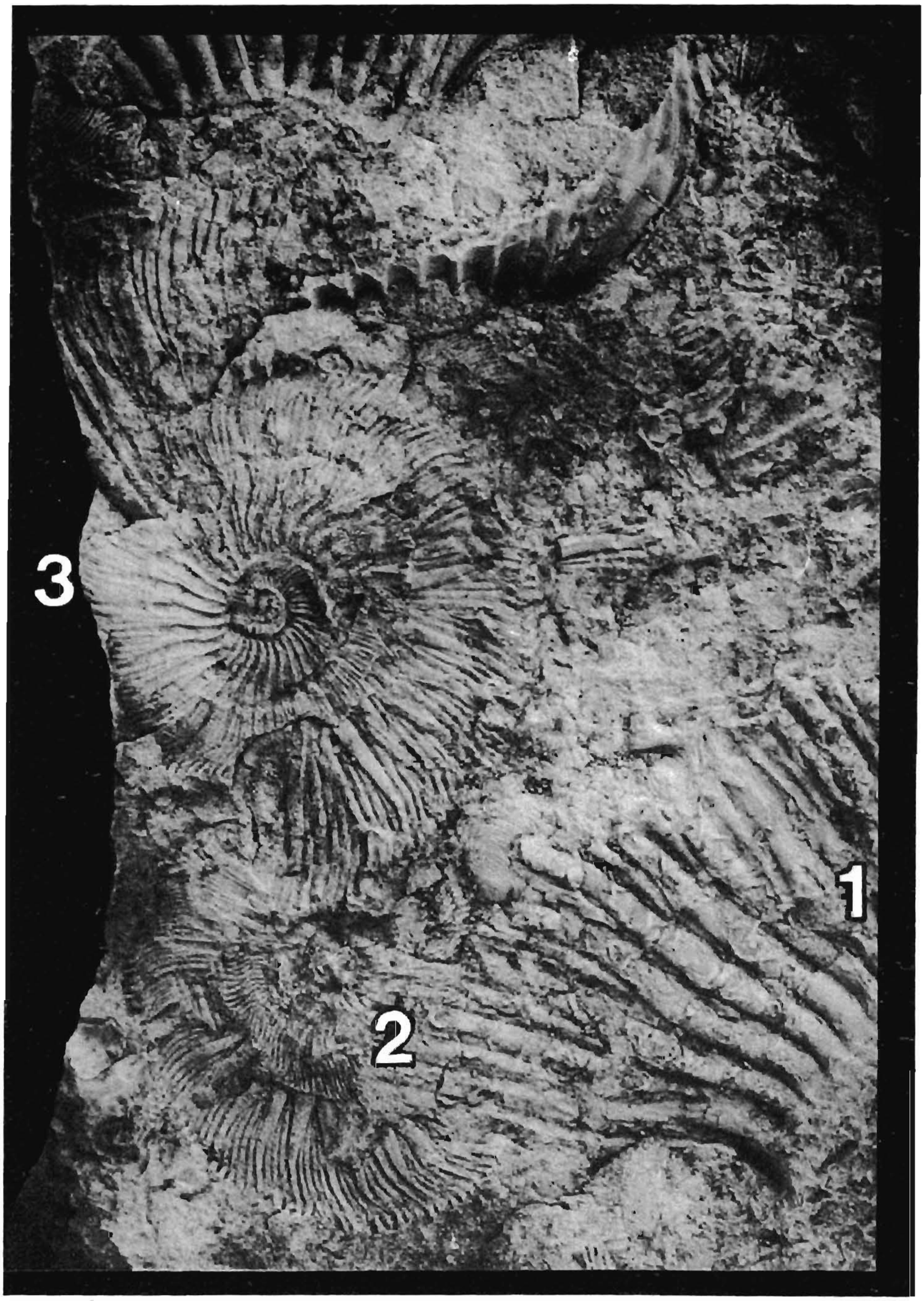
All figures of natural size




*Zaraiskites regularis* sp.n.; Regularis Horizon; Brzostówka, interval *I-B-u*

1 — Paratype; specimen IGPUW/A/29/9; 2 — Paratype; specimen IGPUW/A/29/5; 3 — Paratype; specimen IGPUW/A/29/10

All figures of natural size




*Zaraiskites regularis* sp.n.; Regularis Horizon; Brzostówka, interval *I-B-u*

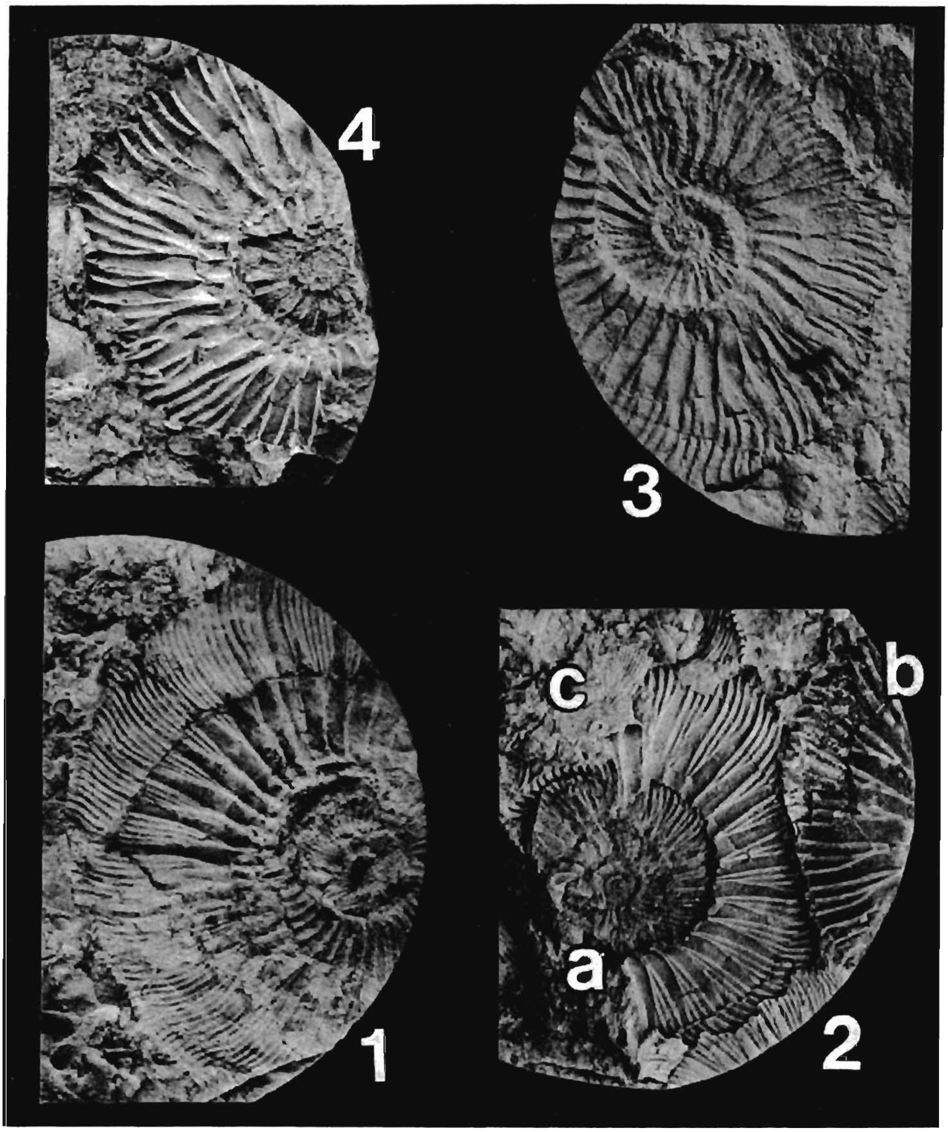
1 – Paratype; specimen IGPUW/A/29/11a; 2 – Paratype; specimen IGPUW/A/29/11b; 3 – Paratype; specimen IGPUW/A/29/11c

All figures of natural size

*Zaraiskites regularis* sp.n.; Regularis Horizon; Brzostówka, interval *I-B-u*

Paratype; specimen IGPUW/A/29/6

Figure of natural size




*Zaraiskites regularis* sp.n.; Regularis Horizon, borehole Strugi-*1*

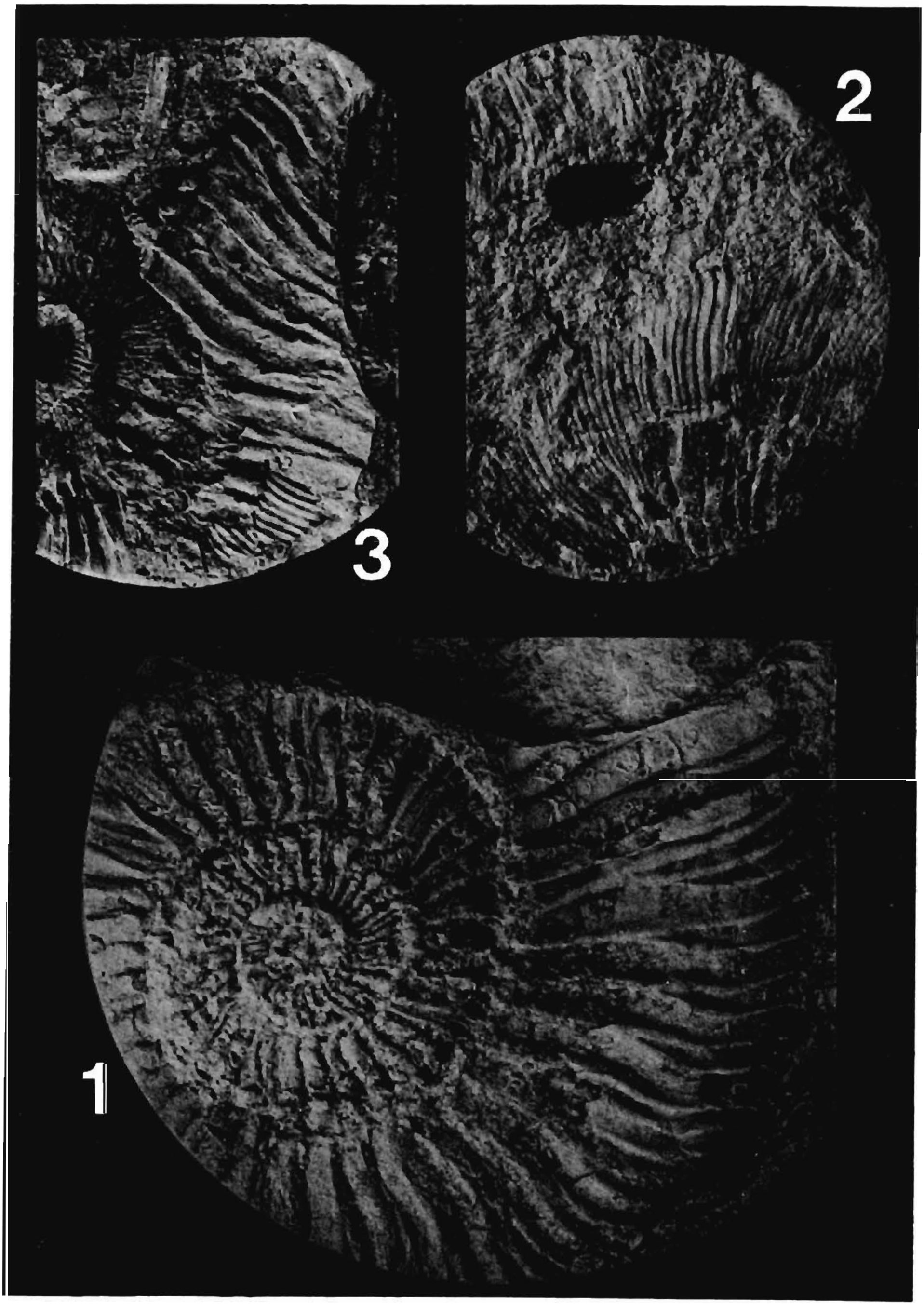
1 – Paratype; specimen IGPUW/A/29/22; depth 255.0m

**2 a, b, c** – Paratypes; specimens IGPUW/A/29/23a,b,c; depth 255.5m

3 – Paratype; specimen IGPUW/A/29/24; depth 256.0m

4 – Paratype; specimen IGPUW/A/29/25; depth 256.0m

All figures of natural size




*Zaraskites regularis* sp.n.; Regularis Horizon

1 — Paratype; specimen IGPUW/A/29/27; borehole Zarzęcin-*3* (depth 148m)
2 — Paratype; specimen IGPUW/A/29/28; borehole Zarzęcin-*1* (depth 120.2-7m)
3 — Paratype; specimen IGPUW/A/29/26; borehole Strugi-*1* (depth 256.0m)

All figures of natural size

defined as the level of first appearance of *Z. regularis* bsp. The upper boundary of the Regularis Horizon coincides by definition with the lower boundary of the Zarajskensis Horizon (*see below*).

The base of the Regularis Horizon has not been recognized by the present writer at Brzostówka, but it can be located on indirect evidence in the bed *F* of LEWIŃSKI (*see* Text-figs 2 and 3). The species *Zaraiskites zarajskensis* (MICHALSKI) has been reported from bed *F* by LEWIŃSKI (1923), which is a significant information as forms now referrable to *Z. regularis* sp.n. have often hitherto been assigned to *Z. zarajskensis*, and as of the species of the group of *Z. zarajskensis* only *Z. regularis* can be expected to occur at such a deep level at Brzostówka. It can be thus presumed that some of the ammonites found by LEWIŃSKI (1923) in bed *F* represent *Z. regularis*. As the beds *b-1* and *b-2* of Brzostówka (Text-fig. 3), which have not yielded any forms of *Z. regularis*, and represent the Scythicus Horizon, can be equated with the basal part of the bed *F*, the base of the Regularis Horizon can be expected to lie at some higher level within the bed *F* which is *c*. 5m thick.

From this it can be concluded that the Regularis Horizon is 20 – 25m thick at Brzostówka (Text-fig. 2). This interpretation is consistent with occasional finds of *Zaraiskites regularis* in patchy exposures and boreholes in the region of Tomaszów Mazowiecki (*e.g.* KUTEK 1961b; *and* Pl. 9, Figs 1-4, Pl. 10, Figs 1-3 in this paper), in part-sections which in most cases cannot be corelated precisely with particular levels of the interval *I* of Brzostówka, but which indicate a fairly large range of vertical distribution of *Z. regularis*. In particular, some specimens of ammonites were obtained by the present Author (KUTEK 1962a, b) from material dug out in the vicinity of Tomaszów Mazowiecki, at Brzostówka, Niebrów and near the Wolborka river; at Brzostówka this was a level between interval *I-B-u* and bed *F*. These specimens, most of them of poor preservation, were then assigned to *Z. zarajskensis* (MICHALSKI), *Z. quenstedti* (ROUILLIER), and *Z. scythicus* (VISCHNIAKOFF), but they can now be identified as *Z. regularis* sp.n.

As yet no systematic vertical changes of the range of morphological variability of the forms assigned to *Zaraiskites regularis* sp.n. could be recognized in the Regularis Horizon.

A specimen found in bed *F* at Brzostówka was figured by LEWIŃSKI (1923, Pl. 11, Fig. 3) as "*Virgatites (Provirgatites?) bohdanowiczi* n.sp.". This incomplete specimen is very strongly involute still at an estimated diameter of over 100mm. It reveals fine dense ribbing on inner whorls, and a coarser but tightly arranged virgatotome ribbing on the last preserved whorl, *c*. 60mm high. A trace left on this whorl by a still larger whorl indicates that the discussed form had a diameter well over 150mm.

As recognized by LEWIŃSKI (1923, p. 98), this form does not accord with any species of *Zaraiskites* (= *Provirgatites*). On the other hand, it reveals morphological characters found in forms of *Pseudovirgatites* and, in particular, is most closely comparable with *P. scruposus* (OPPEL, 1865). As the range of morphological variability of this species is poorly known (*comp.* ZEISS 1977, p. 371), the specimen figured by LEWIŃSKI can be referred to as *Pseudovirgatites* cf./or aff. *scruposus* (OPPEL).

*ZARAISKITES ZARAJSKIENSIS* (MICHALSKI, 1890) BIOSPECIES

According to the data provided by MICHALSKI (1890) and LEWIŃSKI (1923), the interval *II* of Brzostówka yielded forms of *Zaraiskites* that were ascribed to *Z. zarajskensis* (MICHALSKI) (MICHALSKI 1890, pp. 98, 417, Pl. 6, Fig. 5; *and* LEWIŃSKI 1923, p. 103, Pl. 11, Figs 1-2), *Z. pilicensis* (MICHALSKI) (MICHALSKI 1890, pp. 117, 417; *comp.* Pl. 6, Fig. 10), and *Z. alexandrae* (LEWIŃSKI) (LEWIŃSKI 1923, p. 95, Pl. 10, Figs 1-3). Note, however, that all the forms referred by LEWIŃSKI (1923) without reservation to *Z. pilicensis* (MICHALSKI) came from the interval *I* of Brzostówka, and that these forms appear to differ from *Z. pilicensis* as interpreted by MICHALSKI (1890).

A comprehensive description of *Zaraiskites zarajskensis* can be found in the paper by MICHALSKI (1890). The species *Z. pilicensis* was largely based on paleontological material from Brzostówka (MICHALSKI 1890, pp. 121, 425), and its name refers to the Pilica River. The latter species differ from *Z. zarajskensis* in that its virgatotome ribbing consists of ribs with less numerous secondaries. The species *Z. alexandrae* was based on very poor material, and all the figured specimens of this species present but fragments of whorls (LEWIŃSKI 1923, Pl. 10, Figs 1-3). The latter species seems to have been established to comprise specimens that could not be easily accomodated in *Z. zarajskensis* or *Z. pilicensis*.

All the forms of *Zaraiskites* from interval *II* of Brzostówka clearly belong to the group of *Z. zarajskensis*: the bifurcate ribbing of inner whorls is replaced at a small diameter by long-lasting, regular virgatotome ribbing. Reversal to more simple, trifurcate and bifurcate ribbing is revealed by outer whorls of macroconchs (LEWIŃSKI 1923, Pl. 10, Figs 2-3; Pl. 11, fig. 1). On the other hand, the number of secondaries in virgatotome ribs is highly variable, ranging from up to four to up to nine in figured specimens.

A distinctive feature, that allows to distinguish the forms of *Zaraiskites* from interval *II* from the earlier forms included in *Z. regularis* sp.n., is that the interspaces between sheaves of neighboring virgatotome ribs are distincly broader than the interstices between secondary ribs within the sheaves. This contrast is more strongly marked at a well-developed stage of virgatotome ribbing than at smaller diameter (*see e.g.* MICHALSKI 1890, Pl. 6, Fig. 10), and the interspaces may become less wide between sheaves comprising particularly great numbers of secondary ribs. There is also some variation in figured forms with respect to the discussed morphological character; the interspaces seem to be particularly large in forms attributed to *Z. pilicensis* (see MICHALSKI 1890, Pl. 6, Fig. 10), and least spectacular in forms assigned to *Z. alexandrae* by LEWIŃSKI (1923, Pl. 10, Fig. 1).

Significantly, the combined range of morphological variability shown by the forms of *Zaraiskites zarajskensis*, *Z. pilicensis*, and *Z. alexandrae* is about as broad as that revealed by *Z. regularis* sp.n., which is undoubtedly the evolutionary predecessor of the zaraiskitids occurring in interval *II* of Brzostówka. Therefore, it is proposed to include the forms that have hitherto been assigned to *Zaraiskites zarajskensis* (MICHALSKI, 1890), *Z. pilicensis* (MICHALSKI, 1890), and *Z. alexandrae* (LEIWŃSKI, 1923), and can be interpreted as mere morphological variants of one biological species, in one formal species named *Zaraiskites zarajskensis* (MICHALSKI, 1890). This name, which has most widely been used in literature, is retained because it refers to the type species of the genus *Zaraiskites*. As the occurrences of forms representing the reinterpreted species *Z. zarajskensis* are confined to the Zarajskensis Horizon (*see below*), it can be interpreted as a biospecies as well as a morphospecies.

Ammonites are very rare in the highest Volgian deposits of the region of Tomaszów Mazowiecki, where the horizons *III* and *IV* have hitherto yielded only about twenty specimens. Most of these specimens have been figured by the present Author (KUTEK 1967), and in this paper (Plates 11 – 14). The specimens have been found in the Kcynia Formation, in the "serpulite" of interval *IV* and in the topmost three meters of interval *III* at Brzostówka, and in interval *III/IV* in the quarries at Sławno. The ammonites are preserved as moulds, in part also as external imprints, and are not distincly flattened.

All these ammonites can now be identified as forms of *Zaraiskites*. In some earlier papers of the present Author (KUTEK 1962a, b) one of the specimens concerned was assigned to *Zaraiskites zarajskensis* (MICHALSKI), and some other fragmentary specimens referred to as belonging to *Zaraiskites* or *Virgatites*. This was an example of application of the vertical concept of taxonomy to imperfect specimens.

The ammonites from the intervals *III*, *IV* and *III/IV* are closely comparable morphologically with forms of *Zaraiskites* from the interval *II* of Brzostówka, and display a similar range of variability. For instance, one of the specimens illustrated (Pl. 11, Fig. 1) is very close to the specimen of *Z. zarajskensis* from Brzostówka figured by MICHALSKI (1890); and another one (Pl. 12, Fig. 2) is reminiscent of *Z. alexandrae*, as defined by LEWIŃSKI (1923). In general, the forms now discussed exhibit the diagnostic characters of the group of *Z. zarajskensis*. As for the ratio of secondary to primary ribs at the virgatotome stage of ribbing, the range of variability extends from forms with ribs branching at most into three secondary ribs (Pl. 13, Fig. 1), to forms with ribs with up to nine secondaries (Pl. 11, Fig. 1; *compare also* Pl. 11, Fig. 2; Pl. 12, Figs 1-2; Pl. 13, Figs 2-5; Pl. 14, Fig. 2). Outer whorls of large specimens (macroconchs) of comparable size show bifurcate ribbing (Pl. 12, Fig. 1) or bifurcate ribs alternating with trifurcate ones (Pl. 14, Fig. 1); this may suggest variation in end-size of macroconchs. The irregular ribbing seen in the last whorl of one of the illustrated specimens (Pl. 13, Fig. 2) may be suggestive of adapertural modification of ribbing of an adult microconch.

The forms of *Zaraiskites* from intervals *III, IV* and *III/IV* also reveal the distinctive broad interspaces between sheaves of virgatotome ribs (Pls 11 – 14). These interspaces may shrink between sheaves with a high number of secondaries (Pl. 11, Fig. 1; Pl. 13, Fig. 5). The question may arise whether the forms of *Zaraiskites* from higher levels of the Kcynia Formations (intervals *II, IV* and *III/IV*) reveal, statistically at least, a tendency to enlarge the interspaces here discussed. As yet, however, the available well-dated paleontological material does not allow to substantiate such a supposition. As for particular specimens, some otherwise closely comparable forms from interval *II* may have as well, or even better, developed interspaces, as forms from the higher intervals (*compare* Pl. 6, Fig. 5 *in* MICHALSKI 1890, *with* Pl. 11, Fig. 1 in this paper). Hence, all the forms of *Zaraiskites* from the intervals *III, IV* and *III/IV* are also interpreted as belonging to *Zaraiskites zarajskensis* (MICHALSKI, 1890), morphospecies and biospecies.

It is worth pointing out that the distinctively large interspaces between sheaves of virgatotome ribs make it possible to identify even small fragments of whorls as belonging to *Zaraiskites zarajskensis* bsp. This, in turn, facilitates the recognition of the Zarajskensis Horizon.

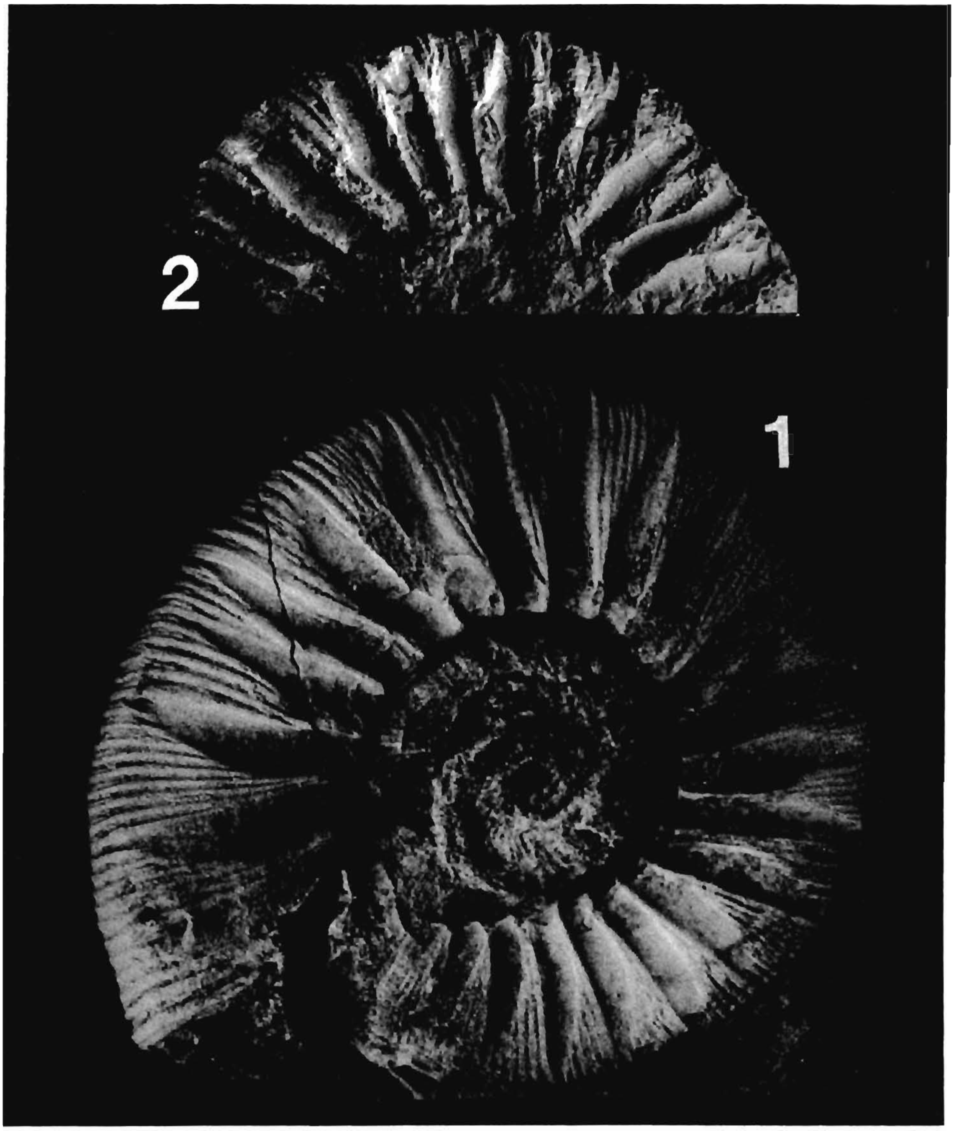
## THE ZARAJSKENSIS HORIZON

It is proposed to establish the Zarajskensis Horizon as the upper horizon of the Zarajskensis Subzone (Text-fig. 2). The lower boundary of the Zarajskensis Horizon is defined as the level of first appearance of *Zaraiskites zarajskensis* (MICHALSKI, 1890) biospecies, the index of this horizon.

At Brzostówka, *Zaraiskites zarajskensis* bsp. is known to occur in the basal portion of the Kcynia Formation (interval *II*), and does not yet appear in the Pałuki Formation in interval *I-B-u* (Text-fig. 2), which yielded forms of *Z. regularis* bsp. However, no ammonites have yet been found in the intervening topmost part of the Pałuki Formation, a few (2 – 3?) metres thick. On the other hand, it is significant that forms of *Z. regularis* bsp. but no forms referrable to *Z. zarajskensis* bsp. have hitherto been found at high levels in the Pałuki Formation in other sections of the region of Tomaszów Mazowiecki, and elsewhere in Poland. Hence the base of interval *II* (which coincides with the junction of the Pałuki and Kcynia Formations) is taken as the base of the Zarajskensis Horizon.

As the Kcynia Formation is overlain disconformably by Neocomian sediments in the region of Tomaszów Mazowiecki, it is highly probable that some portion of the Zarajskensis Horizon, of unknown thickness, has been removed by erosion. The preserved thickness of this horizon at Brzostówka can be estimated to be about 40m (Text-fig. 2).

The upper boundary of the Zarajskensis Horizon can be defined as coinciding with the upper boundary of the Zarajskensis Subzone and the

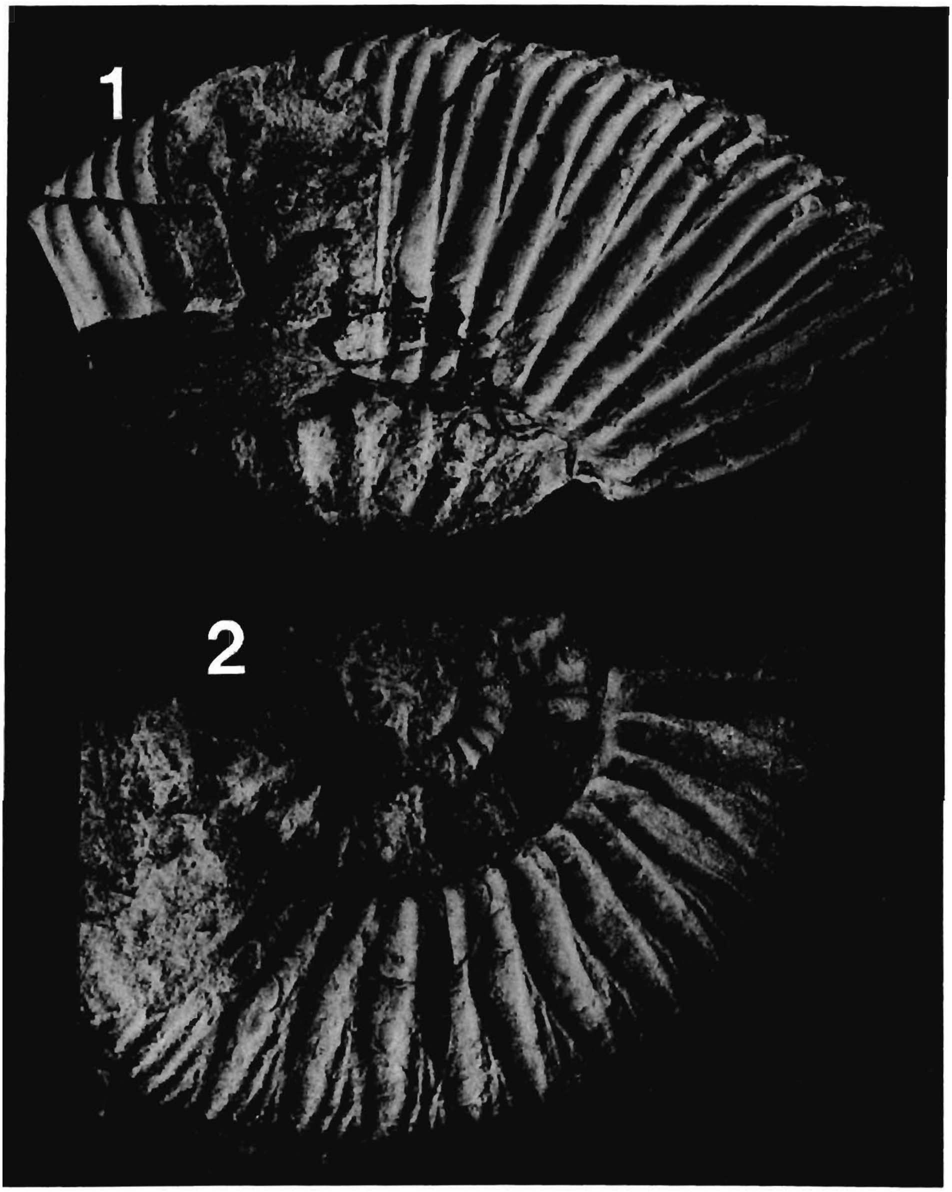



*Zaraiskites zarajskensis* (MICHALSKI); Zarajskensis Horizon

1 – Specimen IGPUW/A/29/30 (refigured *from* KUTEK 1967, Pl. 1); Brzostówka, interval *IV*

2 – Specimen IGPUW/A/29/34; Brzostówka, interval *III*

All figures of natural size

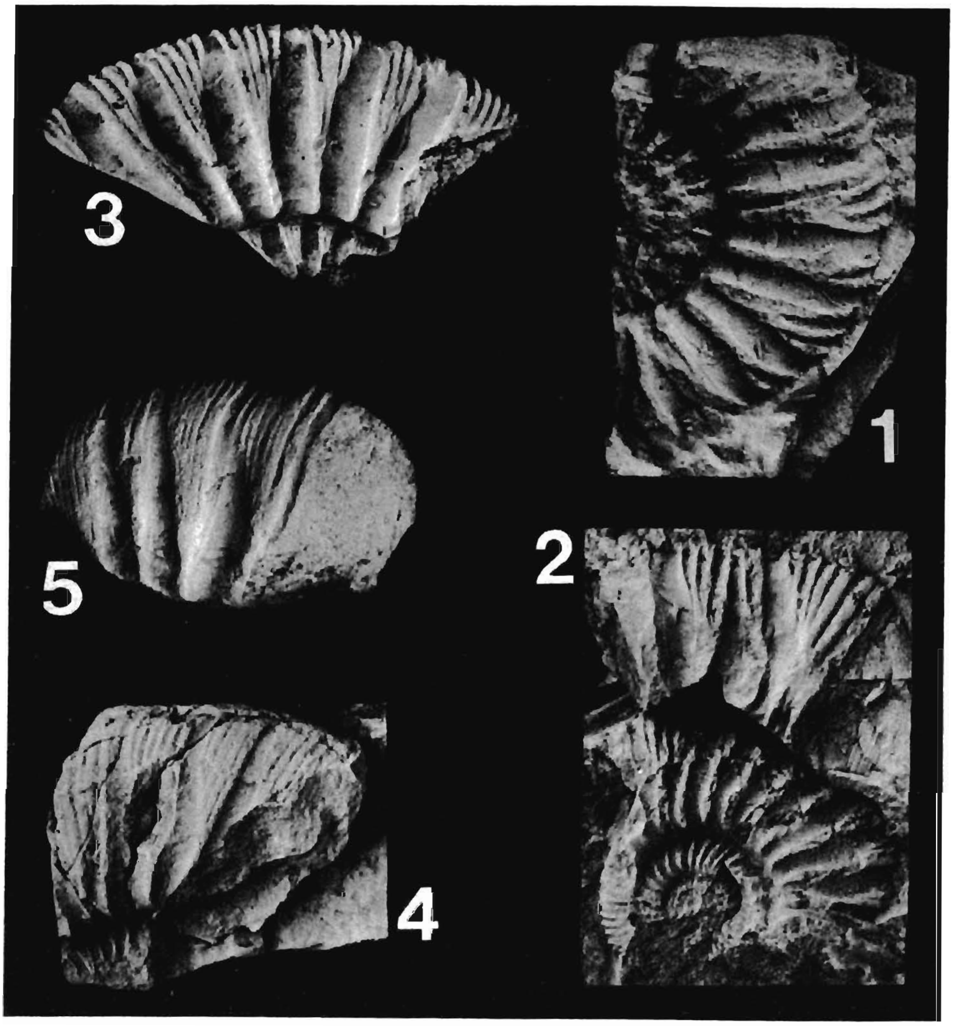



*Zaraiskites zarajskensis* (MICHALSKI); Zarajskensis Horizon

1 – Specimen IGPUW/A/29/35; Sławno, interval *III*/*IV*

2 – Specimen IGPUW/A/29/31 (refigured *from* KUTEK 1967, Pl. 2, Fig. 3); Brzostówka, interval *IV*

All figures of natural size




*Zaraiskites zarajskensis* (MICHALSKI); Zarajskensis Horizon

1 – Specimen IGPUW/A/29/38; Sławno, interval *III/IV*
2 – Specimen IGPUW/A/29/36; Sławno, interval *III/IV*
3 – Specimen IGPUW/A/29/37; Brzostówka, interval *III*
4 – Specimen IGPUW/A/29/39; Brzostówka, interval *IV*
5 – Specimen IGPUW/A/29/40; Brzostówka, interval *IV*

All figures of natural size


*Zaraiskites zarajskensis* (MICHALSKI); Zarajskensis Horizon

1 – Specimen IGPUW/A/29/32 (refigured *from* KUTEK 1967, Pl. 2, Fig. 1); Brzostówka, interval *IV*

2 – Specimen IGPUW/A/29/41; Sławno, interval *III/IV*

All figures of natural size

Scythicus Zone. This boundary, in turn, can be regarded as equivalent to the base of the Virgatus Zone, marked by the transformation of *Zaraiskites* into *Virgatites*. This boundary, however, cannot be recognized in Poland on the basis of ammonites because of the absence of *Virgatites* in Poland.

Several ammonites not assigned to *Provirgatites* (=*Zaraiskites*) were reported from the horizon *II* of Brzostówka by LEWIŃSKI (1923). The collection of LEWIŃSKI being lost, all the information available is that found in his paper published in 1923. Some of the ammonites concerned have been misinterpreted taxonomically. For instance, the specimen figured by LEWIŃSKI (1923, Pl. 8, Fig. 1) as *Perisphinctes* cf. *boidini* DE LORIOL can be interpreted as a form of *Zaraiskites* in which the bifurcate ribbing developed on outer whorls of macroconchs appears at a relatively small diameter. Some specimens, however, do rise problems, *e.g.* that figured by LEWIŃSKI (1923, Pl. 9, Fig. 1) as "*Perisphinctes quadrisclssus* n.sp.". This is a fragmentary specimen of poor preservation. It shows primary ribs branching into four secondary ribs on the last, non-septated large whorl (*c.* 80mm high), and bifurcate ribbing on the preceding, septated whorl. This specimen is reminiscent of the large specimen of *Pseudovirgatites scruposus* (OPPEL, 1865) figured by VETTERS (1905, Pl. 21, Fig. 1) and refigured by ZEISS (1977, Pl. 1, Figs 1-2), and displays similarity with the holotype of this species refigured by ZEISS (1977, Pl. 2, Fig. 7), which is also a highly imperfect, fragmentary specimen.

## SUBDIVISION OF THE SCYTHICUS ZONE: A SUMMARY

The Scythicus Zone has been subdivided in the region of Tomaszów Mazowiecki into four horizons: the Quenstedti, the Scythicus, the Regularis, and the Zarajskensis Horizons. All these horizons are based on successive assemblages of *Zaraiskites*, which are interpreted as biospecies. These are: *Z. quenstedti* (ROUILLIER, 1849) bsp., *Z. scythicus* (VISCHNIAKOFF, 1882) bsp., *Z. regularis* (sp.n.) bsp., and *Z. zarajskensis* (MICHALSKI, 1890) bsp. The Quenstedti and Scythicus Horizons, which are based on species of the group of *Z. scythicus*, are assigned to the Scythicus Subzone, and the Regularis and Zarajskensis Horizons, based on species of the group of *Z. zarajskensis*, to the Zarajskensis Subzone (Text-fig. 2).

In the section of Brzostówka, there is a barren interval with no ammonites beneath the base of the Scythicus Horizon (Text-fig. 3); the base of the Regularis Horizon has been located in bed *F* of LEWIŃSKI on indirect evidence; and no ammonites have been collected from the topmost few metres of the Pałuki Formation beneath the base of the Zarajskensis Horizon. Hence, the question may arise whether some additional assemblages of *Zaraiskites* exist, stratigraphically and morphologically intermediate between those interpreted as *Z. quenstedti* bsp., *Z. scythicus* bsp., *Z. regularis* bsp., and *Z. zarajskensis* bsp. Up to date, however, no such intermediate assemblages have been recognized; and occasional finds of zaraiskitids in patchy exposures and boreholes beyond Brzostówka, in part-intervals which could not be correlated with desirable precision with particular levels of the Brzostówka section, could invariably be accomodated on morphological grounds within the four biospecies recognized at Brzostówka. Moreover, data from Brzostówka as well as those concerning the evolution of the lineage (KUTEK & ZEISS 1994) leading from *Virgataxioceras* (topmost Kimmeridgian) via *Ilowaiskya* and *Pseudovirgatites* (Lower Volgian) to *Zaraiskites*, point to a more punctualistic than gradualistic mode of evolution of the Virgatitinae: none or only minor morphological changes in forms of ammonites can be recognized in expanded intervals, whilst major morphological changes take place at sharp boundaries (as at the base of the Middle Volgian at Brzostówka), or in narrow intervals which in some cases are but intervals of correlation uncertainty.

It is not, of course, to be expected that the succession of forms of *Zaraiskites* described in this paper represents a entirely complete picture. At the time being, however, there are no possibilities to subdivide the Scythicus Zone into still more precise biostratigraphic units, useful in regional and interregional correlations.

In order to retain the traditional Scythicus Zone, and the Scythicus and Zarajskensis Subzones, the Quenstedti, Scythicus, Regularis and Zarajskensis Horizons have been established at the horizon rank of biostratigraphic classification. However, the paleontological status of these horizons, which are based on successive assemblages of *Zaraiskites*, is about the same as that of the Klimovi, Sokolovi, Pseudoscythica, and Tenuicostata Zones of the Lower Volgian, which are based (KUTEK & ZEISS 1974) on successive assemblages of *Ilowaiskya*. Significantly, the Scythicus Zone attains a considerable thickness of about 75m in the region of Tomaszów Mazowiecki (Text-fig. 2), a thickness comparable with the total thickness of the Lower Volgian Substage (*c.* 60m) in that region; and the Regularis Horizon, for instance, is twice as thick (20–25m) as the Klimovi Zone (*c.* 12m), which is developed in the same lithofacies of the Pałuki Formation (KUTEK & ZEISS 1994). This may suggest a considerable span of time corresponding to the Scythicus Zone.

## SUCCESSION OF ASSEMBLAGES OF *ZARAISKITES* IN CENTRAL AND NORTHERN POLAND

As remarked by KUTEK & ZEISS (1974), a large proportion of ammonites reported from the Polish Volgian in earlier papers (*e.g.* KUTEK 1961a, b, 1962a, b; DEMBOWSKA 1965, 1973) were taxonomically misidentified, or interpreted in accordance with taxonomical concepts different from that applied in this paper. These papers, of course, were indicative of a vertical distribution of ammonites different form that now recognized in the region of Tomaszów Mazowiecki. A striking consequence of those taxonomical interpretations was that several taxa, which are now known to occur in different stratigraphic horizons near Tomaszów Mazowiecki, and also in Russia, were reported to have overlapping stratigraphic ranges; the alleged occurrence of *Virgatites* in association with *Zaraiskites quenstedti* (ROUILLIER), reported by DEMBOWSKA (1973), may be cited as an extreme example.

Most information on Volgian ammonites occurring in Central and northern Poland, beyond the region of Tomaszów Mazowiecki, was delivered by DEMBOWSKA (1965, 1973). All the ammonites described and figured in these papers were found in boreholes, so that the collections mostly consist of incomplete specimens. Some of them cannot be identified with desirable precision, but the following interpretations can be suggested for some of the forms, figured by DEMBOWSKA (1965, 1973), that represent the topmost Lower Volgian and the Scythicus Zone.

Significantly, a fairly large number of forms indicative of the Tenuicostata Zone, which attains a fairly large thickness near Tomaszów Mazowiecki, has been figured by DEMBOWSKA (1973). These are, for instance: *Ilowaiskya tenuicostata* (MIKHAILOV) (*e.g.* DEMBOWSKA 1973, Pl. 3, Figs 5-6; Pl. 4, Fig. 3); *Pseudovirgatites puschi simplicior* (KUTEK & ZEISS) figured by DEMBOWSKA (1973, Pl. 7, Fig. 5) as *Zaraiskites* sp.; *P. puschi zaraiskoides* (KUTEK & ZEISS) figured by DEMBOWSKA (1973, Pl. 6, Fig. 3) as *Z.* cf. *zarajskensis* (MICHALSKI) and refigured (DEMBOWSKA 1980 *and* 1988, Pl. 156, Fig. 3) as *Z. zarajskensis* (MICHALSKI); *Pseudovirgatites* sp. figured by DEMBOWSKA (1973, Pl. 4, Figs 1-2; Pl. 5, Fig. 3) as *Z. quenstedti* (ROUILLIER); and *Isterites* cf. *subpalmatus* (SCHNEID) figured by DEMBOWSKA (1973, Pl. 5, Fig. 6) as *Z. scythicus* (VISCHNIAKOFF).

To *Zaraiskites quenstedti* (ROUILLIER) there can be assigned forms figured by DEMBOWSKA (1973, Pl. 5, Fig. 1) as *Z. quenstedti* (ROUILLIER) and *Virgatites* sp. ind. (DEMBOWSKA 1973, Pl. 8, Fig. 1).

No unequivocal specimens diagnostic of the Scythicus Horizon seem to have been figured by DEMBOWSKA (1973), although some forms (*e.g.* that shown in Pl. 5, Fig. 4) may represent *Zaraiskites scythicus* (VISCHNIAKOFF) as understood in this paper. The scarcity of material referable to the Scythicus Horizon appears to be consistent with the small thickness of this horizon, as recognized at Brzostówka.

Forms figured as *Zaraiskites zarajskensis* (MICHALSKI) (DEMBOWSKA 1965, Pl. 1, Fig. 3), *Z.* cf. *zarajskensis* (MICHALSKI) (DEMBOWSKA 1973, Pl. 6, Fig. 3), *Z. pilicensis* (MICHALSKI) (DEMBOWSKA 1973, Pl. 6, Figs 1-2), *Zaraiskites* sp. (*f*) (DEMBOWSKA 1973, Pl. 6, Fig. 6), and *Virgatites virgatus* (BUCH) (DEMBOWSKA 1965, Pl. 1, Fig. 2) can now be accomodated in *Zaraiskites regularis* sp.n.

All the forms mentioned above, which represent the Tenuicostata Zone and the Scythicus Zone up to the Regularis Horizon, come from the Pałuki Formation. None of the specimens figured by DEMBOWSKA (1965, 1973) can be ascribed to *Zaraiskites zarajskensis* (MICHALSKI) bsp., which appears not to be represented in that formation in any region of Poland. One ammonite, referred to as *Zaraiskites* (cf. *alexandrae* LEWIŃSKI), was reported by DEMBOWSKA (1973, p. 26) from limestones attributable to the Kcynia Formation. This may be a form representing *Z. zarajskensis* bsp.

In general, a revision of the data presented in the comprehensive paper of DEMBOWSKA (1973) allows to conclude that the succession of ammonites revealed by the section of Brzostówka can also be recognized in other regions of Central and northern Poland. These data are also consistent with the interpretation that the chronostratigraphic position of the junction of the Pałuki and Kcynia Formations does not distinctly differ in the region of Tomaszów Mazowiecki and in other regions of Central Poland, corresponding, approximately at least, to the boundary of the Regularis and Zarajskensis Horizons of the Scythicus Zone.

## ALLEGED OCCURRENCES OF *VARGATITES* IN THE VOLGIAN OF POLAND

Ammonites of the genus *Virgatites* have repeatedly been reported by several authors (*e.g.* DEMBOWSKA 1965, 1973, 1980, 1988; MALINOWSKA 1980, 1988); MAREK & *al.* 1989) to occur in deposits of the Polish Volgian. A critical review of the paleontological evidence in support of this opinion is given below.

A specimen of *Virgatites virgatus* (BUCH) coming from Russia was presented in a text-figure by PAWŁOWSKA (1958). This is a misleading illustration because the origin of this specimen is not clearly indicated in that paper (*comp.* KUTEK 1961b, 1962a).

A specimen found at Antoninów near Tomaszów Mazowiecki, in strata corresponding to the interval *I* of Brzostówka, was figured by KUTEK (1961b, Text-figure) as *Virgatites virgatus* (BUCH). This specimen was later reinterpreted by KUTEK (1962a) as a form belonging to the group of *Z. zarajskensis*. It can now be accomodated in *Zaraiskites regularis* sp.n.

A specimen from the borehole Biesiekierz-Gorzewo figured by DEMBOWSKA (1965, Pl. 1, Fig. 2) as *Virgatites virgatus* (BUCH) appears to be conspecific with another specimen from this borehole figured by her (DEMBOWSKA 1965, Pl. 1, Fig. 3) as *Zaraiskites zarajskensis* (MICHALSKI) and refigured (DEMBOWSKA 1973, Pl. 6, Fig. 3) as *Z.* cf. *zarajskensis* (MICHALSKI). As remarked above, both these specimens can now be included in *Z. regularis* sp.n.

The specimen figured by DEMBOWSKA (1965, Pl. 1, Fig. 1) as *Virgatites virgatus* (BUCH) and refigured as *Virgatites* (?) sp. (DEMBOWSKA 1973, Pl. 8, Fig. 1) displays to a remarkable diameter the dense (bifurcate, then virgatotome) ribbing characteristic of *Zaraiskites quenstedti* (ROUILLIER). This specimen is closely comparable, for instance, with one of the specimens of *Z. quenstedti* figured by VISCHNIAKOFF (1882, Pl. 3, Fig. 3). Significantly, the Polish specimen has been found in the borehole Józefów-*KT-11* at a level but 10cm higher than another specimen, which was correctly identified as *Zaraiskites quenstedti* (ROUILLIER) by DEMBOWSKA (1973, Pl. 5, Fig. 1).

A specimen from the borehole Krzeszowice-*KT-30* was figured and refigured by DEMBOWSKA (1973, Pl. 8, Fig. 2; 1980 *and* 1988, Pl. 150, Fig. 2) as *Virgatites pusillus* (MICHALSKI). This is a small incomplete specimen, with a diameter of *c.* 40mm, that shows on the last whorl preserved a fairly distant ribbing composed of bifurcate and trifurcate ribs and one occasional polyploke rib. This specimen cannot be identified with confidence on its own merit, and can be compared with forms belonging to different genera, *e.g.* with morphological variants of *Zaraiskites scythicus* (VISCHNIAKOFF) in which distant ribbing appears at extremely small diameters (*comp.* MICHALSKI 1890, Pl. 7, Fig. 7; Pl. 13, Fig. 10; *and* KUTEK & ZEISS 1974, Pl. 29, Fig. 3), and even with inner whorls of *Isterites masoviensis* illustrated by KUTEK & ZEISS (1974, *e.g.* Pl. 22, Fig. 1). The specimen ascribed to *V. pusillus* was found in the borehole Krzeszkowice in association with a form figured as "*Zaraiskites* sp. (c)" by DEMBOWSKA (1973, Pl. 7, Fig. 2). The latter specimen, which shows fairly distant bifurcate ribbing at diameters of 40 to 70mm, is also hard to interpret taxonomically. One possible interpretation is that it is an extreme morphological variant of *Z. scythicus* (VISCHNIAKOFF) bsp. (*comp.* KUTEK & ZEISS 1974, Pl. 32, Fig. 2). In any case, there is no convincing evidence that the specimen figured as *Virgatites pusillus* (MICHALSKI) really belongs to the genus *Virgatites*.

No other Polish specimens supposed to represent *Virgatites* have been figured. In absence of any evidence to the contrary, all the reported occurrences of *Virgatites* in the Polish Volgian should be interpreted as misidentified forms of *Zaraiskites* (and of *Isterites*?), so more as all the Polish forms presumed to belong to *Virgatites* have been reported to occur exclusively in the Pałuki Formation, and invariably in association with *Zaraiskites* (comp. *e.g.* data *in* DEMBOWSKA 1973). As indicated above, the Pałuki Formation contains forms of

*Zaraiskites* referable to the Quenstedti, Scythicus and Regularis Horizons, but none indicative of the Zarajskensis Horizon, the highest horizon of the Scythicus Zone. In this context, there is no evidence substantiating the establishment in the Pałuki Formation of a zone with *Virgatites pusillus*, as suggested by DEMBOWSKA (1973), or the Virgatites pusillus Zone (MALINOWSKA 1980, 1988), as a zone including *Virgatites pusillus, Zaraiskites zarajskensis, Z.* cf. *alexandrae, Z. scythicus, Z. quenstedti*, and *Z. pilicensis*, and corresponding to the Russian Virgatus Zone that does not contain any species of *Zaraiskites* (comp. DEMBOWSKA 1973, Table 17).

As a continuous succession ranging from the Middle Volgian (Scythicus Zone) up into the Upper Berriasian and including sediments of the Purbeckian facies is preserved in some regions of cratonic Poland (MAREK & *al.* 1989), it can be expected than a portion of this succession corresponds to the Russian Virgatus Zone. However, the corresponding stratigraphic interval cannot be distinguished in Poland on the basis of ammonites. As yet, all available data indicate that the youngest figured Jurassic ammonites hitherto found in cratonic Poland are those from the Kcynia Formation (intervals *II–IV*) of the region of Tomaszów Mazowiecki.

## CORRELATIONS WITH RUSSIAN SECTIONS

The Dorsoplanites panderi Zone, which is now distinguished in Russia as the lowest zone of the Middle Volgian Substage (GERASSIMOV & MIKHAILOV 1966; MESEZHNIKOV 1982, 1988), was previously referred to (ROZANOV 1906; ILOVAISKY & FLORENSKY 1941; MIKHAILOV 1957, 1962, 1964) as the Zone of *Zaraiskites scythicus* or the Zone of *Zaraiskites scythicus* and *Dorsoplanites panderi*. As both the range of the Scythicus Zone, as defined in Poland, and that of the Panderi Zone of Russia, correspond to the stratigraphic range of the genus *Zaraiskites*, these zones are equivalent stratigraphically. No occurrences of *Dorsoplanites* and *Pavlovia* have been reported from Poland, except for two nuclei from Pomerania assigned to *Pavlovia* by WILCZYŃSKI (1962, Pl. 8, Figs 4-5). Hence, there are no reasons that would justify a replacement of the traditional Scythicus Zone by the Panderi Zone in Poland.

The stratigraphic distribution of particular morphological forms of *Zaraiskites* has not yet been recognized with desirable precision in Russian sections. There is no doubt, however, that forms included in the four successive biospecies of *Zaraiskites* in Poland have their morphological counterparts in Russia. For instance, the specimens of *Z. quenstedti* (ROUILLIER) figured by VISCHNIAKOFF (1882, Pl. 3, Figs 3-5) reveal the distinctive characters of *Z. quenstedti* bsp. As remarked above, the lectotype of *Z. scythicus* (VISCHNIAKOFF 1882, Pl. 3, Fig. 1) corresponds to *Z. scythicus* bsp., and counterparts of forms of *Z. regularis* bsp. may be expected to occur among the forms assigned by MICHALSKI (1890) to *Z. stschukinensis*. The Russian forms of *Z. zarajskensis* and *Z. pilicensis* described by MICHALSKI (1890) correspond to *Z. zarajskensis* bsp., as well as those figured by PČELINCEV (1916, Pl. 1, figs 3-4) as *Z. zarajskensis*. This morphological parallelism suggests that the evolution of *Zaraiskites* followed the same path in cratonic Poland and in regions of the Russian Platform.

The Panderi Zone has been subdivided in Russia into the lower Pavlovia pavlowi Subzone and the upper Zaraiskites zarajskensis Subzone (MIKHAILOV 1962, 1964; GERASSIMOV & MIKHAILOV 1966; MESEZHNIKOV 1982, 1988). The Pavlovi Subzone, which contains *Z. quenstedti* (ROUILLIER) and *Z. scythicus* (VISCHNIAKOFF), corresponds to the Scythicus Subzone of Poland. The species *Z. zarajskensis* (MICHALSKI), which ranges throughout the Russian Zarajskensis Subzone, has been reported to occur in association with *Z. quenstedti* and *Z. scythicus* in the lower portions of this subzone (GERASSIMOV & MIKHAILOV 1966; MESEZHNIKOV 1980, 1988); this overlap, however, is not clearly indicated in sections described by MIKHAILOV (1964) in an earlier paper. As the Russian papers presenting information on the subdivision of the Panderi Zone are not accompanied by paleontological descriptions of species of *Zaraiskites*, and as Russian forms of *Zaraiskites* have not been monographed for the last 100 years, it is not possible to interpret unequivocally the alleged stratigraphic overlap of *Z. quenstedti*, *Z. scythicus*, and *Z. zarajskensis*. There should be no doubt, however, that a part at least of the Russian Zarajskensis Subzone corresponds to the Zarajskensis Subzone of Poland.

In this context it is worth remembering that these three species of *Zaraiskites* were also reported to overlap at Brzostówka in the lower part of the Zarajskensis Subzone (KUTEK 1962a, b); this interval is now ascribed to the Regularis Horizon, and the forms previously referred to as *Z. quenstedti*, *Z. scythicus* and *Z. zarajskensis* accomodated in *Z. regularis* sp.n.

## CORRELATIONS WITH THE TITHONIAN STAGE

Two possibilites of correlations with the Tithonian Stage are provided by the section of Brzostówka, one at the level of the topmost Lower Volgian, the second at the level of the Zarajskensis Subzone (the Regularis Horizon).

The presence of ammonites of the group of *Isterites palmatus* at Brzostówka and in the Neuburg Formation of Franconia permits to suppose that the topmost lower Volgian of Poland (the Tenuicostata Zone) has its time equivalent in a high portion of the Neuburg Formation. This, together with some other data, allowed to conclude that the boundary between the Lower and Middle Volgian corresponds approximately to that between the Middle and Upper Tithonian (KUTEK & ZEISS 1974, 1975, 1988; ZEISS 1983).

This correlation of the Lower/Middle Volgian boundary with the Middle/Upper Tithonian boundary was challenged by MESEZHNIKOV (1982) and

JELETZKY (1984) but a new set of data indirectly supporting this correlations was presented by KUTEK & WIERZBOWSKI (1986) and KUTEK & ZEISS (1988). These data can be summarized as follows: an ammonite close to *Pseudovirgatites scruposus* (OPPEL) has been reported from Brzostówka from near the junction of the Scythicus and Zarajskensis Subzones; *P. scruposus* has been found in association with an ammonite of the group of *Z. zarajskensis* and calpionellids of the Calpionellid Zone *A* at Woźniki in the Polish Carpathians (KSIĄŻKIEWICZ 1974, MORYCOWA 1974); *P. scruposus* has been reported by NEUMAYR (1871) to occur in association with a clearly Late Tithonian assemblage of ammonites at Kyjov in Slovakia; forms of *Pseudovirgatites* have been reported from Upper Tithonian sections of the Transdanubian Mountains of Hungaria by VIGH (1984); and an ammonite referable to the group of *Z. zarajskensis* has been found in association with calpionellids of the Calpionellid Zone *A* in Bulgaria by NOWAK (1971), in strata probably belonging to the Upper Tithonian Microcanthum Zone (SAPUNOV 1979). From these data it can be concluded that, first, *Pseudovirgatites scruposus* (OPPEL, 1865) is a Late Tithonian fossil and, second, that the Polish Zarajskensis Subzone has its time equivalent somewhere in the Upper Tithonian, at levels included in the Calpionellid Zone *A* (see Text-fig. 4).

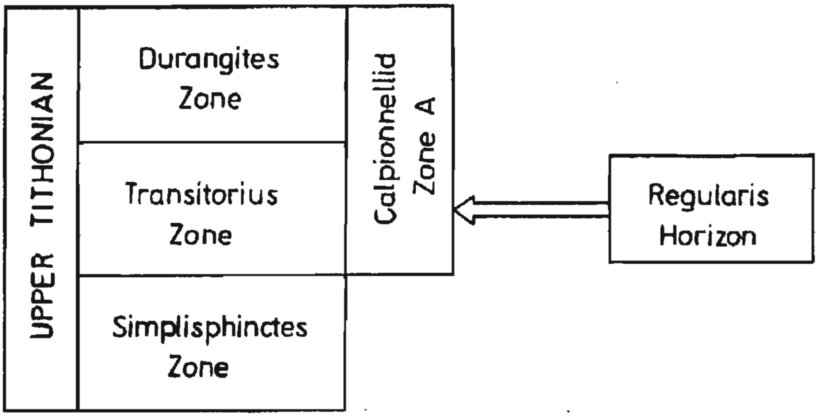



Fig. 4. Correlation of the Regularis Horizon with the zonation of the Upper Tithonian Substage

The new data from Brzostówka presented in this paper permit to restate this correlation with some more precision. The specimens of *Zaraiskites* found in association with calpionellids at Woźniki (KSIĄŻKIEWICZ 1974, Pl. 1, Fig. 1) and in Bulgaria (NOWAK 1971, Pl. 1), which display regular virgatotome ribbing with narrow interspaces between sheaves of virgatotome ribs, can be accomodated among species of *Zaraiskites* only in *Z. regularis* sp.n. Another specimen from Woźniki (KSIĄŻKIEWICZ 1974, Pl. 1, Fig. 3), which shows bifurcate and trifurcate ribs on a large whorl, may also belong to this species.

Two other specimens from Woźniki (KSIĄŻKIEWICZ 1974, Text-fig. 2, Pl. 1, Fig. 1; ZEISS 1977, p. 371) represent *Pseudovirgatites scruposus* (OPPEL). From this it follows that the stratigraphic range of *P. scruposus* overlaps with that of *Z. regularis*. A more important conclusion is that the Regularis Horizon, which is the lower horizon of the Zarajskensis Subzone of the Scythicus Zone, has its equivalent in the Upper Tithonian Substage in an interval forming part of the Calpionellid Zone *A*, now currently in use. In terms of the zonal subdivision of the Upper Tithonian established by TAVERA (1985; *see also* OLÓRIZ & TAVERA 1989) this is an interval located above the Simplisphinctes Zone, and probably in the Transitorius Zone (Text-fig. 4).

As suggested above, both the Lower Volgian Tenuicostata zone and the Middle Volgian Scythicus Zone correspond to a considerable span of time. Hence these zones should correspond to fairly large portions of the Middle and Upper Tithonian. As the Regularis Horizon corresponds to a fairly high level within the Upper Tithonian (Text-fig. 4), not much room is left in the Tithonian to accomodate the higher portions of the Volgian Stage (the Zarajskensis Horizon of the Scythicus Zone, and the Virgatus, Nikitini and Oppressus Zones of the Middle Volgian, as well as the Fulgens, Subditus and Nodiger Zones of the Upper Volgian; *comp.* MESEZHNIKOV 1988). This indirectly supports the correlations proposed *e.g.* by ZEISS (1983), HOEDEMAEKER (1987) and SEY & KACHALOVA (1993), according to which the Upper Volgian is of Berriasian age. A more comprehensive discussion of the Tithonian/Volgian correlations is postponed to another paper by KUTEK & ZEISS, which will present new paleontological material from the topmost Kimmeridgian and Lower Volgian of Central Poland.

The correlations between the Volgian and Tithonian Stages proposed by KUTEK & ZEISS (1974, 1975) and ZEISS (1977, 1983) were once more criticized by JELETZKY in a paper published in 1989. However, most of the additional data presented by KUTEK & WIERZBOWSKI (1986) and KUTEK & ZEISS (1988) were not known to him, and *Zaraiskites* and *Pseudovirgatites scruposus* (OPPEL) were again interpreted as pre-Late Tithonian fossils. A few evident errors found in JELETZKY's paper can here be pointed out. Obviously (*see* Text-figs 2 and 3), erroneous is his statement (p. 160) that in the Brzostówka section Lower Volgian strata ("beds of the *Pseudovirgatites puschi* Subzone of the *Ilowaiskya pseudoscythica* Zone") "underlie immediately and conformably the *Zaraiskites zarajskensis* Subzone". A finishing touch is given to JELETZKY's paper (p. 167) by the statement: "Finally, *Pseudovirgatites scruposus* was found in association with *Zaraiskites* cf. *zarajskensis* at Woźniki in southern Poland (KSIĄŻKIEWICZ 1963) which confirms once more the *semiforme/verruciferum* age of this zone". Thus, a pre-Late Tithonian age was attributed by JELETZKY to these ammonites but he overlooked that they were found in association with calpionellids of undoubtedly Late Tithonian age (KSIĄŻKIEWICZ 1974, MORYCOWA 1974).

JELETZKY (1989, pp. 150-151) also commented on the occurrences of *Zaraiskites* cf. *zarajskensis* reported from Franconia by ZEISS (1968); these ammonites were tentatively reinterpreted as "virgatotome developments" of *Isterites* by KUTEK & ZEISS (1975). One specimen from Neuburg was figured as *Z.* cf. *zarajskensis* (MICHALSKI) by ZEISS (1968, Pl. 26, Fig. 7). This is a fragment of whorl showing a few virgatotome ribs with up to five secondaries, alternating with intercalatory ribs. In this context it is worth of note that this specimen, if a form of *Zaraiskites*, would have its morphological counterparts at Brzostówka not in *Z. zarajskensis* bsp., but in *Z. quenstedti* bsp.

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