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Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

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In memory of Professor Jan Kutek – "Janek" –
prominent student of the Jurassic System in Poland and our colleague

Key words: ammonites, stratigraphy, correlation, Tithonian, "Volgian", "Bolonian–Portlandian", palaeogeography.

Abstract. The Tithonian ammonite succession at the Owadów–Brzezinki quarry, central Poland shows the presence of Subboreal ammonites of both NE European ("Volgian") and NW European ("Bolonian–Portlandian") affinity, making possible the correlation between the relevant ammonite subdivisions. The former are represented by *Zaraiskites* – *Z. regularis* Kutek and *Z. zarajskensis* (Michalski) as well as an early form of *Virgatites* – *V. gerassimovi* Mitta which enable the recognition of the upper part of the Scythicus Zone (the Zarajskensis Subzone) and the lower part of the Virgatus Zone (the Gerassimovi Subzone) of the "Middle Volgian". The latter are represented by *Virgatopavlovia*, which enables the correlation with the Fittoni Zone of the uppermost "Bolonian", and by still younger assemblage of small-sized virgatitids – such as *V. pusillus* (Michalski), showing similarity to *Progalbanites albani* (Arkell) of the Albani Zone of the lowermost "Portlandian". The new species established include: *Zaraiskites lewinskii* sp. nov. which represents a new member of the virgatitid lineage linking an older *Z. pommerania* (Arkell) with younger small-sized *Virgatites*, as well as two species of the genus *Virgatopavlovia* – *V. janeki* sp. nov. and *V. dembowskae* sp. nov. The appearance of ammonites of NW and NE European affinity in central Poland resulted from the opening of the new sea routes possibly related with tectonic activity in northern European areas at the transition from Early to Late Tithonian.

INTRODUCTION

The youngest Late Jurassic deposits in the epicratonic area of Poland actually crop out at Sławno, in the Owadów–Brzezinki quarry – located about 19 km southeast of Tomaszów Mazowiecki (central Poland) (Fig. 1). Presently, it is the only outcrop of uppermost Jurassic (Tithonian) deposits in the territory of extra-Carpathian Poland: the celebrated sections that existed in the past at Brzostówka, now within the town limits of Tomaszów Mazowiecki, are no longer accessible for study because of the urban development; on the other hand the old quarries in north-western Poland, in Pomerania, such as Czarnogłowy (Zarnglaff) and Świętoszewo (Schwanteshagen) are almost completely flooded.

The importance of the Owadów–Brzezinki quarry is that it provides the succession of youngest marine deposits of the Upper Jurassic which succeed the well-known marly deposits of the "Lower" and lower part of the "Middle Volgian", well dated by ammonites and described in many papers on

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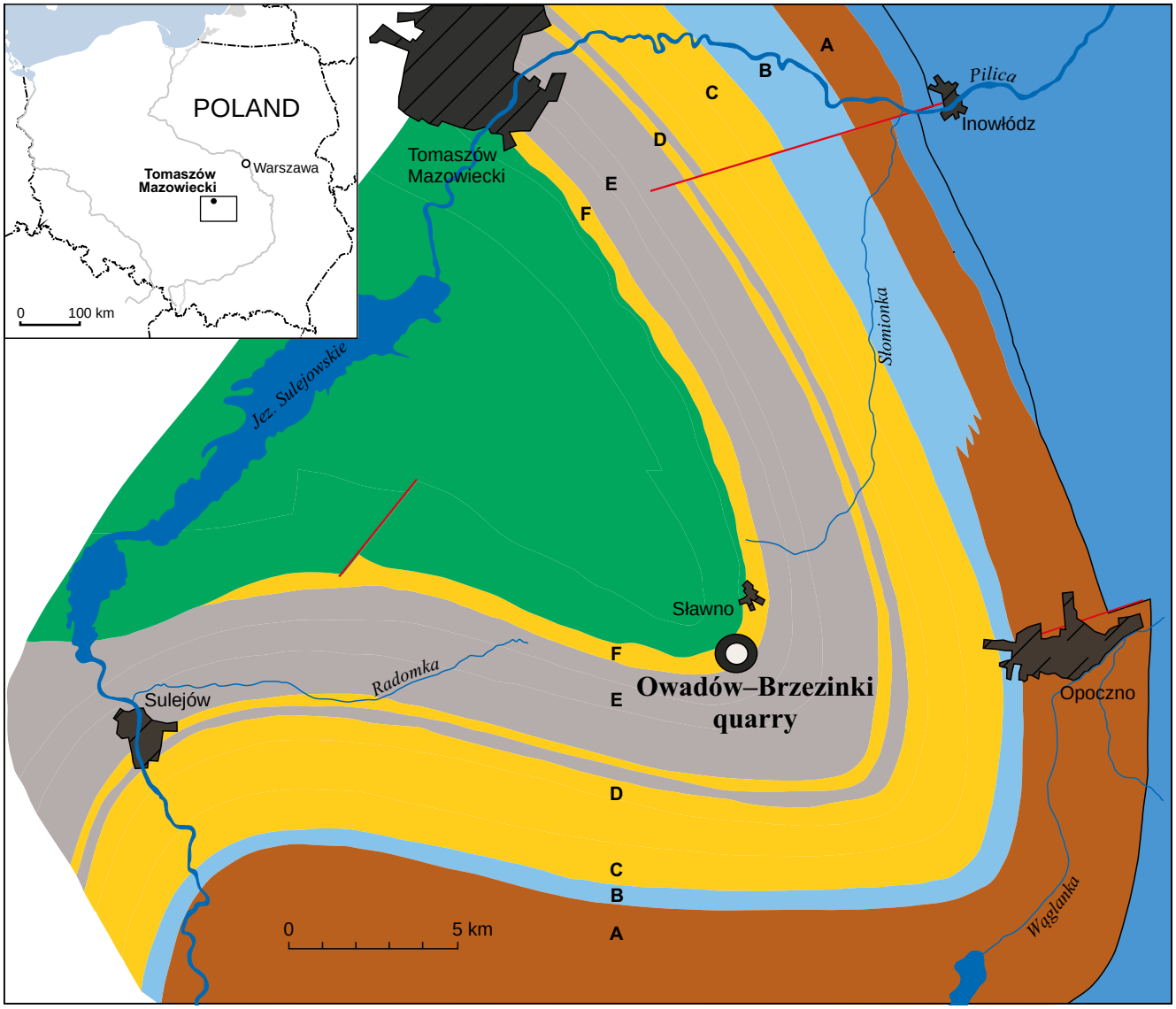

Fig. 1. Location map of the Owadów–Brzezinki quarry on the background of geological map of Tomaszów syncline (after Matyja, Wierzbowski A., 2014)

Middle Jurassic – darkblue; Upper Jurassic: A – Częstochowa Sponge Limestone Fm., B – Pilica Fm., C – Coral Limestone Fm., D – Oolite Fm., E – Pałuki Fm., F – Kcynia Fm. (main type of lithologies shown in colours: brown – sponge megafacies deposits, lightblue – micritic limestones, yellow – shallow water carbonate deposits, gray – siliciclastic deposits); Cretaceous – green. Inset shows the position of the area of study in Poland

the Brzostówka section at Tomaszów Mazowiecki as well as many cores in the Tomaszów Mazowiecki and Sulejów areas (*e.g.* Michalski, 1890; Lewiński, 1923; Kutek, Zeiss, 1974, 1997; Kutek, 1994, and other papers cited therein). The correlation of deposits from the Brzostówka area with those from the Owadów–Brzezinki quarry is evident because of lithological similarity of the sections and similarity of the ammonites. A fairly thick succession of limestones seen in the Owadów–Brzezinki quarry has its equivalent in the topmost part of the Brzostówka section subdivided by Lewiński (1923) into his units II, III and IV: but the stratigraphical interpretation of these deposits was based on a few and generally fragmentarily preserved ammonites (see Lewiński, 1923; Kutek, 1967, 1994), and it differs markedly from that presented herein.

The oldest deposits temporarily exposed at the bottom of the Owadów–Brzezinki quarry are blue-grey (yellowish when weathered) silty marls and marly clays representing the topmost part of the Pałuki Formation (and the topmost part of the Brzostówka Marl Member, see Maty-

Fig. 2. General view of the Owadów–Brzezinki quarry; the units (I–IV) of the Kcynia Formation are indicated; Q – Quaternary deposits

ja, Wierzbowski A., 2014). These marly deposits, accessible down to about 2.5 m from the top of the unit, show the presence of a particular thin marly layer (0.1 m thick, 1m below the top) which is crowded with oysters, brachiopods and ammonites (Błażejowski *et al.*, 2014). Ammonites from these deposits were collected mostly from rubble: thus, besides a few specimens collected *in situ*, the bulk of them cannot be localized precisely in the studied part of the succession.

The majority of the succession exposed in the Owadów–Brzezinki quarry is represented by limestones corresponding to the Kcynia Formation (formation VII – limestone-evaporatic (Kcynia) of Dembowska, 1979). It attains about 26 metres in thickness. The deposits may be subdivided into four units, as follows (from the base, see Błażejowski *et al.*, 2014; see also Figs 2, 3):

I. Thick-bedded, fine-grained chalky limestones with a diversified marine fauna (ammonites, bivalves, echinoderms) – 9.1 m.
II. Three thick-bedded micritic limestones beds with a poor fauna (bivalves, brachiopods, shrimps, lobsters, calcareous tubes of polychaetes) distinguished by underlying and overlying thin marly layers – 2.2 m.

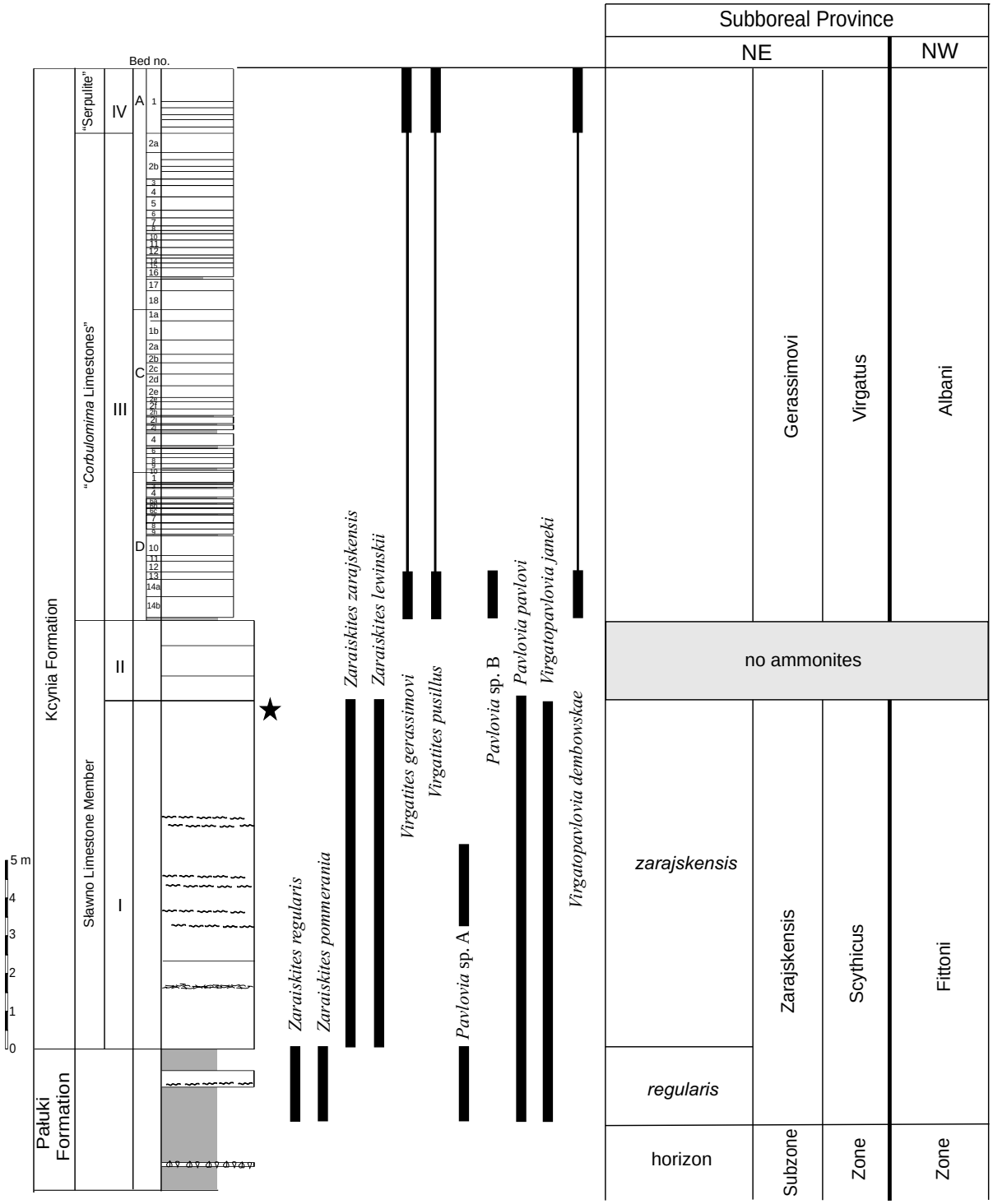

Fig. 3. Biostratigraphical interpretation of the succession from the Owadów–Brzezinki quarry; the position of the chitinoidellid horizon is asterisked

The deposits of units I and II are distinguished herein as the Sławno Limestone Member (which lithostratigraphical classification differs from that given previously by Matyja and Wierzbowski A. (2014) where all the limestone deposits from the Owadów–Brzezinki section were attributed to that member).

III. Well-bedded micritic limestones consisting mostly of beds several centimetres thick, which split into thin flags, and marly intercalations – the detailed correlation of the particular sections (A, C, D) makes possible distinction of large number of beds in this unit – each of them marked with a letter referred to a particular section and a bed number. The most characteristic faunal feature is the mass occurrence of small-shelled bivalves *Corbulomima obscura* (in the past attributed to the genus *Corbula*), and thus the deposits may be called the "*Corbulomima* Limestones" – "heralding the Purbeckian facies" (Kutek, 1994); highly fossiliferous strata in the lower part of the unit (beds D_{12}, D_{13}) – yielded unusually well-preserved marine and terrestrial fossils as well as many of ammonites which are described herein; 12.8 m.

IV. Organodetrital limestones rich in *Nanogyra* oysters, bryozoans and serpulids – forming in places small bioherms, and called sometimes "Serpulite" (*e.g.* Lewiński, 1923); ammonites occur sporadically; the lower boundary of the unit is marked by a well developed omission-surface encrusted with oysters and with very dense burrows which attain a diameter of 0.4–0.5 cm and range down into the underlying limestones of unit III down to about 0.6 m below the surface; the upper boundary of the unit is the erosional surface with overlying Quaternary deposits.

The succession of the deposits of the Kcynia Formation at Owadów–Brzezinki represents a transition from the offshore, possibly fully-marine, environment of the Sławno Limestone Member to the near-shore and lagoonal environments of the younger deposits (Wierzbowski H. *et al.*, 2016a, b).

An unique feature of Owadów–Brzezinki is that it represents one of the most important palaeontological sites in Upper Jurassic deposits which yield unusually well preserved fossils, both terrestrial and marine organisms, deposited mostly in a lagoonal environment, such as horseshoe crabs, decapod crustaceans, land insects (dragonflies, beetles, grasshoppers), remains of various fishes, and marine reptiles, pterosaurs, but also ammonites, numerous bivalves and brachiopods (Kin, Błażejowski, 2012; Kin *et al.*, 2013; Błażejowski *et al.*, 2014, 2015; Błażejowski, 2015; Feldman *et al.*, 2015; Tyborowski, in press; Tyborowski *et al.*, 2016; Błażejowski *et al.*, 2016, this issue). In consequence, the quarry may be regarded as a new "taphonomic-window" into the latest Jurassic – similar to those previously described from southern Germany, such as Solnhofen and Nussplingen, but being younger then them. The importance of the current study of Owadów–Brzezinki employing ammonites lies thus in establishment of its detailed stratigraphical and palaeogeographical position.

AMMONITE STRATIGRAPHY

The stratigraphical interpretation of the deposits underlying those of our studied section and those cropping out in the already mentioned clay-pits at Brzostówka have been the subject of numerous studies in the past (Michalski, 1890; Lewiński, 1923; Kutek, 1967, 1994; Kutek, Zeiss, 1974, 1994, 1997, and other papers cited therein). These are marly deposits corresponding to the Pałuki Formation (formation VI (Pałuki) of shaly-marly-siltstone of Dembowska, 1979) which yielded abundant ammonites. They were attributed to the "Lower Volgian" (the Klimovi Zone, the Sokolovi Zone, the Pseudoscythica Zone, and the Tenuicostata Zone), as well as to the lower part of the "Middle Volgian" – the Scythicus Zone, including the Scythicus Subzone below, and the lower part of the Zarajskensis Subzone above. The ammonites are represented mostly by forms of the subfamily Ilowaiskyinae Zeiss, 1968 (with the genus *Ilowaiskya* Vialov, 1940) and the subfamily Virgatitinae Spath, 1923 (with the genus *Zaraiskites* Semenov, 1898), typical of the "Volgian" in its type-area, the European Russia. Additionally Tethyan Haploceratacеae – including *Neochetoceras*, and ammonites of the genus *Sutneria* have been reported from the lower part of the succession (the Klimovi and the Sokolovi zones) (see Kutek, Zeiss, 1997), whereas ammonites of the genus *Isterites* Barthel, 1969, which are present in common with Submediterraean areas of Franconia in southern Germany, appear in some intervals in the upper part of the succession (from the Tenuicostata Zone up to the lowermost part of the Scythicus Zone – Kutek, Zeiss, 1974, 1997); in the same interval the genus *Pseudovirgatites* Vetters, 1905 appears, which has a special phylogenetic importance because it links *Ilovaiskaya* with later *Zaraiskites* (Kutek, Zeiss, 1974; see also Rogov, 2004), but, on the other hand, it shows a wide distribution in the Submediterranean-Mediterranean areas (see *e.g.* Zeiss, 1977; Kutek, Wierzbowski A., 1986).

The assemblage of ammonites (34 specimens) that come from the topmost part of the Pałuki Formation, representing the lowest part of the succession exposed in the Owadów–Brzezinki quarry and described herein, may be interpreted as belonging to two different systematic groups. The first corresponds to the subfamily Virgatitinae Spath, 1923 and constitutes a large majority of the assemblage (71%). Some of these ammonites are typical specimens of the genus *Zaraiskites*, which may be easily accommodated in the species *Zaraiskites regularis* Kutek (see Kutek, 1994). These ammonites show typical features of that species (generally very dense biplicate ribbing on the inner whorls replaced by regularly developed virgatotome ribbing (Pl. 1: 1–2, Pl. 2: 1–3, see also palaeontological part of this study).

The related ammonites in the topmost part of the Pałuki Formation, but not encountered in older deposits, are forms showing a virgatotome style of ribbing similar to that of the genus *Zaraiskites*, but differing mostly in presence of loosely-spaced ribs in the inner whorls. These ammonites are middle-sized (about 70–110 mm in diameter) when fully grown specimens (Pl. 5: 1–3, see also palaeontological descriptions). They are comparable to "*Provirgatites*" *pommerania* of Arkell (1935, pl. 26: 1–1a), as based on specimen from the Świętoszewo (formerly Schwanteshagen) quarry in Pomerania. This species was compared originally with the "Portlandian" type-representative of the genus *Progalbanites* Spath, 1936 – "*Provirgatites" albani* (Arkell) by Arkell (1935, pl. 26: 2). Later on (Dzik, 1994), the species "*Provirgatites*" *pommerania* was placed in the genus *Zaraiskites* (*i.e.* in subfamily Virgatitinae Spath, 1923), but recognized as closely related to *Progalbanites albani* (Arkell) from the English lowest Portland Beds, and even as its direct phyletic ancestor. Such an interpretation is also accepted in the present study, and forms coming from Owadów–Brzezinki are referred to as *Zaraiskites pommerania* (Arkell) – *Z.* cf. *pommerania* (Arkell), and treated as early representatives of the offshoot of the main *Zaraiskites* lineage.

The second group of specimens, which is less commonly encountered and constitute about 29% of the whole assemblage studied, is represented by forms not described so far from Poland. These are represented both by micro and macroconchs which are very close to representatives of the genus *Virgatopavlovia* as described from southern England by Cope (1978). They can be placed in the subfamily Pavloviinae Spath, 1931, and recognized as a new species, *Virgatopavlovia janeki* sp. nov. (including *V.* sp. nov. aff. *fittoni* Cope; see Cope, 1978), showing the presence of bifurcated ribs on the inner whorls, resembling very much those of *Epipallasiceras* (Pl. 8: 6, Pl. 9: 1–2, Pl. 10: 2; see also palaeontological descriptions; see also Spath, 1936; Cope, 1978; Callomon, Birkelund, 1982). Moreover, rare ammonites of the genus *Pavlovia* comprise large specimens (Pl. 17), but it is difficult to identify these more closely.

The stratigraphical position of the topmost part of the Pałuki Formation, using the ammonites discussed, may be commented upon as follows (Fig. 3). The occurrence of the typical "Middle Volgian" genus *Zaraiskites* makes possible the correlation of these deposits with the Scythicus Zone, whereas the occurrence of *Z. regularis* (Kutek) enables the recognition of the upper part of that zone – the Zarajskensis Subzone, and more precisely its lower part – the *regularis* horizon. This is in general agreement with the opinion of Kutek (1994), who correlated the upper part of the Pałuki Formation at Brzostówka with the *regularis* horizon. The topmost few meters (2–3 m?) of the formation were recognized by Kutek (1994, fig. 2) as lying above his "I–B–u" interval, and which did not at that time yield any ammonites; the present finds indicate precisely that the *regularis* horizon ranges up to the top of the Pałuki Formation.

The occurrence of ammonites of the genus *Virgatopavlovia* is indicative of the Fittoni Zone of southern England (Dorset), and a correlation with the uppermost part of the Kimmeridge Clay (Cope, 1978, 2015a), and north-eastern Scotland (in silty clays intercalations within the Helmsdale Boulder Beds Formation – Cope, 2015b) *i.e.* it defines the uppermost "Bolonian" at the base of the "Portlandian" in its historical meaning (see *e.g.* Cope, 1993). The occurrence of heavily ribbed inner whorls on *Virgatopavlovia janeki* sp. nov., comparable with *V.* sp. nov. aff. *fittoni* sensu Cope (1978, fig. 11), in the topmost part of the Pałuki Formation suggests, moreover that its stratigraphical position is markedly above the lower part of the Fittoni Zone.

The main part of the Owadów–Brzezinki sucession is represented by limestones corresponding to the Kcynia Formation. Ammonites (41 specimens) coming from the lower part of this formation (from the Sławno Limestone Member), like those from the underlying deposits of the Pałuki Fm. are representatives of the subfamily Virgatitinae as well as Pavloviinae Spath, 1931. Ammonites of the subfamily Virgatitinae are more common (61%), being represented by the genus *Zaraiskites.* Two species are recognized: *Zaraiskites zarajskensis* (Michalski) and *Z. lewinskii* sp. nov. – both of them showing enlarged distances between the particular sheaves of virgatotome ribs. The former species (Pl. 3: 1–2, Pl. 4: 1) is a typical "Middle Volgian" ammonite, indicative of the *zarajskensis* horizon of the upper part of the Zarajskensis Subzone of the Scythicus Zone. The species *Z. lewinskii* shows sparsely placed ribs on the inner whorls (Pl. 6: 1–3, Pl. 7: 1–2, Pl. 8: 1), and it possibly represents a continuation of the lateral offshoot of the main lineage of the genus known so far only from the area of Poland, like its direct descendant – *Z. pommerania* described from the immediately older deposits of the Pałuki Fm. The occurrence of this newly distinguished species in the uppermost part of the Zarajskensis Subzone is here firmly established. It should be remembered that our stratigraphical interpretation of the deposits of the Sławno Limestone Member as corresponding to the *zarajskensis* horizon of the upper part of the Zarajskensis Subzone is in full agreement with older stratigraphical interpretation of these deposits by Kutek (1994). The ammonites of the subfamily Pavloviinae (39% of the total number of specimens) are represented similarly as in the underlying deposits of the Pałuki Formation, mostly by representatives of the genus *Virgatopavlovia*, the species *V. janeki* sp. nov., which indicates correlation with the Fittoni Zone of southern England, occurring markedly above

its lower part (Pl. 10: 1, Pl. 11, Pl. 12: 2, Pl. 13; Fig. 3). Rare specimens of *Pavlovia pavlovi* (Michalski) have been found both in upper part of the Pałuki Formation and in the Sławno Limestone Member of the Kcynia Formation (Pl. 15: 4, Pl. 16: 2). The occurrence of this ammonite is indicative of the entire Russian Panderi Zone – and thus it is in full accordance with the correlation given (*cf*. Mitta, 1993).

The upper part of the Owadów–Brzezinki succession is represented by two informally named units of the Kcynia Formation: the "*Corbulomima* Limestones" (III) and, above, the "Serpulite" (IV) (see Figs 2, 3). Palaeontological exploration has yielded fairly numerous collection of ammonites (although the ammonites occur uncommonly) consisting of 41 specimens: these represent both Virgatitinae (51%) and Pavloviinae (49%) in nearly equal proportions. The Virgatitinae are represented by the genus *Virgatites* – *V. gerassimovi* (Mitta) (Pl. 2: 4, Pl. 3: 3, Pl. 4: 2) and *V. pusillus* (Michalski) (Pl. 8: 2–4). The interpretation of these species is based mostly on the characters of the inner whorls – which, if visible (unfortunately in some specimens only), make possible their attribution to the genus *Virgatites*; on the other hand, not one of the studied specimens with inner whorls preserved can be compared with the genus *Zaraiskites.* These observations indicate that the deposits in question are referrable to the lower part of the Virgatus Zone – *i.e.* to the Gerassimovi Subzone of the Russian Middle Volgian (*cf*. Mitta, 1993). This stratigraphical interpretation of the deposits differs from that given by Kutek (1994, and earlier papers cited therein), who assigned them to the upper part of the Zarajskensis Subzone of the Scythicus Zone, but the small number of ammonite specimens at his disposal and their poor preservation were possibly the reason for such an interpretation.

Ammonites of the Virgatitinae occurring in the youngest part of the studied Owadów–Brzezinki section show generally smaller sizes when compared with older ammonites of the subfamily. The same feature is observed when comparing these youngest Virgatitinae from Owadów–Brzezinki with the corresponding species from Russia: *V. gerassimovi* specimens described herein are generally smaller than the Russian specimens illustrated by Mitta (1983, 1993) which is a result of the acceleration (in term of heterochrony) in morphological development of the Polish specimens; also *V. pusillus* may be treated as a form showing advanced features of heterochrony (mostly acceleration) in its morphological development (called the "tachymorphic development" after Mitta, 1993; see also palaeontological chapter herein). The latter youngest Virgatitinae in the succession studied may also be considered as being related to *Progalbanites albani* (Spath) from the basal part of the British "Portlandian". The genus *Progalbanites* according to Spath (1936, p. 30–31) has been treated as being "very close to the inner whorls of *Crendonites* […], and included in the present family" – *i.e.* in Pavloviinae Spath, 1931 (see also Casey, 1967; Wimbledon, Cope, 1978). On the other hand, Dzik (1994, p. 135), noted that "*Progalbanites albani* (Spath) from the base of the Portlandian in Great Britain shows much resemblance to *Zaraiskites pommerania*, […] and may be its successor […], dense bifurcate ribbing is almost absent in its ontogeny […] so it can be compared only with more advanced virgatitids (not older *Z. pommerania*)", and thus it clearly has been referred to the subfamily Virgatitinae Spath, 1923. Such taxonomical interpretation of *Progalbanites* has important stratigraphical consequences: if the roots of *Progalbanites* are really in the Russian–Polish virgatitids, and its appearance at the beginning of the "Portlandian" in southern England is an effect of migration (Dzik, 1994), the genus *Progalbanites* appeared a lateral end-member of the virgatitid group whose small-size and special type of ornamentation resulted from heterochrony. The remarkable similarity in the type of ornamentation between some small-sized *Virgatites,* such as *Virgatites pusillus* (described herein) and *Progalbanites*, including the presence of similar tri-quadruplicate ribs on the inner whorls (see Pl. 8: 2–4 herein; see also Buckman, 1926, pl. 675; Arkell, 1935, pl. 26: 2; Spath, 1936, pl. 20: 2, pl. 24: 2) seems to confirm such an interpretation. A similar opinion on a possible close relation between *Virgatites* and *Progalbanites* was noted by Mesezhnikov (1988, p. 53; and earlier opinions cited therein).

The data given suggest that the youngest deposits of the succession studied at Owadów–Brzezinki ("*Corbulomima* Limestones" and "Serpulite") can be correlated with the Albani Zone of the lowermost "Portlandian" of southern England (Fig. 3, see also Zeiss, 2005). Additionally, the occurrence of ammonites of the subfamily Pavloviinae in the material studied seems to be evidence in favour of such a stratigraphical interpretation: (1) the occurrence of the newly established species *Virgatopavlovia dembowskae* sp. nov. (Pl. 15: 1–3, Pl. 16: 1), whose inner whorls show similarity to early *Epipallasiceras* of the *E.* aff. *costata* Spath group which is reported from the basal part of the Portland Sand, *i.e.* the Albani Zone of southern England (Callomon, Birkelund, 1982, p. 355–356; see also Buckman, 1926, pl. 693); (2) the occurrence of ammonites of the genus *Pavlovia* referred to as *Pavlovia* n. sp. B (Pl. 16: 3) similar to late representatives of the genus such as *Pavlovia* (*Lydistratites*) *lyditicus* Buckman (see Buckman, 1922, pl. 353A; see also Cope, 1978, p. 490; Wimbledon, 1984, p. 536) from the Upper Lydite Bed of Buckinghamshire, and close forms known from upper part of the Portland Sand of Dorset – directly above the Albani Zone, possibly from the Glaucolithus Zone.

CONCLUSIONS

Two ammonite zonations can be applied for subdivision of the Owadów–Brzezinki succession: one of NE Subboreal character of the Russian Platform and successive "Volgian" faunas of Virgatitinae, and that of NW Subboreal character corresponding mostly to the area of southern England (and northern France) with its "Upper Kimmeridgian" and "Portlandian" and successive faunas of Pavloviinae (Fig. 3). The NE Subboreal ammonite zones recognized in the succession include elements from the upper part of the Scythicus Zone (corresponding to the Zarajskensis Subzone), and the lower part of the Virgatus Zone (corresponding to the Gerassimovi Subzone), whereas the NW Subboreal ammonite zones include elements from the Fittoni Zone and the Albani Zone. The Zarajskensis Subzone of the Scythicus Zone can be correlated with the Fittoni Zone, and the studied part of the Virgatus Zone with the Albani Zone. Similar correlation was given previously by Casey and Mesezhnikov (1986) and Mesezhnikov (1988) who correlated the Zarajskensis Subzone with the Fittoni Zone, and the lower and middle parts of the Virgatus Zone with the bulk of the Albani Zone.

Also additional correlation of the zonations with Boreal areas such as East Greenland can be made. The early Boreal representatives of *Epipallasiceras* like *E. rotundiformis* (Spath) and a very close form "*Pavlovia* aff. *rugosa*" (see Spath, 1936, p. 55–56, pl. 12: 1ab, pl. 19: 3ab) show characteristic long pairs of closely-spaced secondaries, but this feature is "confined largely to the inner whorls, the ribbing on the body chamber reverting to that of normal *Pavlovia*" (Callomon, Birkelund, 1982, p. 355). In the material studied from Owadów–Brzezinki a similar development of ribbing is observed in the inner whorls of specimens attributed to the genus *Virgatopavlovia.* The ammonites studied of NW Subboreal character bear thus some resemblance to early representatives of the Boreal ammonites of the genus *Epipallasiceras* which are indicative of the Boreal Gracilis Zone (*cf.* Callomon, Birkelund, 1982, with earlier papers cited therein).

Microfossil studies of the succession at Owadów–Brzezinki have revealed the presence of a thin horizon at the top of unit I of the Sławno Limestone Member which yields early calpionellids of the genera *Borziella*, *Chitinoidella* and *Daciella*, indicative of a lower part of the Boneti Subzone of the Chitinoidella Zone (Pszczółkowski, 2016, this issue, see also Matyja *et al.*, 2016). The horizon is at the top of the Scythicus Zone/ Fittoni Zone, and below the ammonites indicative of the Virgatus Zone/ Albani Zone (Fig. 3). The Chitinoidella Zone is widely recognized in Tethyan areas being placed at the top of the Lower Tithonian, spanning the upper part of the ammonite Fallauxi Zone, through the Ponti Zone, and ranging into the Microcanthum Zone (Upper Tithonian) (see *e.g.* Enay, Geyssant, 1975). The horizon with chitinoidellids from the lower part of the Boneti Subzone in the Owadów–Brzezinki succession indicates the close proximity of the boundary between the Lower and the Upper Tithonian (see Pszczółkowski, 2016).

The correlation of the ammonite successions studied with the Tethyan succession herein differs markedly from that proposed by Kutek and Zeiss (1988, 1997), and Kutek (1994) who correlated the lower parts of the Zarajskensis Zone (the *regularis* horizon) with some lower parts of the Calpionellid Zone A, *i.e.* with the Upper Tithonian, markedly above its lower boundary. One of the most important premises for such a stratigraphical interpretation was the occurrence of Zone A calpionellids in matrix of the ammonites from Tethyan sections referred to *Zaraiskites* sp. by A. Zeiss (in Nowak, 1971) and by Książkiewicz (1974), and later to as *Z. regularis* by Kutek (1994). However, as indicated by Rogov (2004, p. 43), all these determinations are disputable because of the poor preservation of ammonites, which makes any confident identification difficult; further, the presence of virgatotome ribbing alone is not an unequivocally indicative systematic feature, because it is also encountered in many the Upper Tithonian ammonites. On the basis of the stratigraphic distribution of ammonites in common in the "Volgian" and Tithonian stages, the Lower/Upper Tithonian boundary (corresponding to the boundary of the Ponti and Microcanthum zonal boundary) is indicated as lying within the "Volgian" Virgatus Zone (Rogov, 2014). This interpretation is close to that indicated herein.

Some palaeogeographic observations can also be made relating to the studied succession in central Poland. The sudden appearance of the ammonites of the family Pavloviinae, showing close relations to those of southern England, indicates the opening of new sea routes, possibly related with tectonic activity in northern European areas. In southern England (north Wiltshire to Buckinghamshire) these tectonic phenomena resulted in occurrence of well-known stratigraphic gap, with some upper parts of the Upper Kimmeridge Clay and the lowest Portlandian Sand missing, with first ammonite fauna occurring above of the Glaucolithus Zone (Arkell, 1935; Cope, 1978; Wimbledon, 1984, and other papers cited therein), and reflecting the uplift of northwestern part of Britian (*e.g.* Cope, 2015b, fig. 1); in northern Poland, in western Pomerania, a marked stratigraphical gap occurs including a large part of the Upper Kimmeridgian and the lower part of the Tithonian (the "Lower" to lower part of the "Middle Volgian") well below a higher part of the "Middle Volgian" deposits (Wilczyński, 1962). The occurrence of ammonites of the Albani Zone in the one of the phases of coastal progradation in the Frederikshavn Formation corresponding to regional subsidence in the Danish Ba-

sin (Birkelund, Pedersen, 1980; Nielsen, 2003) may also be related with this tectonic activity.

SYSTEMATIC PALAEONTOLOGY

The following abbreviations are used in the description of the ammonites: D – diameter of specimen in mm; Wh – whorl height as a percentage of D; Ud – umbilical diameter as a percentage of D; PR – number of primary ribs per whorl (or half a whorl when indicated).

Specific names are used in the study in sense of "morphospecies" having vertical ranges as opposed to isochronous "horizontal" assemblages thought to represent the variable "biospecies" members in particular lineages (see Dzik, 1985, 1994). Such an approach results from unusually large variability within assemblage in an horizon especially of the subfamily Virgatitinae where the development of morphological features was strongly controlled by heterochrony in its many aspects – of both paedomorphosis and peromorphosis types (cf. *e.g.* Landman, Geyssant, 1993, and earlier papers cited therein). It is difficult to evaluate the taxonomical importance of these features, however, and recognize if they were controlled only by local environmental conditions. And if they had only a temporary and reversible character in time, or if they influenced the evolutionary development of the whole group of ammonites, having a real phylogenetical importance. In such a situation, the distinction of morphospecies for well-defined morphologically groups seems the only solution, and this approach should precede any wider environmental and phylogenetical considerations. The problem is related also to the occurrence of closely related dimorphic forms (micro- and macroconchs) showing similar sequences of change in ornamentation, but with indices of final maturation corresponding to earlier or later stages of the morphological development. Such micro and macroconchs, placed herein in a single species, are often treated in geological literature as sexual counterparts, but the problem of their origin (sexual morphs or not) is complicated by patchy occurrence of such forms – both in their stratigraphical ranges, but also in their geographical distribution (taking into account the data from other areas). All these phenomena are briefly recorded below in the description of particular species, but a more thorough discussion about these problems is outside the scope the present study, and will be given elsewhere.

Collections studied consist of 120 specimens gathered over many years from the Owadów–Brzezinki quarry. Specimens were originally collected by M. Zielińska during her M.Sc. studies. Subsequently, more ammonites were collected by A. Kin, but the largest part of collection has been gathered during regular exploration of the section under the leadership of B. Błażejowski, as well as during field-work by the authors of the current study. The ammonites are housed in the Museum of the Polish Geological Institute – National Research Institute (collection number MUZ PIG AK2.II.1-18) and in the Museum of the Faculty of Geology, University of Warsaw (collection number MWG UW ZI/78/001-102).

Family **Virgatitidae** Spath, 1923

Subfamily **Virgatitinae** Spath, 1923

Genus *Zaraiskites* Semenov, 1898

Type species: *Zaraiskites zarajskensis* (Michalski, 1890)

Two groups of ammonites may be distinguished in the materials studied. The first group consists of *Z. regularis* and *Z. zarajskensis* and shows the typical *Zaraiskites* ornamentation: dense biplicate ribbing on inner whorls, and a more loosely spaced ribbing thereafter; virgatotome on middle whorls in macroconchs (and on final whorls in microconchs), and – biplicate ribs on outer whorls in large-sized macroconchs. The second group consists of *Z. pommerania* and the newly established species *Z. lewinskii*, which differs in its generally less dense ribbing, especially on the inner whorls, and its more massive and irregular character. Moreover, the virgatotome stage of ribbing is characterized by a smaller number of secondary ribs (up to 3–4) in the virgatotome sheaves. All the specimens encountered of the second group are represented by a one-sized morph of the microconch type, attaining about 75 to 135 mm in final diameter.

Zaraiskites regularis Kutek, 1994
(Pl. 1: 1–2, Pl. 2: 1–3; Fig. 4)

1994. *Zaraiskites regularis* sp. n.; Kutek, p. 15–18, pl. 3: 2, pls 4–10 (with given synonymy).

1994. *Zaraiskites pommerania* (Arkell); Dzik, p. 129–130, pl. 2.

2013. *Zaraiskites regularis* Kutek; Rogov, p. 806, fig. 4: 1.

Material. – 11 specimens coming from the topmost part of the Pałuki Formation.

Discussion. – The specimens collected show a wide range of variability, similar to that indicated by Kutek (1994). The ribbing on inner whorls is generally dense (PR = 35 to 40 at D = 30–50 mm), in some specimens, however, it is markedly less dense (PR = 25–27 at D = 40–50 mm) (Pl. 1: 1), as seen also in some paratypes (Kutek, 1994, pl. 3:2). The less densely ribbed morphotype shares some affinity with *Z. pommerania* (Arkell). The distance between secondary ribs within particular virgatotome rib sheaves and in between them is generally similar in the bulk of specimens

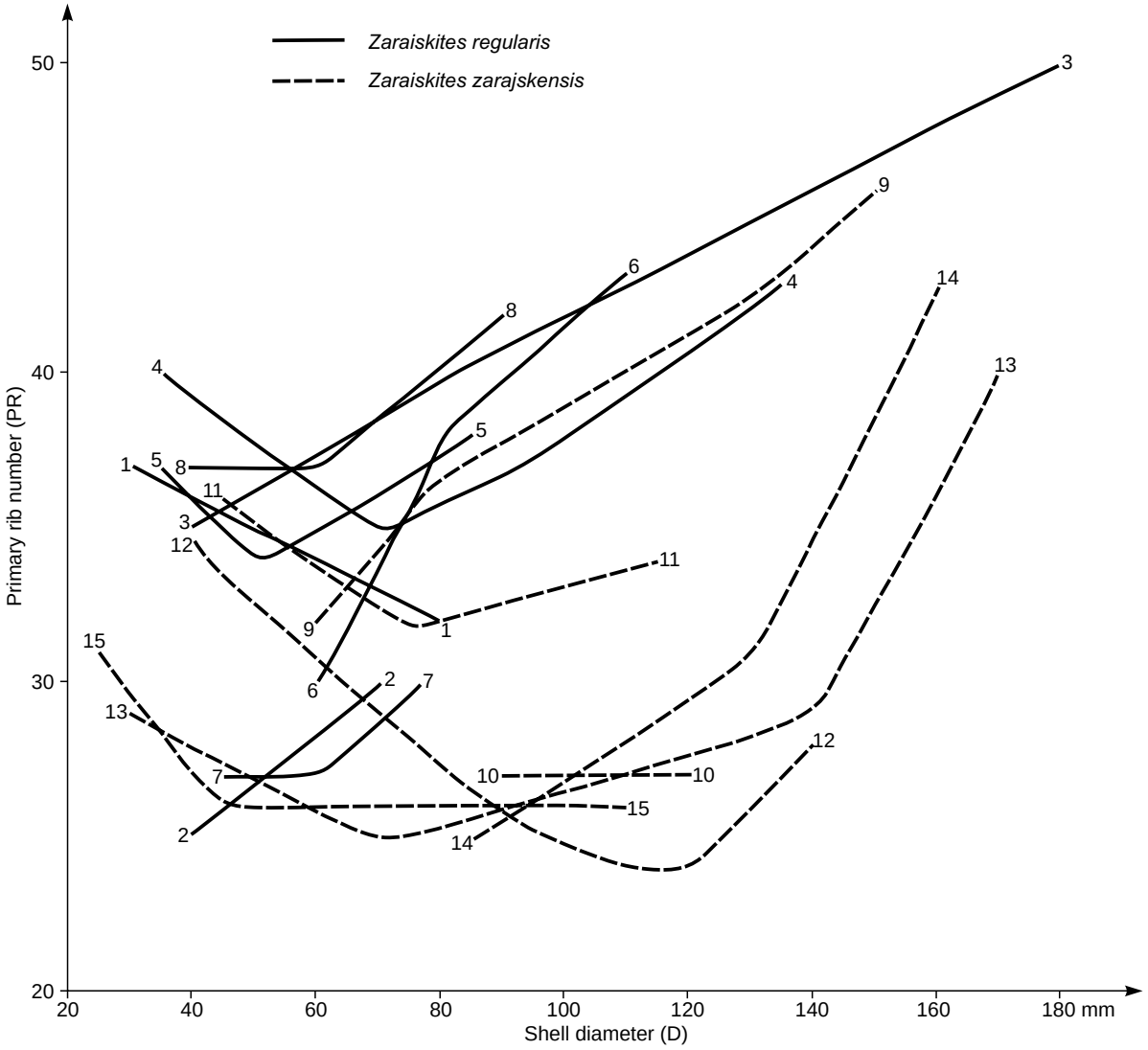

Fig. 4. Number of primary ribs (PR) against shell diameter (D) for *Zaraiskites regularis* (Kutek) and *Zaraiskites zarajskensis* Michalski)

Z. regularis: 1 – specimen no. MWG UW ZI/78/003; 2 – specimen no. MWG UW ZI/78/001 (Pl. 1: 1); 3 – specimen no. MWG UW ZI/78/023 (macroconch); 4 – specimen no. MWG UW ZI/78/098 (macroconch; Pl. 2: 2); 5 – specimen no. MWG UW ZI/78/099 (microconch; Pl. 2: 3); 6 – holotype – see Kutek (1994, pl. 5: 1); 7 – paratype – see Kutek (1994, pl. 3: 2); 8 – paratype – see Kutek (1994, pl. 4: 2).

Z. zarajskensis: 9 – specimen no. MWG UW/ ZI/78/029; 10 – specimen no. MWG UW/ZI/78/037 (Pl. 3: 1); 11 – specimen no. MWG UW/ZI/78/044; 12 – specimen no. MUZ. PIG AK2.II.1; 13 – specimen no. MUZ PIG AK2.II.4; 14 – specimen no. MUZ PIG AK2.II.5 (Pl. 4: 1); 15 – specimen of the type series of *Z. zarajskensis*, see Michalski (1890, pl. 6: 5).

studied – which is the typical feature of the species, but in some specimens (Pl. 2: 3) – especially at the end of whorls with virgatotome ribbing – the spaces between rib sheaves become larger, resembling somewhat a younger *Z. zarajskensis*.

As indicated by Kutek (1994), the species is evidently dimorphic: the microconchs show virgatotome ribbing possibly up to the end of the last whorl, and in that case the proximity of the final aperture may be recognized by commonly appearing constrictions at diameters about 90–100 mm (Pl. 2: 3; see also Kutek, 1994, pl. 4: 2, pl. 5: 1); the macroconchs attain at least 180 mm, but the largest of them is up to about 300 mm (Pl. 1: 2), which is comparable to diameter of the largest specimen described by Dzik (1985, see also synonymy) which may attain final diameter between 240–300 mm. Macroconchs are characterized also by occurrence of biplicate and single ribs on the outer whorls, and this type of ribbing may appear between about diameters

80 mm and 130 mm in various specimens (Fig. 4), directly succeeding the virgatotome stage of ribbing. The coiling in microconchs and on the inner whorls of macroconchs is involute, whereas in the outer whorl of macroconchs it is markedly evolute.

Occurrence: The specimens described come from the *regularis* horizon of the Zarajskensis Subzone of the Scythicus Zone, in the uppermost part of the Pałuki Fm. The species occurs also in the somewhat older deposits of the Pałuki Fm. in central and northern Poland (see Kutek, 1994, and earlier papers cited therein). The species has a wide distribution in the central part of the Russian Platform (Rogov, 2013).

Zaraiskites zarajskensis (Michalski, 1890)
(Pl. 3: 1–2, Pl. 4: 1; Fig. 4)

1890. *Perisphinctes zarajskensis* n. sp.; Michalski, p. 98–110, pl. 6: 1–5.

1890. *Perisphinctes pilicensis* n. sp.: Michalski, p. 117–121, pl. 6: 10.

1923. *Provirgatites zarajskensis* Michalski; Lewiński, p. 103–104, pl. 11: 1–1a, 2.

1923. *Provirgatites alexandrae* n. sp.; Lewiński, p. 95–97, pl. 10: 1–3.

1993. *Zaraiskites zarajskensis* (Michalski, 1890); Mitta, p. 65–67, pl. 7: 1–2.

1994. *Zaraiskites zarajskensis* (Michalski, 1890) biospecies; Kutek, p. 20–22, pars (without illustrated specimens).

Materials. – 9 specimens, and several fragmentarily individuals preserved attributed with cf. reservation.

Discussion. – The ribbing of inner whorls is dense and resembles very much that of the specimens attributed to the species by Michalski (1890) and Mitta (1993): in specimens studied at D = 30–40 mm, PR = 29–35. The coiling of the inner whorls is involute, but it soon becomes evolute with a growing diameter. The most characteristic ornamentation consists of rather loosely spaced virgatotome ribs with 5–6 secondaries in each sheave. The spaces between the virgatotome sheaves are markedly larger than the spaces between the secondary ribs within the sheaves – which is a typical feature of the species (Kutek, 1994). The virgatotome ribbing ranges from a diameter of about 35–40 mm diameter up to 100–140 mm. This type of ornamentation is succeeded in bulk of the specimens studied by a more simple ornamentation composed of trifurcate and biplicate ribs – which is commonly recognized as representative of the outer whorl of macroconchs of *Z. zarajskensis* (Kutek, 1994; see also Lewiński, 1923). The proximity of the final aperture is indicated by occurrence of densely placed bifurcate or trifurcate, or even single ribs and common constrictions – such a type of ribbing occurs in specimens at 130 mm, at 160 mm, but in some the biplicate ribs commence at diameters up to 200 mm (Fig. 4). Only two specimens attaining diameters of about 100–120 mm show the presence of virgatotome ribbing, which ends with a distinct constriction, sometimes followed by a few trifurcate ribs; these specimens do not show any sign of the final aperture, however, and it is open question whether they are fully grown (and then represent microconchs) or not.

Summarizing the observations given, it may be noted that the specimens studied referred to *Z. zarajskensis* are represented mostly by macroconchs, and that the microconchs (if they occur) are much less common. An opposite tendency may be noticed in materials coming from Russia, where those most commonly described are smaller specimens (possibly microconchs; see Mitta, 1993, pl. 7: 1–2), and the macroconchs "occur occasionally and are insufficiently studied" (Rogov, 2013, p. 803).

Occurrence. – The specimens described come from the *zarajskensis* horizon of the Zarajskensis Subzone of the Scythicus Zone, in the lowermost part of the Kcynia Formation – unit I of the Sławno Limestone Member in central Poland. The species is known also from the Zarajskensis Subzone of the central part of the Russian Platform (Mitta, 1993).

Zaraiskites pommerania (Arkell, 1934)
(Pl. 5: 1–3; Fig. 5)

1935. *Provirgatites pommerania* sp. nov.; Arkell, p. 340, pl. 26: 1–1a.

1994. *Zaraiskites pomerania* (Arkell); Dzik, p. 130, pl. 1: 2a, b.

non 2013. *Zaraiskites pommerania* (Arkell); Rogov, p. 804–805, fig. 4: 2, 4, 9.

Material. – 4 specimens referred to that species and two referred as cf. species.

Description. – Specimens range from about 80 to about 110 mm in diameter, and show the presence of dense single and biplicate ribs following a final constrictions at the end of the last whorl, which indicates the proximity of the final peristome (Pl. 5: 1); the phragmocone/body chamber boundary, recognized at a diameter 62 mm (Pl. 5: 2), indicates that the body-chamber is a one whorl in length. The coiling is weakly involute to weakly evolute. The ribbing is distant on the inner whorls and number of primary ribs is fairly small (at D = 20–40 mm, PR = 18–24), whereas on the outer whorl their number increases and its equals 27–32 (Fig. 5). The ribbing on the inner whorls is mostly biplicate (but there are some oblique single ribs), and it is followed by ribbing of the virgatotome type, with three to four secondaries appearing in the middle of the whorl on the last whorl. The distance between the secondary ribs of a sheave and between sheaves is generally similar on both the inner whorls and a

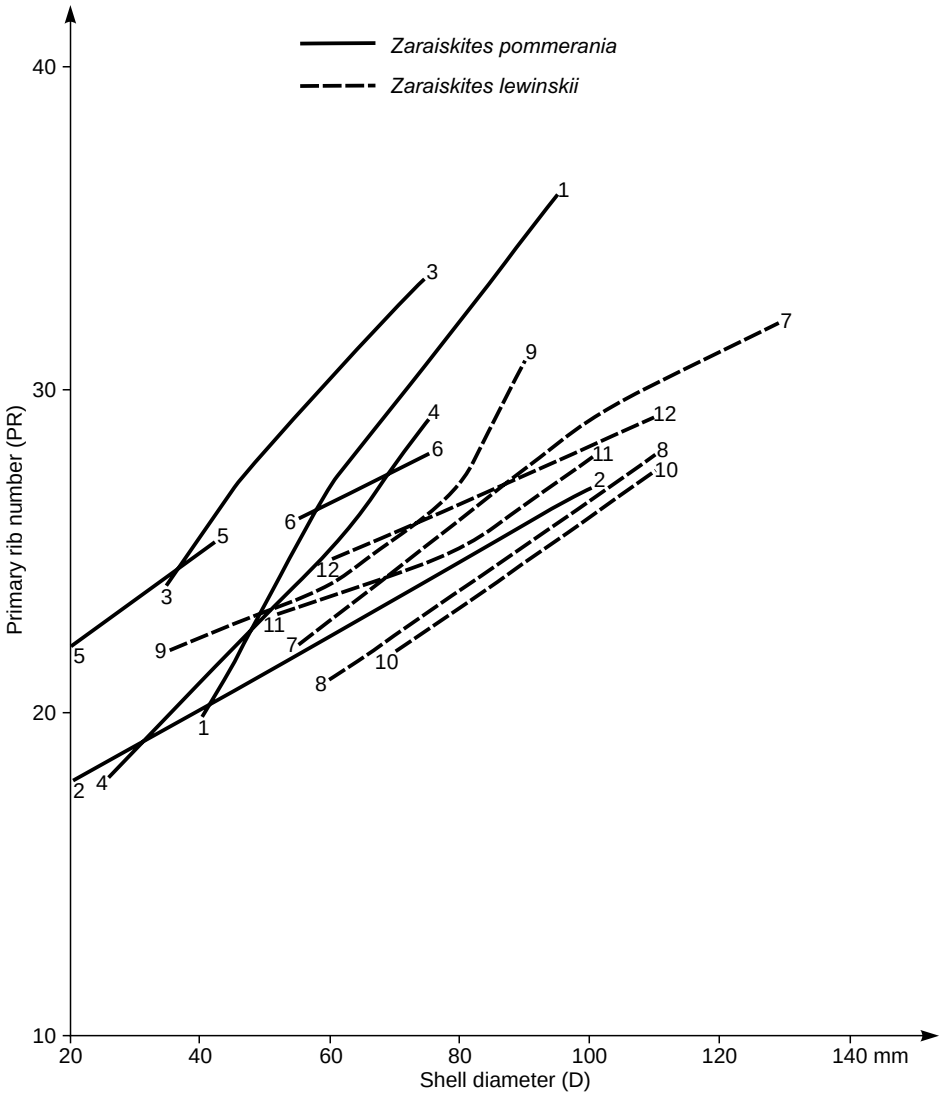

Fig. 5. Number of primary ribs (PR) against shell diameter (D) for *Zaraiskites pommerania* (Arkell) and *Zaraiskites lewinskii* sp. nov.

Z. pommerania: 1 – specimen no. MWG UW ZI/78/014 (Pl. 5: 1); 2 – specimen no. MWG UW ZI/78/019 (Pl. 5: 2); 3 – specimen no. MWG UW ZI/78/022; 4 – specimen no. MWG UW ZI/78/061 (Pl. 5: 3); 5 – specimen no. MWG UW ZI/78/101 a; 6 – holotype – see Arkell (1935, pl. 26: 1–1a).

Z. lewinskii: 7 – specimen no. MUZ PIG AK2.II.2 (holotype, Pl. 7: 1); 8 – specimen no. MWG UW ZI/78/039 (paratype , Pl. 6: 1); 9 – specimen no. MWG UW ZI/78/047 (paratype, Pl. 6: 2); 10 – specimen no. MWG UW ZI/78/096 (paratype, Pl. 6: 3); 11 – specimen no. MWG UW ZI/78/008 (paratype, Pl. 7: 2); 12 – specimen no. MUZ PIG AK2.II.6 (paratype, Pl. 8: 1).

large part of the last whorl; the interspaces between the sheaves become commonly larger at the end of the last whorl – which is also related with development of constrictions.

Discussion. – The species shares a clear affinity with a loosely ribbed variant of *Zaraiskites regularis* Kutek (Kutek, 1994, pl. 3: 2, pl. 6: 1, pl. 9: 4) which could be interpreted as its possible forerunner. It shows, however, somewhat thicker and sparsely placed ribs. It cannot be treated as a morphological variant of *Z. regularis* because its morphology is different and represented in the succession studied by only one morph whose origin was possibly controlled by heterochrony (progenesis?). It represents possibly the roots of a separate lineage of *Zaraiskites*, possibly endemic in Poland, and not known in the Russian Platform – the "home area" of *Zaraiskites*. It should be remembered that the specimens from Russia referred by Rogov (2013) to *Z. pommerania* (Arkell) do not belong to that species because they show dense ribbing on the inner whorls, which is a typical feature of the main group of the genus *Zaraiskites*.

Occurrence. – The species occurs in the *regularis* horizon of the Zarajskensis Subzone of the Scythicus Zone, in the uppermost part of the Pałuki Formation in central Poland, and corresponding deposits in north-western Pomerania.

Zaraiskites lewinskii sp. nov.
(Pl. 6: 1–3, Pl. 7: 1–2, Pl. 8: 1; Fig. 5)

Type material. – Holotype (figured in Pl. 7: 1) and five paratypes (figured in Pl. 6:1–3, Pl. 7: 2, Pl. 8: 1); moreover, two incomplete specimens but with the aperture preserved.

Type locality. – Owadów–Brzezinki quarry at Sławno.

Type horizon. – *Zarajskensis* horizon of the Zarajskensis Subzone of the Scythicus Zone, the Sławno Limestone Member of the lower part of the Kcynia Formation.

Derivation of the name. – In memory of Professor Jan Lewiński, a student of the uppermost Jurassic ("Volgian") fauna of central Poland.

Diagnosis. – Ammonites of middle size (from 95 to about 140 mm) when fully grown; inner whorls showing sparsely placed ribs; the outer whorl shows the presence of virgatotome ribs which consist commonly of three-four secondaries in every sheave; the distance between the rib-sheaves is larger than between the secondary ribs within each sheave; constrictions and crowded single, biplicate and triplicate ribs commonly occur at the final peristome.

Description. – Ammonites of a final size ranging from about 95 to about 140 mm in diameter. The coiling is moderately involute to evolute on the middle whorls, and markedly evolute on the last whorl (at D = 90–130 mm, Wh oscillates between 30 and 34, whereas Ud – between 40 and 47). The inner whorls are covered with loosely spaced, rather sharp, possibly mostly biplicate ribs. Number of primary ribs (PR) attains about 20–25 per whorl at D = 40–60 mm. On the outer whorls, the ribs are commonly virgatotome (with about 3–4 secondary ribs in the sheaves), some triplicate ribs showing polygyrate subdivision are also encountered. The last part of the whorl shows the presence of constrictions and modification of the ribbing, which becomes triplicate and biplicate towards the end of the whorl; the ribs are usually crowded preceding the final peristome (Pl. 6: 2, Pl. 7: 2; Fig. 5).

Discussion. – The species *Z. lewinskii* differs from *Z. pommerania* mostly in marked interspaces between the particular rib-sheaves on the last whorl; moreover the outer whorl is more evolute and shows more distant ribbing (Fig. 5).

Occurrence. – The species occurs in the *zarajskensis* horizon of the Zarajskensis Subzone of the Scythicus Zone, in the lowermost part of the Kcynia Fm. – unit I of the Sławno Limestone Member.

Genus *Virgatites* Pavlow, 1892

Type species *Virgatites virgatus* (v. Buch, 1830)
Virgatites gerassimovi Mitta, 1983
(Pl. 2: 4, Pl. 3: 3, Pl. 4: 2; Fig. 6)

?1967. *Zaraiskites zarajskensis* (Michalski); Kutek, p. 43, pl. 1.

1983. *Virgatites gerassimovi* Mitta sp. nov.; Mitta, p. 99, pl. 2: 1.

1993. *Virgatites gerassimovi* Mitta, 1983; Mitta, p. 60–62, pl. 5: 1–4, text-fig. 20.

?1994. *Zaraiskites zarajskensis* (Michalski); Kutek, p. 21, pl. 11: 1.

2012. *Zaraiskites* ex gr. *zarajskensis*; Kin, Błażejowski, fig. 5A.

2013. *Zaraiskites* ex gr. *zarajskensis*; Kin *et al*., fig. 3.

Material. – Five specimens; and several fragments of outer whorls found in the same stratigraphical level, which although they cannot be unequivocally referred to that species (because of similarity of ornamentation of outer whorls between *V. gerassimovi* and *Z. zarajskensis*), could belong to the genus *Virgatites*.

Description. – Ammonites of a final size attaining a diameter of about 145 mm (Pl. 2: 4; Fig. 6), but often smaller, about 120 mm in diameter (Pl. 3: 3), or less. The coiling of inner and middle whorls is involute (at D = 65–78 mm, Wh = 38–39, Ud = 26–30), whereas that of the outer whorl is markedly evolute (at D = 100–115 mm, Wh = 33–34, Ud = 40–43). The whorl section of the outer whorl is seen in a single specimen only, where it is a high-oval that tapers towards the venter. The ornamentation of the innermost whorls is generally poorly visible, but in a few specimens the occurrence of sparsely-placed, short, swollen primary ribs may be observed (Pl. 3: 3). Middle whorls are characterized by occurrence of virgatotome ribs consisting of about 5 secondary ribs in every sheave – with its base placed very low near the umbilical wall (Pl. 4: 2). The ornamentation of the outer whorl consists of virgatotome ribs each composed of 5–9 secondary ribs which appear in the middle of the whorl, well above a rather sharp primary rib. The number of primary ribs increases towards the middle whorls, and then markedly decreases on the outer whorl (Fig. 6). The last part of the outer whorl shows the presence of densely placed, three to four, single and biplicate (may be also triplicate), ribs at about 120 mm (Pl. 3: 3), which suggests the presence of the final peristome. On the other hand, about a quarter of the outer whorl is preserved, corresponding to a diameter of about 145 mm in another specimen that shows the presence of densely placed, single and biplicate, ribs which are similar in character to those occurring on the outer whorls of macroconchs of some *Zaraiskites* – such as *Z. zarajskensis*.

Discussion. – The specimens discussed are closely comparable with those of *Virgatites gerassimovi* Mitta as described from central Russia by the author of the species (see

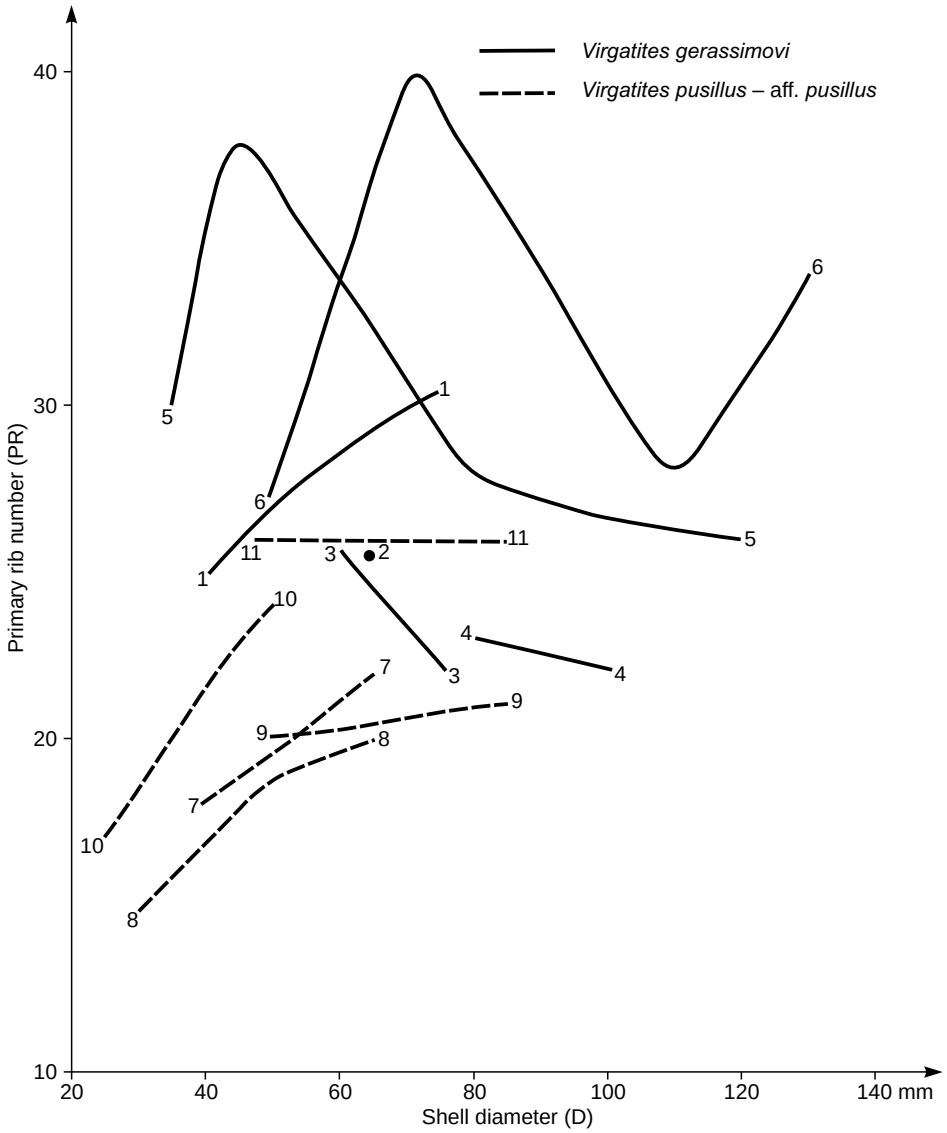

Fig. 6. Number of primary ribs (PR) against shell diameter (D) for *Virgatites gerassimovi* Mitta and *Virgatites pusillus* (Michalski) – *V.* aff. *pusillus* (Michalski)

V. gerassimovi: 1 – specimen no. MWG UW ZI/78/053; 2 – specimen no. MWG UW ZI/78/055 (Pl. 4: 2); 3 – specimen no. MWG UW ZI/78/074; 4 – specimen no. MWG UW ZI/78/085 (Pl. 2: 4); 5 – specimen no. MUZ PIG AK2.II.14 (Pl. 3: 3); 6 – holotype – see Mitta (1983, pl. 2: 1).

V. pusillus: 7 – specimen no. MWG UW ZI/78/059 (Pl. 8: 2); 8 – specimen no. MWG UW ZI/78/073 (Pl. 8: 3); 9 – specimen no. MWG UW ZI/78/088; 10 – specimen no. MWG UW ZI/78/091 (Pl. 8: 4); 11 – *V.* aff.*pusillus* (specimen no. MWG UW ZI/78/084, Pl. 8: 5).

Mitta, 1983, 1993). It should be remembered, however, that the poorly preserved inner whorls of the specimens studied cause some difficulties when it comes to the detailed comparison of the early stages of development of ornamentation, but nevertheless, the occurrence of fragmentarily preserved, short, swollen primary ribs in our specimens indicates unequivocally their affinity to *V. gerassimovi*. On the other hand, the character of the ornamentation of the middle and outer whorls of *V. gerassimovi* and those of *Z. zarajskensis*, which is treated as its direct phyletic ancestor, are generally very similar (Mitta, 1993), and the identification of specimens with poorly preserved inner whorls is difficult. Such is the case with a single specimen from the Kcynia Formation ("Serpulite unit") at Brzostówka (central Poland) originally referred to *Zaraiskites zarajskensis* by Kutek (1967, 1994 – cf. synonymy above), but whose identifica-

tion as *V. gerassimovi* seems plausible. This specimen has a strongly deformed phragmocone (up to 83 mm diameter) showing dense ribbing in the middle whorl; the periumbilical part of the inner and middle whorls is damaged and the ornamentation cannot be studied, which makes difficult any unequivocal taxonomic interpretation.

The specimens studied from Poland referred to herein as *V. gerassimovi* differ from specimens of that species described from Russia by Mitta (1983, 1993) in their generally smaller size. This phenomenon resulted from acceleration (in term of heterochrony) in morphological development of the Polish specimens, which generally show the disappearance of involute coiling and related type of ornamentation, and appearance of advanced virgatotome ornamentation at smaller diameters, when compared with the Russian specimens. This feature is expressed also by the small size of a particular single specimen studied, which already attains macroconch biplicate ornamentation at a diameter of about 145 mm: there being no comparable representatives among specimens described from Russia.

Occurrence. – The specimens studied comes from the "*Corbulomima* Limestones" (III) and the "Serpulite" (IV) units, the middle and upper parts of the Kcynia Formation in the section studied. The species occurs also in the central Russian Platform, where it is treated as indicative of the Gerassimovi Subzone of the lowermost Virgatus Zone (Mitta, 1983, 1993).

Virgatites pusillus (Michalski, 1890)
(Pl. 8: 2–4; Fig. 6)

1890. *Olcostephanus pusillus* n.sp.; Michalski, p. 34–42, pl. 2: 2–7; pl. 13: 3–4.

1993. *Virgatites pallasianus* (d'Orbigny, 1845); Mitta, p. 54–56 (pars), pl. 2: 3–4.

non 1973. *Virgatites pusillus* (Michalski); Dembowska, p. 106–107, pl. 8: 2.

Material. – Four specimens attributed to the species, and one (Pl. 8: 5) referred to as *V.* aff. *pusillus*.

Description. – Specimens have final diameters that reach from about 70 to about 90 mm. The coiling of the inner to middle whorls is weakly involute to weakly evolute, the coiling of the outer whorl is strongly evolute (at D = 65–80 mm, Wh = 33.5–34.5, Ud = 40–43). The ornamentation of the inner whorls is observed in two specimens only; it consists of short, somewhat swollen, sparsely-placed primary ribs, and more numerous secondary ribs (about 3–4 per primary rib as observed in Pl. 8: 4) which appear close to the umbilical wall. The middle whorls show mostly the presence of biplicate and triplicate (with polygyrate subdivision) ribs; on the outer whorl of larger specimens the ribbing becomes more irregular: the ribs are biplicate, triplicate, sometimes even quadruplicate with furcation point placed about the middle of the whorl, and the commonly occurring narrow constrictions are usually followed by a single rib. The distances between the sets of secondary ribs of each primary are larger than those between the secondary ribs. The number of primary ribs per whorl (PR) in middle and outer whorls becomes rather stable, ranging from about 18 to 24 (Fig. 6).

Discussion. – The specimens described compare well with specimens of *V. pusillus* (Michalski) as described by Michalski (1890). Mitta (1993) recognized *V. pusillus* as a junior synonym of *V. pallasianus* (d'Orbigny) because of the continuous range of variability of the specimens which made it impossible to separate the two species. In the material studied from central Poland, all the morphs recognized may be attributed to *V. pusillus* only, and this suggests somewhat different status of this form when compared with *V. pallasianus*, which is so far not recognized in the material studied in Poland. This is the reason – that the name *V. pusillus* is retained in the present study.

The special status of the species *V. pusillus* was indicated previously by Michalski (1890), who indicated the close similarity of the ornament of its last whorl to that observed on the outer whorl of *V. virgatus* at a much larger diameter, to complete absence of ornamentation typical of the middle whorls of the latter. The same feature in the morphological development of ornamentation of *V. pusillus* (in fact *V. pallasianus* treated as a senior synonym of *V. pusillus*) was noted by Mitta (1993), who showed that it is characterized by a strong reduction (to total disappearance) of the bidichotomous stage of ribbing, which is typical of several species of the "main" lineage of *Virgatites* such as *V. gerassimovi* and *V. virgatus*. Similar development is shown in a single specimen in the collection studied (Pl. 8: 5), referred to as *Virgatites* aff. *pusillus* (Michalski). It is about 85 mm in diameter and fully grown as indicated by crowding of the last ribs at the end of the whorl, and it shows several features of *V. pusillus* (smaller size, similar character and density of ribbing on the inner whorls, see Fig. 6), but the presence on the last whorl of very numerous secondary ribs which indicate an affinity to *V. gerassimovi*. Founded on all these observations the species *V. pusillus* may be treated as a form showing advanced features of heterochrony (mostly acceleration) in its morphological development (called "tachymorphic development" after Mitta, 1993).

Several specimens which came mostly from the beds with *Zaraiskites* from the borehole cores of central Poland were referred to as *Virgatites* in the past, including also some placed in the species *V. pusillus* (see *e.g.* Dembowska, 1973, and earlier papers cited therein). However, none of these specimens belongs to the genus *Virgatites*, but represent different specimens possibly related to the genus

Zaraiskites, or closer interpretation is difficult because of their fragmentary preservation (Kutek, 1994). It may be added that not one of the specimens discussed shows the presence of short, swollen primary ribs in the inner whorls which is typical of the genus *Virgatites*.

Occurrence. – The specimens studied come from the "*Corbulomima* Limestones" (III) and the "Serpulite" (IV) units representing the middle and upper parts of the Kcynia Formation. The species is known also from the central Russian Platform, where it co-occurs with *V. gerassimovi* in the Gerassimovi Subzone of the Virgatus Zone (Mitta, 1993).

Family **Dorsoplanitidae** Arkell, 1950

Subfamily **Pavloviinae** Spath, 1931

Genus *Pavlovia* Ilovaisky, 1917

Type species: *Pavlovia iatrensis* var. *primaria* Ilovaisky, 1917

Representatives of the genus *Pavlovia* are rarely encountered in the succession studied. Different species seem to be present, but some of them could be closely identifiable in the future when a larger collection is gathered. The specimens represent rather coarsely ribbed representatives of the genus, but differences in the character of the ribbing and final sizes of the specimens make possible their subdivision into three groups possibly representing separate species.

A single specimen (Pl. 17) from the topmost part of the Pałuki Formation is a large individual attaining a size of 195 mm, but it is without the final part of the body-chamber (the preserved part of body chamber is somewhat less than a whorl in length). The specimen shows moderately evolute coiling in the middle whorls, and more evolute coiling of the last whorl. The ribbing is moderately dense on middle whorls and outer whorl (PR = 36 at D = 100 mm; PR = 38 at D = 190 mm), and it consists of biplicate, markedly prorsiradiate, ribs with a lower furcation point placed about the middle of the whorl. The ribbing of the inner whorls is rather distant, fairly sharp, but that of the outer whorl is stouter. Two shallow constrictions followed by a single rib are observed on the outer whorl. Another, similar, but more fragmentarily preserved specimen (Pl. 12: 1) about 170 mm in diameter, from a middle part of the Sławno Limestone Member consists mostly of the phragmocone with an initial part of the body chamber. It shows moderately evolute coiling and stout biplicate, prorsiradiate ribbing with a lower point of rib division, both on the inner and outer whorls: the ribbing on the inner whorls is distant (number of primary ribs per half a whorl equals about 10 at D = 40 mm, and 15 at D = 90 mm); on the outer whorl preserved the number of primary ribs per half a whorl equals 22 at D = 170 mm. Because of the lack of wider materials, the specimens studied are referred to as *Pavlovia* sp. A, but their similarity to another specimen kept in an "open nomenclature" and referred to as *Pavlovia* sp. B by Cope (1978, p. 508, fig. 8) from the Rotunda Zone of the Upper Kimmeridge Clay of Dorset may be noted.

Two specimens (Pl. 15: 4, Pl. 16: 2) from the topmost Pałuki Formation, and the lower part of the Kcynia Formation – unit I of the Sławno Limestone Member, are small specimens attaining a diameter of about 50–60 mm in diameter but fully grown, as shown by presence of constrictions on the final part and termination of the last whorl. The ribbing is typical of *Pavlovia*: sharp, strongly biplicate – Y-shaped, and widely spaced (about 18–21 primary ribs at D = 20–60 mm). Our specimens seem closest to *Pavlovia pavlovi* (Michalski) as broadly interpreted by Mitta (1993) who included in this species both more involute and more evolute forms including *Pavlovia menneri* Mikhailov, 1957 (see also Mikhailov, 1966). The specimens studied show that sparse primary ribbing appears already at small diameters, and in this they differ from the bulk of Russian specimens of the species in which dense ribbing appears commonly in inner whorls (see Mitta, 1993, pl. 17: 1–9; and other specimens placed in the synonymy therein). It should be noted that dense ribbing is observed on the most innermost whorls of our specimens up to about diameters 5 mm: such early disappearance of dense ribbing is not treated as having any systematic importance, however, because of the occurrence of such similarly ornamented specimens in Russian collections (see *e.g.* Mitta, 1993, pl. 17: 6a, b; Mikhailov, 1966, pl. 8: 3a, b). In the past, the only specimens referred to the genus *Pavlovia* in Poland were identified as *P. pavlovi* (Michalski) by Wilczyński (1962, p. 79–80, pl. 8: 4–5) from Western Pomerania (Czarnogłowy quarry): these are whorl fragments showing both whorl-section and characteristics of ribbing similar to those of *P. pavlovi*, but their fragmentary preservation makes an unequivocal determination difficult.

Two specimens (Pl. 16: 3) coming from the Kcynia Formation, from the "*Corbulomima* Limestones" (unit III), attain diameters of about 140 to 170 mm, and show the presence of a partly preserved body chamber. The larger of them is possibly fully grown, but the peristome is not preserved. Specimens show very evolute coiling (at D = 100–140 mm, Wh = 26–28, Ud = 47) and distant, biplicate ribbing; the ribs are stout, rectiradiate, and the bifurcation point placed fairly high on the whorl side. The variation in primary rib density shows a tendency to a gradual increase of primary ribs (PR) in each whorl as diameter (D) increases: at D = 40 mm, PR = about 20; at D = 70 mm, PR = 26; at D = 100–140 mm, PR = 15–17 (per half a whorl). Narrow constrictions bordered by single ribs are fairly common. These specimens cannot be unequivocally compared with

any known species, and thus they are referred to as *Pavlovia* sp. B. It should be noted, however, the similarity in the coiling and in the character of ribbing of our specimens to poorly known representatives of British *Pavlovia* – such as the only known large specimen of *Pavlovia* (*Lydistratites*) *lyditicus* Buckman (see Buckman, 1922, pl. 353A; see also Cope, 1978, p. 490) from the Upper Lydite Bed of Buckinghamshire, and close forms known from upper part of the Portland Sand of Dorset – directly above the Albani Zone.

Genus *Virgatopavlovia* Cope, 1978

Type species *Virgatopavlovia fittoni* Cope, 1978

The name *Virgatopavlovia* was introduced for ammonites showing on their inner whorls sharp bifurcated ribs with closely spaced secondaries of the *Epipallasiceras* type, and "irregular ribbing frequently virgatotome, but also with polygyrate, bifurcate or simple ribs and intercalatory secondaries" on the outer whorl of macroconchs, and "mainly bifurcate ribs… but occasional polygyrate and simple ribs on the outer whorl of microconchs" (Cope, 1978, p. 515). The representatives of the genus have so far been described only from the Dorset coast, as well as north-eastern Scotland (Cope, 1978, 2015a, b) and the new discovery in central Poland represents the first occurrence of these ammonites outside the UK.

The characteristics of the inner whorls of the genus *Virgatopavlovia* indicates its close relationship to the genus *Epipallasiceras* (see Cope, 1978). The latter was originally interpreted as a subgenus of *Pavlovia* by Spath (1936, p. 29; see also Arkell *et al.*, 1957), but recently it has been treated as an independent genus because of its well-defined character of ornamentation and importance for correlation. The genus *Epipallasiceras* is "easily recognized by the highly characteristic bifurcation of its ribs into pairs of closely spaced secondaries" (Callomon, Birkelund, 1982, p. 355), and it is represented by several successive faunas in the East Greenland Boreal succession. Although the relation between *Epipallasiceras* and *Virgatopavlovia* remains unclear (see Cope, 1978, p. 524), it seems that the two are closely related: if *Epipallasiceras* is really a little younger than *Virgatopavlovia*, the former might have developed from the latter "by paedomorphic retention of its juvenile ornament" (Cope, 2015a). On the other hand, because both these genera seem to be at least partly time-equivalents (Callomon, Birkelund, 1982), but showing different palaeogeographical distribution, another kind of heterochrony (peramorphosis – hypermorphosis) may be also taken into account here to explain the connection between the two ammonite groups (cf. *e.g.* Landman, Geyssant, 1993).

Specimens attributed to the genus *Virgatopavlovia* from the Owadów–Brzezinki section generally show a large affinity to the more heavily ornamented representatives of the genus from the UK, such as the *V.* sp. nov. aff. *fittoni* of Cope (1978), which is especially similar to the newly established species *V. janeki* sp. nov. Another species *V. dembowskae* from the studied succession in Poland is stratigraphically younger and it has no direct counterpart in other areas.

Ammonites discussed of the genus *Virgatopavlovia* bear also some similarity to those of *Michalskia*, a genus known from central Russia. The latter differs, however, in the character of its inner whorls, which show regularly bifurcated ribs with widely spaced secondary branches of the *Pavlovia* type (cf. Mitta, 1993, pl. 18; cf. also Michalski, 1890).

Virgatopavlovia janeki sp. nov.

(Pl. 8: 6, Pl. 9: 1–2, Pl. 10: 1–2, Pl. 11, Pl. 12: 2, Pl. 13; Fig. 7)

1978. *Virgatopavlovia* sp. nov. aff. *fittoni* Cope; Cope, p. 521, pl. 56: 1.

Type material. – Holotype – macroconch (figured in Pl. 11) and five paratypes both macroconchs (Pl. 9: 1, Pl. 10: 1, Pl. 13) and microconchs (Pl. 8: 6, Pl. 10: 2); and ten other less-complete specimens (Pl. 9: 2, Pl. 12: 2), and a specimen (Pl. 14) referred to as *V.* aff. *janeki*.

Type locality. – Owadów–Brzezinki quarry at Sławno.

Type horizon. – Upper part of the *regularis* horizon and the whole *zarajskensis* horizon of the Zarajskensis Subzone of the Scythicus Zone; from the topmost part of the Pałuki Formation to the lower part of the Kcynia Formation – unit I of the Sławno Limestone Member.

Derivation of the name. – In memory of professor Jan Kutek – to his colleagues "Janek" – an eminent student of the Upper Jurassic ammonite faunas, and especially of the uppermost Jurassic ("Volgian") of central Poland.

Diagnosis. – Dimorphic: macroconchs attaining about a diameter of 180–190 mm, but sometimes even more (Pl. 13) when fully grown; microconchs possibly about 60–90 mm in diameter; the inner whorls showing widely spaced, sharp, bifurcate ribs with closely spaced, long secondaries. On the outer whorl in microconchs the ribs are biplicate and triplicate-polygyrate: on the outer whorl of macroconchs the ribs become more massive, triplicate with distinct polygyrate subdivision, and the lower branch is located at about one/third up the whorl side. At the end of the last whorl in macroconchs the simple ribs as well as the additional secondary ribs may appear preceding the aperture.

Description. – The species is represented by microconchs (diameter 60–90 mm) and macroconchs (180–190 mm, and possibly up to about 210 mm); the phragmocone/ body chamber boundary is recognized in a few specimens: at a diameter of about 40–60 mm in smaller forms, possibly microconchs, and at about 120–140 mm up to about 180 mm in macroconchs; the body chamber is about

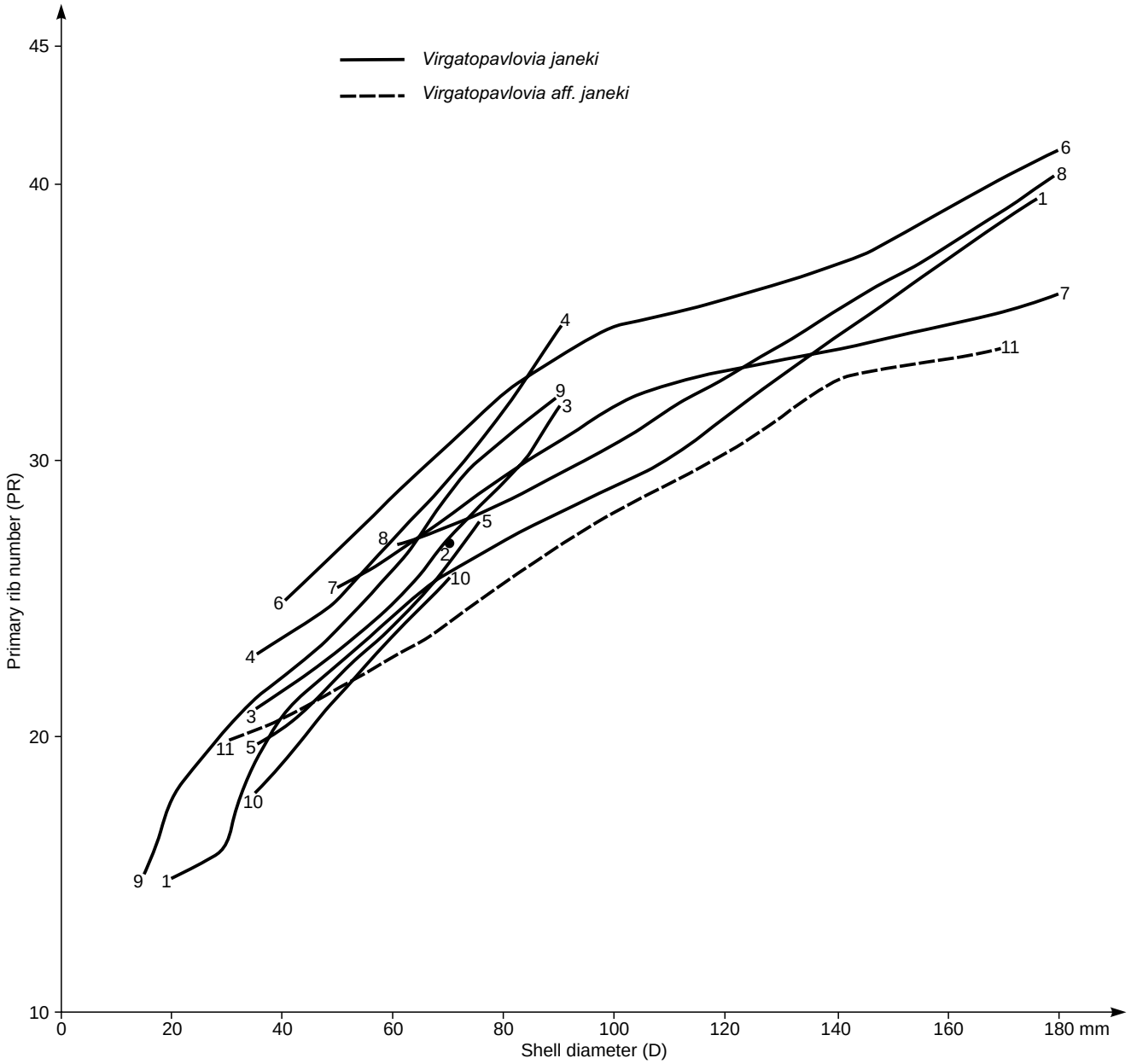

Fig. 7. Number of primary ribs (PR) against shell diameter (D) for *Virgatopavlovia janeki* sp. nov. and *V.* aff. *janeki*

V. janeki : 1 – specimen no. MWG UW ZI/78/032 (holotype, macroconch, Pl. 11); 2 – specimen no. MWG UW ZI/78/010 (paratype, microconch, Pl. 8: 6); 3 – specimen no. MWG UW ZI/78/011 (Pl. 9: 2); 4 – specimen no. MWG UW ZI/78/036 (paratype, microconch, Pl. 10: 2); 5 – specimen no. MUZ PIG AK.2.II.7 (?microconch, Pl. 12: 2); 6 – specimen no. MWG UW ZI/78/018 (paratype, macroconch, Pl. 9: 1); 7 – specimen no. MWG UW ZI/78/030 (paratype, macroconch, Pl. 10: 1); 8 – specimen no. MWG UW ZI/78/046 (paratype, macroconch, Pl. 13); 9 – specimen no. MWG UW ZI/78/015; 10 – specimen no. MWG UW ZI/78/007; 11 – *V.* aff. *janeki*, specimen no. MWG UW ZI/78/052 (Pl. 14).

one whorl in length. The coiling on the inner whorls of macroconchs and in microconchs is weakly involute to weakly evolute; on the outer whorl of macroconchs the coiling becomes moderately evolute (at D = 180–190 mm, Wh = 28.5–31.5; Ud equals about 43). A single specimen (Pl. 14) referred to as *V.* aff. *janeki* sp. nov. shows more evolute coiling in the middle and outer whorls (at D = 120–170 mm, Wh = 29.0–31.5, Ud = 44–47). The ribbing on the inner whorls in the species is rather distantly spaced, and the number of primary ribs grows with diameter; at D = 20–30 mm,

PR = 15–20; at D = 50–60 mm, PR = 22–28 (Fig. 7). The ribs are mostly biplicate, prorsiradiate with closely spaced long secondaries with a lower point of rib division, resembling somewhat those of the earliest Boreal *Epipallasiceras* – *E. rotundiformis* (Spath) (cf. Spath, 1936, pl. 19: 3a, b; see also Callomon, Birkelund, 1982, p. 355). Triplicate ribs may appear already at about 60 mm. The body chamber in microconchs shows the presence of constrictions, often bordered by single ribs; the final peristome is nowhere preserved. The middle and outer whorls of macroconchs show the presence of common triplicate ribs with polygyrate pattern, besides, there occur some biplicate ribs (the number of which in some specimens, especially from the lowest beds yielding the species (see Pl. 9: 1), may be quite large). The number of primary ribs on the outer whorl of macroconchs ranges about 34–40 at D = 170–190 mm. The presence of a final peristome is recognized in a few macroconch examples: shown by denser ribbing, appearance of single and biplicate ribs, as well as some intercalatory ribs and constrictions.

Discussion. – The species bears some resemblance to *Virgatopavlovia fittoni* and its possible dimorphic counterpart *V. hounstoutensis* (described by Cope, 1978); it differs, however, in having more distant ribbing on the inner whorls, in the presence of more massive ribs on the outer whorl, and in the larger final sizes of macroconchs. The large macroconch referred to as *Virgatopavlovia* sp. nov. aff. *fittoni* by Cope (1978, p. 521, pl. 56: 1) shows a marked similarity to the newly described species *V. janeki* sp. nov., and it is included in its synonymy.

Occurrence. – The specimens studied come from the upper part of the *regularis* horizon and the *zarajskensis* horizon of the Zarajskensis Subzone of the Scythicus Zone, in topmost part of the Pałuki Formation to the lower part of the Kcynia Formation – unit I of the Sławno Limestone Member. The species is known also from the middle part of the Fittoni Zone – from the Hounstout Marl and Hounstout Clay members of the uppermost Kimmeridge Clay of Dorset (Cope, 1978, text-fig. 11; see also synonymy herein).

Virgatopavlovia dembowskae sp. nov.
(Pl. 15: 1–3, Pl. 16: 1; Fig. 8)

2012. ?*Virgatites* sp., Kin, Błażejowski, p. 377, fig. 5B.

Type material. – Holotype – (figured in Pl. 16 : 1; wrongly referred in the past to ?*Virgatites* sp., see synonymy) and three paratypes (figured in Pl. 15: 1–3), and five less complete specimens.

Type locality. – Owadów–Brzezinki quarry at Sławno.

Type horizon. – Lower part the Virgatus Zone, the Gerassimovi Subzone; the "*Corbulomima* Limestones" (III) and the "Serpulite" (IV) units representing the middle and upper parts of the Kcynia Formation.

Derivation of the name. – In memory of Dr. Jadwiga Dembowska – a student of the uppermost Jurassic deposits and their ammonites in central and northern Poland.

Diagnosis. – Ammonites attaining usually about 125–130 mm in diameter when fully grown, but sometimes larger, finally attaining about 150 mm. The inner whorls showing widely spaced, sharp primaries, bifurcate, with closely spaced secondaries. On the outer whorl, the ribs are biplicate and triplicate – with distinct polygyrate form – the lower branch of subdivision is located at about half of the whorl height. At the end of the last whorl the ribs become crowded, and constrictions occur commonly.

Description. – The final diameter is at about 125–130 mm (in one specimen at about 150 mm in final diameter); the phragmocone/body chamber boundary is recognized in a few specimens only: at about 60 mm, and about 90 mm diameter; body chamber is about one whorl in length. The coiling on inner whorls is involute; on the outer whorl coiling becomes markedly evolute (at D = 100–130–mm, Wh = 28–34, Ud = 43–49, but some specimens shows less evolute coiling – *e.g.* at D = 125 mm, Wh = 33, Ud = 35.5). The ribbing of inner whorls is distant, and the number of primary ribs is growing with diameter; at D = 20–30 mm, PR = 17–24; at D = 50–60 mm, PR = 22–27. The ribs are prorsiradiate, sharp, biplicate, rarely triplicate, with closely spaced secondaries and with furcation point placed about mid-whorl or even somewhat higher on the whorl flank. The ribbing resembles that of the Boreal *Epipallasiceras* of the *E.* aff. *costata* Spath group (*cf.* Surlyk *et al.*, 1973, pl. 2: 2a, b; Birkelund, Pedersen, 1980, figs 5–6; Callomon, Birkelund, 1982, p. 355, with given references). Triplicate ribs become very common on the outer whorl, where some biplicate ribs can also occur; the ribbing is often somewhat flexuous, and triplicate ribs are polygyrate – with lower secondary rib splitting off the main stem about the mid-height of whorl, and an upper secondary rib appearing much higher at about 2/3 up the whorl height. The number of primary ribs (PR) reaches about 28 to about 40 at D = 100–150 mm (Fig. 8). The proximity of the final peristome is marked by crowding of ribs – the appearance of biplicate (sometimes also triplicate) and single ribs, and the occurrence of constrictions on a short part of the whorl.

Discussion. – The species *V. dembowskae* sp. nov. is very close to *V. janeki* sp. nov., but it differs in having different final sizes – though all belong to a single size category (and morph) when compared with those of *V. janeki* sp. nov., which is represented by smaller microconchs and larger macroconchs. Moreover, *V. dembowskae* sp. nov. shows sharper ribbing also on the outer whorl, and a point of rib furcation higher on the whorl. Interesting comparisons are also possible between *V. dembowskae* sp. nov. and some larger Boreal specimens of the *Epipallasiceras* aff. *costata*

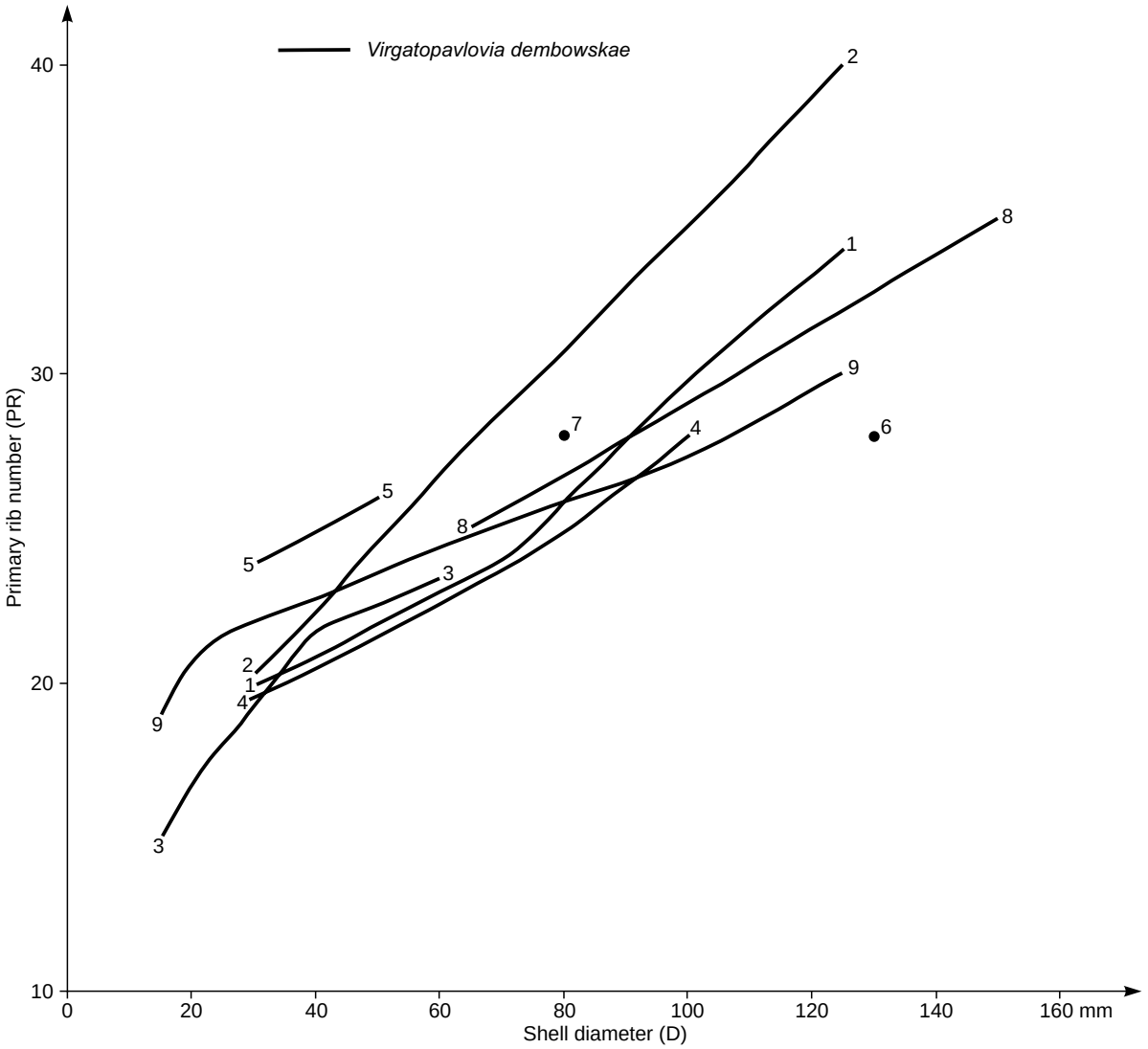

Fig. 8. Number of primary ribs (PR) against shell diameter (D) for *Virgatopavlovia dembowskae* sp. nov.

1 – specimen no. MUZ PIG MK2.II.17 (holotype, Pl. 16: 1); 2 – specimen no. MWG UW ZI/78/028 (paratype, Pl. 15: 1); 3 – specimen no. MWG UW ZI/78/075 (paratype, Pl. 15: 2); 4 – MUZ PIG AK2.II.3 (paratype, Pl. 15: 3); 5 – specimen no. MWG UW ZI/78/082; 6 – specimen no. MWG UW ZI/78/087; 7 – specimen no. MWG UW ZI/78/092; 8 – specimen no. MWG UW ZI/78/093; 9 – specimen no. MUZ PIG AK2.II.15.

Spath group (see Birkelund, Pedersen, 1980, fig. 6) which show their outer whorls, attaining about an 80 mm diameter, with the occurrence of triplicate ribs very similar to those observed in the Polish specimens studied.

Some resemblance between *V. dembowskae* and a form referred to as *Acuticostites bitrifurcatus* Mitta (see Mitta, 1993, p. 77–79, pl. 12: 1, 4) from Panderi Zone of the "Middle Volgian" of European Russia may be also noticed. This Russian species shows the presence of triplicate ribs with polygyrate subdivision on the outer whorl somewhat similar to those of *V. dembowskae*, but the characteristics of the inner whorls of the two species are quite different. The genus *Acuticostites* was based on a smaller-sized species *A. acuticostatus* which shows very sharp ribbing in the inner whorls, consisting of sparsely placed single and biplicate, almost rectiradiate or weakly prorsiradiate, ribs (Michalski, 1890, pl. 5: 2–5), as opposite to *V. dembowskae* where the ribs are strongly prorsiradiate. The presence of peri-umbilical swellings in the innermost whorls of *Acuticostites* indicates its very close affinity to *Virgatites* (Michalski, 1890, p. 93–97, pl. 5: 3–4), and its ornament differs markedly from that developed in *Virgatopavlovia*.

Occurrence. – The species occurs in the lower part the Virgatus Zone – the Gerassimovi Subzone; the "*Corbulomi-*

ma Limestones" (III) and the "Serpulite" (IV) units representing the middle and upper parts of the Kcynia Formation at Owadów–Brzezinki.

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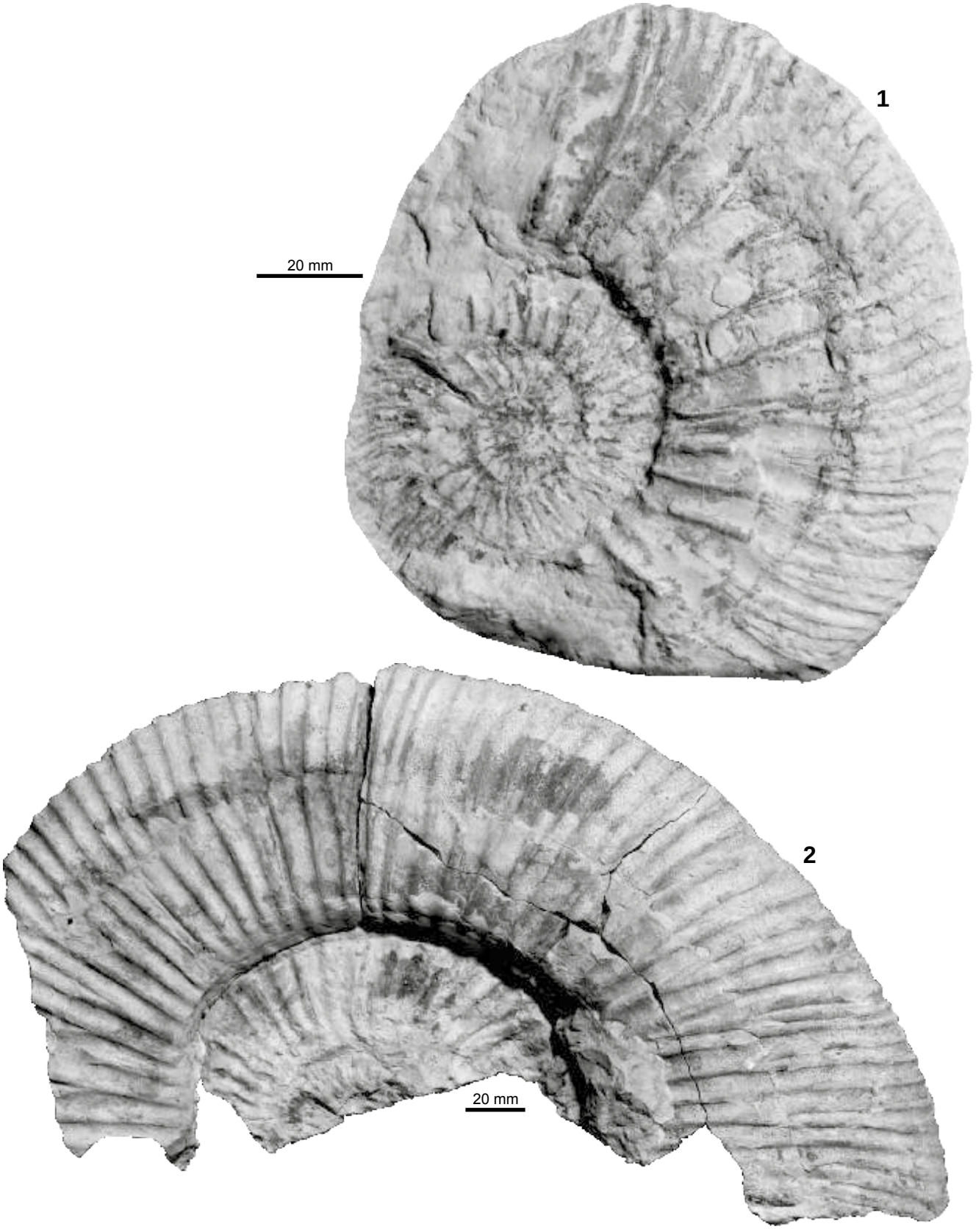
PLATE 1

Fig. 1. *Zaraiskites regularis* Kutek, phragmocone, Pałuki Fm., specimen no. MWG UW ZI/78/001.

Fig. 2. *Zaraiskites regularis* Kutek, macroconch, fragment of outer whorl preserved is the body chamber, Pałuki Fm., specimen no. MWG UW ZI/78/012.



Bronisław A. MATYJA, Andrzej WIERZBOWSKI — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

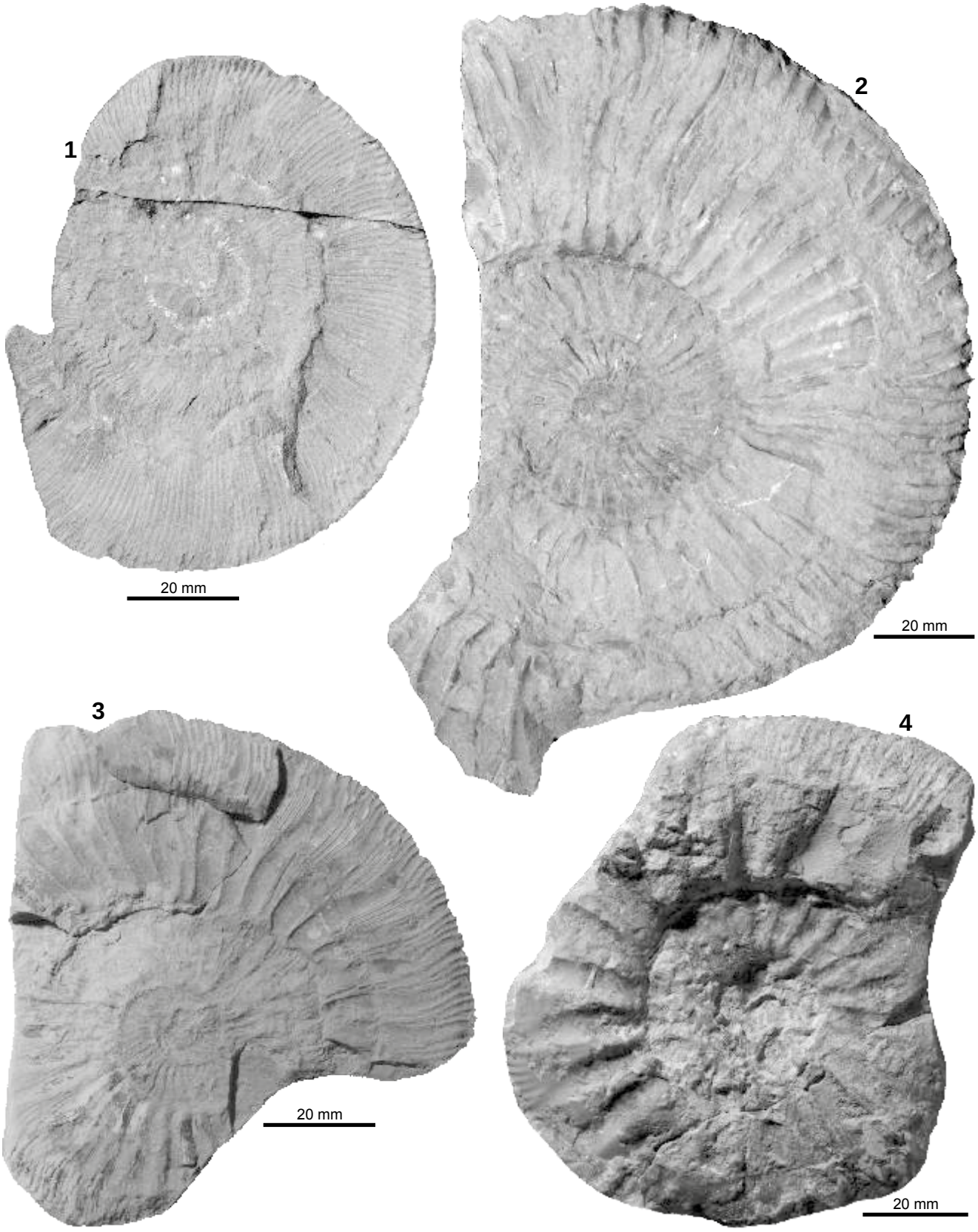
PLATE 2

Fig. 1. *Zaraiskites regularis* Kutek, Pałuki Fm.,specimen no. MWG UW ZI/78/097.

Fig. 2. *Zaraiskites regularis* Kutek, macroconch, phragmocone, Pałuki Fm., specimen no. MWG UW ZI/78/098.

Fig. 3. *Zaraiskites regularis* Kutek, microconch, Pałuki Fm., specimen no. MWG UW ZI/78/099.

Fig. 4. *Virgatites gerassimovi* Mitta, phragmocone, Kcynia Fm., unit IV, specimen no. MWG UW ZI/78/085.



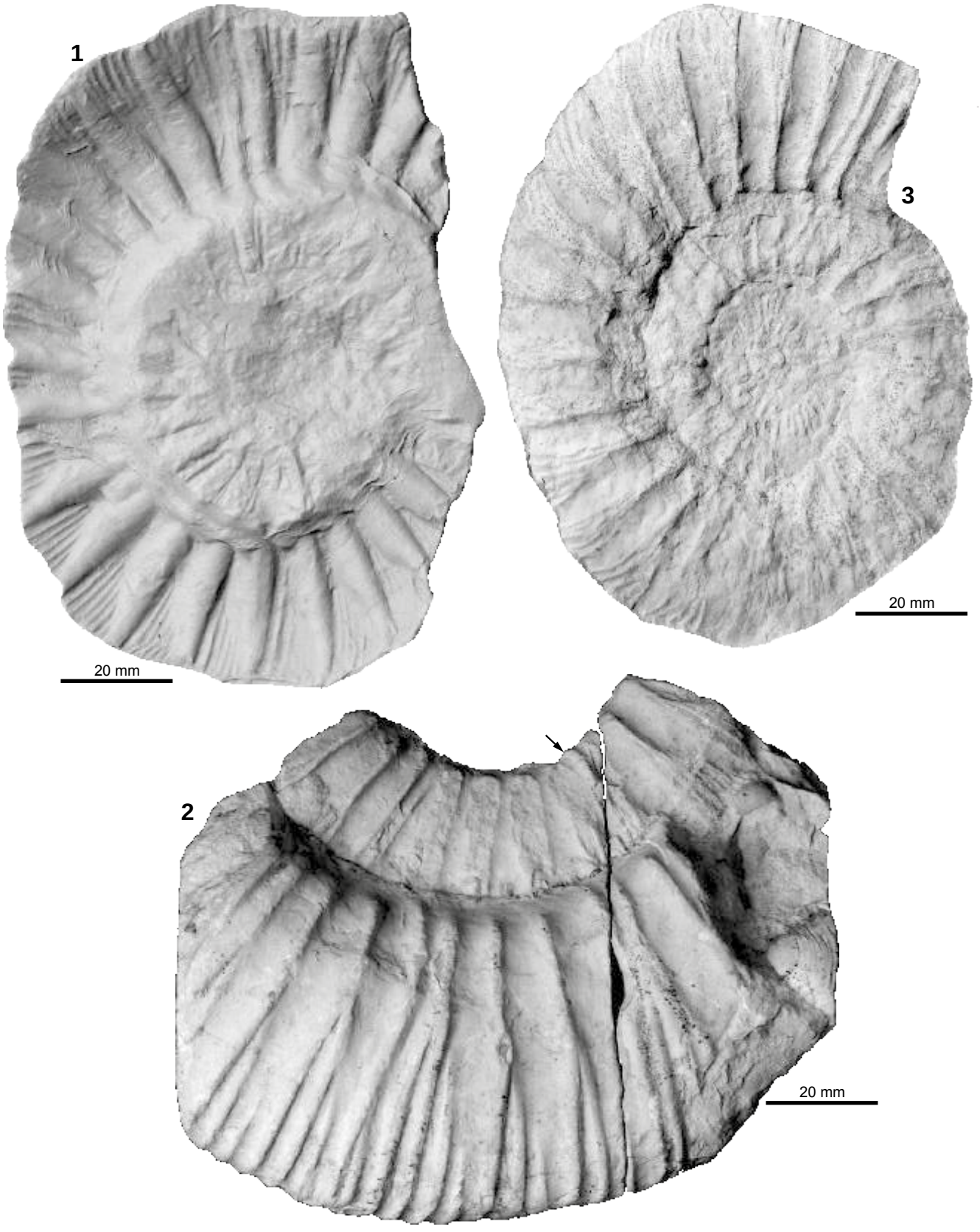
Bronisław A. MATYJA, Andrzej WIERZBOWSKI — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

PLATE 3

Fig. 1. *Zaraiskites zarajskensis* (Michalski), Kcynia Fm., unit I, specimen no. MWG UW ZI/78/037, plaster cast of the negative.

Fig. 2. *Zaraiskites zarajskensis* (Michalski), ?macroconch, phragmocone/body chamber boundary at about 80 mm in inner whorl, (arrowed), Kcynia Fm., unit I, specimen no. MWG UW ZI/78/038.

Fig. 3. *Virgatites gerassimovi* Mitta, fully grown specimen, Kcynia Fm., unit III, specimen no. MUZ PIG AK2.II.14.



Bronisław A. MATYJA, Andrzej WIERZBOWSKI — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

PLATE 4

Fig. 1. *Zaraiskites zarajskensis* (Michalski), macroconch, phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit I, specimen no. MUZ PIG AK2.II.5.

Fig. 2. *Virgatites gerassimovi* Mitta, Kcynia Fm., unit III, specimen no. MWG UW ZI/78/055, plaster cast of the negative.

Bronisław A. MATYJA, Andrzej WIERZBOWSKI — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

PLATE 5

Fig. 1. *Zaraiskites pommerania* (Arkell), fully grown specimen, Pałuki Fm., specimen no. MWG UW ZI/78/014.

Fig. 2. *Zaraiskites pommerania* (Arkell), fully grown specimen, phragmocone/body chamber boundary is arrowed, Pałuki Fm., specimen no. MWG UW ZI/78/019.

Fig. 3. *Zaraiskites pommerania* (Arkell), phragmocone/body chamber boundary is arrowed, Pałuki Fm., specimen no. MWG UW ZI/78/061.

Bronisław A. MATYJA, Andrzej WIERZBOWSKI — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

PLATE 6

Fig. 1. *Zaraiskites lewinskii* sp. nov., paratype, phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit I, specimen no. MWG UW ZI/78/039.

Fig. 2. *Zaraiskites lewinskii* sp. nov., paratype, fully grown specimen, phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit I, specimen no. MWG UW ZI/78/047.

Fig. 3. *Zaraiskites lewinskii* sp. nov., paratype, phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit I, specimen no. MWG UW ZI/78/096.

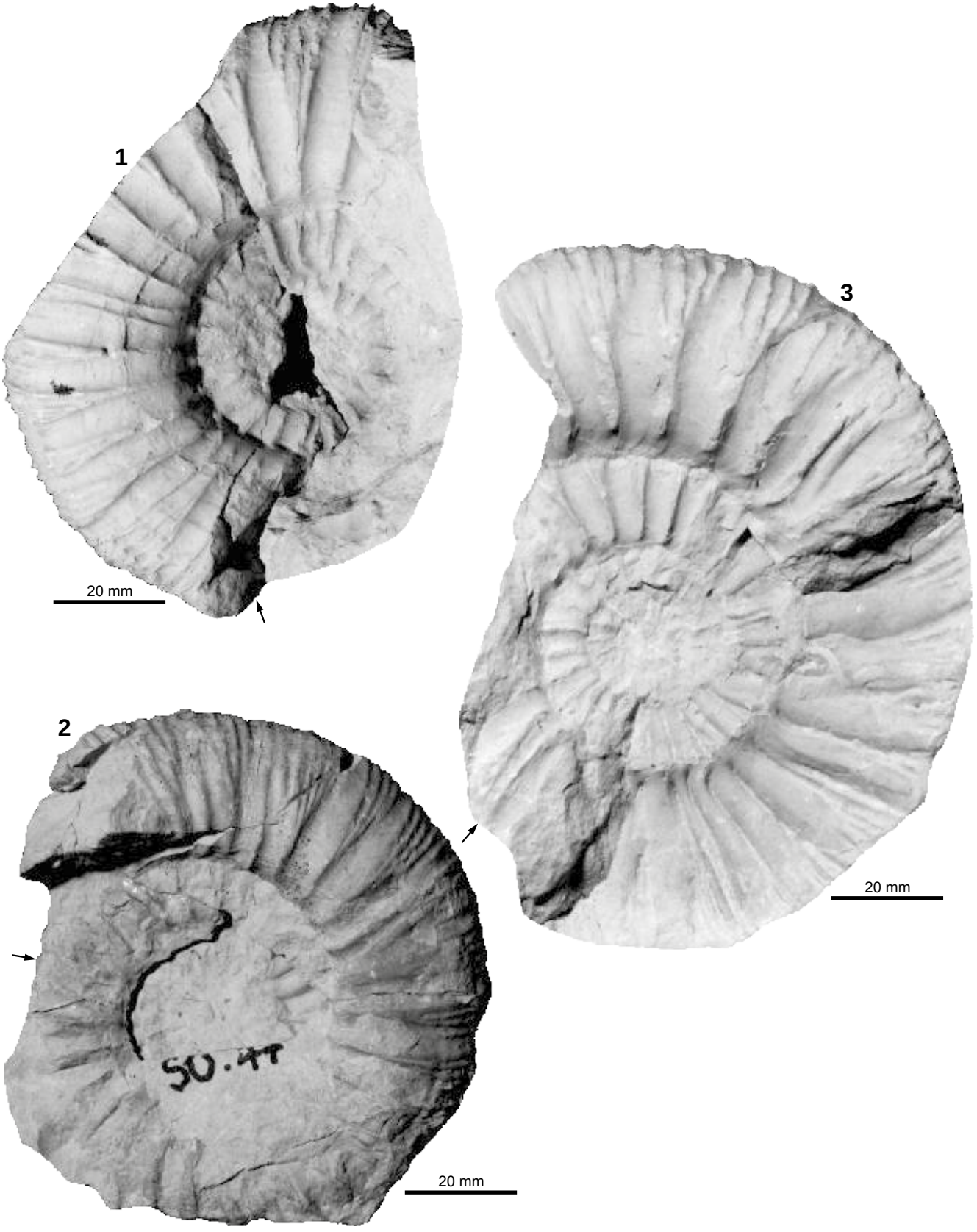


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PLATE 7

Fig. 1. *Zaraiskites lewinskii* sp. nov., holotype, Kcynia Fm., unit I, specimen no. MUZ PIG AK2.II.2.

Fig. 2. *Zaraiskites lewinskii* sp. nov., paratype, fully grown specimen, phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit I, specimen no. MWG UW ZI/78/008.

Bronisław A. MATYJA, Andrzej WIERZBOWSKI — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

PLATE 8

Fig. 1. *Zaraiskites lewinskii* sp. nov., paratype, Kcynia Fm., unit I, specimen no. MUZ PIG AK2.II.6.

Fig. 2. *Virgatites pusillus* (Michalski), Kcynia Fm., unit III, specimen no. MWG UW ZI/78/059.

Fig. 3. *Virgatites pusillus* (Michalski), phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit III, specimen no. MWG UW ZI/78/073.

Fig. 4. *Virgatites pusillus* (Michalski), Kcynia Fm., unit III, specimen no. MWG UW ZI/78/091, plaster cast of the negative.

Fig. 5. *Virgatites* aff. *pusillus* (Michalski), intermediate between *V. gerassimovi* and *V. pusillus*, Kcynia Fm., unit IV, specimen no. MWG UW ZI/084.

Fig. 6. *Virgatopavlovia janeki* sp. nov., paratype, microconch, Pałuki Fm., specimen no. MWG UW ZI/78/010.

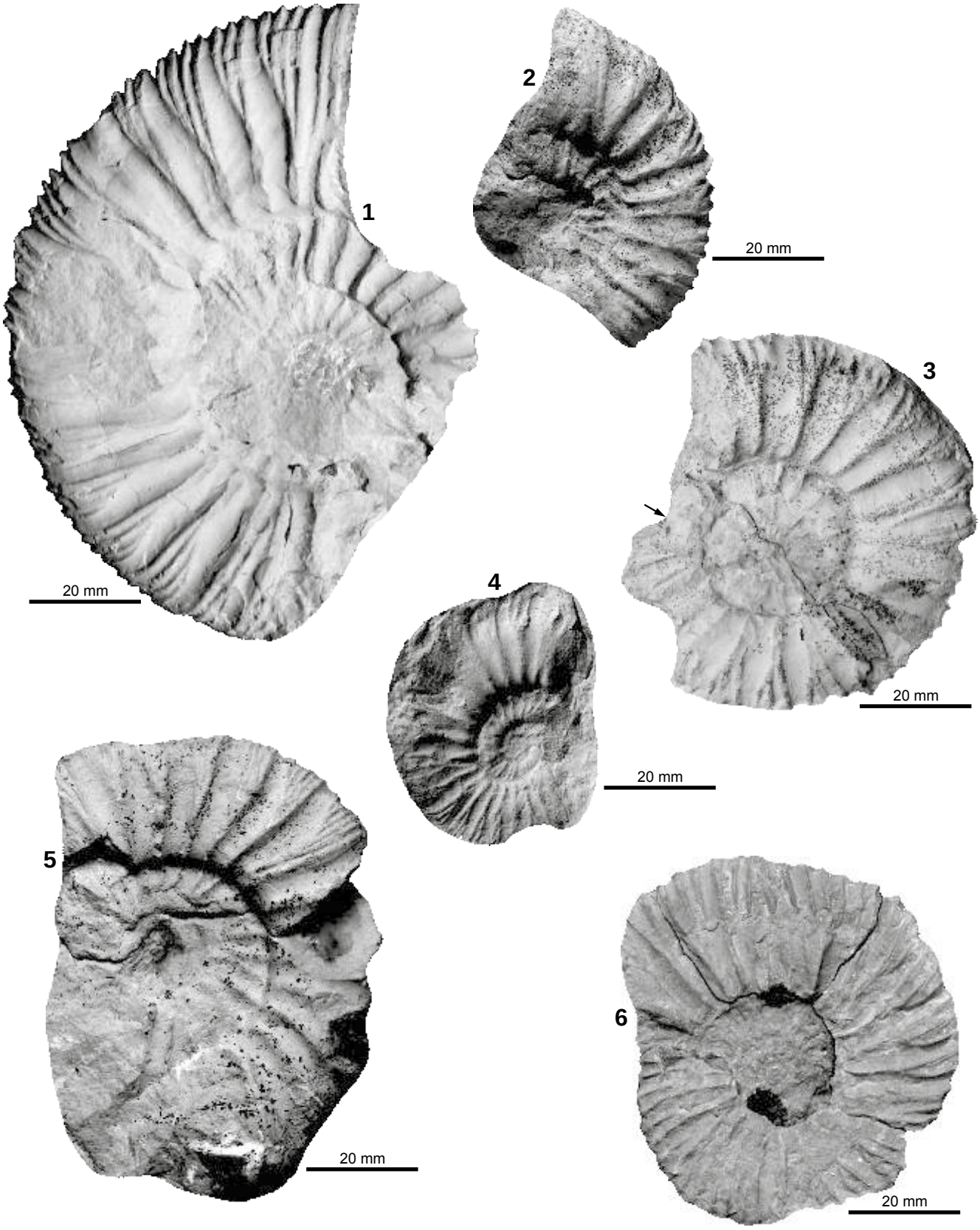

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PLATE 9

Fig. 1. *Virgatopavlovia janeki* sp. nov., paratype, macroconch, phragmocone/body chamber boundary is arrowed, Pałuki Fm., specimen no. MWG UW ZI/78/018.

Fig. 2. *Virgatopavlovia janeki* sp. nov., Pałuki Fm., specimen no. MWG UW ZI/78/011.

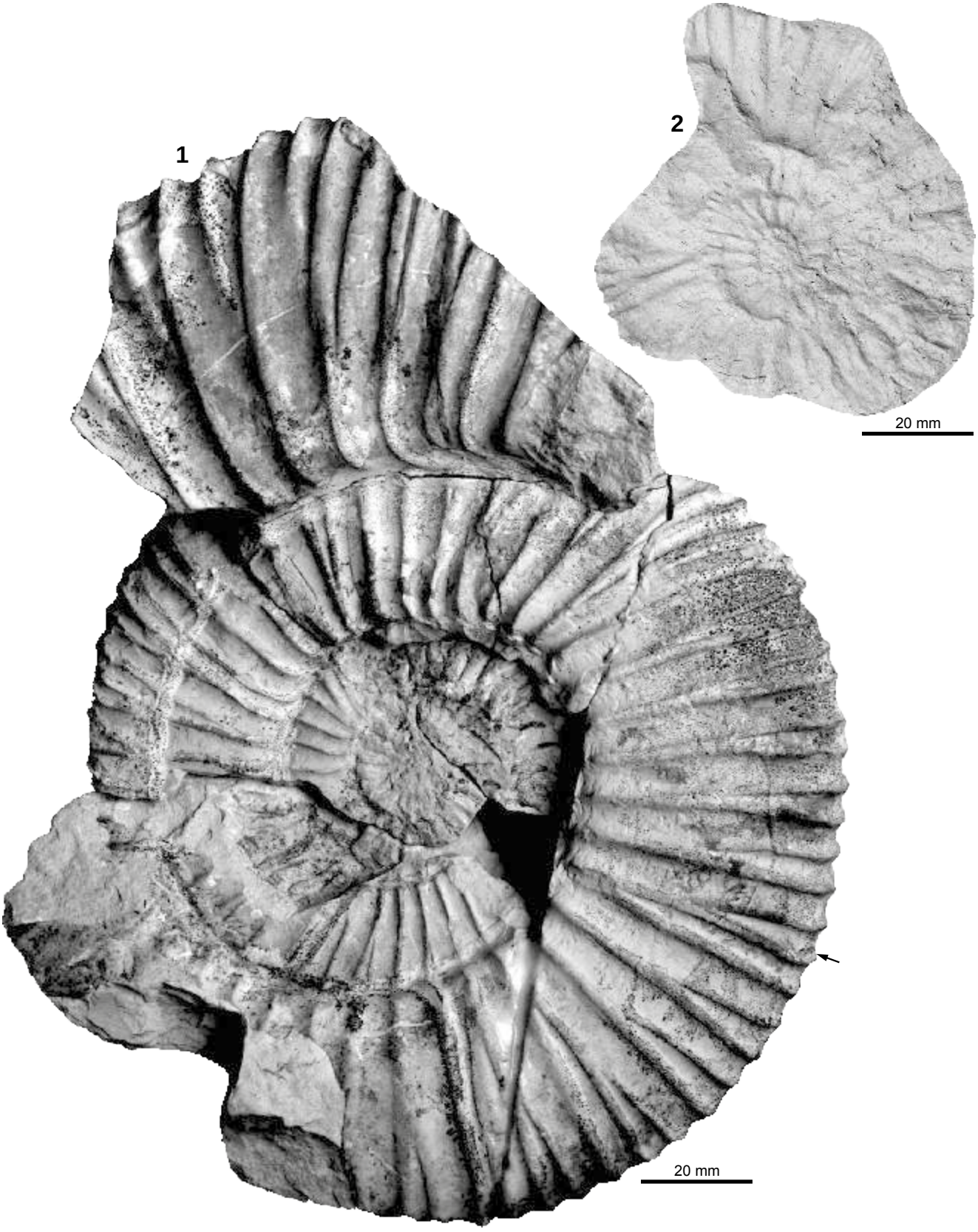

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PLATE 10

Fig. 1. *Virgatopavlovia janeki* sp. nov., paratype, macroconch, preserved part of the outer whorl represents body chamber, Kcynia Fm., unit I – base, specimen no. MWG UW ZI/78/030.

Fig. 2. *Virgatopavlovia janeki* sp. nov., paratype, microconch, Pałuki Fm, specimen no. MWG UW ZI/78/036.

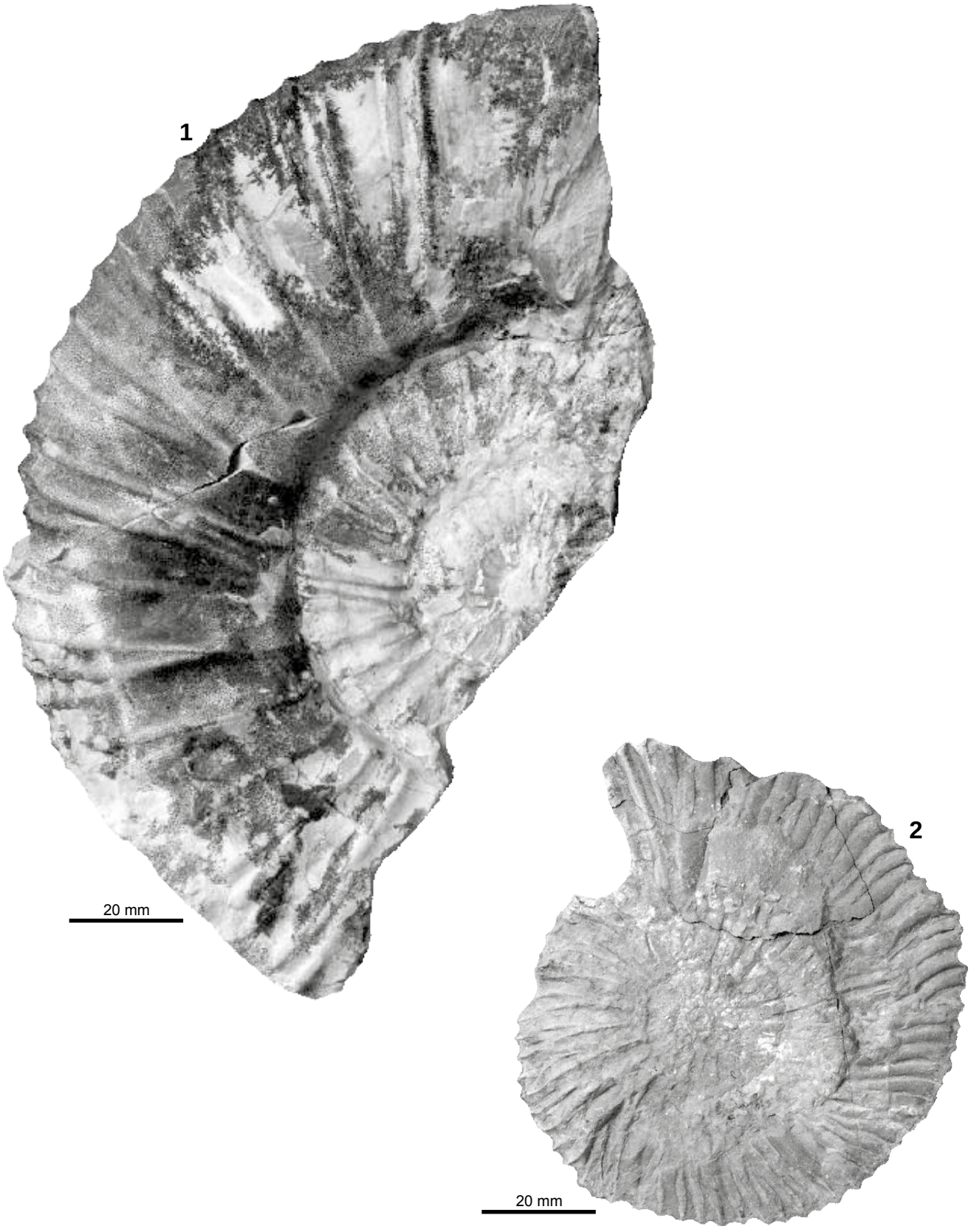

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PLATE 11

Fig. 1. *Virgatopavlovia janeki* sp. nov., holotype, macroconch, phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit I, specimen no. MWG UW ZI/78/032.

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PLATE 12

Fig. 1. *Pavlovia* sp. A, phragmocone with initial part of the body chamber (arrowed), Kcynia Fm., unit I – middle part, specimen no. MWG UW ZI/78/006.

Fig. 2. *Virgatopavlovia janeki* sp. nov., ?microconch, Kcynia Fm., unit I , specimen no. MUZ PIG AK2.II.7.

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PLATE 13

Fig. 1. *Virgatopavlovia janeki* sp. nov., paratype, macroconch, phragmocone with initial part of the body chamber (arrowed), Kcynia Fm., unit I, specimen no. MWG UW ZI/78/046.

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PLATE 14

Fig. 1. *Virgatopavlovia* aff. *janeki* sp. nov., macroconch, phragmocone/body chamber boundary is arrowed, Kcynia Fm., unit I, specimen no. MWG UW ZI/78/052.

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PLATE 15

Fig. 1. *Virgatopavlovia dembowskae* sp. nov., paratype, preserved part of outer whorl is body chamber, Kcynia Fm., unit III, specimen no. MWG UW ZI/78/028.

Fig. 2. *Virgatopavlovia dembowskae* sp. nov., paratype, Kcynia Fm., unit III, bed D_{12}, specimen no. MWG UW ZI/78/075.

Fig. 3. *Virgatopavlovia dembowskae* sp. nov., paratype, specimen is somewhat obliquely deformed, preserved part of outer whorl is body chamber, Kcynia Fm., unit III, specimen no. MUZ PIG AK2.II.3.

Fig. 4. *Pavlovia pavlovi* (Michalski), fully grown specimen, Pałuki Fm., specimen no. MWG UW ZI/78/102.

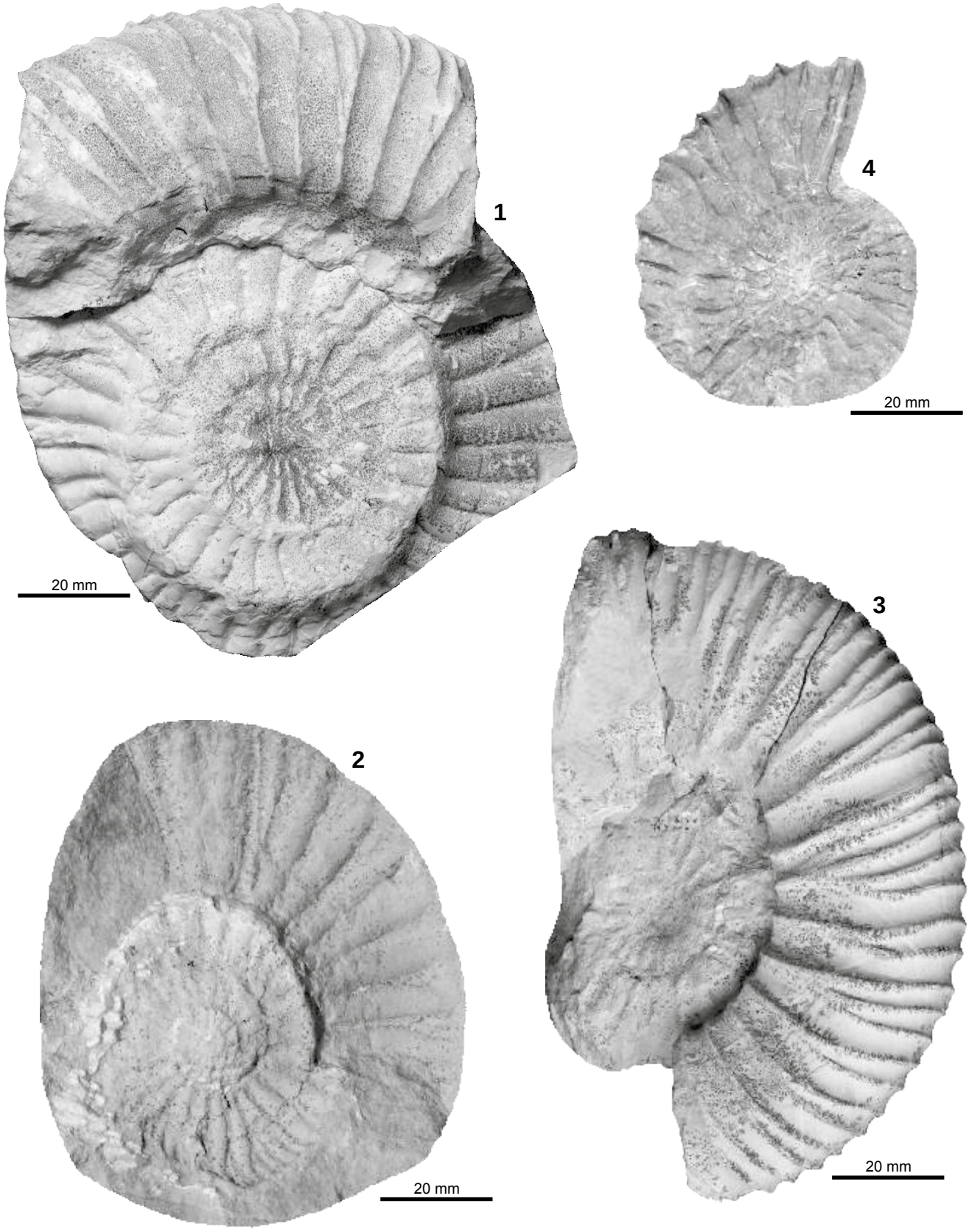

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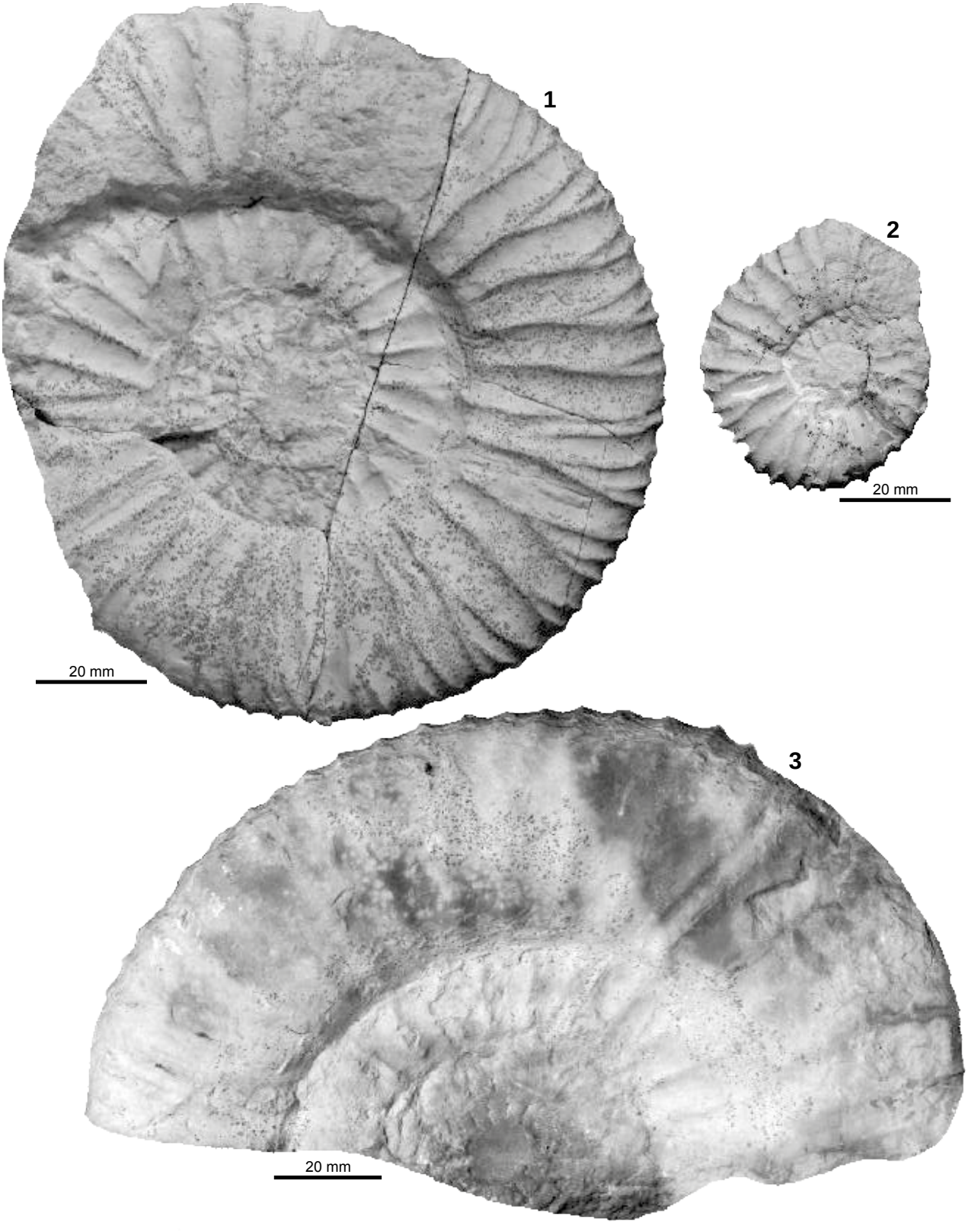
PLATE 16

Fig. 1. *Virgatopavlovia dembowskae* sp. nov., holotype, Kcynia Fm., unit III, specimen no. MUZ PIG AK2.II.17.

Fig. 2. *Pavlovia pavlovi* (Michalski), fully grown specimen, Kcynia Fm., unit I, specimen no. MWG UW ZI/78/080.

Fig. 3. *Pavlovia* sp. B., preserved part of outer whorl is body chamber, Kcynia Fm., unit III, specimen no. MUZ PIG AK2.II.16.



Bronisław A. MATYJA, Andrzej WIERZBOWSKI — Ammonites and ammonite stratigraphy of the uppermost Jurassic (Tithonian) of the Owadów–Brzezinki quarry (central Poland)

PLATE 17

Fig. 1. *Pavlovia* sp. A., phragmocone/body chamber boundary is arrowed, Pałuki Fm., specimen no. MWG UW ZI/78/054.

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