Frasnian Atrypida (Brachiopoda) from Silesia (Poland) and the age of the eo-Variscan collision in the Sudetes

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ABSTRACT
Frasnian (Late Devonian) Atrypida (Brachiopoda) from the Świebodzice Depression in the Sudetes (Silesia, south-western Poland) are revised. Three species are recognised. *Kyrtatrypa barnimi* n. sp. is the first described Late Frasnian species of the genus and one of the latest representatives of the genus before the atrypide extinction at the Frasnian-Famennian boundary. *Pseudogruenewaldtia tschernyschewi* Rzhonsnitskaya, 1960 is described for the first time outside the type area of the species, the Timan Mts. It allows to date the entire fauna to the Late Frasnian. *Spinatrypa mariaetheresiae* n. sp. is similar to coeval *S. lambermontensis* Mottequin, 2003 and *S. rossica* Rzhonsnitskaya *in* Rzhonsnitskaya *et al.*, 1998 in having a high tongue (low in most representatives of the genus) but differs from them in ornamentation density. This species is represented by two morphotypes; an analogous dimorphism was described in some *Spinatrypina* Rzhonsnitskaya, 1964. A synoptic table of Devonian atrypides from the Sudetes is given. At present, given the lack of conodonts and unclear status of other diagnostic macrofauna, atrypide brachiopods are the best time markers giving a pre-Famennian *terminus ante quem* for the eo-Variscan collision of Bohemia and Saxothuringia.

KEY WORDS
Brachiopoda,
Atrypida,
Sudetes,
Devonian,
Frasnian,
Variscan orogeny,
new species.

RÉSUMÉ
Atrypides (Brachiopodes) frasniens de la Silésie (Pologne) et l'âge de la collision éo-varisque dans les Sudètes.
La révision systématique des brachiopodes atrypides du Frasnien (Dévonien supérieur) de la Dépression de Świebodzice dans les Sudètes (Silésie, sud-ouest de la Pologne) conduit à reconnaître trois genres et trois espèces. *Kyrtatrypa barnimi* n. sp. est la première espèce du genre décrite du Frasnien supérieur et en est l'un des derniers représentants avant l'extinction des atrypides à la limite Frasnien-Famennien. *Pseudogruenewaldtia tschernyschewi* Rzhonsnitskaya, 1960 est décrite pour la première fois en dehors de ses localités-types dans le Timan. Sa présence permet de dater la faune entière du Frasnien supérieur. *Spinatrypa mariaetheresiae* n. sp. ressemble aux espèces contemporaines *S. lambermontensis* Mottequin, 2003 and *S. rossica* Rzhonsnitskaya *in* Rzhonsnitskaya *et al.*, 1998 par une languette prononcée (peu importante chez la majorité des représentants du genre) mais elle en diffère par la densité de l'ornementation. Cette espèce possède deux morphotypes, situation analogue au dimorphisme décrit chez certaines *Spinatrypina* Rzhonsnitskaya, 1964. Un tableau synoptique résume la distribution des atrypides dans le Dévonien des Sudètes. Étant donné l'absence de conodontes et les doutes au sujet de l'âge des autres espèces de la macrofaune, les brachiopodes atrypides donnent actuellement la meilleure datation – un *terminus ante quem* pré-famennien – de la collision éo-varisque de la Bohême avec la Saxo-Thuringie.

MOTS CLÉS
Brachiopodes,
Atrypides,
Sudètes,
Dévonien,
Frasnien,
orogenèse varisque,
espèces nouvelles.

INTRODUCTION

Geotectonic setting of the fauna

The Sudetes (or Sudeten Mountains, Polish and Czech: Sudety, German: Sudeten), geographically a mountain range on the border of Silesia (Poland) and Bohemia (Czech Republic) and geologically the north-eastern edge of the Bohemian Massif (Fig. 1A, B), are composed of a mosaic of previously independent geologic units (Fig. 1C) (Cymerman 1998, 2000; Żelaźniewicz 1995, 1997; Franke & Żelaźniewicz 2000; Mazur *et al.* 2006; Halamski & Racki 2005 provided a series of stratigraphic columns). Metamorphic rocks are onlapped by Late Devonian to Carboniferous sedimentary basin sequences (McCann *et al.* 2008: 496). One of them, the Świebodzice Depression (Bełka & Narkiewicz 2008) yielded a relatively well preserved Frasnian brachiopod fauna described by Dames (1868) and Gunia (1962, 1968). The aim of the present paper is to revise the representatives of the order Atrypida occurring in this area, to discuss other occurrences of atrypide brachiopods in the Sudetes, and to point out their value as time-markers of the eo-Variscan collision between Bohemia and Saxo-Thuringia.

The Devonian of the Sudetes

In the Sudetes, Devonian macrofaunas are relatively rare due to extensive Variscan metamorphism (Franke & Żelaźniewicz 2000). Poorly preserved metamorphosed Middle Devonian corals occur in Mały Bożków in the Kłodzko Metamorphic Complex (further, Kłodzko Unit) (Hladil *et al.* 1999). Late Devonian faunas are known only from the Świebodzice Depression, the Bardo Unit (or Bardo Structure), and the Kłodzko Unit along its tectonic contact with the Bardo Structure. Frasnian corals, brachiopods, and molluscs were reported from several localities of the Świebodzice Depression (Dames 1868; Gunia 1962, 1966, 1968). Famennian ammonoids, corals, and (poorly preserved) brachiopods occur in the classic local-

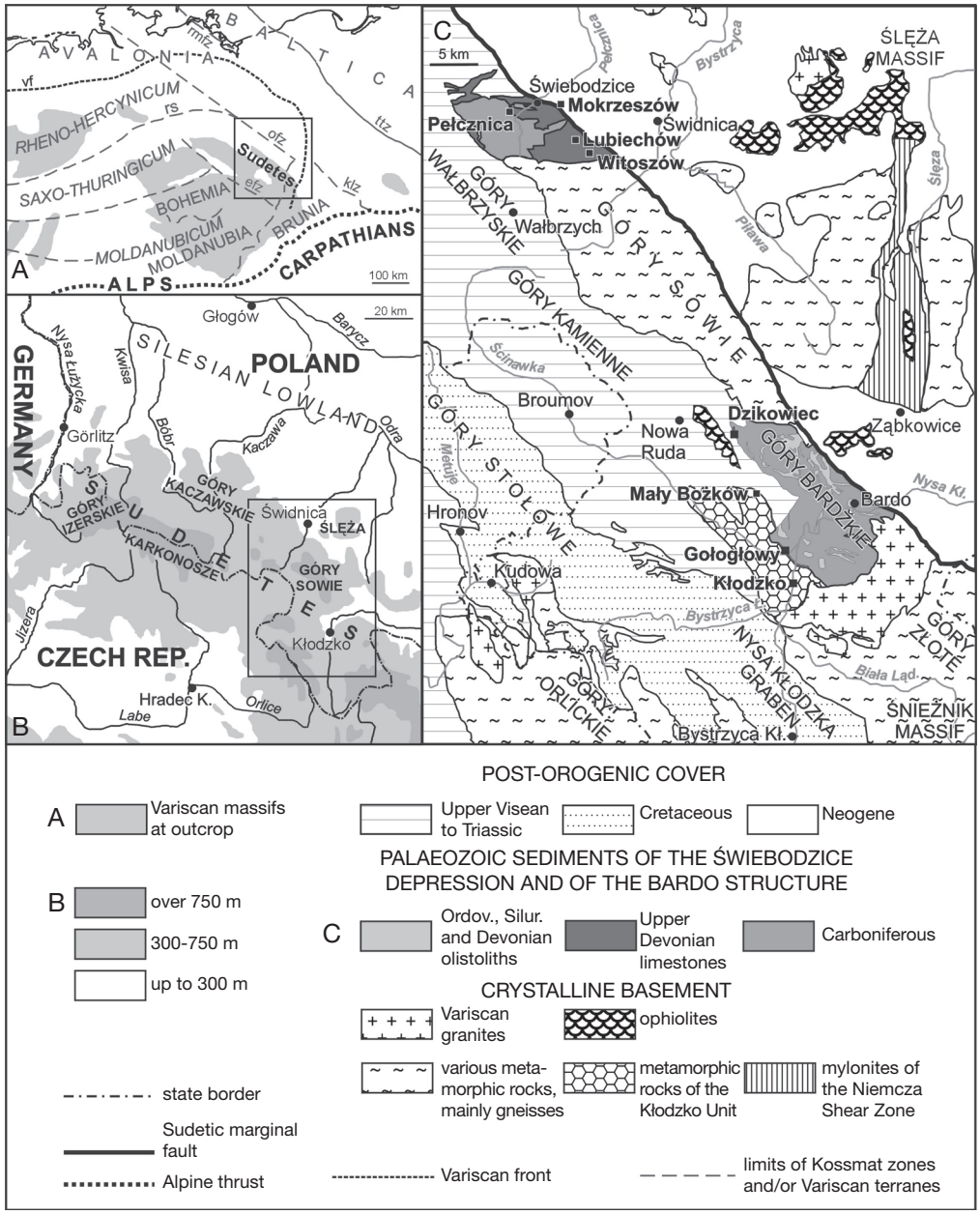

Fig. 1. — Geological setting of the studied fauna. Simplified, modified, and redrawn after Romer (1960), Kodym (1966), Sawicki (1967), Pharaoh (1999), Franke & Żelaźniewicz (2000), Aleksandrowski & Mazur (2002), Haydukiewicz & Muszer (2002) and Żelaźniewicz (2005): **A**, structural scheme of the Variscan Europe; terranes in Roman capitals; Kossmat zones in Italic capitals; the rectangle denotes the area shown in B; **B**, topographic map of the Sudetes; the rectangle denotes the area shown in C; **C**, schematic geological map of the central part of the Sudetes. Mountain Ranges and other geomorphologic units in full capitals, rivers italicised, localities discussed in the text in boldface, other town names in Roman characters. Abbreviations (tectonic limits): **efz**, Elbe fault zone, **klz**, Kraków-Lubliniec zone; **ofz**, Odra fault zone; **rmfz**, Rømø-Møn fracture zone; **rs**, Rheic suture; **ttz**, Teisseyre-Tornquist zone; **vf**, Variscan front.

ity of Dzikowiec (Ebersdorf; Bardo Unit) (von Buch 1839; Tietze 1871; Schindewolf 1937; Lewowicki 1959; Berkowski 2002 and references therein; Dzik 2006). Frasnian brachiopod faunas have also been reported from Gołogłowy and Kłodzko, two localities belonging to the Kłodzko Unit (Bederke 1924; Oberc 1957; Gunia 1977).

This study is based in large part on re-description of samples from the Świebodzice Depression kept in the Museum of Natural Sciences in Berlin and at the Wrocław University. They have been collected by Th. Otto, Wilhelm Barnim Dames, Tadeusz Gunia, and (additionally) Ferdinand Roemer. No atrypid material from the Bardo Structure (neither this of Erich Bederke nor that of Tadeusz Gunia) could have been traced either in Wrocław (with the rest of Bederke's collection) or in Berlin. Those specimens are considered lost, and consequently could not be revised in detail; corresponding occurrences of atrypide brachiopods are briefly discussed at the end of the paper. New material could be found in Mokrzeszów (Świebodzice Depression) only (courtesy of Kamil Pluta).

The Świebodzice Depression is interpreted as a Variscan synorogenic basin and its stratigraphical sequence is entirely composed of Upper Devonian to Lower Carboniferous clastics containing limestone lenses and pebbles (Gunia 1968; Teisseyre 1968; Stupnicka 1997; Kulczyński & Burliga 2004; Bełka & Narkiewicz 2008). Atrypides were reported from the following localities: Mokrzeszów (formerly Oberkunzendorf; the main locality), Witoszów Górny, Pełcznica, and Lubiechów.

In Mokrzeszów a large limestone lens within the Pogorzała Formation (Porębski 1981) was once quarried. Since 1870 the outcrop (50°49'30"N, 16°21'42"E; locality 15 sensu Gunia 1968) is partially flooded, wherefore it is usually referred to as "the lake Daisy" (see detailed description by Porębski 1981: 143-144), now a nature reserve (Klimko *et al.* 2001; Szczęśniak 2004) and a geotouristic site (Ihnatowicz *et al.* 2011). The lower part of the section is constituted by massive limestone with rare and fragmentary corals. It is overlaid by alternating limestone and marl beds that yielded rich fauna and flora, including algae (*Sphaerocodium zimmermanni* Rothpletz, 1911), receptaculitids, foraminifers, corals (e.g., *Sudetia* Różkowska, 1960, *Tabulophyllum* Fenton & Fenton, 1924, *Disphyllum* de Fromentel, 1861), gastropods, bivalves, cephalopods, and numerous brachiopods (Dames 1868; Dybowski 1873; Grocholski 1969; Gunia 1962, 1966, 1968; Różkowska 1962, 1979; Różkowska & Fedorowski 1972; Porębski 1981; Schröder 2002). The largest and the best preserved part of the studied material comes from the higher (marly) part of the section. At present not more than 20 m of limestone is cropping out in that locality (K. Pluta, pers. comm. November 2010).

On the contrary, in the other localities of the Świebodzice Depression (Lubiechów, Pełcznica, Witoszów Górny) brachiopods are known only from pebbles contained in stratigraphically younger (Famennian to Lower Carboniferous) conglomerates (Gunia 1966).

Abbreviations

Collection acronyms

MB	Museum für Naturkunde, Berlin;
MGUWr	Muzeum Geologiczne, Instytut Nauk Geologicznych, Uniwersytet Wrocławski, Wrocław, Poland;
PIG	Państwowy Instytut Geologiczny, Warszawa, Poland.

Locality names

The correspondence between German (used before 1945) and Polish (after that date) forms of the locality names is given in the Table 1.

SYSTEMATIC PALAEONTOLOGY

Phylum BRACHIOPODA Duméril, 1805
Class RHYNCHONELLATA
Williams *et al.*, 1996
Order ATRYPIDA Moore, 1952
Family Atrypidae Gill, 1871

Genus *Kyrtatrypa* Struve, 1966

Type species. — *Atrypa* (*Kyrtatrypa*) *culminigera* Struve, 1966. Eifel Mts, middle Eifelian.

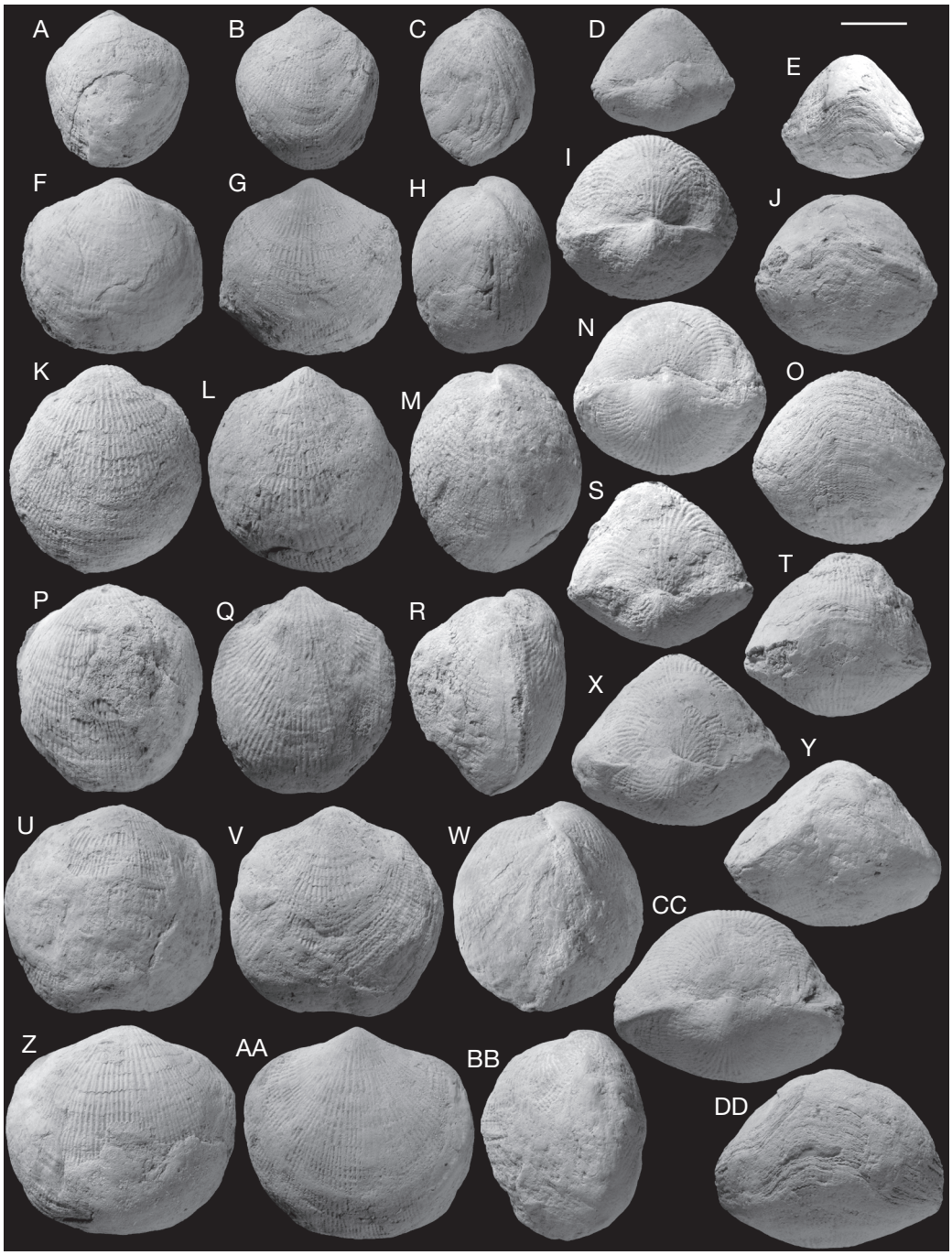

FIG. 2. — *Kyrtatrypa barnimi* n. sp., Mokrzeszów (Oberkunzendorf), Late Frasnian: **A**-**E**, paratype, articulated shell MB.B 2417.2; **F**-**J**, paratype, articulated shell MB.B 2422.5; **K**-**O**, holotype, articulated shell MB.B 2425; **P**-**T**, paratype, articulated shell MB.B 2422.2; **U**-**Y**, paratype, articulated shell MB.B 2422.6; **Z**-**DD**, paratype, articulated shell MB.B 2422.1. **A**, **F**, **K**, **P**, **U**, **Z**, dorsal views; **B**, **G**, **L**, **Q**, **V**, **AA**, ventral views; **C**, **H**, **M**, **R**, **W**, **BB**, lateral views; **D**, **I**, **N**, **S**, **X**, **CC**, posterior views; **E**, **J**, **O**, **T**, **Y**, **DD**, anterior views. Scale bar: 1 cm.

TABLE 1. — Overview of occurrences of atrypide brachiopods in the Devonian of the Sudetes.

Locality		Age	Identification according to previous authors			Identification according to the present author
			Before 1945	After 1945		
Bardo Structure and Kłodzko Unit	Gołogłowy (Hollenau)	Frasnian	*Atrypa reticularis* sensu Bederke, 1924	—		Atrypida indet.
	Kłodzko (Glatz)	Frasnian	*Atrypa reticularis* sensu Michael 1914, 1920; Bederke 1924; Finckh *et al.* 1942	*Spinatrypa* sp. sensu Gunia, 1977		*Spinatrypa* sp.
	Dzikowiec (Ebersdorf)	Famennian	*Atrypa fibrosissima* sensu Tietze, 1871	—		Brachiopoda indet.
Świebodzice Depression	Mokrzeszów (Ober-Kunzendorf), Witoszów Górny (Ober-Bögendorf), Pełcznica (Polsnitz), Lubiechów (Liebichau)	Frasnian (at least partly, possibly entirely Late Frasnian)	*Atrypa reticularis* sensu Dames, 1868	*Spinatrypa aspera* sensu Gunia, 1966	*S. tubaecostata* sensu Gunia, 1968	*Spinatrypa mariaetheresiae* n. sp.
				Spinatrypa bifidaeformis sensu Gunia, 1966		
				Atrypa reticularis sensu Gunia, 1966		*Kyrtatrypa barnimi* n. sp.
			Atrypa zonata sensu Dames, 1868	*Atrypa* ex gr. *reticularis* sensu Grocholski, 1969		*Pseudogruenewaldtia tschernyschewi*

Kyrtatrypa barnimi n. sp.
(Figs 2-4)

Atrypa reticularis – Dames 1868: 496, 497. — ?Gunia 1966: 310, pl. 8: 9.

Atrypa ex gr. *reticularis* – Grocholski 1969: 246 (e.p.), non pl. 5: 2.

TYPE MATERIAL. — Articulated shell MB.B.2425, holotype. 58 paratypes: MB.B 2416-2418, 2419c, 2420, 2422, 2426, 2427; PIG 139.II.35-37; MGUWr 191s, 323s, 5361s.1-7 and fragments MGUWr 5359s, 5361s, 5363s.

ETYMOLOGY. — In honour of Wilhelm Barnim Dames (1843-1898), collector of a large part of the type material.

TYPE HORIZON. — Pogorzała Formation, Late Frasnian.

TYPE LOCALITY. — Abandoned quarry "Lake Daisy", Mokrzeszów (Oberkunzendorf), Świebodzice Depression, Sudetes, Poland.

STRATIGRAPHIC AND GEOGRAPHIC RANGE. — Only type locality and horizon.

DIAGNOSIS. — *Kyrtatrypa* with slightly to markedly dorsibiconvex shell and moderately fine ornamentation. Spiralia of about eight whorls.

DESCRIPTION

Shell approximately as wide as long (width to length ratio from 0.86 to 1.15; mean value 1.01, N=23), rounded through subrectangular to subtriangular in outline, slightly to markedly dorsibiconvex, up to 35.7 mm wide and to 27.0 mm thick. Maximum width and thickness at ⅓ to ½ of the shell length

from the umbo. Anterior commissure rectimarginate in young specimens to uniplicate in adults, its deflexion rounded to triangular in outline, very low to low, occupying ⅓ to ½ of the shell width. Ventral interarea anacline; ventral beak strong, incurved, appressed to the dorsal valve. Dorsal interarea and beak not visible. Ribs undulose, relatively fine, straight, 5-6(-7) per 5 mm at anterior commissure, new ones arising by bifurcation on both valves. Growth lamellae fine. Frills (Fig. 3) up to 16 mm long.

Interior (Fig. 4): shell relatively thick walled, with a thick tertiary layer. Ventral valve: pedicle callist thick and continuing anteriorly for about 5 mm; teeth stout, with strong lateral lobes; dental nuclei absent. Dorsal valve: median septum moderately strong; a weak cardinal process in form of a pad, enclosed within the cardinal pit; hinge plates stout; socket plates thin, arcuate; crural base strong, jugal process rather long and stout; spiralia of about 8 thin whorls.

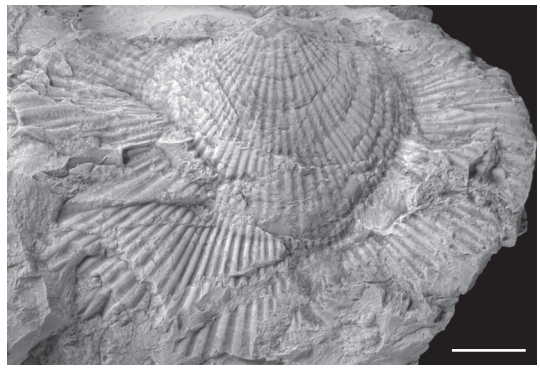

Fig. 3. — *Kyrtatrypa barnimi* n. sp. Specimen with preserved frills in ventral view. MB.B.2418.1. Mokrzeszów (Oberkunzendorf), Late Frasnian. Scale bar: 5 mm.

Discussion

This species is assigned to *Kyrtatrypa* Struve, 1966 on account of its dorsibiconvex to aequibiconvex shell and presence of frills. Its internal structures are very similar to those of *Kyrtatrypa culminigera* Struve, 1966 (Copper 2002: fig. 947e-g), except for a higher number of spiralia whorls (11) in the latter. The internal structures of *Kyrtatrypa balda* Havlíček, 1987 (Havlíček 1987: fig. 2) are also similar to those of the described species.

Kyrtatrypa barnimi n. sp. differs from *K. brandonensis* (Stainbrook, 1938) from the Lower Frasnian Cedar Valley beds of Iowa in its finer ornamentation (Stainbrook 1938). *Kyrtatrypa*? *teicherti* (Coleman, 1951), a poorly known taxon from the Frasnian of Western Australia, has a flatter ventral valve and finer ornamentation (Coleman 1951; Grey 1977); the generic assignment of this species is uncertain (Ma *et al.* 2006: 798). The nearest species seems to be the early Givetian *Kyrtatrypa* n. sp. from Błonia Sierżawskie near Świętomarz (see Halamski & Segit 2006) in the northern part of the Holy Cross Mountains (*K. pauli*, *nomen nudum*, Halamski 2004: text-fig. 31-33; pl. 6: 8, 7: 1-4; = *Kyrtatrypa* sp. *sensu* Zapalski 2005) from which the species described here differs in less convex dorsal valve and more convex ventral one, smaller apical angle, and more dense ornamentation.

The genus *Kyrtatrypa* was once supposed to occur up to the end of the Frasnian stage (Copper 1998: fig. 1); however, its Late Frasnian occurrences have appeared doubtful (Copper 2002: 1396) due to imprecise biostratigraphic dating (Racki 1998: 396) and uncertain taxonomy (Ma *et al.* 2006: 798). As a matter of fact, Frasnian representatives of *Kyrtatrypa* are scarce, including only *K. brandonensis* from Iowa and *K. teicherti* from the Canning Basin (see above for details); both taxa come from lower parts of the Frasnian. Consequently, *K. barnimi* n. sp. from the Late Frasnian represents probably the last known representative of the genus and, additionally, the first Frasnian species from Europe.

It may be noted that this species is distinguished from co-occurring *Pseudogruenewaldtia tschernyschewi* Rzhonsnitskaya, 1960 by the presence of frills (present in several representatives of the subfamily Atrypinae Gill, 1871, absent in the Pseudogruenewaldtiinae Rzhonsnitskaya, Yudina & Sokiran, 1997; see Copper 2002).

Genus *Pseudogruenewaldtia* Rzhonsnitskaya, 1960

Type species. — *Pseudogruenewaldtia tschernyschewi* Rzhonsnitskaya, 1960. Timan, Late Frasnian.

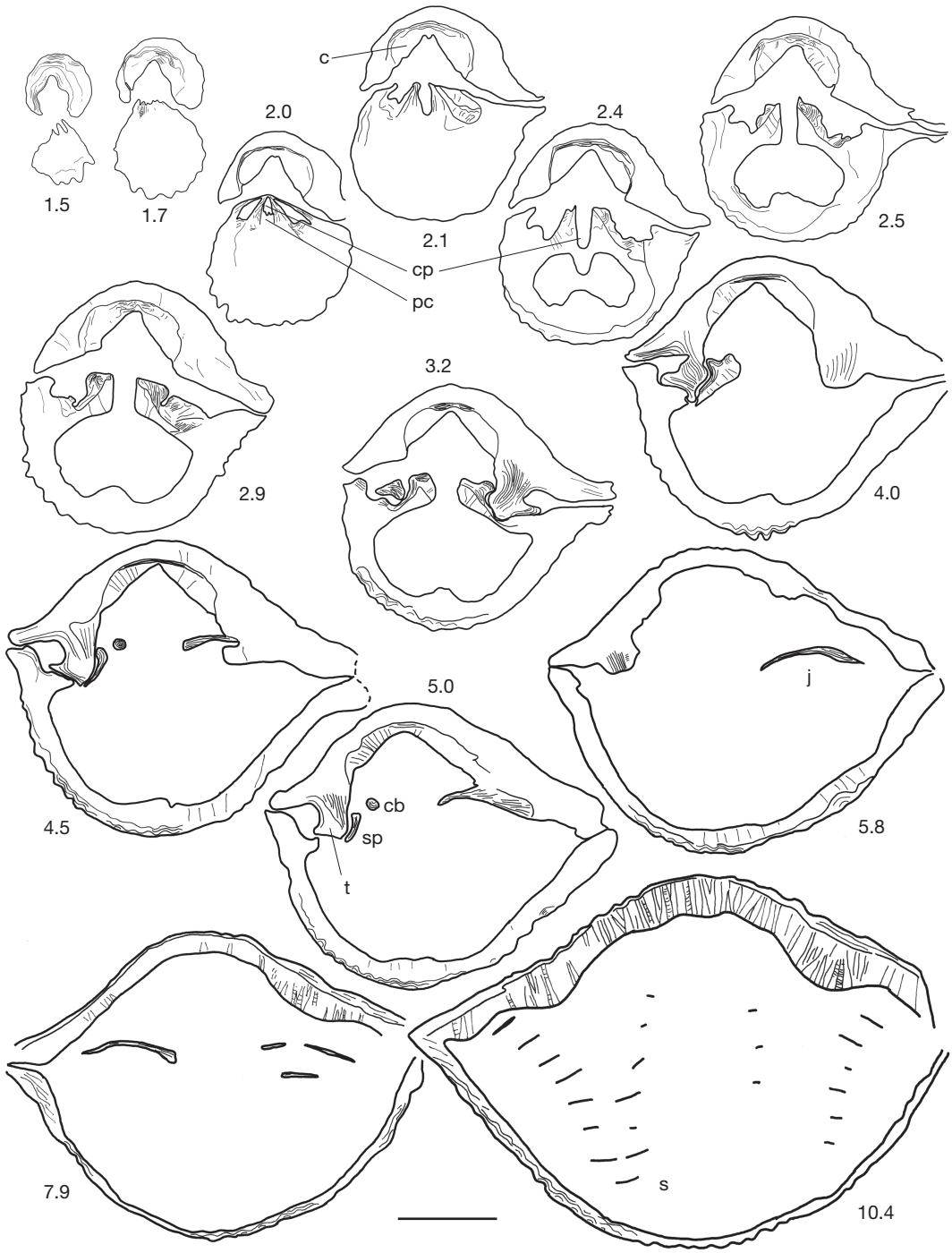

Fig. 4. — *Kyrtatrypa barnimi* n. sp., serial sections of the specimen MB.B.2422.10; Mokrzeszów (Oberkunzendorf), Late Frasnian. Internal structures: **c**, pedicle callist; **cp**, cardinal pit; **cb**, crural base; **j**, jugal plate; **pc**, cardinal process; **s**, spiralium; **sp**, socket plate; **t**, tooth. Scale bar: 5 mm.

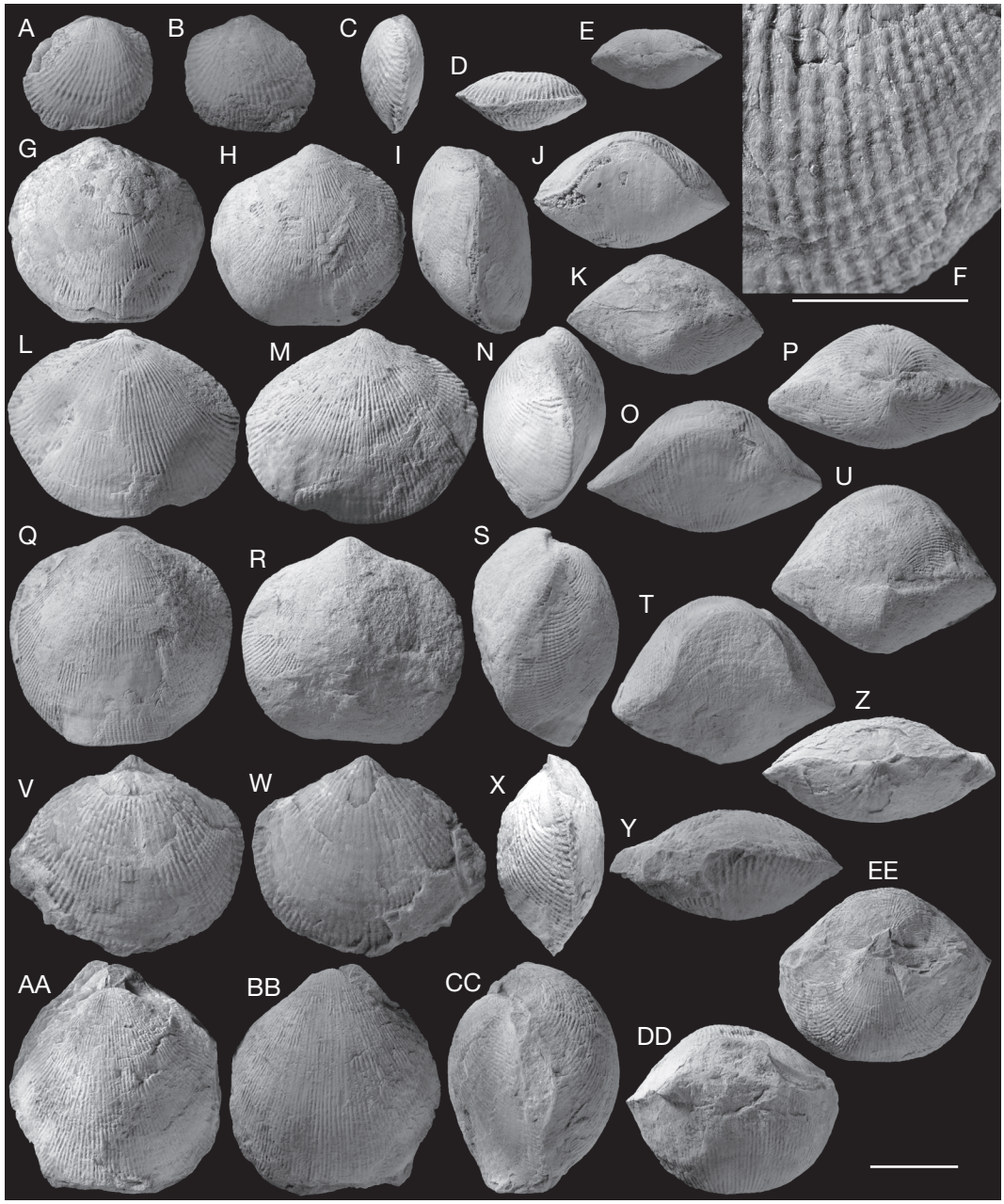

Fig. 5. — *Pseudogruenewaldtia tschernyschewi* Rzhonsnitskaya, 1960; Mokrzeszów (Oberkunzendorf), Late Frasnian: **A**-**E**, articulated shell MGUWr 5364s.1, specimen figured by Grocholski (1969; pl. 5: 2) as *Atrypa* ex gr. *reticularis*; **F**, **V**-**Z**, articulated shell MGUWr 5364s.1; **G**-**K**, articulated shell MB.B.2421.1; **L**-**P**, articulated shell MB.B.297.10; **Q**-**U,** articulated shell MB.B.2421.2; **AA**-**EE,** articulated shell MB.B.297.1. **A**, **G**, **L**, **Q**, **V**, **AA**, dorsal views; **B**, **H**, **M**, **R**, **W**, **BB**, ventral views; **C**, **I**, **N**, **S**, **X**, **CC**, lateral views; **D**, **J**, **O**, **T**, **Y**, **DD**, posterior views; **E**, **K**, **P**, **U**, **Z**, **EE**, anterior views; **F**, microornamentation. Scale bars: F, 5 mm; all others, 1 cm.

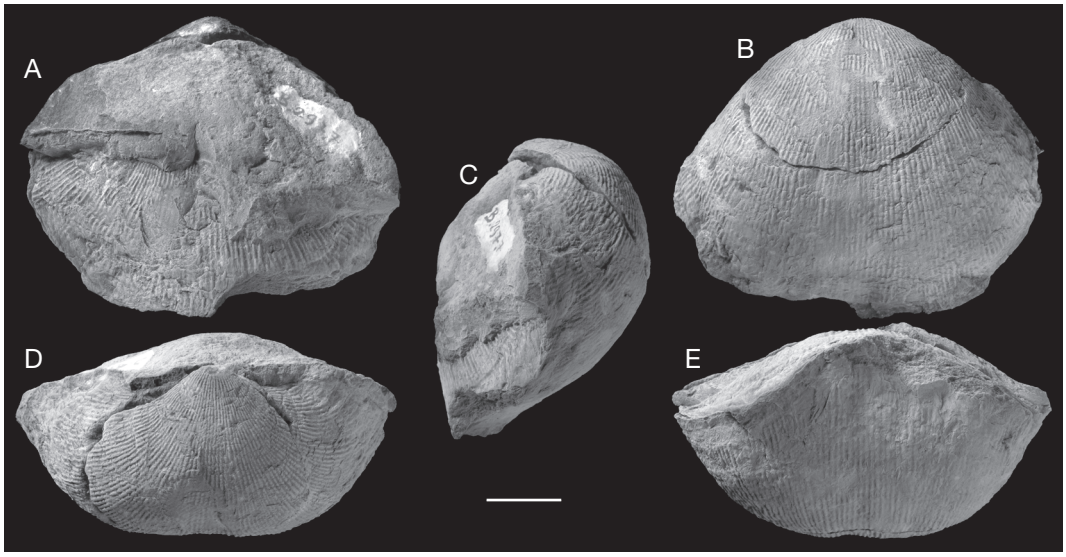

Fig. 6. — *Pseudogruenewaldtia tschernyschewi* Rzhonsnitskaya, 1960. The largest specimen in the collection, articulated shell MB.B.297.7. Mokrzeszów (Oberkunzendorf), Late Frasnian: **A**, dorsal view; **B**, ventral view; **C**, lateral view; **D**, posterior view; **E**, anterior view. Scale bar: 1 cm.

Pseudogruenewaldtia tschernyschewi
Rzhonsnitskaya, 1960
(Figs 5; 6)

Pseudogruenewaldtia tschernyschewi Rzhonsnitskaya, 1960: 46, pl. 1: 7, pl. 2: 4; 1964: 107, pl. 2: 6, pl. 5: 4. — Rzhonsnitskaya *et al.* 1998: 328, figs 19, 20.

Atrypa zonata – Dames 1868: 497, pl. 11a-c.

Grunnewaldtia latilinguis – Ljaschenko 1959: 175, pl. 51: 5-7 [lapsus calami pro *Gruenewaldtia*].

Atrypa ex gr. *reticularis* – Grocholski 1969: 246, pl. 5: 2 (e.p.).

Material examined. — 21 articulated shells from Mokrzeszów, MB.B.297.1-10, 2419.1-2, 2420.1-2; MGUWr 5358s.1-6, 5360s.

Description

Shell up to 49.4 mm wide (mean value in the sample 29.8 mm), more often wider than long (width to length ratio from 0.88 to 1.44; mean value 1.07, N=10), rounded in outline, dorsibiconvex in young specimens, ventribiconvex (e.g., Fig. 5Q-U) to dorsibiconvex (e.g., Fig. 5AA-EE) in adults. Maximal width somewhat anteriorly to midlength (½ to ⅗ of the shell length), maximal thickness posteriorly to midlength (⅓ to ½ of the shell length). Anterior commissure uniplicate, its deflexion rounded in outline, relatively low, occupying ⅓ to ⅗ of the shell width. Ventral interarea concave, apsacline in young specimens; beak (foramen not observed) strongly incurved in older specimens, the interarea becoming thus anacline. Dorsal interarea not visible. A shallow flat-bottomed ventral sulcus is present in the largest specimens, its width at anterior commissure being ⅙ of that of the shell. Ribs undulose, fine, 8-10 per 5 mm at anterior commissure, new ones appearing (especially in posterior part) by bifurcation, seldom by intercalation. Growth lamellae (preserved only exceptionally) imbricate.

Interior not studied.

Discussion

The agreement of the described brachiopods from Mokrzeszów in external form (general shape and presence of a similar ventral furrow in the largest specimens), character and density of ornamenta-

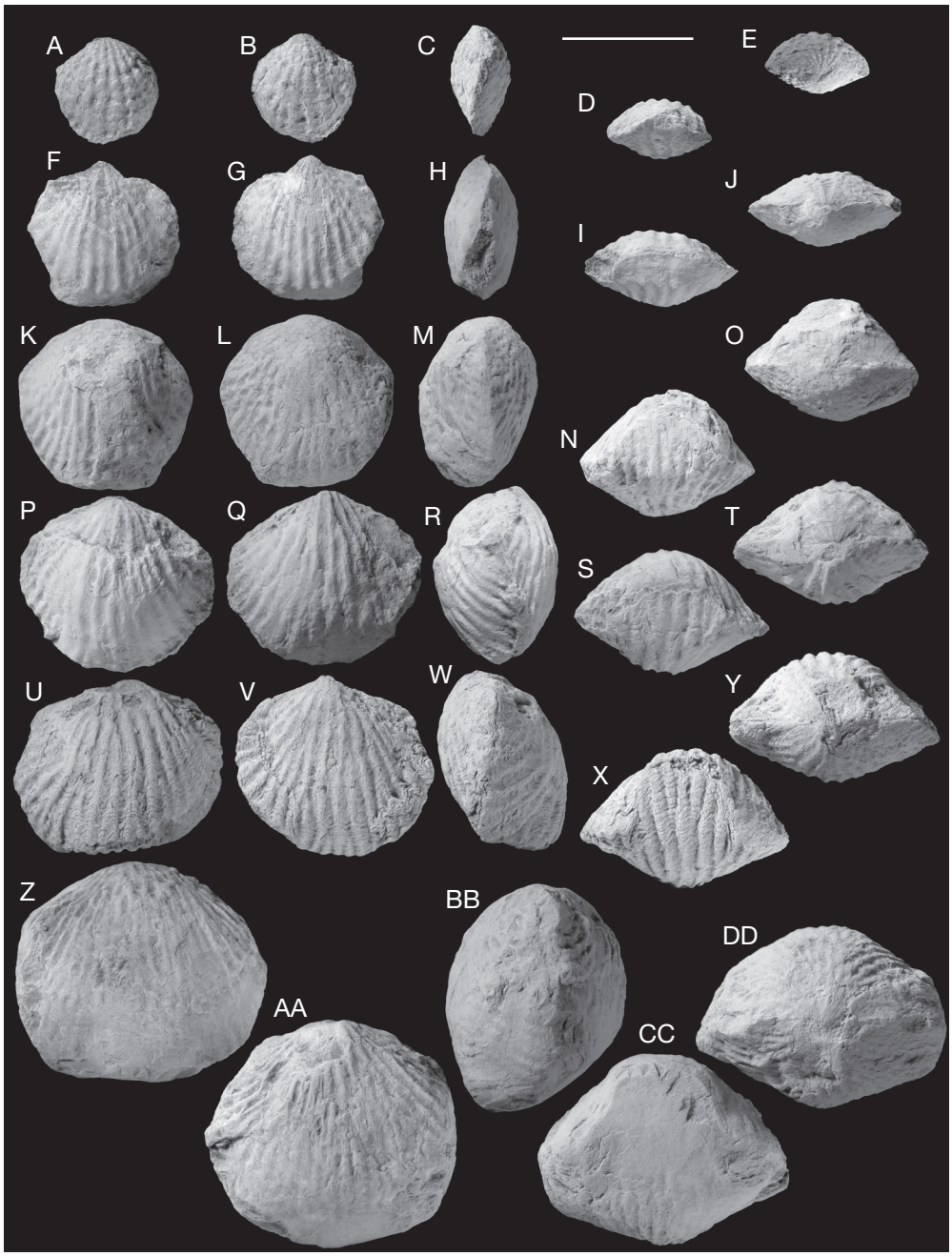

Fig. 7. — *Spinatrypa mariaetheresiae* n. sp., Mokrzeszów (Oberkunzendorf), Late Frasnian: **A**-**E**, paratype, articulated shell MGUWr 5360s.1 figured by Gunia (1968: pl. 7: 18, 19) as *S. bifidaeformis*; **F**-**J**, paratype, articulated shell MGUWr 5361s.1, corresponding to *S. aspera sensu* Gunia, 1966; **K**-**O**, paratype, articulated shell MB.B.2539; **P**-**T**, paratype, articulated shell MGUWr 5360s.2 corresponding to *S. bifidaeformis sensu* Gunia, 1968; **U**-**Y**, holotype, articulated shell MB.B. 2424.2; **Z**-**DD**, paratype, articulated shell MB.B.2424.1. **A**, **F**, **K**, **P**, **U**, **Z**, dorsal views; **B**, **G**, **L**, **Q**, **V**, **AA**, ventral views; **C**, **H**, **M**, **R**, **W**, **BB**, lateral views; **D**, **I**, **N**, **S**, **X**, **CC**, posterior views; **E**, **J**, **O**, **T**, **Y**, **DD**, anterior views. Scale bar: 2 cm.

tion with the type material of *Pseudogruenewaldtia tschernyschewi* from Timan (northern Urals, Russia) make strong case for the conspecificity of both samples even if interior of the described material could not be studied because of scarcity of the collection. *Pseudogruenewaldtia elongata* Alekseeva, 1996 from north-eastern Siberia, has much more elongate shells.

For discussion of differences with *Kyrtatrypa barnimi* n. sp. co-occurring in the same outcrop, see above. The stratigraphic implications of the presence of *Pseudogruenewaldtia tschernyschewi* in the studied material are discussed below.

Reworked representatives of *Pseudogruenewaldtia* occur in Famennian volcanoclastics (Langenaubacher Tuffbrekzie) in the Dill Syncline (Rhenish Massif, Hessia, Germany) (Copper, pers. comm. 2011).

The peculiar palaeogeographic distribution of *Pseudogruenewaldtia tschernyschewi* (Timan, Bohemia, possibly Rhenish Massif; absent either in the Central Devonian Field or in the Holy Cross Mountains) would have been explained by a migration route along the southern margin of Fennoscandia through the Latvian Isthmus had it not been for brackish conditions in these regions in the Frasnian (Lebedev *et al.* 2010). A straighter dispersion route is to be invoked and the absence of the discussed species in the abovementioned regions is more probably related to the patchiness of the record.

Genus *Spinatrypa* Stainbrook, 1951

TYPE SPECIES. — *Atrypa hystrix* var. *occidentalis* Hall, 1858 *sensu* Stainbrook 1945 (lapsus calami pro *Atrypa aspera* var. *occidentalis* Hall, 1858). Iowa, Late Givetian Cedar Valley limestone.

Spinatrypa mariaetheresiae n. sp.
(Figs 7; 8)

Spinatrypa aspera – Gunia 1966: 310, 311.

Spinatrypa bifidaeformis – Gunia 1968: 166, pl. 7: 18, 19.

TYPE MATERIAL. — Articulated shell MB.B. 2424.2, holotype. 13 paratypes: MB.B.2414-2415; MGUWr 5360s (*Spinatrypa bifidaeformis sensu* Gunia, 1966; Witoszów, outcrop 15), 5361s (*Spinatrypa aspera sensu* Gunia, 1968; Witoszów, outcrop 15), 5364s.1-4, 5365s.

ETYMOLOGY. — In honour of Mary Theresa Olivia Fürstin von Pless, Reichsgräfin von Hochberg, Freifrau zu Fürstenstein (1873-1943), called Daisy, a former owner of the type outcrop, organiser of humanitarian aid during both World Wars.

TYPE HORIZON. — Pogorzała Formation, Late Frasnian.

TYPE LOCALITY. — Abandoned quarry "Lake Daisy", Mokrzeszów (Oberkunzendorf), Świebodzice Depression, Sudetes, Poland.

STRATIGRAPHIC AND GEOGRAPHIC RANGE. — Świebodzice Depression, Mokrzeszów and Witoszów, Frasnian (most probably in both cases Late Frasnian).

DIAGNOSIS. — *Spinatrypa* with high, pronounced tongue, sixteen to twenty ribs, stout teeth and large dental cavities.

DESCRIPTION

Shell usually slightly wider than long (W/L from 0.95 to 1.16; mean value 1.06, N=8), subcircular in outline, nearly aequibiconvex to markedly dorsibiconvex, up to 24.0 mm wide (mean value 17.4 mm), rather thick in older specimens. Maximal width and thickness slightly posteriorly to midlength. Apical angle about 120-130°. Anterior commissure uniplicate, its deflexion rounded (more seldom subtrapezoidal) in outline, very high; occupying ⅔ of the shell width. Ventral beak (preserved only in young specimens) acute, nearly straight. Ventral interarea orthocline. Ribs spinose strong, rounded, 3-4 per 5 mm at anterior commissure, new ones appearing by bifurcation. Growth lamellae (seldom preserved) strong, 3-4 per 5 mm in central part of the shell; traces of spine insertion at intersection of growth lamellae with ribs.

Interior (Fig. 8). Ventral valve: dental cavities very large; teeth strong and massive. Dorsal valve damaged in apical region in the sectioned specimen; sockets strong, crura ventrally directed.

DISCUSSION

This species is included within *Spinatrypa* on account of its coarse costation and large dental cavities. Its high, pronounced tongue is more or less constant in adult specimens (Fig. 7N, S, X, CC).

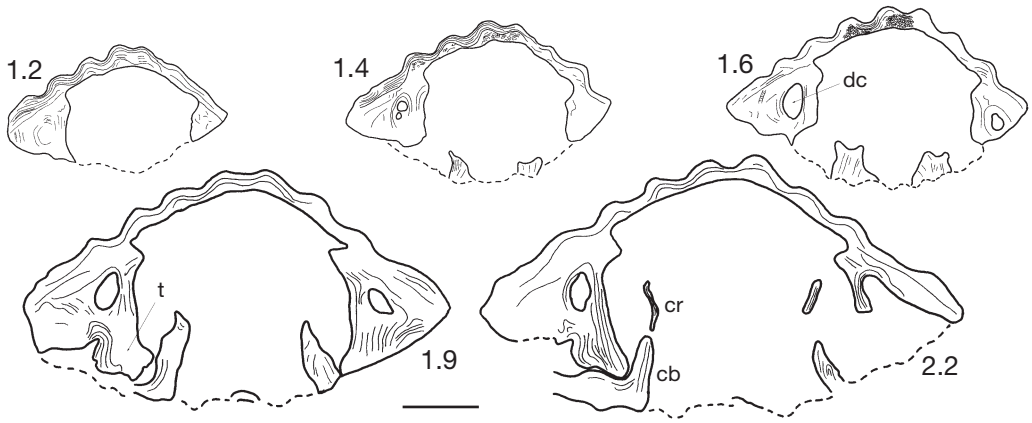

FIG. 8. — *Spinatrypa mariaetheresiae* n. sp. Serial sections of a slightly dorsally decorticated specimen MGUWr 8998s; Mokrzeszów (Oberkunzendorf), Late Frasnian. Abbreviations (internal structures): **cb**, crural base; **cr**, crus; **dc**, dental cavity; **t**, tooth. Scale bar: 1 mm.

The great majority of Frasnian representatives of the genus *Spinatrypa* possess much less pronounced tongue. This is the case of *S. bunkeri* Day & Copper, 1998, *S. planosulcata* (Webster, 1888), *S. rockfordensis* (Fenton & Fenton, 1924), *S. thompsoni* Day & Copper, 1998, and *S. trulla* (Stainbrook, 1945) from western North America (Day & Copper 1998), *S. ningxiangensis* Zhao *in* Yang *et al.* 1977 (see Ma 1992), *S. subkwangsiensis* (Tien, 1938) both from China (Ma *et al.* 2006), *S. longispina* (Rigaux, 1872) from Boulonnais (northern France; see Godefroid 1988), *S. plicata* (Rzhonsnitskaya, 1964) from Russia (Rzhonsnitskaya *et al.* 1998), *S. montanensis* (Kindle, 1908) from Montana (Laird 1947), *S. tribulosa* Norris, 1992 from Arctic Canada (Norris *et al.* 1992). This may be said also about approximately coeval *Spinatrypa* ex gr. *bifidaeformis* (Tschernyschew, 1887) and *Spinatrypa* ex gr. *semilukiana* Lyashenko, 1959 from the Holy Cross Mts. (Racki & Baliński 1998), and slightly older *Spinatrypa semilukiana* Ljaschenko, 1959 from the Dębnik Anticline (Baliński 1979, 2006). *Spinatrypa hystrix* (Hall, 1858) from New York and *S. obsolescens* (Cooper & Dutro, 1982) from New Mexico have very low, obsolescent costae (Cooper 1944; Cooper & Dutro 1982).

Two Frasnian taxa from New Mexico, *Spinatrypa compacta* Cooper & Dutro, 1982 and *S. trulla decorticata* Cooper & Dutro, 1982 may possess a large tongue. The former differs from the Sudetes material in its straight shoulder line and the latter is usually wider (Cooper & Dutro 1982).

Spinatrypa lambermontensis Mottequin, 2003 from the Late Frasnian of the Vesdre nappe and the Dinant Synclinorium (southern Belgium; see also Mottequin 2008: 501; erroneously reported from the Pragian by Hubert *et al.* 2007: 260) is quite similar to the form described here in overall shape, yet its ornamentation is slightly finer (usually over 20 ribs in total; 16-20 in the coarse-ribbed variant of our species). Moreover, *S. mariaetheresiae* possesses large dental cavities, whereas only small dental nuclei are present in *S. lambermontensis* (Mottequin 2003: fig. 4).

Spinatrypa rossica Rzhonsnitskaya *in* Rzhonsnitskaya, Markovskii, Yudina & Sokiran, 1998 from the Late Frasnian of SW Urals may also possess a strong tongue but the ornamentation is very coarse (total number of ribs 10-14; Rzhonsnitskaya *et al.* 1998). Serial sections of this species have unfortunately not been provided.

In view of the comparison with all available Frasnian taxa of the genus *Spinatrypa* presented above the material from the Frasnian of the Sudetes is best described as a new species. It may be noted that the two nearest species, namely *S. lambermontensis* Mottequin, 2003 and *S. rossica* Rzhonsnitskaya, 1998 are both also Late Frasnian in age. The Givetian

species *Isospinatrypa givetica* Rzhonsnitskaya, 1968 from the Kuznetsk basin (Rzhonsnitskaya 1975: pl. 24, figs 7, 8) may possess a similar tongue but is always aequibiconvex.

The material from Mokrzeszów contain two forms with similar ornamentation pattern but different ornamentation density. The commoner form has coarser costae and costellae (Fig. 7A-Y), whereas the rarer form possesses finer radial ornamentation (Fig. 7Z-DD). In view of nearly identical shape (in particular, the characteristic tongue) they have been interpreted as two morphotypes of a single species. A similar dimorphism has been reported in *Spinatrypina soetenica* (Struve, 1964) (Eifel Mts, Lower Givetian; Copper 1967) and *Spinatrypina* (*Exatrypa*) *relicta* Racki & Baliński, 1998 (Ługawa Hill, Holy Cross Mts, Late Frasnian; Racki & Baliński 1998: 284).

Both *Spinatrypa aspera* sensu Gunia, 1966 and *S. bifidaeformis* sensu Gunia, 1968 correspond to *Spinatrypa* sp. described here. However, the sample of *Spinatrypa tubaecostata* sensu Gunia, 1966 [non *Spinatrypina tubaecostata* (Paeckelmann, 1913)] is a mixture of fragmentarily preserved atrypids (probably all three species described here), indeterminable in large part.

ATRYPIDE DISTRIBUTION IN THE DEVONIAN OF THE SUDETES

The Mokrzeszów sample is the only one that may be considered (with minor reservations) as representing a true assemblage and its age may be established more precisely (Late Frasnian, see below). The material from the other localitites in the Świebodzice Depression comes from pebbles, wherefore it is not assured that all taxa are coeval. Suffice it to say that all identified atrypide taxa are the same as in the Late Frasnian Mokrzeszów section.

Atrypides were also reported from the Kłodzko Unit and the Bardo Structure under the catch-all name "*Atrypa reticularis*" (Michael 1914, 1920; Bederke 1924; Finckh *et al.* 1942). Neither description nor illustration of specimens from Gołogłowy was given in the referred publications and the original material could not be traced. Further field work by Oberc (1957) did not yield any new specimens. These brachiopods are therefore referred to as Atrypida indet. Concerning the Kłodzko locality, Gunia (1977) managed to find new atrypide material which he identified as *Spinatrypa* sp. These specimens are lacking; however, Gunia's generic identification, when checked on material form other localities, was mostly confirmed, wherefore this name has been accepted.

Atrypa fibrosissima Tietze, 1871 was described from the Famennian of Dzikowiec on the basis of two poorly preserved, decorticated specimens (MGUWr 8994s). As a matter of fact, this material is unidentifiable even at order level.

A synoptic table of occurrences of atrypide brachiopods in the Sudetes is given in Table 1.

THE AGE OF THE BRACHIOPOD FAUNA AND ITS IMPLICATIONS FOR THE TECTONICS OF THE SUDETES

A preliminary remark to be made is that no Frasnian conodonts have ever been found in any of the sections that have yielded brachiopods being the object of the present paper; in particular, absence of conodonts in Mokrzeszów was stressed by Różkowska (1979: 9). Only Famennian conodont faunas have been described (Freyer 1968; Chorowska 1974a, b; Dzik 2006). Frasnian conodonts reported from the north-eastern part of the Bardo Unit (Haydukiewicz 1979) come from an allochthonous sequence (Wajsprych 1995; "Ordovician, Silurian, and Devonian olistoliths" in Fig. 1C) and thus cannot be used for dating the brachiopod-bearing strata of the autochthonous (parautochthonous) sequence (see also Haydukiewicz & Muszer 2002 and references therein). The stratigraphy of the discussed strata is therefore based solely on macrofauna. In particular, atrypide brachiopods are good time markers due to their global disappearance during the Frasnian-Famennian extinction (Copper 1998, Racki 1998, Racki & Baliński 1998). Consequently, even poorly preserved (identifiable at order level) specimens are useful for dating purposes.

Atrypide-yielding deposits in Kłodzko belong to a sedimentary series overlying the metamorphic complex of the Kłodzko Unit. This regional unconformity is of crucial importance for the timing of the eo-Variscan collision in central Sudetes (see below for details). Given the lack of diagnostic microfauna, the dating of this tectono-metamorphic event is based on macrofauna, in large part on brachiopods. There appear therefore two questions requiring discussion: first, to what extent previous macrofauna-based assumptions are confirmed; second, the role of the new evidence related to the atrypides.

The problems related to the age of the brachiopod-bearing deposits will be discussed in the following order: first, hitherto presented evidence; secondly, new data resulting from brachiopod study; last, their implications for the question of the age of the tectonic events in the Sudetes.

HITHERTO PRESENTED DATINGS OF THE LATE DEVONIAN IN THE SUDETES

The Frasnian (early Late Devonian) age of the Mokrzeszów limestone has been established already by Dames (1868: 507), mainly on the basis of presence of *Hypothyridina cuboides* (rhynchonellide brachiopod). A similar, possibly slightly younger age of the overlying schists was suggested by the presence of spiriferide brachiopods identified as *Spirifer verneuili* (Dames 1868: 507, 508). This age determination has never been questioned. It was repeated without further precisions in the explanatory sheet of the geologic map of Prussia and federate states (Cramer *et al.* 1924)

Pawlik (1939) precised a Late Frasnian (to I δ) age on the basis of occurrences of bivalves *Buchiola prumiensis* and *Buchiola angulifera*. The latter species is indeed a good stratigraphic marker, ranging from the *hassi* to *linguiformis* conodont Zones (Late Frasnian), whereas the range of the former is longer (middle Frasnian to earliest Famennian; Grimm 1998). However, the bivalve material of Pawlik (1939) was not figured and *B. angulifera* specimens could not be traced (A. Setlik, pers. comm. 2012). The identifications are therefore impossible to check; Grimm (1998), the author of a monograph of this bivalve subfamily, stated that many previous buchiolid identifications were wrong. Identifications and diagnostic value of other macrofauna reported by Gunia (1962, 1966, 1968) require confirmation. In particular, this concerns poorly preserved allegedly age-diagnostic ammonoids (D. Korn, pers. comm. 2012).

The upper part of the Wapnica section in Dzikowiec (Ebersdorf) is world-famous for its Famennian ammonoid faunas (e.g., von Buch 1839; Tietze 1871; Schindewolf 1937; Lewowicki 1959; Dzik 2006). The age of the lower part of the section, Frasnian according to Gürich (1902), remains in fact unclear. A detailed discussion of the available biostratigraphic evidence is provided by Berkowski (2002: 12-16), according to whom the entire section might belong to the Famennian.

The poorly preserved fauna from the Kłodzko Unit described by Gunia (1977) has been dated either to the Famennian (Owcza Góra) or to a probable Late Frasnian to early Famennian (Kłodzko) on the basis of similarity with the Dzikowiec section. As shown above, such similarity cannot establish a Frasnian age. Also similarly as above, identifications of very poorly preserved allegedly diagnostic macrofauna require confirmation. However, on account of the presence of *Spinatrypa* sp. (material lost, see discussion above) in Kłodzko (Gunia 1977), a pre-Famennian (most probably Frasnian) age may be accepted for the basal part of the carbonate succession.

To sum up this somewhat wearisome reevaluation of previous results:
– in the Świebodzice Depression the brachiopod-bearing sediments in Mokrzeszów have been dated to the Frasnian on the basis of brachiopods, possibly to the Late Frasnian on the basis of bivalves (to be confirmed); other published stratigraphic data require confirmation;
– in Dzikowiec the presence of any Frasnian sediments remains unproven;
– the lower parts of Kłodzko and Gołogłowy sections situated in the contact of the Kłodzko and Bardo Units may be dated to the Frasnian given the presence of atrypide brachiopods (but not on account of other reasons invoked by former authors).

ATRYPIDE BRACHIOPODS AS DATE MARKERS

Up to now, representatives of the genus *Pseudogruenewaldtia* have been reported from only two regions. Both occurrences are dated confidently with conodonts (overview in Racki 1998) to the Late Frasnian. *Pseudogruenewaldtia tschernyschewi* was described from the Lyaiol suite of the Timan-Pechora Province of the East European Platform (dating by Khrustcheva & Kuz'min 1996). *Pseudogruenewaldtia elongata* from the Kolyma-Omolon microplate belongs to the *Theodossia* brachiopod zone, the age of which has also been confirmed by conodonts (Alekseeva *et al.* 1996). In view of the limitation of the entire genus *Pseudogruenewaldtia* to the Late Frasnian, it seems reasonable to admit the same age for the brachiopod-bearing sequence in Mokrzeszów. It may be noted that unlike *Pseudogruenewaldtia* and *Spinatrypa* that are common in the Late Frasnian (Racki 1998), *Kyrtatrypa* has never been reported from so high levels up to now.

THE LATE DEVONIAN IN SILESIA AND THE AGE OF THE EO-VARISCAN COLLISION IN THE SUDETES

The unconformity between the metamorphic rocks of the Bożków Formation belonging to the Kłodzko Unit and the overlying Upper Devonian to Lower Carboniferous conglomerates and limestones (the regional pre-Upper Devonian unconformity) reflects the eo-Variscan collision between Bohemia and Saxothuringia (Kryza *et al.* 1999; Franke & Żelaźniewicz 2000; Aleksandrowski & Mazur 2002; Mazur 2003; Żelaźniewicz 2005; see also Fig. 1A). The unconformable contact was discovered by Bederke (1924) who was misled as to its age due to the dating of the protoliths of the Kłodzko Unit as Silurian, a mistake repeated nearly fifty years later (Gunia & Wojciechowska 1971). Only recently the discovery of metamorphosed Givetian tabulate corals (*Caliapora*; Hladil *et al.* 1999) permitted to fix a biostratigraphically precise *terminus post quem* for the tectono-metamorphic event in the central Sudetes.

The *terminus ante quem* is given by the age of the overlying sediments. Lower levels of localities having yielded atrypide brachiopods (Kłodzko and Gołogłowy) may be dated confidently to the Frasnian (more exactly, pre-Famennian, without further precision, as the collections are missing and the fauna cannot be revised).

A more precise (Late Frasnian) dating is available for the Mokrzeszów limestone in the Świebodzice Depression. It is, however, unclear, to what extent the thick sequence from the Świebodzice Depression can be considered coeval with the basal conglomerate at the border of the Kłodzko Unit and the Bardo Structure.

To sum up: at present, atrypide brachiopods are the best time markers that allow dating the eo-Variscan collision in the central Sudetes. The *terminus ante quem* is the Frasnian or, more exactly, pre-Famennian: the Late Frasnian age given by previous authors is unwarranted although probable.

CONCLUSIONS

1) Frasnian atrypide brachiopods reported previously from the Świebodzice Depression (Sudetes, Silesia, Poland) under various names, belong to three species: *Kyrtatrypa barnimi* n. sp., *Pseudogruenewaldtia tschernyschewi*, and *Spinatrypa mariaetheresiae* n. sp.;
2) this fauna indicates a Late Frasnian age for the brachiopod-bearing sediments in Mokrzeszów (Świebodzice Depression, Sudetes), confirming the age determination of Pawlik (1939) based on (neither described nor figured) bivalves;
3) *Kyrtatrypa barnimi* n. sp. is the of the last representatives of the genus, the only confirmed Late Frasnian species all over the world, and, additionally, the only Frasnian representative of the genus in Europe;
4) this is the first documented occurrence of *Pseudogruenewaldtia tschernyschewi* outside the type area (Timan) and of the genus *Pseudogruenewaltia* outside Russia;
5) *Spinatrypa mariaetheresiae* n. sp. is similar to two other Late Frasnian species, namely *S. lambermontensis* and *S. rossica* in having a high tongue (low in most representatives of the genus). It differs from

both in external and internal features (very large dental cavities in *S. mariaetheresiae* and *S. rossica*, small in *S. lambermontensis*; total number of ribs 16-20 in *S. mariaetheresiae*, ≥ 20 in *S. lambermontensis*, 10-14 in *S. rossica*). Two forms differing in ornamentation density present in the same outcrop are interpreted as morphotypes of a single species; – and 6) at present, given the lack of conodonts and unclear status of most of the allegedly diagnostic macrofauna, atrypide brachiopods are the best time markers that allow dating the collision between Bohemia and Saxothuringia. The *terminus ante quem* is the Frasnian (more exactly pre-Famennian; a Late Frasnian age given by previous authors is unwarranted although probable) based on the presence of atrypide brachiopods in Kłodzko and Gołogłowy.

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