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Palaeontology of the Middle Turonian limestones of the Nysa Kłodzka Graben (Sudetes, SW Poland): biostratigraphical and palaeogeographical implications

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Abstract

The ammonites *Lewesiceras peramplum* Mantell and *?Lewesiceras* sp. are reported from the Upper Cretaceous in the Nysa Kłodzka Graben; they date from the Middle Turonian and ?Coniacian, respectively. The Middle Turonian limestones of the Stara Bystrzyca quarry contain an abundant assemblage of inoceramids (*Inoceramus cuvieri* Sowerby and I. lamarcki Parkinson) and other bivalves, including oysters, as well as brachiopods and trace fossils. Micropalaeontological data show the presence of foraminifers and siliceous sponge spiculae, bryozoans, ostracods and fragments of bivalves and gastropods. The Middle Turonian calcareous deposits belongs to the upper part of the *Inoceramus lamarcki* Zone (late Middle Turonian) and were deposited on a shallow, subtidal offshore shelf. They overlie the Middle Turonian Bystrzyca and Długopole Sandstones, which represent foreshore-shoreface delta deposits. The fossil assemblage suggests a moderate- to low-energy, normal-salinity environment with occasionally an oxygen deficit.

Keywords: Middle Turonian, Sudetes, Nysa Kłodzka Graben, ammonites, inoceramids, biostratigraphy

1. Introduction

Representatives of the ammonite genus *Lewesiceras* are most typical of the Middle-Late Turonian and are known from the North and Transitional European Province and from the North Pacific Province; they are rare in the Tethys Province.

Two specimens of this genus are now described from the Middle Turonian and ?Coniacian deposits in the Nysa Kłodzka Graben (Figs 1–3). One of the specimens, identified as *Lewesiceras peramplum* Mantell has been found for the first time in the Middle Turonian of the Stara Bystrzyca quarry. It is, with its diameter of approx. 45 cm, probably the biggest ammonite ever found in Nysa Kłodzka Graben and probably also in the Sudety Mountains (Fig. 6 A-E). The second specimen has been identified as ?*Lewesiceras* sp. – and has a diameter 33 cm; it forms part of the collection of the Polish Geological Institute – Polish Research Institute, Wrocław (Fig. 6 H-L). The specimen was found by Z. Radwańska, who investigated the Nysa Kłodzka Graben in (the author means: the fifties and sixties) of the 20th century (e.g., Radwańska, 1962, 1964) in the vicinity of Wilkanów (S. Cwojdziński, PGI-PRI Wrocław, pers. comm. 2011) and had not yet a taxonomical assignment (Fig. 1). The ammonite was probably encountered in the Coniacian.

There is little information about large/medium ammonites (for the size categories of ammonites, see: Stevens, 1988; Matsumoto et al., 1990; Tibuleac, 2008) from the Nysa Kłodzka Graben. Only Wroński & Cwojdziński (1984) reported some ammonites (*Peroniceras tricarinatum* d'Orbigny), 40 cm in diameter, from the Upper Turonian. It is likely that the two ammonite specimens described here (*Lewesiceras peramplum* Mantell and ?*Lewesiceras* sp.) represent the biggest ammonites found so far in the Nysa Kłodzka Graben.

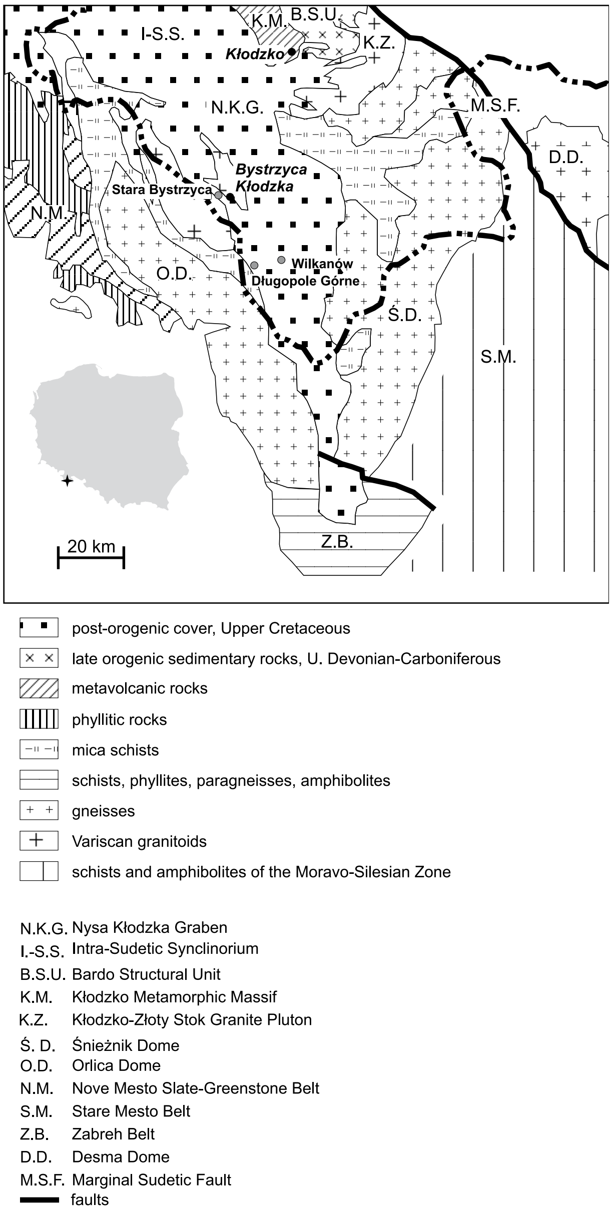


Fig. 1. Tectonic sketch of the Nysa Kłodzka Graben (after Żelaźniewicz & Aleksandrowski, 2008).

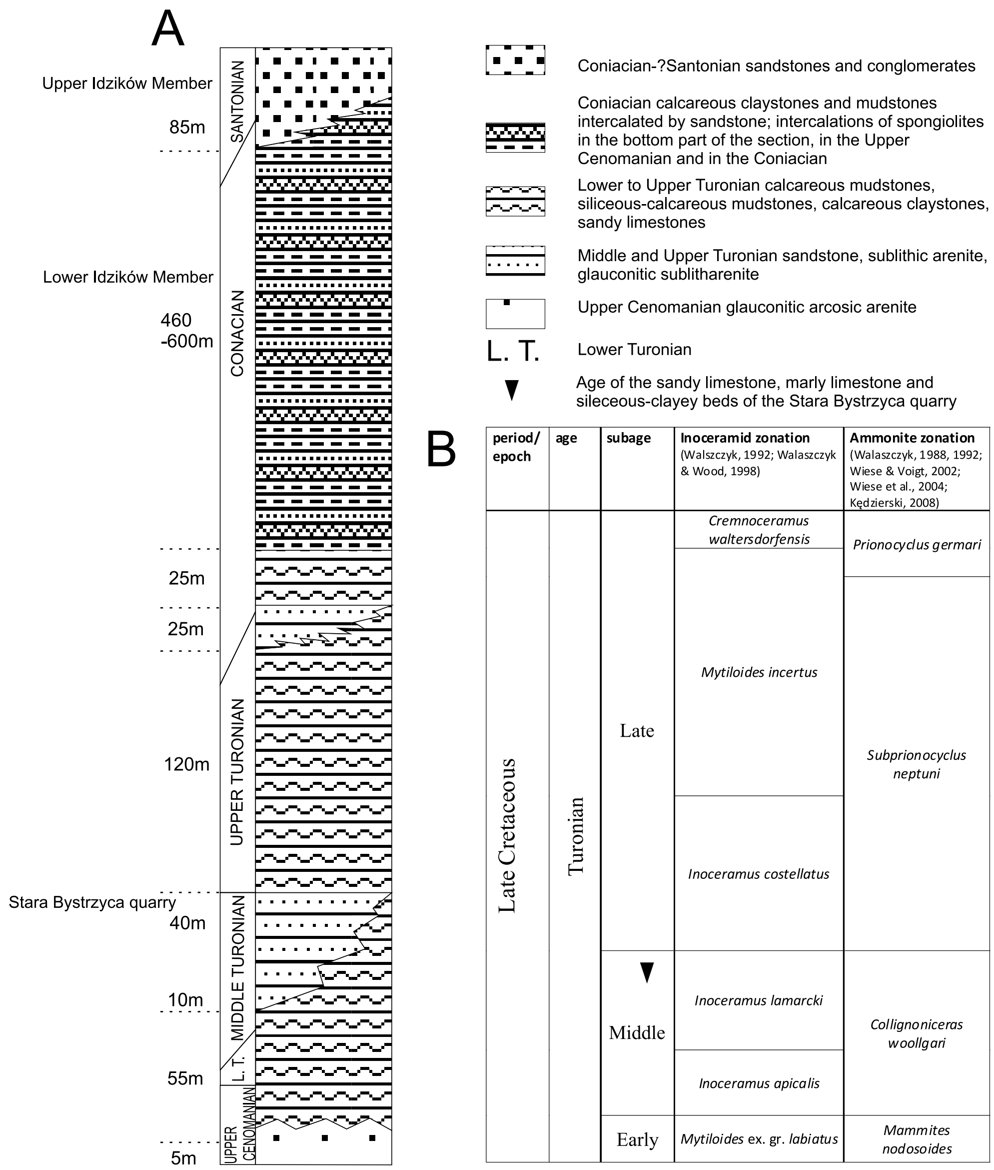
In addition to the *Lewesiceras peramplum* specimen, numerous moulds and shells of the inoceramids *Inoceramus cuvieri* Sowerby and *I. lamarcki* Parkinson were found in the Middle Turonian of the Stara Bystrzyca quarry (Fig. 6 M; Fig. 8 A-I). Fragments of *Inoceramus cuvieri* reach up to 20 cm, while *I. lamarcki* is up to 10 cm and this may indicate that the dimensions of complete inoceramid shells may have diameters of 0.3–0.4 m. One of the biggest pieces of inoceramid shell from this quarry measures 40 cm (J. Wojewoda, Wrocław University, pers. comm. 2011).

The present contribution provides a detailed description of *Lewesiceras peramplum* and ?*Lewesiceras* sp., found by the author and by Z. Radwańska. The inoceramids *Inoceramus cuvieri* and *I. lamarcki* are also described, and other fossils are depicted in this first detailed documentation of the Stara Bystrzyca quarry. Until now, only minor references concerning the lithology and fauna were made, mainly in conference materials and explanations to geological maps (Fistek & Gierwielaniec, 1964; Radwański, 1964, 1965, 1966, 1975; Wroński & Cwojdziński, 1984).

The fauna, especially the inoceramids, ammonites and foraminifers, were used to establish the age of the Stara Bystrzyca sandy and marly limestones, and to reconstruct the palaeogeography and palaeoenvironment.

2. Previous research on Polish Cretaceous ammonites

Ammonites of the genus *Lewesiceras* are rare in the Upper Cretaceous of the Sudety Mountains. An ammonite assigned to *Pachydiscus peramplum* Mantell was found by Andert (1934) in the Middle Turonian of the North Sudetic Synclinorium and in the Intra-Sudetic Synclinorium. Pachucki (1959) mentioned *Pachydiscus* aff. *peramplum* Mantell from Emscherian sediments of the Nysa Kłodzka Graben, but without any information about size and collector. Flegel (1904) reported *Pachydiscus per-*



period/ epoch	age	subage	Inoceramid zonation (Walszczyk, 1992; Walaszczyk & Wood, 1998)	Ammonite zonation (Walaszczyk, 1988, 1992; Wiese & Voigt, 2002; Wiese et al., 2004; Kędzierski, 2008)
Late Cretaceous	Turonian	Late	*Cremnoceramus waltersdorfensis*	*Prionocyclus germari*
			Mytiloides incertus	*Subprionocyclus neptuni*
			Inoceramus costellatus	
		Middle ▼	*Inoceramus lamarcki*	*Collignoniceras woollgari*
			Inoceramus apicalis	
		Early	*Mytiloides* ex. gr. *labiatus*	*Mammites nodosoides*

Fig. 2. Geology of the Nysa Kłodzka Graben.
A: Cenomanian-?Santonian section (slightly modified after Wojewoda, 1997, and Don & Gotowała, 2008); **B:** Chronostratigraphy with inoceramid and ammonite zones (after Kędzierski, 2008, and Wiese et al., 2004).

amplum Mantell from the Upper Turonian of the Stołowe Mountains (Karłów village). In the Geological Museum in Wrocław, a specimen is present of the ammonite *Pachydiscus peramplum* Mantell (diameter: 16 cm) from the German collection (no MGUWr. – 1800s; Fig. 6 F-G), with an inscription 'Carlsberg' (Karłów). There is, however, no information about the collector. This might be the specimen mentioned by Flegel (1904).

Recently, some researchers reported the occurrence of the Pachydiscidae species *Pachydiscus* (*Pachydiscus*) *neubergicus* von Hauer, *Pachydiscus* (*P.*) *perfidus* de Grossouvre, *Pachydiscus* (*P.*) *armenicus* Atabekian and Akopian (Machalski, 2012), *Nowakites talavignesii* d'Orbigny, *Nowakites savini* de Grossouvre, *Nowakites pailletteanus* d'Orbigny, *Nowakites* aff. *pailletteanus* d'Orbigny and *Eupachydiscus isculensis* Redtenbacher (Remin 2010). Jagt-Yazykova (2011; in press) analysed the evolution of mid- and Late Cretaceous ammonites (e.g. Pachydiscidae) from along the Russian Pacific coast.

Large *Lewesiceras peramplum* (diameter 48 cm) have been described from the Middle Turonian of the Opole Trough (Tarkowski, 1991).

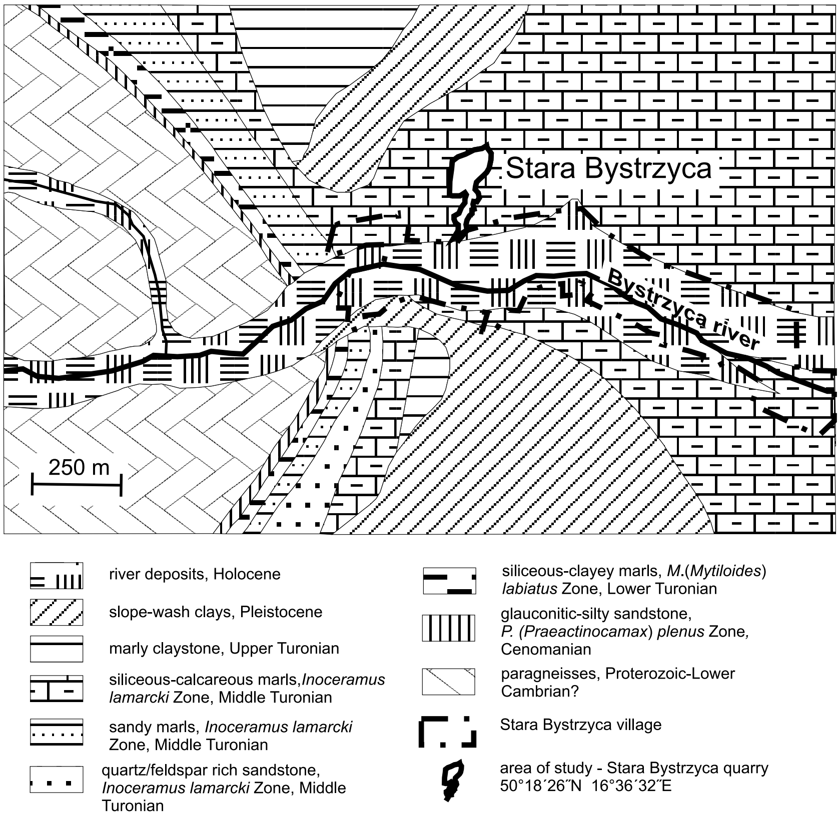


Fig. 3. Geological setting of the Stara Bystrzyca quarry (after Fistek & Gierwielaniec, 1957). Biostratigraphy after Walaszczyk (1992).

Kin (2007) described 26 large ammonites (diameter > 50 cm) assigned to *Lewesiceras peramplum* and *L. mantelli* (Opole Trough, Middle Turonian). This author suggested that all ammonites found by him might belong to one species, because the differences in morphology could be caused by different environmental conditions, for example the presence of predators (see also Trussell & Smith, 2000). The collection of the Society of Friends of the Earth Sciences "Phacops" contains specimens of *Lewesiceras peramplum* (diameters 73 cm, 50 cm) from the Middle Turonian of the NE Mesozoic margin of the Holy Cross Mountains (www.dinozaury.mania.pl/wp/materialy/nau-bio.pdf). Kin & Niedźwiedzki (2012) reported some large to gigantic ammonites, including *Lewesiceras peramplum* (diameter 60 cm) and *L.* ex. gr. *peramplum* (diameter 114 cm), from the uppermost Middle and lower Upper Turonian of the Opole Trough. Uličný et al. (1997) found *Lewesiceras* sp. (diameter 70 cm) in the Upper Turonian of the Bohemian Cretaceous Basin (Czech Republic).

3. Geological setting

The Stara Bystrzyca quarry is situated in the Nysa Kłodzka Graben (Fig. 1), which is one of the youngest tectonics units in the Sudetes (Don & Gotowała, 2008). The graben started developing during the Turonian/Coniacian (Pachucki, 1959; Don & Don, 1960; Komuda & Don, 1964; Jerzykiewicz, 1970, 1971; Radwański, 1975; Don, 1996; Wojewoda, 1997; Don & Wojewoda, 2004, 2005; Kędzierski, 2005) and it is filled with clastic deposits of Cenomanian–Santonian age, that overlay metamorphic rocks of the Orlica-Śnieżnik Dome (Żelaźniewicz & Aleksandrowski, 2008) (Fig. 2). The thickness of the Cretaceous succession, which consists of marls, siliceous-clayey mudstones and limestones separated by the Middle and Late Turonian Quader Sandstone – (Fig. 2 A), exceeds 1200 m in the Nysa Kłodzka Graben (Wojewoda, 1997).

Fistek & Gierwielaniec (1964), Radwański (1966) and Wroński & Cwojdziński (1984) reported the presence of two units of marls in the Middle Turonian: the first unit is 10 m thick and the second 50 m. The thickness of the intercalated Quader Sandstone (Bystrzyca and Długopole Sandstone) in the vicinity of Stara Bystrzyca ranges from 45 to 60 m (Don & Don, 1960; Komuda & Don, 1964; Radwański, 1965, 1975; Wroński & Cwojdziński, 1984).

The youngest deposits in the Nysa Kłodzka Graben (sandstones and conglomerates of the Upper Idzików Member) are currently considered as being of Coniacian and Santonian age (Don & Wojewoda, 2004; Wojewoda, 2004).

4. The Middle Turonian of the Stara Bystrzyca quarry

Calcareous-siliceous deposits outcrop in the Stara Bystrzyca quarry, located in the centre of the village; the quarry occurs near a fault that separates Late Cretaceous sediments from Proterozoic rocks of the Bystrzyca-Orlica Dome (Figs 1, 3). The Middle Turonian sediments of the Stara Bystrzyca quarry are represented by sandy and marly limestones with intercalations of siliceous-clayey beds (Figs 3, 4, 5). The ammonite *Lewesiceras peramplum* Mantell was found in the western wall (Fig. 4 B), while abundant inoceramids *Inoceramus cuvieri* Sowerby and *I. lamarcki* Parkinson occur mainly on the eastern wall (Fig. 4 A). Other bivalves (*Lima canalifera* Goldfuss, *Lima elongata* Geinitz, *Lima granulata* Nilsson, *Pecten membranaceus* Nilsson, *Pecten virgatus* Nilsson) and sponges prevail in the western and northern walls of the quarry. Oysters (*Exogyra cornuarietis* Nilsson-Griepenkerl, *Exogyra* sp.) are abundant in all walls of the quarry.

Analysis of thin sections shows that the most common matrix is calcareous and not clayey as was suggested earlier (Pachucki, 1959; Radwański, 1975). The deposits in the Stara Bystrzyca quarry thus are sandy limestones, although marly limestones occur as well (Lorenc, 1978; Manecki & Muszyński, 2008). Apart from that, 0.05-mm grains occur (at the boundary between sand and silt); they consist mostly of quartz and rare feldspars, muscovite and opaque minerals (Fe-oxides or coalified organic matter). Bioclasts (siliceous sponge spiculae, fragments of bivalve and gastropod shells, ostracods and bryozoans) are quite common.

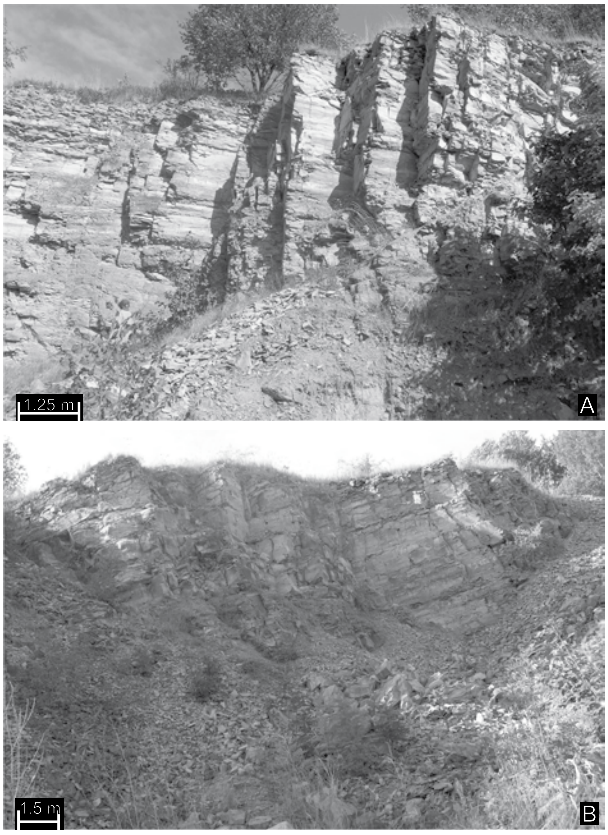


Fig. 4. The Stara Bystrzyca quarry.
A: The north-eastern wall which contains abundant inoceramids; **B:** The western wall where the specimen of *Lewesiceras peramplum* Mantell was found.

5. Systematic descriptions of the fossils

The literature used to determine the fossils included works by Scupin (1912–1913), Andert (1934), Moore (1968), Kennedy & Wright (1981), Malinowska (1984), Walaszczyk (1988, 1992), Tarkowski (1991) and Kaesler (1996). Foraminifers observed in thin sections were determined on the basis of works by Witwicka (1958), Moore (1964), Jerzykiewicz & Teisseyre (1974), Teisseyre (1975, 1992), Gawor-Biedowa (1980), Walaszczyk et al. (2004a) and Kędzierski et al. (2012).

All specimens are stored in the collection of the Geological Museum, University of Wrocław (catalogue numbers from MGUWr–5453s to MGUWr–5484s and MGUWr–5487s).

5.1. Ammonoidea

Order Ammonoidea Zittel, 1884
Suborder Ammonitina Hyatt, 1889
Superfamily Desmoceratoidea Zittel, 1895
Family Pachydiscidae Spath, 1922
Genus *Lewesiceras* Spath, 1939
Synonyms
Ammonites peramplus Mantell, 1822
Lewesiceras peramplus Young, 1979
Lewesiceras peramplum Wright and Kennedy, 1984

5.1.1. *Lewesiceras peramplum* Mantell, 1822
(Fig. 6 A-E)

1840. *Ammonites lewesiensis* Mantell; H.B. Geinitz, p. 39
1842. *Ammonites peramplus* Mantell; H.B. Geinitz, p. 67, pl. 12, fig. 2; pl. 13, fig. 4
1904. *Pachydiscus peramplus* Mantell; K. Flegel, p. 21
1934. *Pachydiscus peramplus* Mantell; H. Andert, pp. 397–398
1972. *Lewesiceras peramplum* Mantell; R. Marcinowski and M. Szulczewski, pp. 532–535, pl. 4, figs 1–2
1981. *Lewesiceras preramplum* Mantell; W.J. Kennedy and C.W. Wright, pp. 495–500, pl. 74, figs 1–2; 75, figs 1–7; text-figs 1, 2A-B
1988. *Lewesiceras peramplum* Mantell; I. Walaszczyk, pl. 4, fig. 3
1991. *Lewesiceras peramplum* Mantell: R. Tarkowski, pp. 125–126, pl. 21, fig. 3; pl. 22, fig. 4

For a comprehensive synonymy, see Kennedy & Wright (1981), Kennedy et al. (1983), Walaszczyk (1988), and Tarkowski (1991).

Material

A single specimen, stored at Geological Museum, University of Wrocław, No MGUWr–5453s, preserved as an internal mould.

Specimen's description

The specimen from the Stara Bystrzyca quarry is an internal mould with a diameter of approx. 45 cm. As some part of a whorl is missing on the ventral side, the initial diameter of this ammonite might have been larger (?49 cm). The large diameter of the ammonite is typical of the genus *Lewesiceras*. Because the suture line is invisible, it is difficult to state if the phragmocone is complete and if the body chamber is present. The suture line has been presented by, among others, Kennedy et al. (1983) and Kennedy & Wright (1981).

The specimen has ornamentation in the form of tubercles that stretch into primary ribs. The umbilicus is covered with a rock fragment but it seems to be narrow, because the tubercles are party visible. On the side of the whorl, at the umbilical margin, eight tubercles of various sizes and eight primary ribs are visible. The largest tubercle is 3 cm wide; the following ones are less distinct. The tubercles pass forwards into lengthwise, straight or slightly curved primary ribs that are poorly marked. Every primary rib is followed by a depression. Smaller secondaries (intercalaries) are not visible. The ventral side is rounded, narrower and smooth. The whorls' height (19.0 cm) is always larger than the whorls' width (13 cm) (see the morphological features of the ammonite shell in Fig. 7). The ornamentation of the early and median portions of the phragmocone (inner whorls) is more expressed than on the external whorls.

In general, the ornamentation gradually disappears, which is a characteristic feature of this species. Adult specimens of *Lewesiceras peramplum* have a sculpture consisting of wide, flat ribs that are developed close to the umbilicus only; occasionally the last whorl is completely devoid of sculptures.

Discussion

Lewesiceras belongs to Pachydiscidae. *Eopachydiscus* Wright 1955 was confirmed as the earliest (Upper Albian) representative of the Pachydiscidae. Matsumoto (2003) described a new ammonite species, *Lewesiceras shimanukii* from the Lower Coniacian of Japan and regarded it as transitional between *Eopachydiscus* and the common species of the genus *Lewesiceras* well known for their enormous size.

Occurrence

The genus *Lewesiceras* is known from the North European Province of the Boreal Realm and from the Northern Transitional Subprovince (Poland, the Czech Republic, Germany, France, Great Britain, Spain, Romania, Bulgaria, S Sweden), but it has also been reported from other regions such as the Pacific Province

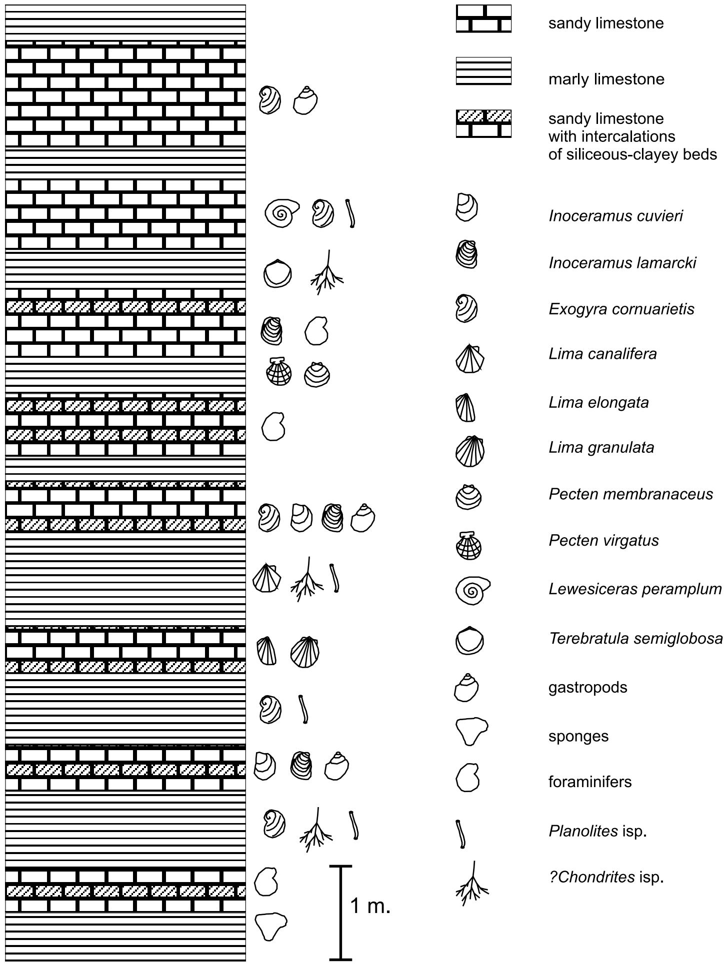


Fig. 5. Section of the Middle Turonian in the Stara Bystrzyca quarry.

or Tethys Province (Japan, Montana (USA), Madagascar, North Africa, S India, Russia) and Asia (Crimea, Causasus, Kazakhstan) (Moore, 1968; Kennedy & Wright, 1979; Matsumoto, 1979; Kennedy & Wright, 1981, Čech, 1989; Lamolda et al., 1989, Tarkowski, 1991; Kaesler, 1996; Marcinowski et al., 1996; Wiese & Kaplan, 2001; Ion et al., 2004; Košťák et al., 2004; Wiese et al., 2004; Ekrt et al., 2008). The genus *Lewesiceras* is known from SE France and this confirms migration of this boreal ammonite, during a cooling phase in the late Middle Turonian, in a southern direction (Wiese & Voigt, 2002; Košťák & Wiese, 2011). It is found from the Upper Cenomanian to the Coniacian in Europe, especially in deposits from the Early to the end of the Middle Turonian (Kennedy & Wright, 1981). According to Kaesler (1996), the genus *Lewesiceras* occurs from the Early Cenomanian to the ?Coniacian of Europe.

From the Lower Turonian, *Lewesiceras peramplum* is known from NW Europe (Monnet & Bücher, 2007); it was found also in the Czech Republic (Tarkowski, 1991; Uličný et al., 1997; Trbušek, 1999), Great Britain, France and Spain (Kennedy & Wright, 1981, Lamolda et al., 1989, Tarkowski, 1991, Woods, 2007), Germany (Andert, 1934) and Bulgaria (Tarkowski, 1991).

From the Middle Turonian, the species was reported from the Opole region (SW Poland) (Walaszczyk, 1988, Tarkowski, 1991, Kin, 2007), the Sudety Mountains (North Sudetic Basin and Intra-Sudetic Basin) (Andert, 1934) and the Bohemian Cretaceous Basin (Czech Republic), Germany, France and England. Seibertz (1978) and Diedrich & Hirayama (2003) reported *L. peramplum* from Germany. It also was found in France and England (Kennedy & Wright, 1979; Tarkowski, 1991; Diedrich & Hirayama, 2003; Woods, 2007). Kennedy & Wright (1981) stated that *Lewesiceras peramplum* is one of the most common ammonites in the Turonian of France, ranging from the Early Turonian to the top of the Middle Turonian (*Mammites nodosoides*

– *Collignoniceras woollgari* Zones). Tarkowski (1991) mentioned Bulgaria and the Czech Republic, whereas Kaplan and Kennedy (1996) reported its Middle Turonian occurrence from Germany.

From the Upper Turonian, the genus was reported by Flegel (1904) from the Intra-Sudetic Basin (Stołowe Mountains). Marcinowski & Szulczewski (1972) described *L. peramplum* from the Mesozoic margin of the Holy Cross Mountains, the Kraków Upland, the Polish Jura Chain-Miechów Synclinorium, the Opole Trough, the northern Caucasus and the Crimea. Tarkowski (1991), Walaszczyk (1988) and Kin (2007) reported this taxon from the Upper Turonian of Poland (Opole Trough, Miechów Synclinorium).

Marcinowski & Szulczewski (1972), Gale (1996), Lomerzheim (1976) and Kennedy et al. (2005b) mentioned this genus from the whole Turonian of Great Britain, France, Germany, the Czech Republic and USA (Colorado).

5.1.2. ?*Lewesiceras* sp.

(Fig. 6 H-L)

Material

A single specimen, housed at the collection of the Polish Geological Institute – Polish Research Institute, Wrocław, preserved as an evolute, internal mould.

Specimen's description

An ammonite with a large, evolute shell (an internal mould). The maximum diameter of the complete shell is about 33 cm. The coiling is evolute with an umbilical diameter of about 12 cm. It seems that the phragmocone is rather complete, and probably the body chamber is partially or complete preserved, but this cannot be ascertained because the suture line is invisible. The ornamentation consists of dense, more or less regular ribs on the phragmocone, starting from the umbilicus. Strong, primary ribs arise from well developed elongated umbilical bullae, and are more or less regular.

The ornamentation is more developed on the inner whorls than on the external ones. The last whorl is rather smooth. The umbilicus is shallow with low, narrow, rounded umbilical shoulders. The ventral side is narrow. The whorl section tends to be compressed and flat-sided. The ornamentation changes on the outer whorls. It consists of about 20 main ribs (sinusoidal) and tubercles-bullae (0.5–1.5 cm). The distance between the ribs ranges from 3.0 to 5.0 cm. The whorl's breadth is 8.0 cm and its height is 13 cm (see the morphological features of the ammonite shell in Fig. 7). All ribs end in marginal tubercles at the ventral side of the shell. On the inner and middle flank, the tubercles are straight and strong, but then bend forwards to become concave on the outer flanks. With regard to the density and shape of the ribbing, the shallow umbilicus and the evolute coiling, the specimen corresponds best to the diagnosis of ?*Lewesiceras* sp. The specimen differs slightly in ornamentation from *L. peramplum* and *L. mantelli*.

According to W.J. Kennedy (Oxford University, pers. comm. 2012), this specimen cannot be ascribed to *Lewesiceras mantelli* or *L. peramplum* because these species have 13–14 primary ribs per whorl. The specimen described has 50% more ribs. The study material is somewhat similar to *Puzosia* (*Mesopuzosia*) sp., but it differs in density and character of the ribs (Moore, 1968; Kaesler, 1996). *Mesopuzosia* has numerous dense and fine ribs, most of which are long, with some shorter ones in between (see Matsumoto et al., 1990). According to W.J. Kennedy (Oxford University, pers. comm. 2012), the specimen does, however, not resemble *P.* (*Mesopuzosia*) sp. either, because the ribs are too strong. The material corresponds well to the genus *Lewesiceras* sp., but due to the lack of species-level distinguishing features, identification at species level is impossible, and even the genus is questionable.

Occurrence

The genus *Lewesiceras* is known from the Lower Cenomanian to the ?Coniacian (Kaesler 1996). According to Kennedy & Wright (1981), it ranges from the Upper Cenomanian to the Coniacian, and is especially common in the Lower and Middle Turonian. Ammonites described as *Lewesiceras* sp. have been reported from Poland (Niedźwiedzki & Kalina, 2003) and from Czech Republic (Wiese et al., 2004). The genus *Lewesiceras* was also described from the Turonian of Poland (Marcinowski & Szulczewski, 1972; Walaszczyk, 1988; Tarkowski,

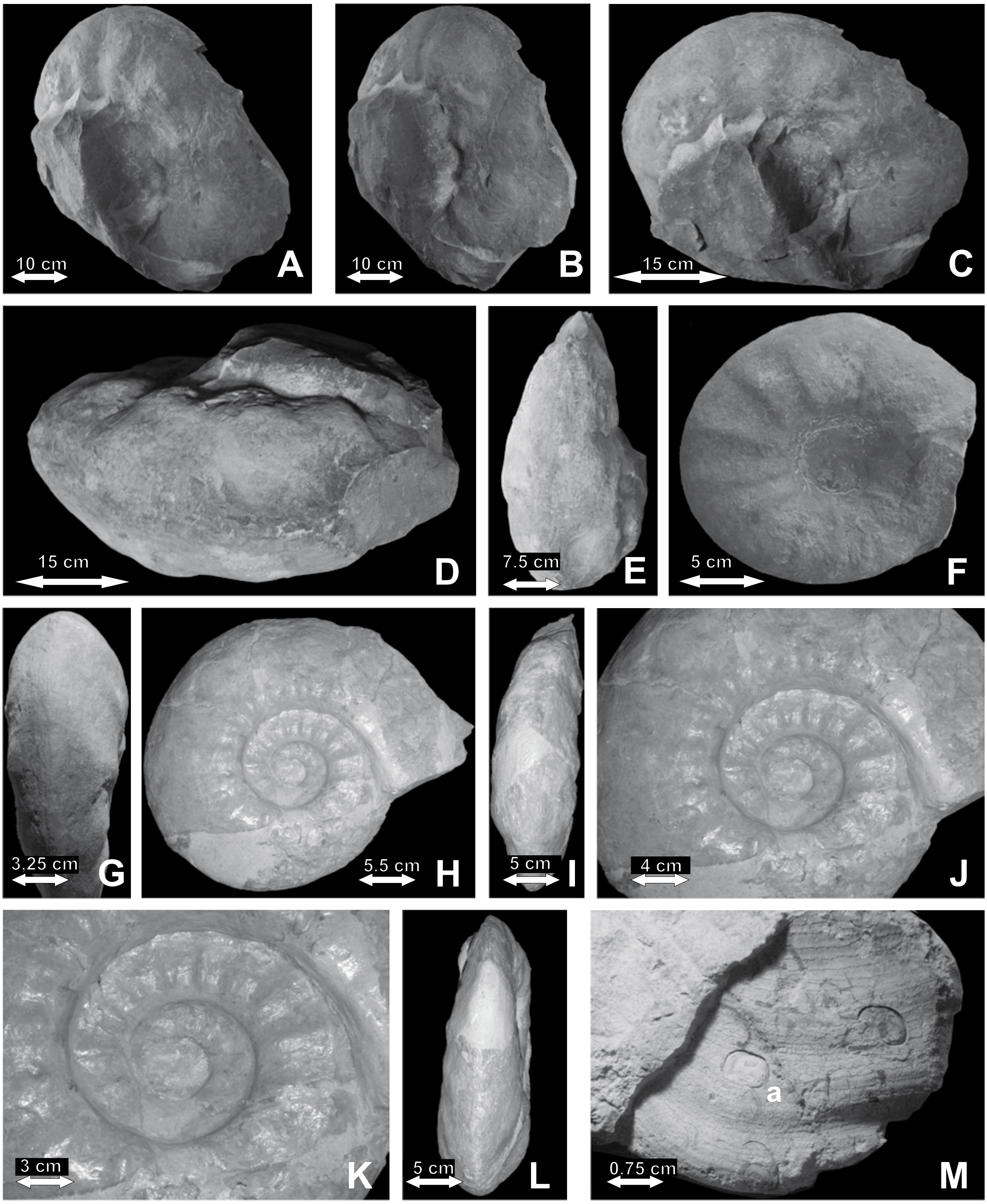
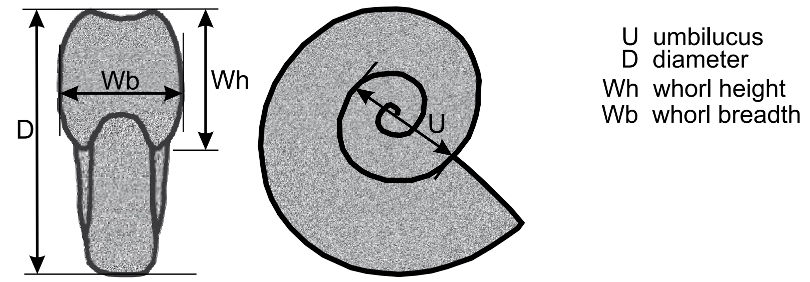


Fig. 6. Late Cretaceous ammonites and inoceramids from the Nysa Kłodzka Graben.
A-E: *Lewesiceras peramplum* Mantell (MGU.Wr – 5453s), Middle Turonian, Stara Bystrzyca quarry; **F-G:** *Pachydiscus peramplum* Mantell from the German collection (?Flegel 1904; no MGUWr.–1800s); **H-L:** ?*Lewesiceras* sp. from the collection of the Polish Geological Institute – Polish Research Institute, Wrocław (specimens found by Radwańska in the middle of the 20th century), taxonomic assignment by the present author. ?Coniacian, Wilkanów (S. Cwojdziński, PGI-PRI Wrocław, pers. comm. 2011); **M:** *Inoceramus cuvieri* Sowerby, Middle Turonian, Stara Bystrzyca quarry (MGUWR–5454s); a) gastropods prints.



specimens	D	Wb	Wh	U	wb/wh
Lewesiceras peramplum MGUWR-5453s	490 mm	130 mm	190 mm	-	70%
?Lewesiceras sp. (coll. PGI-PRI)	330 mm	80 mm	130 mm	120 mm	60%

Fig. 7. Morphological features of an ammonite shell according to Yacobucci (2004), slightly changed. The table shows the values of these features for the specimens of *Lewesiceras peramplum* and ?*Lewesiceras* sp. under investigation.

1991; Kin, 2007; Kin & Niedźwiedzki, 2012) and is also known from the Czech Republic (Čech 1989; Uličný et al., 1997; Trbušek 1999, Wiese et al., 2004; Ekrt et al., 2008) and Germany (Seibertz, 1978; Wiedman, 1989; Kaplan & Kennedy, 1996; Lommerzheim, 1976; Diedrich & Hirayama, 2003). From elsewhere in Europe it was reported from France, England, Spain, Sweden, Bulgaria and Romania (Sornay, 1964; Kennedy & Wright, 1979, 1981; Mortimore & Pommerol, 1991; Tarkowski 1991; Gale, 1996; Ion et al., 2004; Košťák et al., 2004; Woods, 2007). Outside Europe, the genus has been reported from Japan, Montana (USA), Madagascar, northern Africa, S India, Russia, the Crimea, the Causasus and Kazakhstan (Ivannikov, 1967; Collignion, 1971–1972; Matsumoto, 1979; Kaesler, 1996; Marcinowski et al., 1996; Kennedy et al., 2005a; Ayyasami, 2006; Feldman et al., 2007).

5.2. Inoceramidae

Family Inoceramidae Zittel, 1881
Genus *Inoceramus* Sowerby, 1814

5.2.1. *Inoceramus cuvieri* Sowerby, 1822

(Fig. 6 M; Fig. 8 A-C)

1901. *Inoceramus cuvieri* Sowerby; F. Stürm, p. 92, pl. 10, fig. 1

1957. *Inoceramus cuvieri* Sowerby; F. Mitura, p. 275, pl. 27, figs 4,9,10

1984. *Inoceramus cuvieri* Sowerby: L. Malinowska, pp. 362–363, pl. 156, fig. 2

1991. *Inoceramus cuvieri* Sowerby; R. Tarkowski, p. 106, pl. 9 fig. 13; pl. 10, fig. 5

1992. *Inoceramus cuvieri* Sowerby; I. Walaszczyk, p. 31, pl. 11, figs 2–3

1999. *Inoceramus cuvieri* Sowerby; H. Summesberger et al., p. 47, pl. 4, figs 1–2

For a comprehensive synonymy, see Mitura (1957) and Tarkowski (1991).

Material

9 specimens, No MGUWr–5454s to MGUWr–5457s, stored at the Geological Museum of Wrocław University. The fragments of large and medium-sized specimens are preserved in the form of internal moulds, in places containing shell fragments.

Specimens' descriptions

The specimens have flat, slightly convex, thick shells. The biggest specimens are only slightly convex. The outlines of the shells are subtriangular to subquadrate. The fragments are up to 15–18 cm long (Fig. 8 A). The length of the best preserved mould (Fig. 6 M) is 6.0 cm, its height is 6.5 cm, its axial length is 6.0 cm and its secondary axis is 7.0 cm (see the morphological features of the inoceramid shell in Fig. 9). The surfaces of the internal moulds are smooth or slightly undulated with dense, regular, "jagged" growth lines that are typical of this species (Mitura, 1957). These lines are more or less regularly distributed (from 1.0 to 4.0 mm, in most cases approx. 2.0–2.5 mm). The growth rings (rugae) are wide (from 0.6 to over 1.0 cm, max. 2.0–2.5 cm), flat and bear concentric arcs. Traces of the growth lines are visible only partly; they are parallel to the rugae.

The specimens do not differ from the specimens described by Mitura (1957) and Tarkowski (1991). The shape, appearance and ornamentation – which forms a pattern of delicate "jagged" dense growth lines (Fig. 6 M; Fig. 8 C) – suggest that these specimens belong to the species *I. cuvieri*.

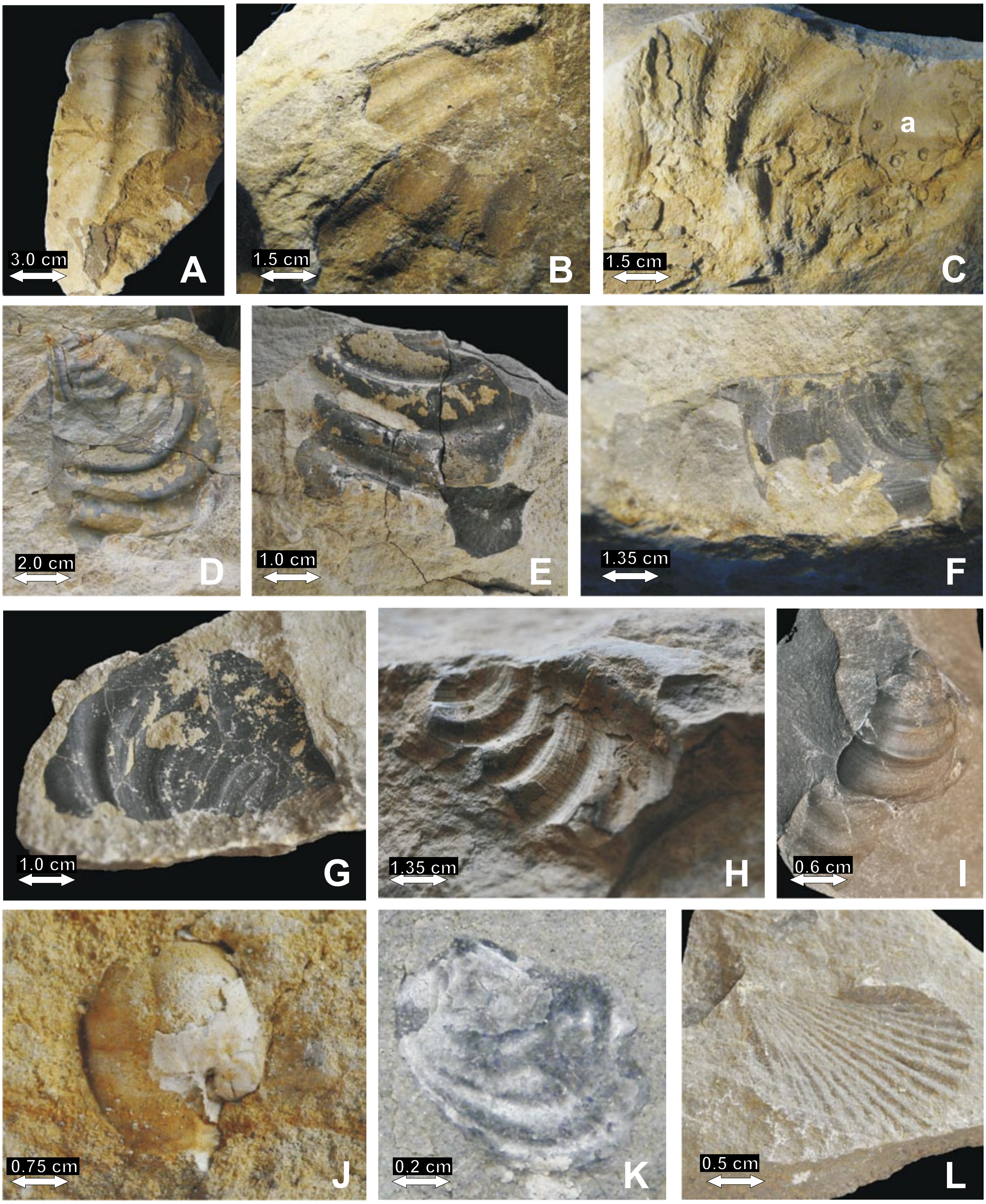
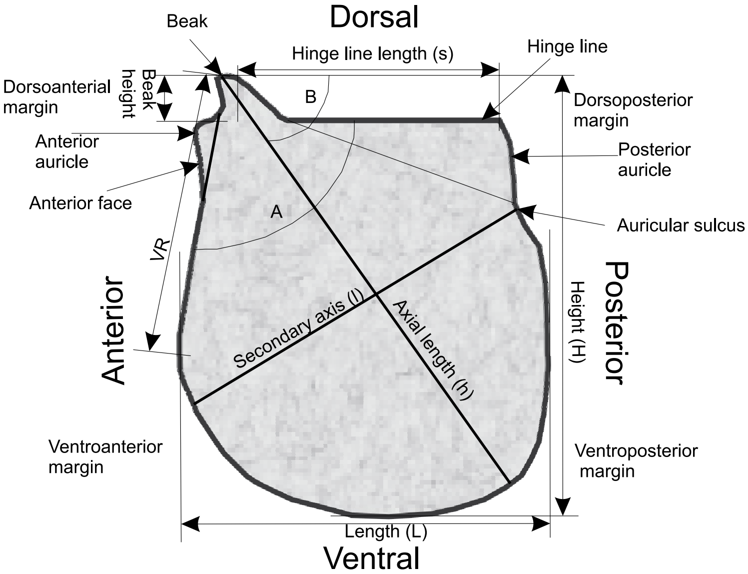


Fig. 8. Inoceramids and other bivalves from the Middle Turonian of the Stara Bystrzyca quarry.
A-C: *Inoceramus cuvieri* Sowerby (MGU.Wr–5455s through MGUWr–5457s); a) gastropods prints; **D-H:** *Inoceramus lamarcki* Parkinson (MGUWr–5458 through 5462s); **I:** *Inoceramus lamarcki* Parkinson, from the collection of the Geological Museum of Wrocław University (collection: Rafał Janek, MGUWR–5487s); **J:** *Exogyra cornuarietis* Nilsson-Griepenkerl (MGUWr–5465s); **K:** *Exogyra* sp. (MGUWr–5467s); **L:** *Lima canalifera* Goldfuss (MGUWr–5473s).



A Anterior hinge angle
B Angle of growth axis
VR Length of anterior margin

specimens	length(L)	height (H)	axial length (h)	secondary axis (l)	beak height (bh)	anterior hinge angle (A)	anterior margin (VR)
I.cuvieri; MGUWr-5454s	6.0 cm	6.5 cm	6.0 cm	7.0 cm	-	-	-
I.lamarcki; MGUWr-5458s	7.0 cm	8.5 cm	10.0 cm	8.0 cm	0.8 cm	105°	3 cm
I.lamarcki; MGUWr-5460s	6.0 cm	6.0 cm	8.0 cm	6.0 cm	-	95°	3 cm
I.lamarcki; MGUWr-5461s	4.5 cm	5.0 cm	5.0 cm	4.0 cm	-	110°	1.5 cm
I.lamarcki; MGUWr-5487s	3.5 cm	7.0 cm	7.5 cm	5.5 cm	-	85 °	3.0 cm

Fig. 9. Morphological features of an inoceramid shell according to Walaszczyk & Wood (1998) and Walaszczyk et al. (2004a), slightly changed. The table shows the values of these features for the specimens of *Inoceramus cuvieri* and *I. lamarcki* under investigation.

Numerous imprints of gastropods are preserved on the internal moulds; their diameters range from 1.5 mm to 3.5 mm and in some cases even reach 1 cm (Fig. 6 M; Fig. 8 C). Fragments of shells, preserved on the internal moulds or in the rock, are 3–5.5 mm thick (on some specimens they are thinner: 1.5–2 mm).

Occurrence

Inoceramus cuvieri Sowerby is known from the Middle Turonian and the lower Upper Turonian of the Opole Trough (Poland), the Turonian of England, the Middle and Upper Turonian of the Carpathians, Germany, the Czech Republic, Canada and the USA (Tarkowski 1991). It is also known from the Upper Turonian of Russia and Ukraine (Donbas, Crimea, Caucasus), Kazakhstan (Mangyshlak) and Kamchatka. According to Mitura (1957), I. cuvieri occurs in the Middle Turonian (*Inoceramus lamarcki* Zone) in the Łódź Synclinorium (Poland) and in the Upper Turonian of England and Germany. Herman & Spicer (1997) mentioned *I. cuvieri* from the Upper Turonian of NE Russia. Robaszyński et al. (2005) described *Inoceramus cuvieri* from the Middle Turonian of the Paris Basin (France). Summesberger et al. (1999) reported *I. cuvieri* from the Upper Turonian of Austria.

5.2.2. *Inoceramus lamarcki* Parkinson, 1819

(Fig. 8 D-I)

1974. *Inoceramus lamarcki* Parkinson; R. Marcinowski, pl. 25, figs 2 a, b
1984. *Inoceramus lamarcki* Parkinson; L. Malinowska, p. 362, pl. 156, fig. 1
1988. *Inoceramus lamarcki lamarcki* Parkinson; I. Walaszczyk, pl. 3, figs 1,6
1991. *Inoceramus lamarcki lamarcki* Parkinson; R. Tarkowski, pp. 111–112, pl. 7, figs1,3; pl. 8, figs 2–4
1992. *Inoceramus lamarcki* Parkinson; I. Walaszczyk, pp. 30–31, pl. 9, figs 4–7; pl. 10, figs 1–3; pl. 11, figs 1,4

For a comprehensive synonymy, see Walaszczyk (1988) and Tarkowski (1991).

Material

6 specimens, No MGUWr- 5458 to MGUWr–5462; MGUWr–5487s), stored at the Geological Museum of Wrocław University. Three almost complete shells, two entirely preserved moulds and some pieces of shells.

Specimens' descriptions

The medium-sized specimens have triangular outlines and rounded edges. The shells are moderately convex; sometimes they are inflated. The specimens are 3.5–7.0 cm long and 5.0–8.5 cm high; their axial lengths range from 5.0 cm to 10.0 cm and their secondary axes from 4.0 to 8.0 cm (see the morphological features of the inoceramid shell in Fig. 9). The beak is pointed, slightly projecting above the hinge line (beak height: 0.8 cm). The apical angle (anterior hinge angle) varies from 85° to 110°. The most characteristic feature is the occurrence of distinct (weak to strong) concentric, subrounded ribs, regularly increasing in size with relatively wide, flat interspaces. In the juvenile part, they are more or less regularly spaced, while their interspaces gradually increase (from 0.5 cm to 1.5 cm) towards the ventral side of the shell in the adult part.

The rugae are the strongest developed in the anterio-ventral, ventral and ventro-posterior part of the shell (Fig. 8 D, G-I). They become gradually weaker developed when passing onto the dorsal part of the valve. The growth rings (rugae) and spaces between them are covered with poorly visible growth lines, which are more or less symmetrically distributed. The distance between the growth lines increases towards the ventral side and ranges from 1.0 to 4.0 mm. The growth lines are well preserved, and rather straight (not 'jagged' as in specimens described as *I. cuvieri*). They are parallel to the rugae.

These specimens (Fig. 8 D-I) differ in the general outline and pattern of their surface ornament, especially with regard to the growth lines, from specimens recognized as *I. cuvieri*. They show a close similarity to *I. lamarcki*.

Occurrence

Inoceramus lamarcki Parkinson is known from the Middle Turonian of Poland (Opole Synclinorium: Opole, Krzanowice; Miechów Synclinorium; Tarkowski, 1991). It has also been described from the Middle Turonian of England, France, Germany, India and Madagascar. It occurs in the Middle and Upper Turonian of Germany, in the Middle Turonian to the Coniacian in England, and in the Upper Turonian of the East European Platform and Asia (Donbas, Crimea, Caucasus, Mangyshlak and Kamchatka). Walaszczyk (1992) described this species from the Middle to lower Upper Turonian deposits of the Central Polish Uplands.

5.3. Other fossils

In addition to the ammonite *Lewesiceras peramplum* Mantell and the inoceramids *Inoceramus cuvieri* Sowerby and *I. lamarcki* Parkinson, the Middle Turonian sandy and marly limestones with intercalations of siliceous-clayey beds of Stara Bystrzyca contain also other bivalves: *Exogyra cornuarietis* Nilson-Griepenkerl (Fig. 8 J), *Exogyra* sp. (Fig. 8 K), *Lima canalifera* Goldfuss (Fig. 8 L), *Lima elongata* Geinitz (Fig. 10 A-B, E), *Lima granulata* Nilsson (Fig. 10 C-D), *Pecten membranaceus* Nilsson (Fig. 10 G), *Pecten virgatus* Nilsson (Fig. 10 F). Further, the brachiopod *Terebratula semiglobosa* Sowerby (Fig. 10 H) is present. The assemblage of trace fossils comprises ?*Chondrites* isp. (Fig. 10 I), *Planolites beverleyensis* (Fig. 10 J) and *Pl. montanus* (Fig. 10 K-L).

The majority of these taxa were already described by Scupin (1912–1913), Geinitz (1843), Andert (1934) from other outcrops of the Middle Turonian in the Nysa Kłodzka Graben, the Intra-Sudetic Synclinorium and the North Sudetic Synclinorium. Inoceramids were described from Poland (and other countries) by Walaszczyk (1988, 1992), Walaszczyk & Wood (1998), Walaszczyk et al. (2004a,b) and Zonova & Yazykowa (1998).

The Stara Bystrzyca quarry yielded also fragments of sponges, gastropods and an assemblage of mostly benthic calcareous and agglutinated foraminifers (Table 1; Fig. 11). A similar assemblage of foraminiferal benthos and plankton has been described from the Upper Turonian of the Bohemian Cretaceous Basin (Vodrážka et al., 2009).

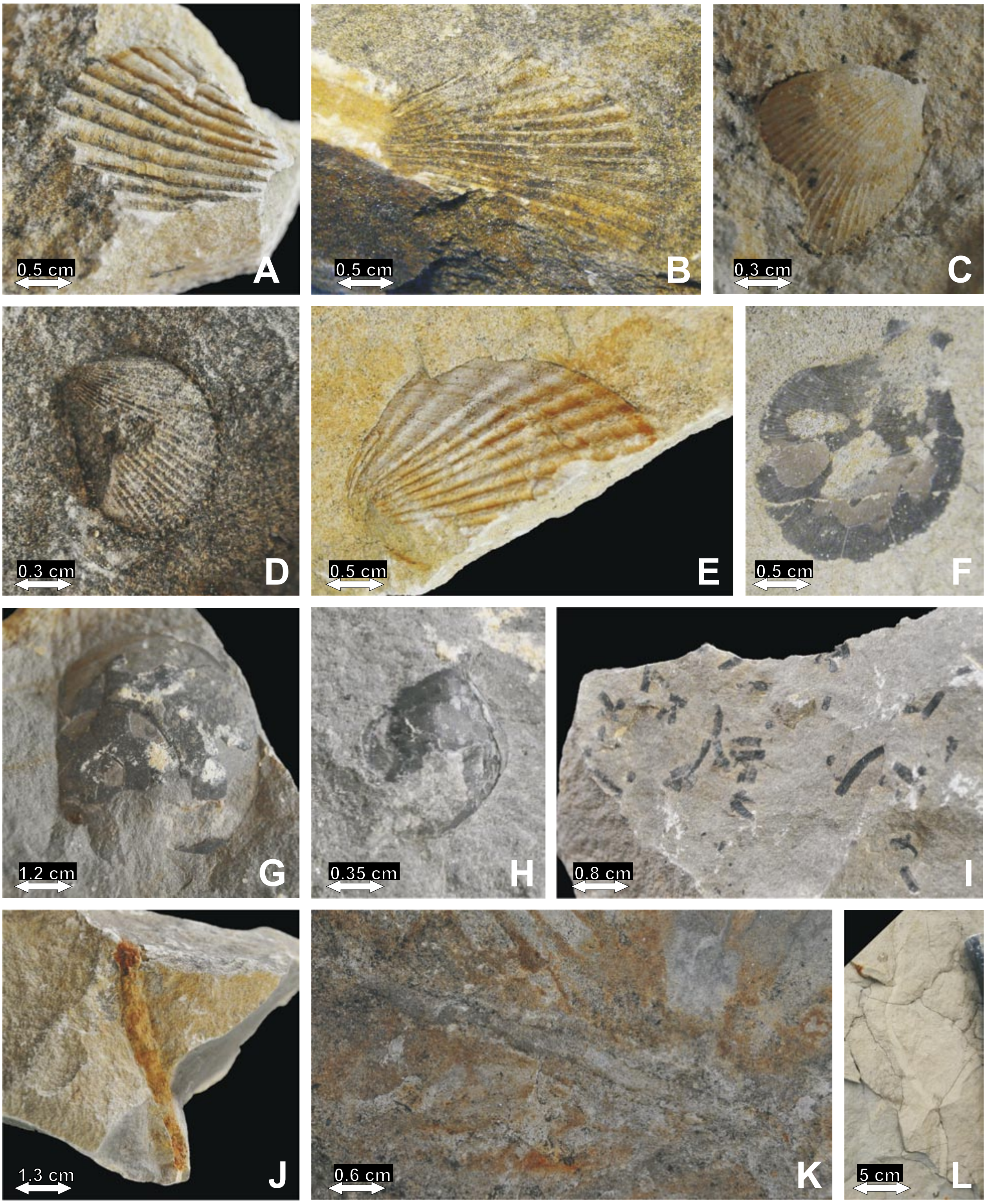
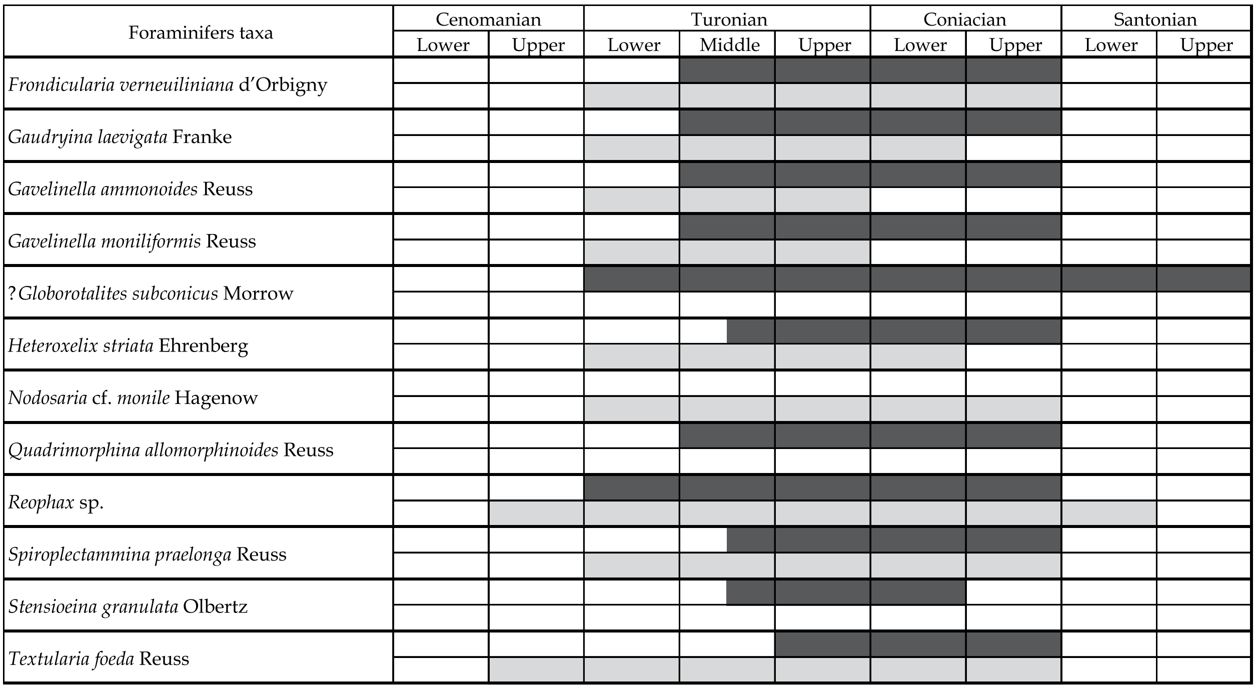


Fig. 10. Bivalves and trace fossils from the Middle Turonian of the Stara Bystrzyca quarry.
A-B: *Lima elongata* Geinitz (MGU.Wr – 5475s through MGUWr–5476s); **C-D:** *Lima granulata* Nilsson (MGUwr–5477s through MGUWr–5478s); **E:** *Lima elongata* Geinitz (MGUWr–5479s); **F:** *Pecten virgatus* Nilsson (MGUWr–5480s); **G:** *Pecten membranaceus* Nilsson (MGUWr–5481s); **H:** *Terebratula semiglobosa* Sowerby (MGUWr–5482s); **I:** ?*Chondrites* isp. (MGUWr–5483s); **J:** *Planolites beverleyensis* (MGUWr–5484s); **K-L:** *Planolites montanus*.

Table 1. Stratigraphic ranges of the foraminifer assemblage in the Middle Turonian deposits of the Stara Bystrzyca quarry.



stratigraphic ranges in the Nysa Kłodzka Graben according to Jerzykiewicz and Teisseyre (1974); Teisseyre (1975); Gawor-Biedowa (1980)

stratigraphic distribution in the North Sudetic Synclinorium after Teisseyre (1992)

6. Stratigraphy of the Stara Bystrzyca limestones

The Nowa Bystrzyca limestones belong to the second level of marls (the siliceous-calcareous marls, *Inoceramus lamarcki* Zone) that overlie the Quader Sandstone (Fistek & Gierwielaniec, 1957, 1964). The first level of marls (the sandy marls, *Inoceramus lamarcki* Zone) is present below the sandstone. Wroński & Cwojdziński (1984), in their explanation to sheet Bystrzyca Kłodzka of the Polish geological map (Wroński, 1981), also mentioned a first marl level of 10 m thick and a second one of 50 m thick; these two levels are separated by the Quader Sandstone (50–60 m).

The most relevant for the biostratigraphy of the Stara Bystrzyca limestone are the inoceramids (*Inoceramus cuvieri*, *I. lamarcki*); the foraminifers are less important. The inoceramids *Inoceramus cuvieri* Sowerby and *I. lamarcki* Parkinson are common in the Stara Bystrzyca quarry and have enormous sizes (Fig. 8 A-C). According to numerous authors, *I. cuvieri* was the most widespread during the middle and upper Middle Turonian (see Walaszczyk, 1992). The second inoceramid, *I. lamarcki*, that also abounds in the Stara Bystrzyca quarry, is typical of the upper part of the Middle Turonian (Walaszczyk, 1992). The joint occurrence of both *I. cuvieri* and *I. lamarcki* indicates a position in the upper part of the *Inoceramus lamarcki* Zone (uppermost Middle Turonian). Because of the common presence of *I. cuvieri* Sowerby and *I. lamarcki* Parkinson, one may assign the Stara Bystrzyca limestones to the upper Middle Turonian (upper part of the *Inoceramus lamarcki* Zone).

Thin-section analysis of the foraminifers allows only an approximate dating of the sandy and marly limestones because most taxa have long stratigraphic ranges; some foraminifers (*Stensioeina granulata* Olbertz, *Heteroxelix striata* Ehrenberg, *Spiroplectammina praelonga* Reuss), however, are known from middle Middle Turonian of the Nysa Kłodzka Graben (Table 1), thus suggesting a middle Middle Turonian age or younger for the sandy, marly limestones and siliceous-clayey beds. Teisseyre (1992) defined

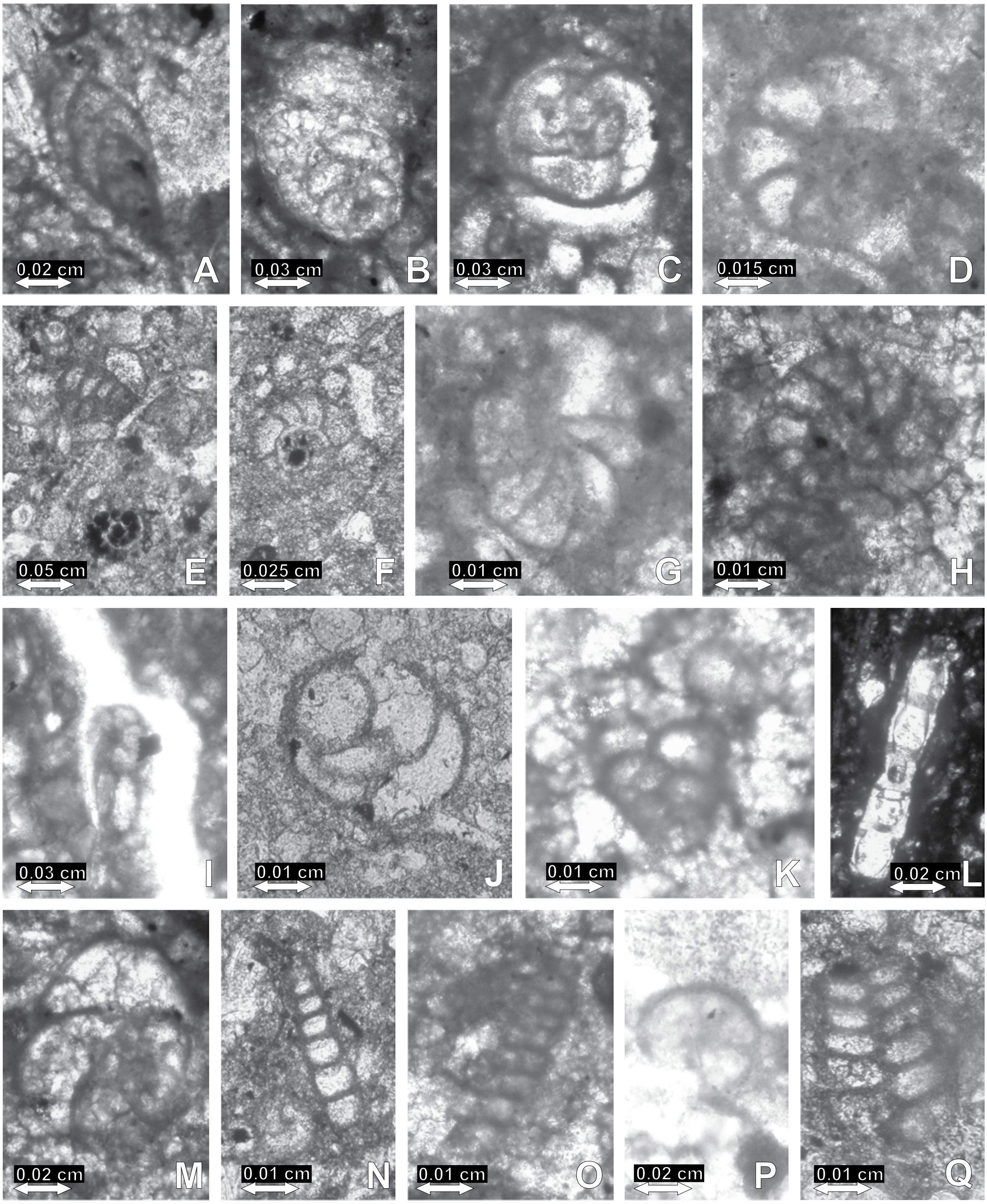


Fig. 11. Assemblage of foraminifers from the Middle Turonian, Stara Bystrzyca quarry.
A: *Frondicularia verneuiliniana* d'Orbigny; **B-C:** *Gaudryina laevigata* Franke; **D:** *Gavelinella moniliformis* Reuss; **E-F:** *Gavelinella ammonoides* Reuss; **G-H:** *Gavelinella moniliformis* Reuss; **I:** ?*Globorotalites subconicus* Morrow; **J-K:** *Heteroxelix striata* Ehrenberg; **L:** *Nodosaria* cf. *monile* Hagenow; **M:** *Quadrimorphina allomorphinoides* Reuss; **N:** *Reopax* sp.; **O:** *Spiroplectammina praelonga* Reuss; **P:** *Stensioina granulata* Olbertz; **Q:** *Textularia foeda* Reuss.

the *Gavelinella moniliformis – Gaudryina* Zone in the North Sudetic Synclinorium; it comprises the latest Lower Turonian to Lower Coniacian. The Bystrzyca limestone could belong to a correlatable zone in the Nysa Kłodzka Graben. The *Gavelinella moniliformis* Zone was also distinguished by Walaszczyk et al. (2004a) in the Middle Turonian of central European Russia.

The *Inoceramus lamarcki* Zone and the same age (the upper part of the *Inoceramus lamarcki* Zone) is also indicated by studies carried out by Radwański (1964), who mentioned the presence of large forms of *I. cuvieri* in the upper Middle Turonian. On the other hand, German and Polish geologists found *I. cuvieri* in the uppermost Turonian and assigned it to the *Inoceramus schloenbachi* Zone (Flegel, 1904; Scupin, 1907, 1912–1913, 1935, 1936). Kędzierski (2005) noticed that the Turonian, as understood by the authors, comprised also a part of the Coniacian. A similar situation occurred in the North Sudetic Synclinorium (Chrząstek, 2008a). This may have resulted in erroneous datings of sediments that contain *I. cuvieri*. Moreover, according to current views, *I. schloenbachi* Bohm (the present *Cremnoceramus crassus crassus*) denotes the Coniacian.

7. Reconstruction of the palaeoenvironment and palaeoecology

The fauna assemblage in the Middle Turonian sandy and marly limestone is indicative of a shallow-marine basin. The bivalves including inoceramids, and most of all oysters, gastropods, sponges, the predominance of benthic foraminifers, as well as the trace fossils, also point to a shallow basin.

The ammonites were probably stenotopic organisms, very sensitive to environmental changes (e.g. oxygenation level, salinity) (Tsujita & Westermann, 1998; Landman et al., 2012; Olivero, 2012). According to Zakharov et al. (2012), remains of ammonites shells are common in Mesozoic epicontinental seas, but rare in oceanic successions. On the other hand, Olivero (2012) reported that the number of ammonite specimens in both shallow- and deep-marine facies is almost the same. According to Matsukawa et al. (2012), Early Cretaceous ammonites inhabited near-shore, intermediate and distal-shelf to upper-slope environments.

Stevens (1988) correlated the presence of large ammonites with eustatic sea-level fluctuations (e.g. Cenomanian-Turonian). He reported that large ammonites lived in the deep-sea and migrated into more shallower settings during rising sea levels. On the other hand, Klug (2002), who examined Emsian and Eifelian ammonites, reported that 70% of the giant ammonites were found in layers which were deposited in shallow environments.

In the Stara Bystrzyca quarry, the abundant inoceramids, represented mainly by *Inoceramus cuvieri* Sowerby (Fig. 6 M, Fig. 8 A-C) and *I. lamarcki* Parkinson (Fig. 8 D-I) consist mainly of fragments that reached lengths of 20 cm, indicating that these forms must have been quite large. The largest piece of an inoceramid shell found in this quarry measures 40 cm (J. Wojewoda, Wrocław University, pers. comm. 2011). According to Hilbrecht & Harries (1996), Ozanne & Harries (2002) and Walaszczyk et al. (2004a), inoceramids have a large ecological tolerance: they are cosmopolitan and may live in various environments. Inoceramids are known from well-oxygenated, shallow-marine to poorly oxygenated, deep-marine settings (Harries & Ozanne 1998; Ozanne & Harries, 2002; Olivero, 2012). According to these authors, inoceramids prefer oxygen-depleted shelf environments, but can also thrive in well-oxygenated settings, including shallow-marine facies.

Ozanne & Harries (2002) and Kumagae et al. (2011) reported a cosmopolitan distribution of inoceramids in Mesozoic marine environments. According to Zonova & Yazykova (1998), the maximum diversity of inoceramids and ammonites was in the Late Turonian. Inoceramids abounded and exhibited a great taxonomical diversity during the Middle Turonian, at the beginning of a regressive cycle. On the other hand, the occurrence of ammonites correlates with transgressive peaks. During the regressive cycles they started to loose their taxonomical diversity, due to the reduction of the extent of the shelf areas (Zonova & Yazykova, 1998; Olivero, 2012).

Radwański (1964) reported that gigantic forms occurred in the upper part of the Middle Turonian, particularly *Inoceramus cuvieri* Sowerby, which are the most common representatives of the inoceramid fauna in the Bystrzyca beds and which can reach a size of 1 m. Maybe these specimens correlate with *Inoceramus hercules* (Heinz) (see Summesberger et al., 1999). According to Radwański (1964), the dominance of giant inoceramids could be a sign of an approaching change of environmental conditions that resulted in the stoppage of the inflow of larval forms. The absence of competition for food with others marine animals enabled the already existing individuals to reach large sizes. According to Radwański (1964), the uppermost beds of the Middle Turonian (*Terebratula semiglobosa* Zone) were deposited under much worse living conditions for the inoceramids, as large inoceramid specimens are rarely encountered in these beds.

Kauffman et al. (2007) described Middle Coniacian-Lower Campanian platyceramids, which commonly reach sizes of over 1 or even 2 m. These giant (chemosymbiotic) types are especially common in calcareous, dysoxic facies with abundant pyrite (Olivero, 2012). According to this author, they have smaller sizes in oxygenated environments. The giant platyceramids prefer settings with a low sedimentation rate and slow bottom currents.

Trace fossils are not common in limestone deposits. Their assemblage in the Stara Bystrzyca quarry (*Planolites montanus*, *Planolites beverleyensis*, and ?*Chondrites*) (Fig. 10 I-L) belongs to the *Cruziana* ichnofacies sensu Seilacher (Seilacher, 1967; MacEachern et al., 2007). Ichnoassemblages comprising *Chondrites* are usually referred to as representing oxygen-deficient conditions (Twitchett & Wignall, 1996; Uličný et al., 1997; Wetzel & Uchman, 2001; Giannetti & McCann, 2010; Rodríguez-Tovar & Uchman, 2010; Zonneveld et al., 2010; Gingras et al., 2011).

Chondrites itself is commonly known as an indicator of poor oxygenation (dysaerobic-exaerobic conditions) (McCann, 1990; Bromley, 1996; Savary et al., 2004; Uchman et al., 2008; Carmona et al., 2009; Knaust, 2009; Giannetti, 2010; Wetzel et al., 2011; Monaco et al., 2012). The *Chondrites* producers tolerate and perhaps even prefer oxygen-deficient conditions, even anoxia, as well as changes in salinity (Bromley & Ekdale, 1984; Savrda & Bottjer 1986; Allington-Jones et al., 2010; Cummings & Hodgson, 2011). According to Allington-Jones et al. (2010), the occurrence of *Chondrites* commonly coincides with an abundance of pyrite. This holds also true for the Stara Bystrzyca quarry, where pyrite mineralizations in marly limestone occur.

According to Malpas et al. (2005), Wetzel & Reisdorf (2007) and Carmona et al. (2009), the ichnoassemblage comprising *Chondrites* and *Planolites* suggests low-energy settings, a low sedimentation rate and deposition in the deepest part of the basin, in an environment with a low oxygen content (offshore shelf).

However, *Planolites* is a facies-crossing ichnotaxon which has been documented from almost all marine and continental environments (Hofmann et al., 2011). *Planolites* can appear in fully marine environments but the tracemaker can live under oxygen-deficient conditions (Martin, 2004; Chen et al., 2011). The tracemakers of *Planolites* and *Palaeophycus* need a fairly low oxygen level in the bottom water (Savrda & Bottjer, 1986; Savrda, 2007; Szulc, 1990, 2000; Chrząstek, 2008b,c; Rodríguez-Tovar et al., 2009; Boyer & Droser, 2011). According to Szulc (1990), the *Planolites-Palaeophycus* assemblage is characteristic of poorly-oxygenated conditions during transgressive maxima. On the other hand, *Planolites* can appear also in well-oxygenated environments (Savrda, 1995; Giannetti & McCann, 2010; Gingras et al., 2011; Hofmann et al., 2011; Phillips et al., 2011).

The sequential appearance of *Chondrites* – *Planolites* – *Thalassinoides* indicates increasing oxygenation (Bromley, 1996; Etter, 1996; Savrda, 2007; Monaco et al., 2012). The tracemakers of *Chondrites* prefer stenohalic conditions (MacEachern & Gingras, 2007), while the producers of *Planolites* are common in fully marine and brackish settings. On the other hand, the producers of *Chondrites* can also be able to survive when the salinity decreases (Allington-Jones et al., 2010).

In summary, the *Chondrites-Planolites* association is environmentally tolerant and occurs in different settings (McCann, 1990). It is particularly dominant in the deeper part of the basin (offshore shelf) and indicates low-oxygen conditions and a normal marine salinity.

In the Middle Turonian Bystrzyca and Długopole Sandstones appears an ichnoassemblage comprising mainly *Ophiomorpha nodosa*, *Thalassinoides suevicus*, *Thalassinoides paradoxicus*, *Curvolithus* and ?*Macaronichnus sp.*, typical of well-oxygenated, high-energy, shallow-marine environments. These trace fossils appear in the intertidal to shallow subtidal (foreshore-shoreface) part of the *Skolithos* ichnofacies (MacEachern et al., 2007; D'Alessandro & Uchman, 2007) and are considered to represent a deltaic environment. In the Middle Turonian sandy and marly limestones, the assemblage of trace fossils comprising only ?*Chondrites*, *Planolites beverleyensis* and *Planolites montanus* (*Cruziana* ichnofacies) suggests sedimentation in a slightly deeper basin. These trace fossils are characteristic of environments with a low rate of sedimentation, and probably less oxygenated conditions. *Chondrites-Planolites* assemblages are typical of offshore shelf settings (Kędzierski & Uchman, 2001; MacEachern et al., 2007; McIlroy, 2007).

On the basis of the fossil assemblage in the Middle Turonian, especially the inoceramids, oysters and trace fossils, one can deduce that the sandy limestones and marls were deposited in a deeper part of the basin (offshore shelf) than the Bystrzyca and Długople Sandstones of the same age. The sedimentation probably took place in a moderate- to low-energy environment with normal marine salinity and occasionally oxygen-deficient conditions.

7.1. Palaeogeographic setting

During the Cenomanian, the sea transgressed to the Nysa Kłodzka Graben from the SW (Bohemian Basin) and from the E (Opole Basin) and land masses became almost entirely flooded during the Early Turonian (Wojewoda, 1997; Biernacka & Józefiak, 2008, 2009). In the Intra-Sudetic Basin, the Nysa Kłodzka Graben and northern parts of the Bohemian Cretaceous Basin, silts and clays were deposited during the Early Turonian (Jerzykiewicz, 1975). In the Middle Turonian, a regression started, but it was interrupted by several phases of increased subsidence (Wojewoda, 1997; Rotnicka, 2005, 2007). A sandy facies developed first in the Middle Turonian (Bystrzyca and Długopole Sandstones). The clastic material of which the sandstones are built, was derived from the massifs that were being uplifted: the East Sudetic Island (Jerzykiewicz, 1975; Wojewoda, 1997). Don and Don (1960) and Radwański (1964, 1968) mention also Orlica Island as a possible source, but Chrząstek & Wojewoda (2011) suggest an Orlica uplift instead of an Orlica Island. The sandstones thin from the NE towards the SW and finally pinch out within calcareous deposits that accumulated in a deeper part of the basin. The transport was directed from North to South and from North-West to South-East. The Bystrzyca and Długopole Sandstones are interpreted as delta deposits (Uličný, 2001; J. Wojewoda, Wrocław University, pers. comm. 2011).

During the Middle Turonian the – until then – single marine basin was divided into a northern basin (with a connection to the North Sea and Atlantic) and a southern basin (with a connection to the Bohemian Basin and the Tethys) (Gawor-Biedowa, 1980; Chrząstek & Wojewoda, 2011). At the Turonian/Coniacian transition, another transgression started. The Cretaceous marine sediments of the Nysa Kłodzka Graben record two transgression maxima, one in the Early Turonian and another one during the late Turonian-Early Coniacian (Gawor-Biedowa, 1980; Schoeneichowa-Jaskowiak & Krassowska, 1988; Teisseyre, 1992, Wojewoda, 1997). The second transgressive maximum is better recorded, because it was due to the maximum subsidence in the area of the Nysa Kłodzka Graben (Jerzykiewicz, 1971, 1975; Wojewoda, 1997; Niedźwiedzki & Salamon, 2005). The transgressive cycles of the Cretaceous Nysa Kłodzka Graben sea fit the European bathymetrical curves of Hancock & Kauffman (1979), Haq et al. (1987), Hancock (1990) and Hancock & Walaszczyk (2004).

8. Conclusions

Investigation of sandy and marly limestones with intercalations of siliceous-clayey beds in the Stara Bystrzyca quarry yielded a specimen of *Lewesiceras peramplum* Mantell with a diameter 45 cm (because a part of a whorl is missing the complete specimen must have measured some 49 cm). This species has not been described earlier from the Middle Turonian sediments of the Nysa Kłodzka Graben area.

A second ammonite, assigned ?*Lewesiceras* sp. (diameter: 33 cm), has been found by Radwańska in the middle of the 20th century in ?Coniacian deposits of the graben, at Wilkanów (S. Cwojdziński, PGI-PRI Wrocław, pers. comm. 2011). Pachucki (1959) mentioned *Pachydiscus* aff. *peramplus* Mantell from the Emscherian of the graben.

Large specimens (up to 20 cm) of the inoceramids *I. cuvieri* Sowerby and *I. lamarcki* Parkinson also occur. The largest inoceramid shell ever found in the Stara Bystrzyca quarry has a diameter of 40 cm (J. Wojewoda, Wrocław University, pers. comm. 2011).

Other bivalves (including oysters) occur as well: *Exogyra cornuarietis* Nilsson-Griepenkerl, *Exogyra* sp., *Lima canalifera* Goldfuss, *Lima elongata* Geinitz, *Lima granulata Nilsson*, *Pecten membranaceus* Nilsson, and *Pecten virgatus* Nilsson. In addition, fragments of sponges, gastropods and brachiopods (*Terebratula semiglobosa* Sowerby) are present, as well as an assemblage of trace fossils (?*Chondrites* isp., *Planolites beverleyensis*, *Planolites montanus*). Thin sections show abundant foraminifers, sponge spiculae, bryozoans, ostracods and gastropods (Table 1).

The fauna, particularly the inoceramids and to a lesser degree the foraminifers, makes it possible to date the sediments as upper Middle Turonian (upper part of the *Inoceramus lamarcki* Zone) (Fig. 2 B).

The sandy and marly limestones with intercalations of siliceous-clayey beds in the Stara Bystrzyca quarry were deposited in a shallow-marine basin (offshore shelf) but in deeper parts than the Middle Turonian Bystrzyca and Długopole Sandstones, which are interpreted as delta deposits (foreshore-shoreface). This conclusion is based on the fossil assemblage, but it should be kept in mind that the trace fossils, representing the *Cruziana* ichnofacies, point to a slightly deeper environment. Both the macro- and trace fossils suggests a moderate- to low-energy environment with normal marine salinity and occasionally poorly oxygenated water.

Two distinct transgressive maxima (Early Turonian and Early Coniacian) took place in the Nysa Kłodzka Graben and adjacent area, whereas a regression culminated during the Middle and Upper Turonian. The transgressive cycle of the Late Cretaceous in the Nysa Kłodzka Graben is consistent with the global sea-level fluctuations indicated by Haq et al. (1987).

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