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The age of Štramberk-type limestone exotics from Kruhel Wielki vicinity in light of calpionellid biostratigraphy (Skole Nappe, Polish Outer Carpathians)

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ABSTRACT:

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The classic exposures of Štramberk-type exotic limestones in the Kruhel Wielki area (Gruszowa-Prałkowce Thrust Sheet, Skole Nappe) have been the subject of numerous studies on their stratigraphy and provenance. Previously, the age of the exotics was assumed to span the late Tithonian–Valanginian interval. However, calpionellid findings from the diverse exotic assemblages presented in this study allow the age of this interval to be narrowed to the late early Tithonian–early Berriasian. The uncertain presence of chitinoidellids in Štramberk-type limestones has been confirmed by the discovery of specimens belonging to the Family Chitinoidellidae. This research has allowed the distinguishing of three zones (*Chitinoidella*, *Crassicollaria*, and *Calpionella*), including six subzones (*Dobeni*, *Boneti*, *Remanei*, *Massutiniana*, *Alpina*, and *Elliptica*) based on representative calpionellid assemblages. Of the total number of 18 identified taxa, 8 were documented in this area for the first time. As a result of these studies, we were able to establish robust age correlations between material from different localities, which will be helpful for the further development of the carbonate platform model for the area.

Key words: Calpionellids; Biostratigraphy; Tithonian; Berriasian; Microfacies; Carpathians; Olistoliths.

INTRODUCTION

Calpionellids are planktonic microorganisms with a calcite lorica, which are distributed in the uppermost Jurassic and Lower Cretaceous marine deposits. They are primarily known from pelagic limestone facies originating from the Tethys region. However, some findings of calpionellids have been confirmed in the areas of the Caribbean (Brönnimann 1954; Furrazola-Bermúdez 1965; Furrazola-Bermúdez and Kreisel 1973; Pszczółkowski *et al.* 2005; Pszczółkowski and Myczyński 2010; López-Martínez *et al.* 2013b), Eastern Africa (Jain *et al.* 2022), Mexico (Trejo 1980; Adatte *et al.* 1994; López-Martínez *et al.* 2013a), and southeastern South America (Kietzmann 2017; Kietzmann *et al.* 2022; Kietzmann and Sturlesi 2023; Kietzmann and Encinas 2025). Due to their widespread distribution, diversification, and rapid evolution, they represent excellent material for biostratigraphic research, particularly in studies of ancient deep marine palaeoenvironments that often lack other markers.

The biostratigraphic potential of calpionellids has been utilised in the Alps since the beginning of the 20th century (e.g., Steinmann 1905). The first attempts to create zones based on calpionellids appeared in the 1950s (e.g., Andrusov 1950). The first modern calpionellid zonation schemes were presented by Remane (1963, 1964). The standard calpionellid zonation was introduced by Allemann *et al.* (1971). It has been further modified by numerous specialists who conducted regional studies on this group (e.g., Bakalova 1977; Remane 1986; Remane *et al.* 1986; Pop 1994, 1997; Reháková 1995; Lakova *et al.* 1999; Reháková and Michalík 1997; Grün and Blau 1997; Andreini *et al.* 2007; López-Martínez *et al.* 2013b). In recent years, attempts to standardise the zonation of the Tethys Realm have been presented in particular by Lakova and Petrova (2013) and Benzaggagh (2020).

Recently, calpionellids have been considered as valuable material that is often analysed in combination with other methods such as magnetostratigraphy and calcareous nannofossils (e.g., Wimbledon *et al.* 2013; Bakhmutov *et al.* 2018; Grabowski *et al.* 2019; Vaňková *et al.* 2019). They have been applied as the main marker of the J/K boundary (e.g., Remane *et al.* 1986; Svobodová *et al.* 2019; Gale *et al.* 2020; Wimbledon *et al.* 2020a, b; Grabowski *et al.* 2026).

Uppermost Jurassic and lowermost Cretaceous rocks constitute an occasional component of deposits forming the Polish section of the Outer Carpathians, apart from the flysch successions from the Silesian Nappe, which are assigned to the lower and upper Cieszyn Beds. Nevertheless, they may also occur as redeposited material, traditionally termed as exotics. They are sporadically found within olistostromes and tectonic mélanges among flysch strata in all the Carpathian nappes (Cieszkowski *et al.* 2009). One of the most common types of exotic rocks in the Polish Outer Carpathians are the upper Tithonian–lowermost Cretaceous deposits collectively classified as Štramberk-type limestone. This term alludes to analogous and contemporaneous exotic limestone blocks that occurred in the vicinity of the Moravian town of Štramberk (Western Carpathians, Czech Republic). A defining characteristic of this limestone is its rich reefal biota community, which includes diverse coral assemblages; however, both Štramberk and Štramberk-type limestone exotics exhibit considerable facies variability (Eliašova 1981; Eliaš and Eliašova 1984; Hoffmann and Kołodziej 2008; Hoffmann *et al.* 2021).

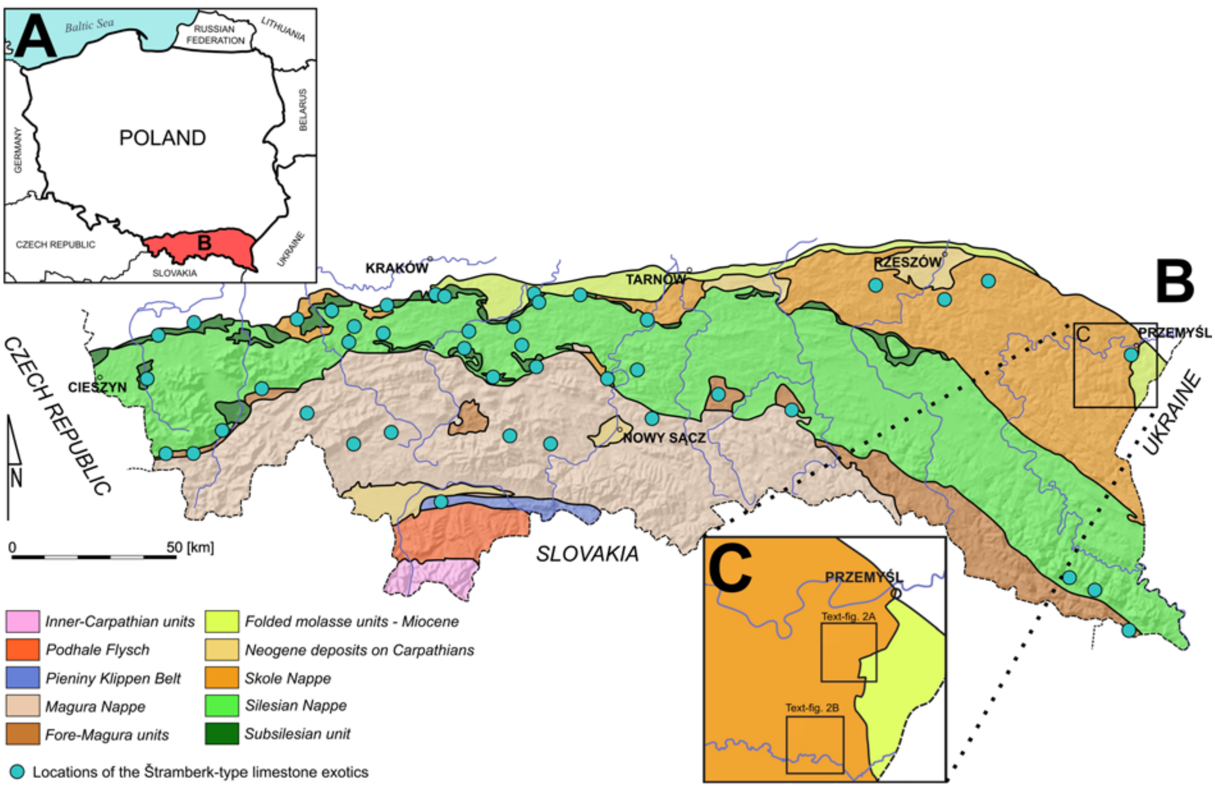
The age of the Moravian Štramberk limestone was determined based on biostratigraphic (Houša 1975; Zeiss 1977) and magnetostratigraphic methods (Houša 1990; Vaňková *et al.* 2019). In general, two intervals were distinguished in Kotouč Quarry in Štramberk: lower Tithonian, documented by ammonites, and the upper 'middle' Tithonian–Berriasian, its identification based on calpionellids (from the *Chitinoidella* Zone to the lower part of the *Calpionella* Zone). Previous studies suggest a comparable late Tithonian to earliest Berriasian age for the Štramberk-type limestone exotics from Poland, based on bivalves, gastropods, brachiopods and ammonites (Wójcik 1914), calpionellids (Morycowa 1964, 1968, 1974, 1988; Geroch and Morycowa 1966; Nowak 1973; Olszewska *et al.* 2011; Kowal-Kasprzyk 2014, 2018), foraminifera (Ivanova and Kołodziej 2010; Olszewska *et al.* 2011), cyrtocrinids (Hess *et al.* 2011), and corals (Morycowa 1964, 1968, 1974; Kołodziej 2015).

Although numerous classic studies have focused on the Carpathian exotics, the majority have concentrated on the western sector of the Polish Outer Carpathians (Nowak 1927; Książkiewicz 1954; Oszczypko 1975; Malik 1978; Burtan *et al.* 1984; Kowal-Kasprzyk 2014; Kowal-Kasprzyk *et al.* 2021; Hoffmann *et al.* 2021). The exotic material examined in this study was identified in its eastern part – the Skole Nappe, which has been the subject of relatively few contemporary studies (Olszewska *et al.* 2011; Łapcik *et al.* 2016). One of the most interesting assemblages of Štramberk-type limestone in this tectonic unit is located near Kruhel Wielki and it has been documented in classic geological literature from the second half of the 19th century (Niedźwiedzki 1876) and in the first decades of the 20th century (Wójcik 1907, 1914). The upper Tithonian–lowest Cretaceous olistoliths from Kruhel Wielki were also the object of palaeontological, biostratigraphic, and facies research through the second half of the 20th and the beginning of the 21st century (Morycowa 1964, 1988; Geroch and Morycowa 1966; Olszewska *et al.* 2011). Despite numerous studies, the precise age and internal biostratigraphic variability of Štramberk-type exotics from Kruhel Wielki area remain insufficiently constrained. Current studies concerning calpionellid biostratigraphy of the Kruhel Wielki Klippe encompassed selected facies types only (Ciborowski and Kołodziej 2001) or referred to obsolete zonations (Morycowa 1964, 1988), which are nowadays considered less precise compared to the later models that were applied in this research (Lakova and Petrova 2013). The challenging aspect that demands revision is the hypothetical occurrence of exotics dated to the *Chitinoidella* Zone, emphasised by Morycowa (1988), but not yet confirmed due to the poor state of preservation of the specimens.

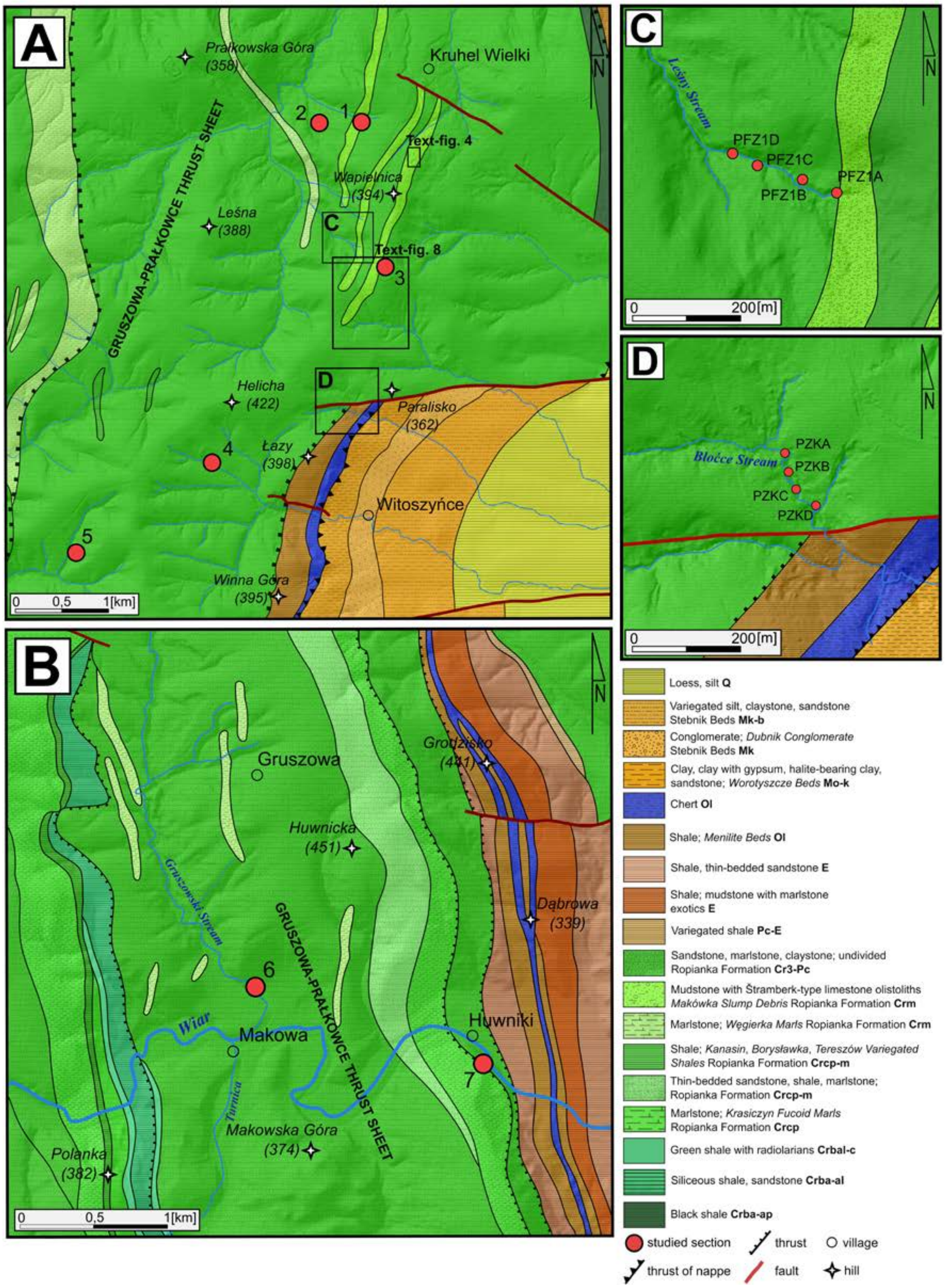
The goal of the present study is: 1) to date the collected exotics of Štramberk-type limestones based on new findings of calpionellids, and 2) to determine the upper stratigraphic limit of the Štramberk-type limestone exotics from the Kruhel Wielki area. To obtain the most precise datings of the exotics, our biostratigraphic investigation encompassed all of the distinguished microfacies types of the exotics found. Identifying their exact age is essential for applying a coeval facies distribution model of the Štramberk-type platform, particularly given the uncertain stratigraphic position of some older Middle and Upper Jurassic exotics documented from Kruhel Wielki by Wójcik (1907).

GEOLOGICAL SETTING

The study area is located in the Polish Western Outer Carpathians (Text-fig. 1), specifically within the easternmost part of the Przemyśl Foothills (Łanczont *et al.* 2021). Geologically, this area represents the eastern part of the Polish Skole Nappe (Text-fig. 1B, C). Its northeastern margin is characterised by a series of thrust sheets (Kotlarczyk 1988a); the current study focuses primarily on the Gruszowa-Prałkowce Thrust Sheet. The examined segment of the Skole Nappe predominantly comprises carbonate-rich and siliciclastic flysch units associated with the Turonian–Palaeocene Ropianka Formation, including: Cisowa Member (Coniacian–Santonian), Wiar Member (Campanian–lower Maastrichtian), Leszczyny Member (upper Maastrichtian), and Wola Korzeniecka Member (Paleocene), as delineated by Kotlarczyk (1978). Significant assemblages of Štramberk-type limestone exotics occur within the Upper Cretaceous part of the Ropianka Formation, particularly in the uppermost Maastrichtian Makówka Slump Debris strata (Kotlarczyk 1978). These deposits frequently coexist with the coeval Węgierka Marl olistoliths, interpreted as shallow-water and shelf deposits originating from the North European Platform (Geroch *et al.* 1979). It is noteworthy that Štramberk-type limestone exotics were documented in this region, specifically within the older Campanian Wiar Member, which includes exotic-bearing strata in the Huwniki section (Kotlarczyk and Krawczyk 1988; this study, 6 in Text-fig. 2B). Additional occurrences



Text-fig. 1. Location of the study area. A – Schematic map of Poland showing the Carpathians. B – Simplified geotectonic map of the Polish Outer Carpathians with the most important exposures of the Štramberk-type limestone exotics (based on Cieszkowski *et al.* 2009 and Kowal-Kasprzyk *et al.* 2021). C – Simplified geotectonic map of the easternmost part of the Skole Nappe.



Text-fig. 2. Detailed geological maps showing the location of the studied sites. A – Geological map of the northern part of the study area (Kruhel Wielki vicinity), based on Gucik *et al.* (2005); explanations: 1 – Prałkowce I, 2 – Prałkowce II, 3 – Iwanowa Góra, 4 – Błonie Stream, 5 – Huszczyński Stream. B – Geological map of the southern part of the study area (Huwniki vicinity), based on Gucik *et al.* (1991, 2005); explanations: 6 – Gruszowski Stream, 7 – Huwniki. C – Geological map of the Kruhel Wielki Quarry (generalised) situated on Wapielnica Hill. D – Geological map showing the exposures of exotics in Leśny Stream section. E – Geological map showing the exposures of exotics in Błoćce section.

of Štramberk-type limestone exotics within the Skole Nappe include the Paleocene Babica Clays (Bukowy 1957) and the Eocene Popiele Beds (Kotlarczyk and Dżułyński 1988). Based on foraminiferal and nannoplankton findings (Bukowy and Geroch 1956; Gaździcka 1995; Woyda *et al.* 2023) in limited sections near Kruhel Wielki, the olistostromes were inferred to be of late Maastrichtian age. New biostratigraphic data, along with general characteristics such as lithology and sedimentary features, enabled the classification of these deposits as the Leszczyny Member (Woyda *et al.* 2023).

Exotic-bearing beds are most commonly found in the easternmost regions of the Gruszowa-Prałkowce Thrust Sheet, while their presence is quite rare in the internal, western part of the Skole Nappe (Kotlarczyk 1978; Gucik 1987; Gucik *et al.* 2005, 2017). This could be a result of the longer distance between the source area and the axis of the Skole Basin, estimated by Łapcik *et al.* (2016) at 22–94 km. Significant assemblages of exotics are exposed in the succession, forming an approximately longitudinal range of hillsides along the thrust of the Skole Nappe (Text-fig. 2A–D). The biostratigraphic analysis of the exotics is challenging due to the lack of continuity, stratigraphic isolation, and their redeposition.

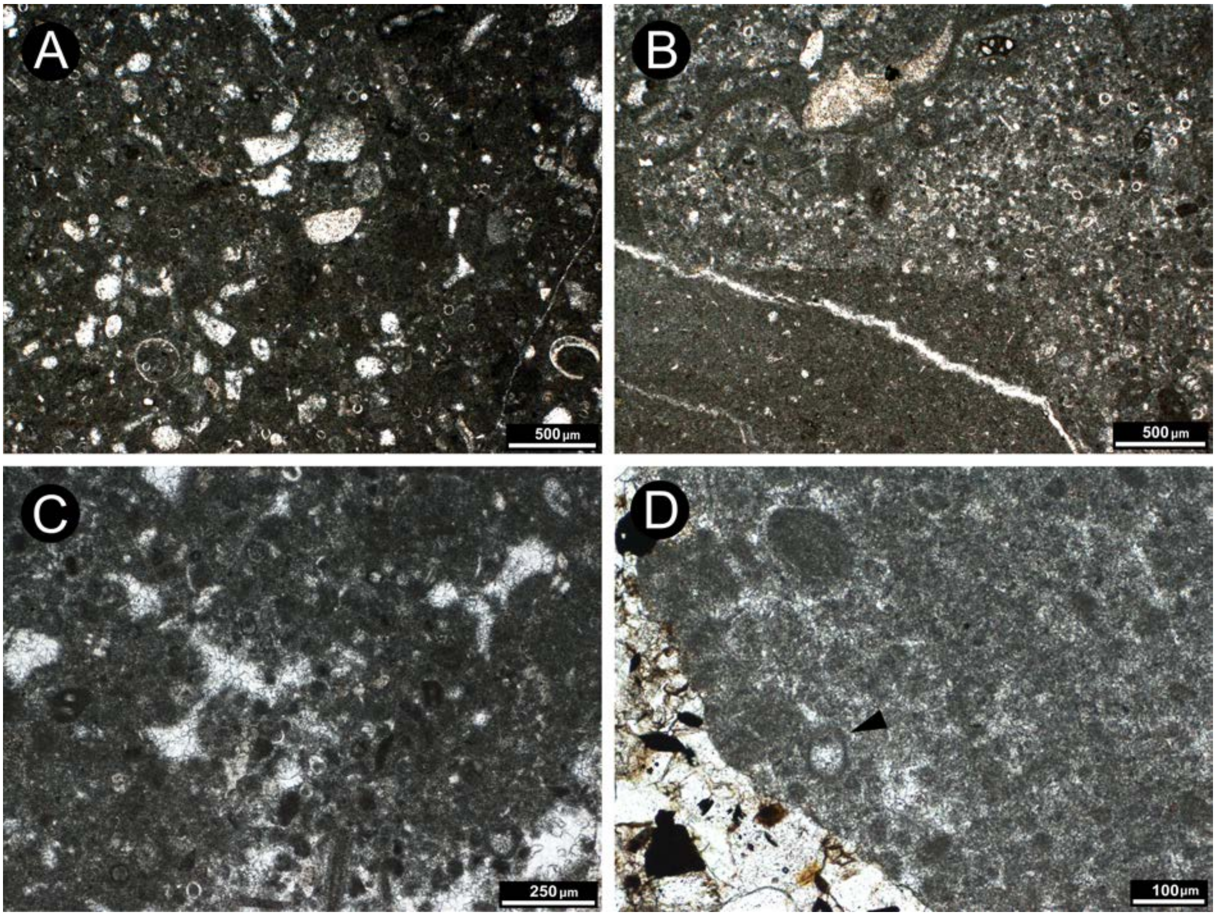
MATERIAL AND METHODS

The fieldwork included mapping of the study area (c. 18 km^2; Text-fig. 2A, B), measuring the exposures, and collecting samples. This stage of the study was supported by the analysis of archival geological maps and drafts (Szajnocha 1901; Gucik 1986, 1988; Gucik *et al.* 2005). Exotics primarily crop out in gorges, streams, and abandoned quarries. The most extensive artificial exposures are situated near Kruhel Wielki (Wapielnica and Iwanowa Góra Hills). Nine selected exposures were thoroughly measured and sampled. The collection was supplemented with exotics from the natural outcrop in the escarpment of Wiar River in Huwniki village (16 km to the south of Przemyśl) and from Gruszowski Stream.

The analysed material consists of a diverse collection of Štramberk-type limestones and derives from 10 localities (Text-fig. 2). The preliminary selection of samples was based on macroscopic field criteria and literature data concerning their occurrences. Macroscopically, four primary lithologies were distinguished: detrital limestone, pelitic limestone, organic limestone, and conglomerate. Part of the studied thin sections were prepared from the Upper Cretaceous microbreccia, traditionally termed the Rapacz Conglomerate, which contains numerous clasts composed of Štramberk-type limestone (Text-fig. 3C, D). Microscopic analysis revealed a diverse range of microfacies and a high diversity of reefal and lagoonal biota, including corals, sponges, microencrusters, and foraminifers. Calpionellids were documented in 10 out of the 15 preliminarily distinguished microfacies types, predominantly occurring in slope/open shelf deposits assigned to calpionellid wackestone and peloid-calpionellid packstone microfacies types (Text-fig. 3A, B). Studied specimens occurred in both clasts and the matrix forming the limestones. A total of 137 standard thin sections were prepared from 59 exotic pebbles collected from debris, 23 samples of exotic klippen, 24 samples of the Rapacz Conglomerate, and 1 sample of the redeposited conglomerate pebble found in the olistostrome in Błonie Stream. Thin sections were examined under Keyence VHX-7000, NIKON SMZ1000, and NIKON ECLIPSE LV100 POL microscopes at the Microscopic Laboratory of the Department of Geochemistry, Mineralogy, and Petrology, Faculty of Geology, University of Warsaw. The samples are stored in the Department of Palaeontology and Earth History, Faculty of Geology, University of Warsaw.

The biostratigraphic analysis included 471 specimens preliminarily classified as calpionellids. More than half of the specimens were not precisely determined due to poor preservation resulting from substantial crystallisation or oblique sectioning of loricae. Studied calpionellids were identified in 46 out of 135 studied thin sections.

The Order Calpionellida Bonet, 1956 is subdivided into two families: Chitinoidellidae Trejo, 1975 and Calpionellidae Bonet, 1956. Chitinoidellids, appearing in uppermost lower and lowest upper Tithonian rocks, are characterised by microgranular (dark in transmitted light) bell-shaped tests. Calpionellids from the upper Tithonian and Lower Cretaceous deposits are composed of hyaline loricae. The most important diagnostic features include: 1) collar shape; 2) lorica size (length and width) and shape; 3) presence of caudal appendix; and 4) lorica composition (hyaline, microgranular or hyaline-organic). Longitudinal sections were used for proper species identification. The stratigraphic ranges and taxonomy of the studied chitinoidellids were derived from the studies of Pop (1997, 1998a, b), Reháková (2002), and Sallouhi *et al.* (2011). The Tethyan calpionellid zonation of Lakova and Petrova (2013) is applied throughout.

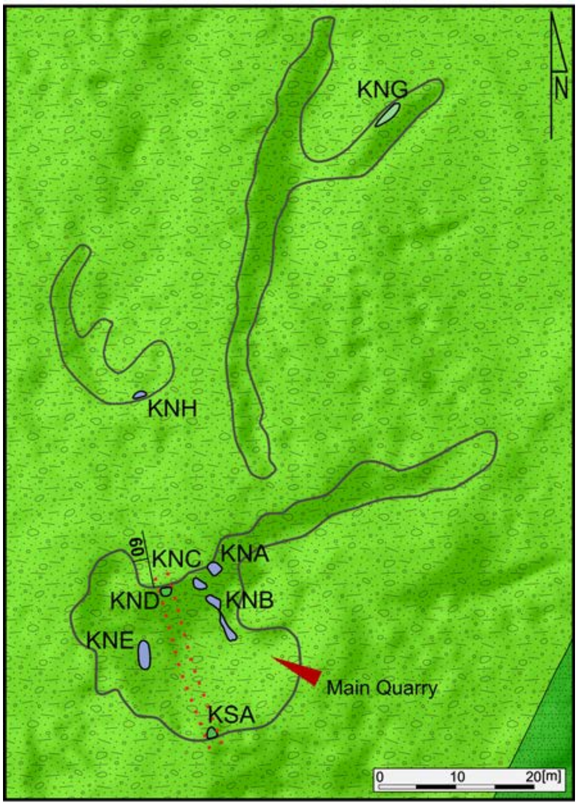


Text-fig. 3. Thin section images of microfacies types rich in calpionellids. A – Calpionellid wackestone, Upper Jurassic *Massutiniana* Subzone (sample KNB1, Wapielnica Hill). B – Peloid-calpionellid packstone, Upper Jurassic *Massutiniana* Subzone (sample KNB1, Wapielnica Hill). C – Peloid packstone, slightly recrystallised, containing calpionellids and chitinoidellids, Upper Jurassic *Remanei* Subzone. Lithoclast from Rapacz Conglomerate (sample KN1, Wapielnica Hill). D – Clast representing the Upper Jurassic *Boneti* Subzone in Upper Cretaceous Rapacz Conglomerate (sample PZKA, Błońce Stream); black arrow points to chitinoidellid specimen.

CHARACTERISTICS OF THE STUDIED EXPOSURES

Kruhel Wielki Quarry–Wapielnica Hill
(49º45’34.70” N; 22º43’53.26” E)

The exposure is located in an abandoned quarry on Wapielnica Hill (Text-fig. 2A and 4) and has been the focus of significant studies on exotics in the Skole Nappe (Niedźwiedzki 1876; Wójcik 1907, 1914; Morycowa 1964, 1988; Geroch and Morycowa 1966; Ciborowski and Kołodziej 2001; Hess *et al.* 2011). Today, only remnants of the former coral-bearing and detrital limestone blocks, along with conglomerates and microbreccia, remain as five separate blocks (KNA, KNB, KNC, KNE, KNH; Text-figs 4–6). It cannot be ruled out that they originally formed a single block, now covered with weathered rock. Secondary tectonic fissures hinder the observation of geological layers and rock formations, but microscopic analysis reveals graded bedding, confirming the eastward dip of these layers. Rounded and angular exotics forming the Upper Cretaceous conglomerate (Text-fig. 7) were found in the northern and southern steep walls of the main quarry (KND and KSA in Text-fig. 4), as well as c. 150 m to the north (KNG in Text-fig. 4). Additionally, a collection of exotic pebbles and angular blocks, measuring up to decimetres, can be found in the debris. In the northern wall of the main quarry, layers of thin-bedded grey calcareous sandstone of the Upper Cretaceous flysch deposits of the Ropianka Formation were found (Text-fig. 7D). Five lime-



Text-fig. 4. Geological sketch-map of Kruhel Wielki Quarry (on Wapielnica Hill; enlarged Text-fig. 2D) showing the location of exposures in Kruhel Wielki Klippen (KNA, KNB, KNE, KNH) and Rapacz Conglomerate (KND, KNG, KSA). Exposures of Rapacz Conglomerate (KND, KSA) are correlated with a dashed red line. The dip of the Upper Cretaceous sandstone is marked in the northern part of the main quarry. Geology after Gucik *et al.* (2005). For other explanations see Text-fig. 2.

stone blocks were logged and sampled (22 samples). Samples were also collected from three exposures of microbreccias in the abandoned quarry (10 samples) and debris, i.e., individual pebbles (42 samples). In total, 74 samples were collected (Appendix 1), of which 37 contained calpionellids in various states of preservation. Among the studied samples, the *Remanei* (sample KN1), *Massutiniana* (samples KNB1, KNC6, KNG3, KRG21, KRG103), *Alpina* (sample KRG23), and *Elliptica* (samples KN4, KN41) subzones were identified.

Iwanowa Góra (49º45'03.13" N; 22º43'41.19" E)

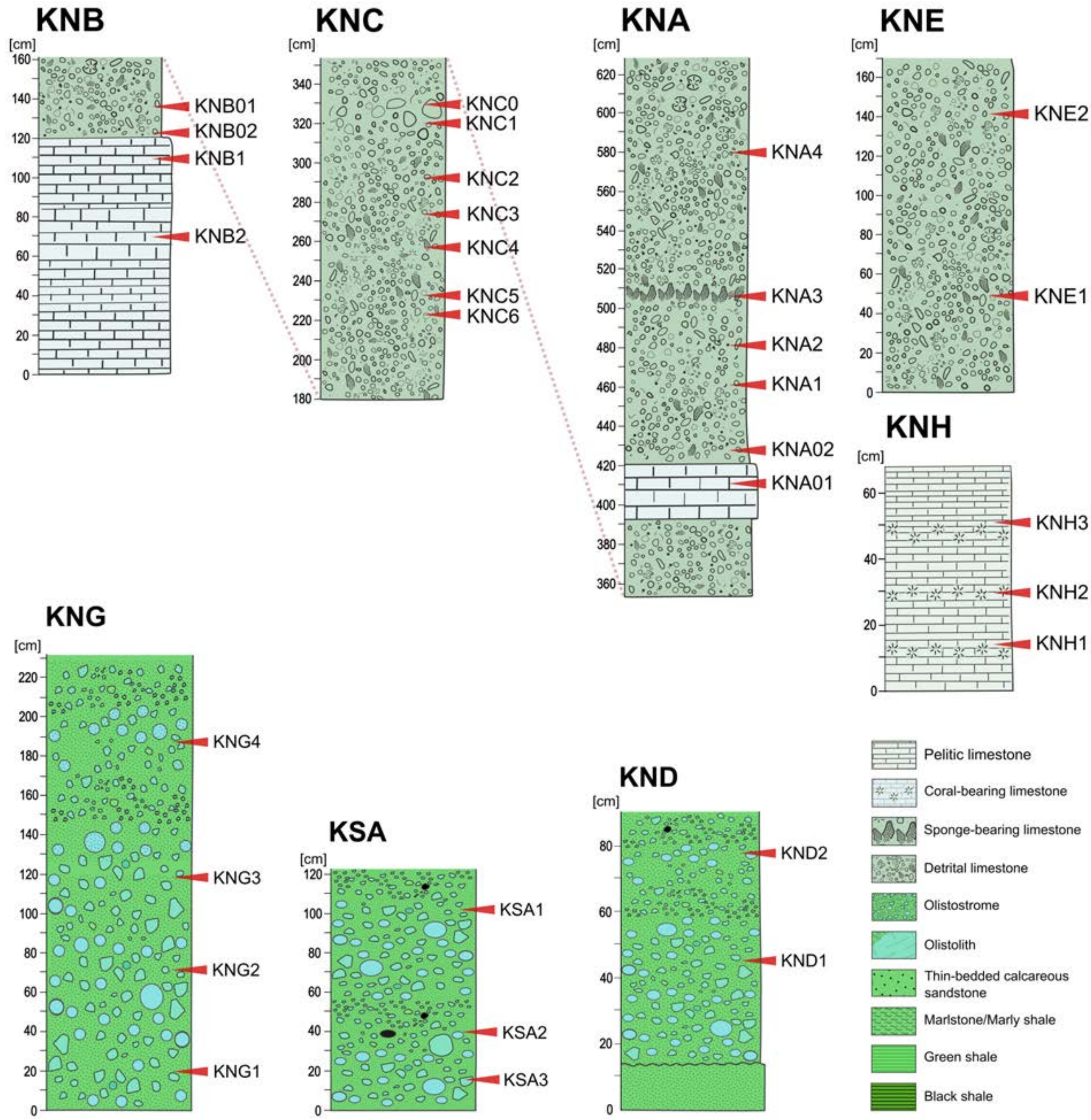
The section is situated on the northern slope of Iwanowa Góra Hill, close to the ruins of Helicha Fort, approximately 1.5 km south of Kruhel Wielki Quarry (3 in Text-fig. 2A and Text-fig. 8). The outcrop is the only one remaining of the three sections documented by Bukowy and Geroch (1956). At this site, the boundary between thin-bedded calcareous sandstone and the olistostrome is well preserved (Text-figs 9 and 10D). Fine, rounded clasts of Štramberk-type limestones predominate within the collected material. Among other lithologies, coal, marlstone and fine angular clasts of the greenish metamorphic rocks were macroscopically recognised. Three beige limestone pebbles were collected for further research (Appendix 1). Two out of three thin sections contained calpionellids. Based on material collected from this site, the *Dobeni* (sample F1) and the *Boneti* (sample F12) subzones were identified.

Grochowski Stream (49º44'45.42" N; 22º43'28.03" E)

The Grochowski Stream site is located at the southern foot of Iwanowa Góra Hill (Text-fig. 8). Exotic rocks occur either in a conglomerate or as loose blocks and pebbles, and are represented by Štramberk-type limestones. The largest outcrop (Grochowski Stream I) is exposed along the northern branch of the stream (Text-figs 8, 9, 10A). In the southern wall, debris-flow deposits composed of limestone clasts and host rocks (grey calcareous sandstone) were observed (Grochowski Stream II, Text-fig. 9). Calpionellids were identified in four out of eight samples collected from pebbles and the Rapacz Conglomerate (Text-fig. 9, Appendix 1). In one sample (IIPZFB), the *Dobeni* subzone was identified. The late Tithonian–Berriasian age of clasts in sample IIPZFC was confirmed by the presence of *Calpionella alpina* Lorenz, 1902.

Leśny Stream (49º45'11.56" N; 22º43'21.50" E)

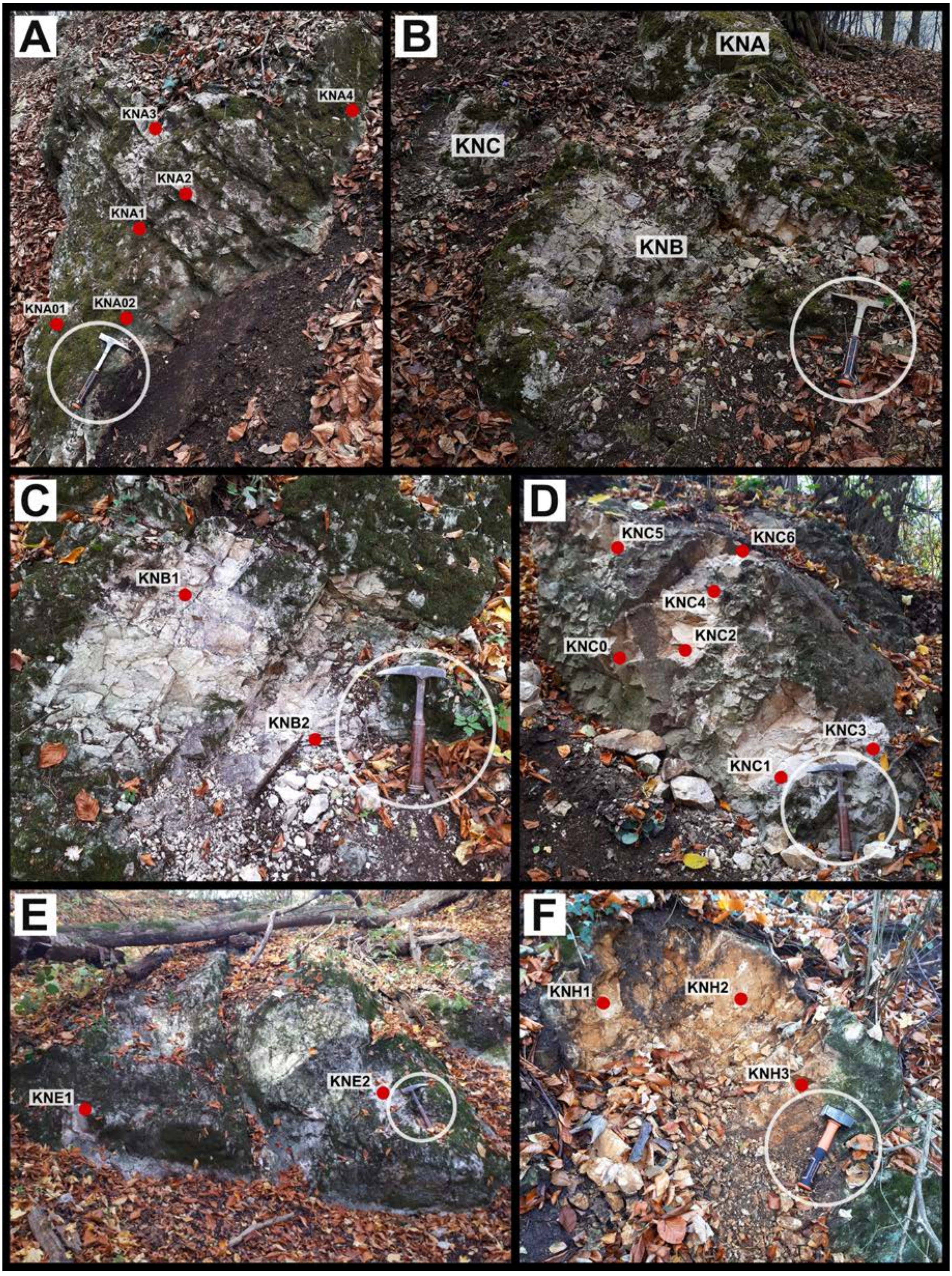
Numerous Štramberk-type limestone exotics were found along an unnamed gorge located on the western slope of Iwanowa Góra Hill (Text-fig. 2C). The two significant accumulations of exotics were identified in the southern branch of the stream and the upper part of Leśny Stream (Text-fig. 10F). The presence of numerous pebbles and blocks at this site is probably a result of a recent landslide (Gucik *et al.* 2005), which affected a series of olistostromes on the western side of Iwanowa Góra and Wapielnica Hills. Besides Štramberk-type limestone exotics, igneous rocks and pebbles of white Cretaceous marlstones were found. A total of four samples were collected and analysed. Calpionellids indicating in general a late Tithonian–Berriasian age were identified in clasts of the conglomerate in one thin section (sample PFZ1A, see Appendix 1).



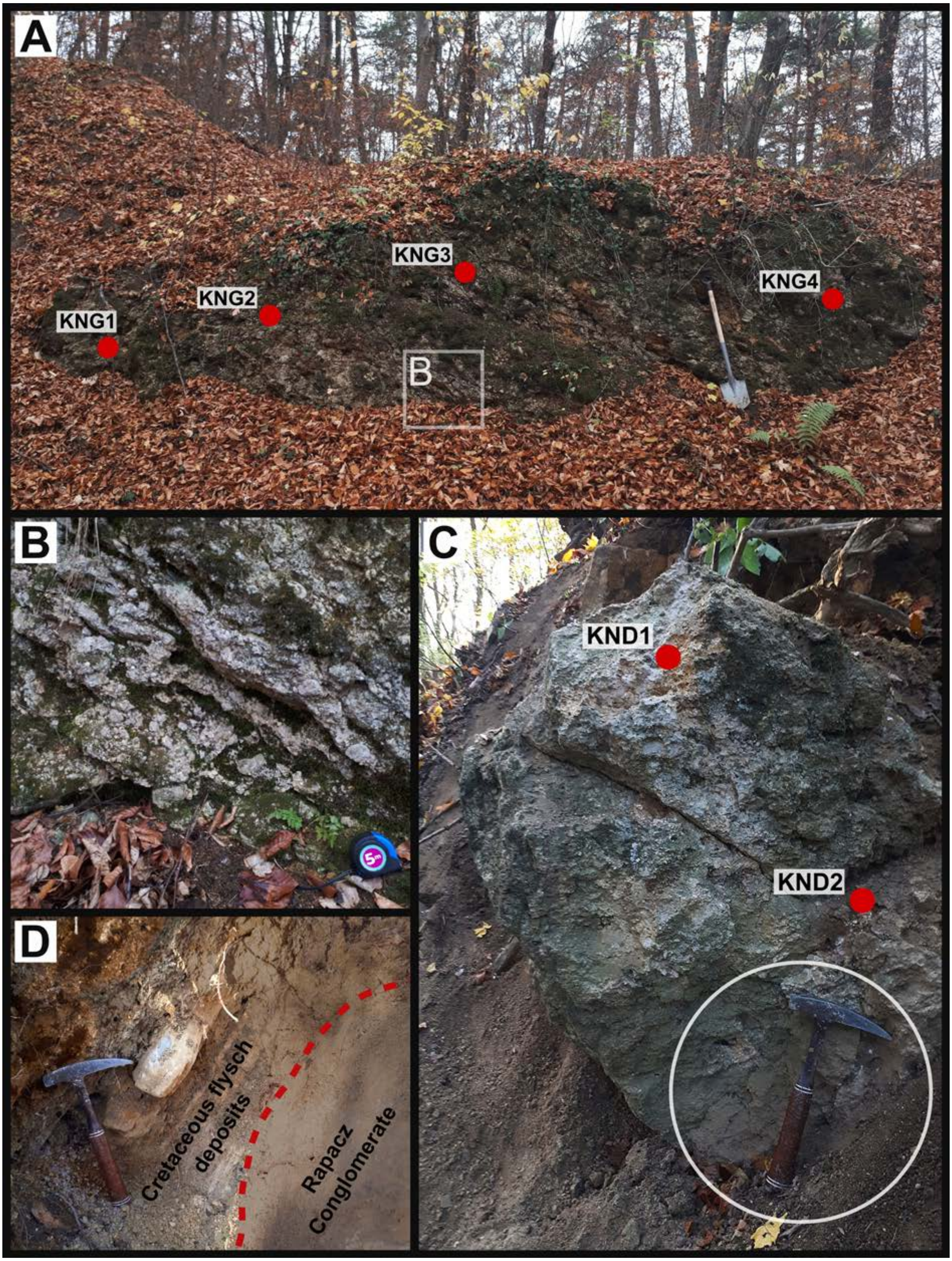
Text-fig. 5. Lithological columns of Kruhel Wielki Klippen and olistostromes of Rapacz Conglomerate exposed in Kruhel Wielki Quarry on Wapielnica Hill. For location of exposures see Text-fig. 4.

Prałkowce (49º45’52.46” N; 22º43’10.31” E)

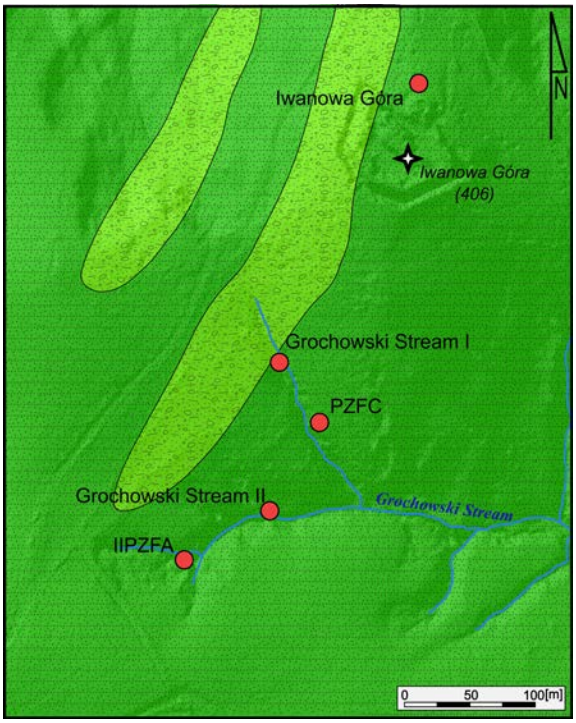
The exotic limestones are located at two sites along an unnamed gorge on the western hillside of Wapielnica Hill (1 and 2 in Text-fig. 2A). Pebbles and angular fragments of the Rapacz Conglomerate are chaotically distributed within the Holocene residuum (Gucik *et al.* 2005). The original location of the olistostrome remains unknown, aside from two small exposures of exotic-bearing beds that were discussed recently (Woyda *et al.* 2023). The collected breccia fragments are angular, hard, and poorly sorted. They are primarily composed of limestone clasts embedded in a grey calcareous sandy matrix, which is similar to that found in flysch successions in the Gruszowa-Prałkowce Thrust Sheet. Three samples



Text-fig. 6. Field photographs of olistoliths on Wapielnica Hill (Kruhel Wielki Klippe). A – Pelitic and detrital limestone (KNA). B – General view of blocks built of pelitic and detrital limestone (KNB and KNC). C – Pelitic limestone (upper part of KNB block). D – Detrital limestone (KNC). E – Detrital limestone, olistolith at the bottom of the quarry (KNE). F – Detrital limestone with corals (KNH). For location of exposures see Text-fig. 4.



Text-fig. 7. Field photographs of olistostromes in Kruhel Wielki Quarry. A – General view of olistostrome situated in the northern part of the Wapielnica Hill (KNG). B – Sedimentary structures in the olistostrome (KNG). C – Olistostrome in an outcrop on the northern main quarry wall (KND). D – Boundary between Cretaceous thin-bedded sandstone and olistostrome (KND). For location of exposures see Text-fig. 4.



Text-fig. 8. Geological sketch-map showing the vicinity of Grochowski Stream; PZFC and IIPZFA are single exotic blocks. Geology after Gucik *et al.* (2005). For explanations see Text-fig. 2.

were collected and examined. The dating of samples using calpionellids was impossible due to their lack in the clasts of microbreccia.

Błoćce Stream (49º44'24.90" N; 22º43'22.49" E)

Błoćce Stream (also known as Błotce) is located in the ravine between Paralisko and Łazy hills (Text-fig. 2D). These hills form a local ridge extending along the margin of the Skole Unit. Exotics have been observed in a few exposures along the stream's northern branch. One of the outcrops revealed a well-preserved contact between marly clay and calcareous sandstone beds, as well as an olistostrome (Text-figs 9 and 10B–C). Four samples were collected and examined. Calpionellids representing the *Boneti* Subzone were successfully identified in one of the samples (PZKA), providing biostratigraphic data for this section.

Błonie Stream (49º44'03.37" N; 22º42'17.29" E)

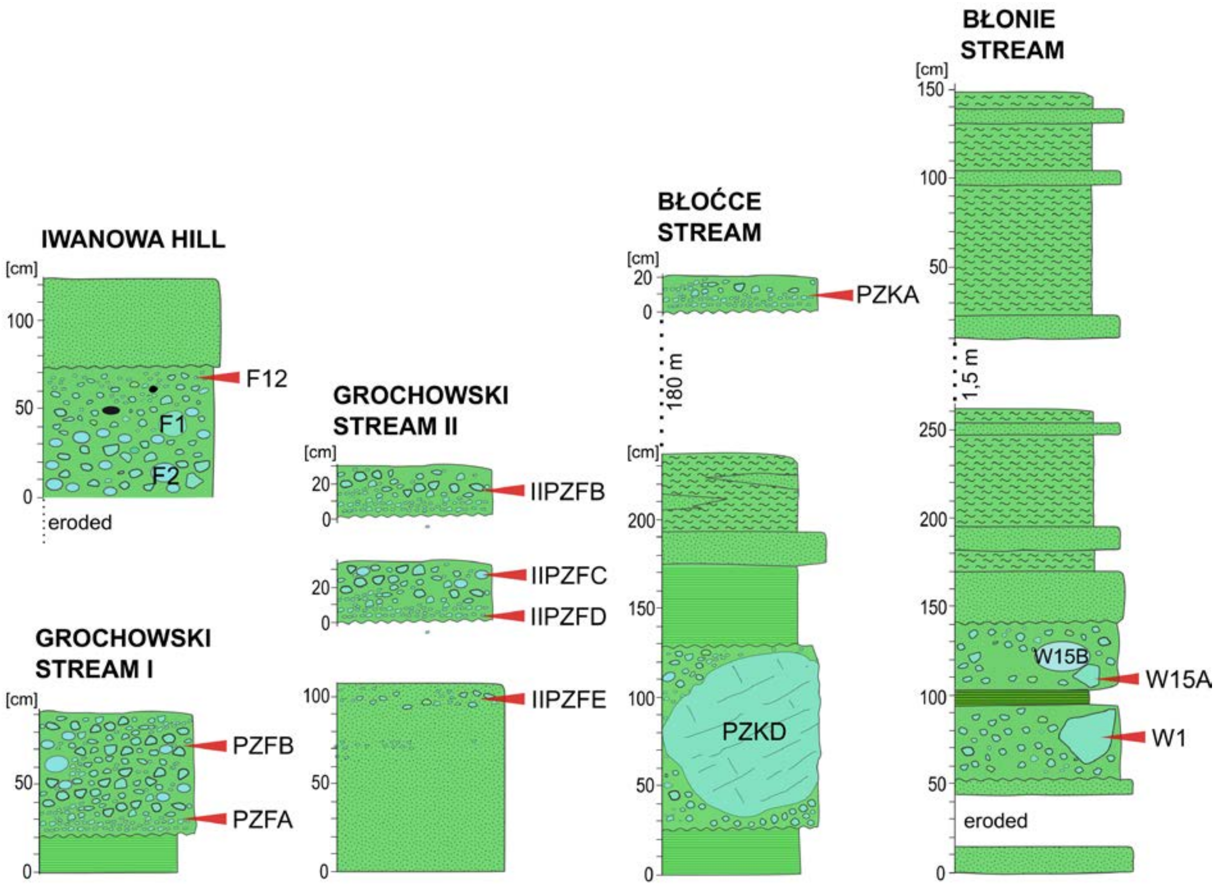
The studied exposure is located on the southern side of an unnamed stream, which is one of the northern branches of Błonie Stream, on the southeastern side of Helicha Hill (4 in Text-fig. 2A). The exotic-bearing beds are intercalated with deposits of the Ropianka Formation. The lower part of the section is represented by thin-bedded black shales, overlain by a 70 cm-thick olistostrome containing Štramberk-type limestone olistoliths, and well-rounded redeposited conglomerate pieces (Text-figs 9 and 10E), also composed of Upper Jurassic–Lower Cretaceous Štramberk-type limestone, metamorphic rocks and marlstone. The matrix of the exotic-bearing beds is composed of brittle grey calcareous sandstone (Ropianka Formation). Higher up in section, a 1-metre-thick series of thin to medium-bedded Węgierka Marl is exposed. Three samples were collected and examined (Appendix 1). The samples were barren in calpionellids as a result of the predominance of strongly recrystallised Štramberk-type clasts in conglomerate (sample W1). Microfacies types identified in the exotic pebbles found in this section (samples W15A, W15B) represent the shallowest internal part of the carbonate platform and lack calpionellids.

Huszczyński Stream (49º43'28.32" N; 22º41'05.92" E)

The Huszczyński Stream is situated in a small valley on the southwestern side of Helicha Hill (10 in Text-fig. 2A). The exposures contain angular blocks and pebbles of Štramberk-type limestone chaotically distributed at the bottom of the valley. Conglomerate clasts composed of fine angular exotic clasts were also recognised, particularly in the lower part of the stream, where they were exposed in the residuum among the sandstones. Three samples were collected for further analysis from loose exotics found in the stream. Poorly preserved chitinoidellids were identified in one sample of the Rapacz Conglomerate (HEW1).

Gruszowski Stream (49º40'01.42" N; 22º40'16.13" E)

The Gruszowski Stream also known as Makówka exposure belongs to the southern part of the studied thrust sheet (6 in Text-fig. 2B) and is primarily composed of deposits of the Ropianka Formation (Gucik *et al.* 2005). Among various exotics, dominated by clasts of Węgierka Marls and subordinate metamorphic rocks of unknown provenance, well-rounded pebbles of Štramberk-type limestone (up to a few decimetres in size) were identified. All of the exotics occur in the 5-metre-thick olistostrome composed of a strongly weathered sandy matrix. The profile of the Gruszowski Stream was thoroughly documented by Kotlarczyk (1988b) and serves as the stratotype for the Makówka Slump Debris. Four samples were collected for further analysis. The samples collected



Text-fig. 9. Lithological columns of selected sections in which the boundaries of olistostromes and Ropianka Formation deposits were identified. For explanations see Text-fig. 5.

from this exposure were barren of calpionellids due to the presence of shallow-marine deposits represented by coated grainstone.

Huwniki (49º39'04.56" N; 22º42'15.85" E)

An exotic-bearing bed, rich in uppermost Jurassic and Lower Cretaceous limestones, crops out along Wiar River (7 in Text-fig. 2B), near the classic Wiar Member marl exposure (Kotlarczyk 1988). Despite the different Campanian age of the matrix (Kotlarczyk and Krawczyk 1988), four thin sections were prepared from one large pebble which was collected for comparative analyses of a variety of Štramberk-type limestone facies. Rare calpionellids representing the *Remanei* Subzone were found in one sample only (H22A) due to the predominance of strongly recrystallised shallow marine facies clasts in the studied rudstones.

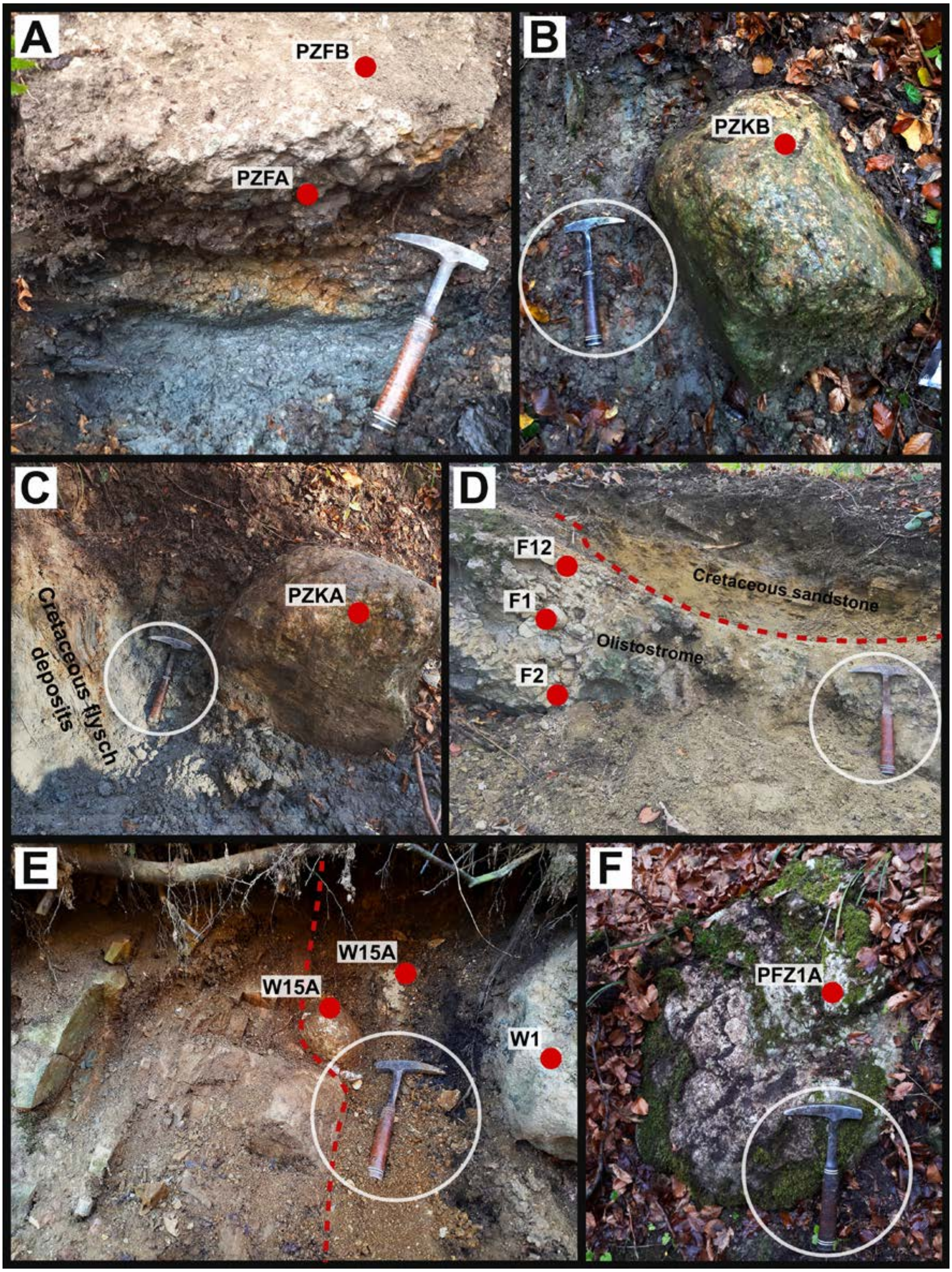
SYSTEMATIC PART

Overall, 213 calpionellid specimens were determined, most of which are assigned to the genus level; however, 5 specimens of chitinoidellids (microgranular, dark in transmitted light) and 12 specimens of calpionellids (hyaline, light in transmitted light) were recognised (Appendix 2). Previous findings of calpionellids in the study area are mentioned in the synonymy lists.

Phylum Ciliophora Doflein, 1901
Order Calpionellida Bonet, 1956
Family Chitinoidellidae Trejo, 1975

Genus *Carpathella* Pop, 1998

TYPE SPECIES: *Carpathella rumanica* Pop, 1998.



Text-fig. 10. Field photographs showing single olistoliths and olistostromes in the vicinity of Kruhel Wielki. A – Olistostrome containing Štramberk-type limestones embedded in green clays of Ropianka Formation, Grochowski Stream. B – Single olistolith of Štramberk-type limestone, Błoćce Stream. C – Olistolith suspended in thin-bedded Upper Cretaceous sandstones, Błotćce Stream. D – Boundary of olistostrome containing Štramberk-type limestone pebbles and thin-bedded Upper Cretaceous sandstones, Iwanowa Góra. E – Olistostrome containing Štramberk-type limestones and pebbles built of conglomerates, Błonie Stream; note series of marlstone of Ropianka Formation on the left. F – Single block of Štramberk-type limestone, Leśny Stream.

Carpathella rumanica Pop, 1998
(Text-fig. 11A, B)

1998a. *Carpathella rumanica* Pop; Pop, pp. 12, 17, pl. 1, figs 18–20.
1998b. *Carpathella rumanica* n. sp.; Pop, pp. 817–820, figs 1–3, 11–13.
2002. *Carpathella rumanica* Pop; Reháková, p. 372, fig. 2.13–2.16.
2013. *Carpathella rumanica* Pop; Lakova and Petrova, p. 206, pl. 5, fig. 8.
2017. *Carpathella rumanica* Pop; Kietzmann, p. 159, fig. 5.9–5.13.
2017. *Carpathella rumanica* Pop; Petrova *et al.*, p. 90, fig. 3.20, 3.21.
2022. *Carpathella rumanica* Pop; Ölveczká and Reháková, p. 56, fig. 6.15.
2022. *Carpathella rumanica* Pop; Kietzmann *et al.*, p. 6, fig. 5c, d.

MATERIAL AND SAMPLES: Iwanowa Góra – sample F1 (2 specimens in the pebble of oolitic grainstone, Text-fig. 9).

DESCRIPTION: A microgranular lorica, which is rounded to slightly oval-shaped, as high as wide to slightly higher than wide. The collar is straight and forms a well-marked shoulder with the lorica bowl. The aboral pole is rounded and lacks a caudal appendage. The observed specimens measure 40–45 µm in length and 30–35 µm in width.

REMARKS: According to Pop (1998b), the lorica shape of *C. rumanica* is similar to that of *Calpionella alpina*.

OCCURRENCE: Uppermost Jurassic; *Dobeni* Subzone in the Western Carpathians (Reháková 2002; Ölveczká and Reháková 2022), western Balkanides (Lakova and Petrova 2013; Petrova *et al.* 2017), also observed within the *Boneti* Subzone and the *Praetintinopsella* Zone in the Southern Carpathians (Pop 1998a, b), and in the *Crassicollaria* Zone in Argentina (Kietzmann 2017) and Chile (Kietzmann *et al.* 2022).

Genus *Daciella* Pop, 1998

TYPE SPECIES: *Daciella banatica* Pop, 1998.

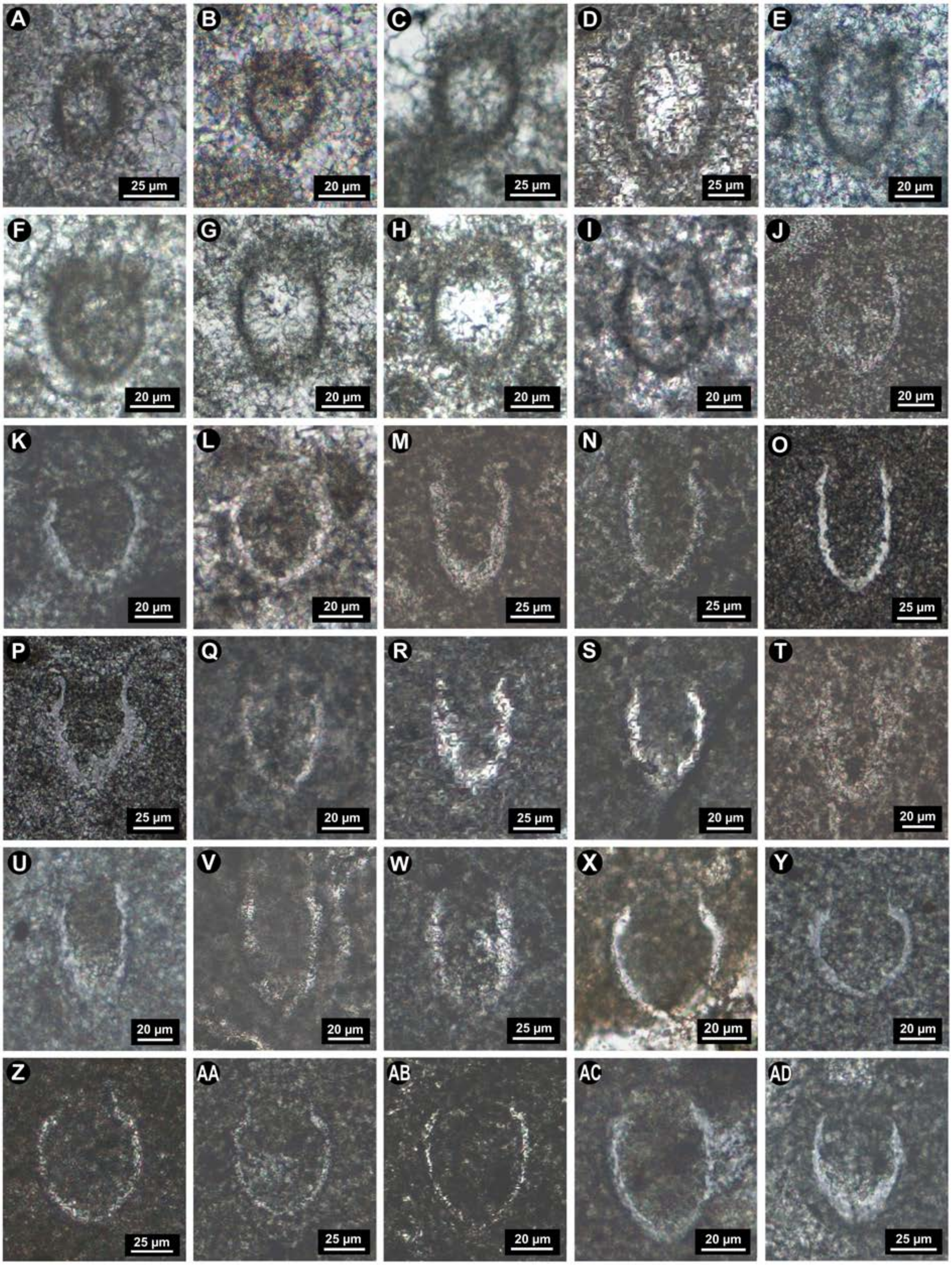
Daciella danubica Pop, 1998
(Text-fig. 11C)

1998a. *Daciella danubica* Pop; Pop, pp. 12, 16, 19, pl. 1, figs 5–7.
1998b. *Daciella danubica* n. sp.; Pop, pp. 819, 821, fig. 2, photos 14–18.
2002. *Daciella danubica* Pop; Reháková, p. 372, fig. 2.17–2.20.
2011. *Daciella danubica* Pop; Sallouhi *et al.*, pp. 651, 652, pl. 1, fig. 17.
2012. *Daciella danubica* Pop; Petrova *et al.*, pp. 56, 73, fig. 4.10, 4.11.
2013. *Daciella danubica* Pop; Lakova and Petrova, p. 208, pl. 1, figs 1–5; pl. 5, figs 9–13.
2014. *Daciella danubica* Pop; Kowal-Kasprzyk, p. 30, fig. 3Q.
2017. *Daciella danubica* Pop; Petrova *et al.*, p. 90, fig. 3.11, 3.12.
2019. *Daciella danubica* Pop; Petrova *et al.*, p. 60, fig. 4.17–4.20.

MATERIAL AND SAMPLES: Grochowski Stream II – sample IIPZFC (two specimens in a clast of peloid grainstone from Rapacz Conglomerate, Text-fig. 9).

DESCRIPTION: The microgranular lorica is conical to ovoid, higher than wide. The aboral pole is

Text-fig. 11. Representative examples of calpionellids recovered from the studied samples (in parentheses; for location of samples see Text-figs 5 and 9). A, B – *Carpathella rumanica* Pop, 1998; *Dobeni* Subzone, *Chitinoidella* Zone (F1). C – *Daciella danubica* Pop, 1998; *Dobeni* Subzone, *Chitinoidella* Zone (IIPZFC). D – *Borziella slovenica* (Borza, 1969); *Dobeni* Subzone, *Chitinoidella* Zone (F1). E, F – *Dobeniella cubensis* (Furrazola-Bermúdez, 1965); *Boneti* Subzone, *Chitinoidella* Zone (KRG25). G – *Chitinoidella boneti* (Doben, 1963); *Boneti* Subzone, *Chitinoidella* Zone (IIPZFB). H, I – *Chitinoidella* sp.; *Boneti* Subzone, *Chitinoidella* Zone (H – KRG106; I – PZKA). J – *Tintinnopsella remanei* Borza, 1969; *Remanei* Subzone, *Crassicollaria* Zone (KNC6). K, L – *Tintinnopsella carpathica* (Murgeanu and Filipescu, 1933); K – *Crassicollaria* Zone (H22); L – *Elliptica* Subzone, *Calpionella* Zone (KN41). M–O – *Crassicollaria intermedia* (Durand Delga, 1957); M – *Massutiniana* Subzone, *Crassicollaria* Zone (KNC6); N, O – *Crassicollaria* Zone (N – KNC0; O – PZFB). P–S – *Crassicollaria brevis* Remane, 1962; P – *Crassicollaria* Zone (KNG3); Q–S – *Massutiniana* Subzone, *Crassicollaria* Zone (KNB1). T, U – *Crassicollaria colomi* Doben, 1963; T – *Crassicollaria* Zone (KNC1); U – *Massutiniana* Subzone, *Crassicollaria* Zone (KNC6). V – *Crassicollaria parvula* Remane, 1962; *Massutiniana* Subzone, *Crassicollaria* Zone (KNB1). W – *Crassicollaria massutiniana* (Colom, 1948); *Crassicollaria* Zone (KRG103). X, Y – *Calpionella alpina* Lorenz, 1902; X – *Crassicollaria* Zone (KNG3); Y – *Elliptica* Subzone, *alpina* Zone (KN41). Z, AA – *Calpionella grandalpina* Nagy, 1986; *Massutiniana–Alpina* subzones (KRG27). AB – *Calpionella elliptalpina* Nagy, 1986; *Massutiniana* Subzone, *Crassicollaria* Zone (KNB1). AC – *Calpionella elliptica* Cadisch, 1932; *Elliptica* Subzone, *Calpionella* Zone (KN4). AD – *Remaniella catalanoi* Pop, 1996; *Elliptica* Subzone, *Calpionella* Zone (KN4). →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20 µm
AC
20 µm
AD
25 µm

acute and usually ends with a short caudal appendage. Specimens sometimes possess preoral swelling. The oral opening is large, with a short cylindrical collar. Observed specimens measure 50 µm in length and 35 µm in width.

REMARKS: According to Pop (1998b), the shape of the lorica strongly resembles *Crassicollaria parvula* Remane, 1962.

OCCURRENCE: Uppermost Jurassic; *Dobeni* Subzone in the Western Carpathians (Reháková 2002; Kowal-Kasprzyk 2014, 2018), western Balkanides (Petrova *et al.* 2012, 2017, 2019; Lakova and Petrova 2013), Maghrebides (Sallouhi *et al.* 2011); *Dobeni* Subzone to *Praetintinnopsella* Zone in the Southern Carpathians (Pop 1998a, b).

Genus *Borziella* Pop, 1997

TYPE SPECIES: *Chitinoidella slovenica* Borza, 1969.

Borziella slovenica (Borza, 1969)
(Text-fig. 11D)

1969. *Chitinoidella slovenica* n. sp.; Borza, pp. 76, 77, pl. 66, fig. 9.
1977. *Chitinoidella slovenica* Borza; Grandesso, pl. 2, figs 8, 9.
1986. *Chitinoidella slovenica* Borza; Borza and Michalík, p. 148, pl. 2, fig. 14.
1998a. *Borziella slovenica* (Borza); Pop, pp. 16, 17, pl. 1, figs 16, 17.
2000. *Chitinoidella slovenica* Borza; Benzaggagh, p. 303, pl. 5, fig. 3.4.
2002. *Borziella slovenica* (Borza); Reháková, p. 372, fig. 2.9–2.12.
2011. *Borziella slovenica* (Borza); Sallouhi *et al.*, pp. 649, pl. 1, figs 18, 20, 21.
2013. *Borziella slovenica* (Borza); Lakova and Petrova, p. 206, pl. 1, figs 9, 10; pl. 5, figs 6, 7.
2017. *Borziella slovenica* (Borza); Kietzmann, pp. 156, 159, figs 4.16–4.18, 5.7, 5.8.
2017. *Borziella slovenica* (Borza); Petrova *et al.*, p. 90, fig. 3.4, 3.5.
2018. *Borziella slovenica* (Borza); Kowal-Kasprzyk, p. 42, fig. 9Q.
2022. *Borziella slovenica* (Borza); Kietzmann *et al.*, pp. 6–8, fig. 5a–c.

MATERIAL AND SAMPLES: Iwanowa Góra – sample F1 (2 specimens in an oolite pebble, Text-fig. 9).

DESCRIPTION: The microgranular lorica is conical to slightly oval-shaped, as high as wide to slightly higher than wide. The short collar is outwardly deflected and forms an annular constriction with the lorica bowl. The aboral pole is rounded to acute, without a caudal appendage. The observed specimens are 75–85 µm long and 60–65 µm wide.

OCCURRENCE: Uppermost Jurassic; *Dobeni* Subzone in the Western Carpathians (Borza 1969; Borza and Michalík 1986; Reháková 2002; Kowal-Kasprzyk 2018), Southern Carpathians (Petrova *et al.* 2017), northern Italy (Grandesso 1977), Maghrebides (Benzaggagh 2000; Sallouhi *et al.* 2011), *Dobeni* and lower *Boneti* Subzones in the Southern Carpathians (Pop 1998a; Lakova and Petrova 2013; Petrova *et al.* 2019), and in southern Argentina and Chile (Kietzmann 2017; Kietzmann *et al.* 2022).

Genus *Dobeniella* Pop, 1997

TYPE SPECIES: *Tintinnopsella bermudezi* Furrazola-Bermúdez, 1965.

Dobeniella cubensis (Furrazola-Bermúdez, 1965)
(Text-fig. 11E, F)

1965. *Tintinnopsella cubensis* n. sp.; Furrazola-Bermúdez, p. 13, figs 1V–W; 3A–L.
1969. *Chitinoidella cubensis* (Furrazola-Bermúdez); Borza, p. 79, pl. 68, fig. 16.
1998a. *Dobeniella cubensis* (Furrazola-Bermúdez 1965); Pop, pp. 11, 17, 19, pl. 1, figs 27–29.
2002. *Dobeniella cubensis* (Furrazola-Bermúdez); Reháková, p. 372, fig. 3.4, 3.6.
2007. *Dobeniella cubensis* (Furrazola-Bermúdez); Andreini *et al.*, p. 191, pl 1, fig. 8a, b.
2011. *Dobeniella cubensis* (Furrazola-Bermúdez); Sallouhi *et al.*, pp. 649, 650, pl. 1, figs 7–10.
2013. *Dobeniella cubensis* (Furrazola-Bermúdez); Lakova and Petrova, p. 208, pl. 5, fig. 29.
2017. *Dobeniella cubensis*; Petrova *et al.*, p. 90, fig. 4.10, 4.11.
2019. *Dobeniella cubensis*; Petrova *et al.*, p. 70, fig. 5.13, 5.14.
2000. *Chitinoidella cubensis* (Furrazola-Bermúdez); Benzaggagh, p. 303, pl. 5, fig. 8.
2021. *Bermudeziella cubensis* (Furrazola-Bermúdez); Benzaggagh, p. 38, fig. 1X, Y.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KRG25 (3 specimens in a fenestral bindstone pebble from debris).

DESCRIPTION: The microgranular lorica is oval, elongated, with maximum width at the mid-lorica bowl. The identified specimen measures 62 µm in length and 43 µm in width. The aperture is wide and surrounded by a small, arched collar. The aboral pole is acute but without a caudal appendage.

OCCURRENCE: Uppermost Jurassic; *Boneti* Subzone in the Western Carpathians (Borza 1969; Reháková 2002), Southern Carpathians (Pop 1998a; Petrova *et al.* 2017), western Balkanides (Lakova and Petrova 2013; Petrova *et al.* 2019), SE France (Lodowski *et al.* 2025), southern Italy (Andreini *et al.* 2007), Maghrebides (Benzaggagh 2000, 2021; Sallouhi *et al.* 2011), and Cuba (Furrazola-Bermúdez 1965; Pszczółkowski and Myczyński 2010).

Genus *Chitinoidella* Doben, 1963

TYPE SPECIES: *Chitinoidella boneti* Doben, 1963.

Chitinoidella boneti (Doben, 1963)
(Text-fig. 11G)

1963. *Chitinoidella boneti* n. sp.; Doben, p. 42, pl. 6, figs 1–5.
1969. *Chitinoidella boneti* Doben; Borza, pp. 78, pl. 67, fig. 14; pl. 68, figs 8–13.
1977. *Chitinoidella boneti* Doben; Grandesso, pp. 3, 4, pl. 2, fig. 1.
1986. *Chitinoidella boneti* Doben; Borza and Michalík, p. 148, pl. 2, figs 15, 16.
1997. *Chitinoidella boneti* Doben; Grün and Blau, pl. 1, figs 1–4.
1998a. *Chitinoidella boneti* Doben; Pop, pp. 12, 16, 17, 20, pl. 1, figs 37, 39.
2002. *Chitinoidella boneti* Doben; Reháková, p. 370, figs 2.1, 4.
2006. *Chitinoidella boneti* Doben; Grabowski and Pszczółkowski, p. 417, fig. 7B.
2007. *Chitinoidella boneti* Doben; Andreini *et al.*, p. 190, pl. 1, figs 3a, 4a.
2008. *Chitinoidella boneti* Doben; Olszewska *et al.*, p. 38, fig. 6a.
2011. *Chitinoidella boneti* Doben; Sallouhi *et al.*, pp. 648, 649, pl. 1.24.
2012. *Chitinoidella boneti* Doben; Benzaggagh *et al.*, p. 259, fig. 6A–B.
2013. *Chitinoidella boneti* Doben; Lakova and Petrova, pp. 206, 208, 213, 214, pl. 1, fig. 18; pl. 5, fig. 21.
2014. *Chitinoidella boneti* Doben; Kowal-Kasprzyk, p. 28, fig. 3A, C.
2015. *Chitinoidella boneti* Doben; Benzaggagh *et al.*, p. 258, fig. 5D–G.
2017. *Chitinoidella boneti* Doben; Kietzmann, pp. 153, 154, fig. 3c.
2017. *Chitinoidella boneti* Doben; Petrova *et al.*, p. 90, fig. 3.22–3.24.
2018. *Chitinoidella boneti* Doben; Kowal-Kasprzyk, pp. 20, 44, fig. 9A, B.
2019. *Chitinoidella boneti*; Petrova *et al.*, p. 70, fig. 5.1, 3.
2019. *Chitinoidella boneti* Doben; Aguirre-Urreta *et al.*, p. 362, fig. 13B, C.
2022. *Chitinoidella boneti* Doben; Ölveczká and Reháková, p. 56, fig. 6.18.

MATERIAL AND SAMPLES: Iwanowa Góra – sample F12 (1 specimen in a coated grainstone pebble, Text-fig. 9), sample IIPZFB (1 specimen in a clast of peloid grainstone from Rapacz Conglomerate, Text-fig. 9).

DESCRIPTION: An oval, elongated-shaped microgranular lorica with a wide aperture. The collar is distinctively outward deflected, forming a variable angle with the lorica bowl. The observed specimens measure 70–80 µm in length and 44–66 µm in width.

REMARKS: Some specimens with broken collars but large loricae were classified as *Chitinoidella* sp. (Text-fig. 11H, I). They were found on Wapielnica Hill – sample KRG106 (1 specimen in a coral-debris-sponge rudstone pebble from debris) and in Błoćce Stream – sample PZKA (1 specimen in a peloidal packstone clast from Rapacz Conglomerate, Text-fig. 9).

OCCURRENCE: Uppermost Jurassic; *Boneti* Subzone in the Western Carpathians (Borza and Michalík 1986; Reháková 2002; Olszewska *et al.* 2005; Grabowski and Pszczółkowski 2006; Olszewska *et al.* 2008; Kowal-Kasprzyk 2014, 2018; Ölveczká and Reháková 2022), Alps (Doben 1963; Grün and Blau 1997), central and southern Italy (Houša *et al.* 2004; Andreini *et al.* 2007), south-eastern France (Lodowski *et al.* 2025), Maghrebides (Benzaggagh and Atrops 1995; Boughdiri *et al.* 2009; Sallouhi *et al.* 2011; Benzaggagh *et al.* 2015), Iran (Benzaggagh *et al.* 2012), Cuba (Pszczółkowski and Myczyński 2010), and Chile (Aguirre-Urreta *et al.* 2019; Kietzmann *et al.* 2022; Kietzmann 2017; Kietzmann and Encinias

2025). Occasionally noted in the *Praetintinnopsella* Zone and the lowest *Remanei* Subzone in the western Balkanides (e.g., Lakova and Petrova 2013; Petrova *et al.* 2019) and Southern Carpathians (Pop 1998a; Petrova *et al.* 2017).

Family Calpionellidae Bonet, 1956

Genus *Tintinnopsella* Colom, 1948

TYPE SPECIES: *Calpionella carpathica* Murgeanu and Filipescu, 1933.

Tintinnopsella remanei Borza, 1969
(Text-fig. 11J)

1969. *Tintinnopsella remanei* n. sp.; Borza, p. 108, pl. 80, figs. 7–16.
1980. *Tintinnopsella remanei* Borza; Nowak, p. 338, pl. 91, fig. 4.
1986. *Tintinnopsella remanei* Borza; Borza and Michalík, p. 149, pl. 3, figs 7, 8.
1987. *Tintinnopsella remanei* Borza; Řehánek, p. 35, pl. 18, fig. 8.
2013. *Tintinnopsella remanei* Borza; Lakova and Petrova, p. 208, pl. 1, fig. 34; pl. 5, figs 42, 43.
2016. *Tintinnopsella remanei* Borza; Michalík *et al.*, p. 328, fig. 8D.
2019. *Tintinnopsella remanei* Borza; Aguirre-Urreta *et al.*, p. 362, fig. 13E.
2019. *Tintinnopsella remanei* Borza; Petrova *et al*., p. 70, fig. 8.1–8.6.
2022. *Tintinnopsella remanei* Borza; Ölveczká and Reháková, p. 56, fig. 6.20.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KNC6 (1 specimen in a peloidal packstone clast in coral-sponge-debris rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KN1 (1 specimen in a peloidal packstone clast from Rapacz Conglomerate, Appendix 1).

DESCRIPTION: The hyaline lorica is fine and oval in longitudinal section. The observed specimens measure 45 µm in length and 40 µm in width. In the middle part, it is often rounded. Close to the aperture, the lorica narrows and bends perpendicularly. The collar is short, cylindrical and outwardly deflected. The aboral part is rounded.

OCCURRENCE: Uppermost Jurassic; *Crassicollaria* Zone (mainly *Remanei* Subzone) in the Western Carpathians (Borza 1984; Nowak 1980; Řehánek 1987; Michalík *et al.* 2016; Kowal-Kasprzyk 2018), western Balkanides (Lakova *et al.* 1997; Lakova *et al.* 1999; Lakova and Petrova 2013), Maghrebides (Benzaggagh and Atrops 1995), and Chile (Aguirre-Urreta *et al.* 2019).

Tintinnopsella carpathica
(Murgeanu and Filipescu, 1933)
(Text-fig. 11K, L)

1933. *Calpionella carpathica* n. sp.; Murgeanu and Filipescu, p. 63, fig. 1c.
1948. *Tintinnopsella carpathica* (Murgeanu et Filipescu 1933); Colom, p. 245, pl. 2, figs 10–31; pl. 13, figs 53, 54.
1966. *Tintinnopsella* cf. *carpathica* (Murgeanu et Filipescu); Geroch and Morycowa, p. 296, pl. 24, fig. 11.
1969. *Tintinnopsella carpathica* (Murgeanu et Filipescu); Borza, pp. 92–94, pl. 78, figs 1–16; pl. 79, figs 1–8.
1980. *Tintinnopsella carpathica* (Murgeanu et Filipescu); Nowak, pp. 337, 338, pl. 91, fig. 2.
1986. *Tintinnopsella carpathica* (Murgeanu et Filipescu); Borza and Michalík, p. 149, pl. 3, figs 3, 5.
2001. *Tintinnopsella carpathica* (Murgeanu et Filipescu); Ciborowski and Kołodziej, p. 346, fig. 2.5.
2008. *Tintinnopsella carpathica* (Murgeanu et Filipescu); Olszewska *et al.*, p. 45, fig. 7E.
2011. *Tintinnopsella carpathica* (Murgeanu et Filipescu); Olszewska *et al.*, p. 25, fig. 11F.
2013. *Tintinnopsella carpathica* (Murgeanu et Filipescu); Lakova and Petrova, pp. 208, 210, pl. 1, figs 35, 36; pl. 2, fig. 34; pl. 3, figs 41–44; pl. 4, figs 47–49; pl. 5, figs 38–41; pl. 6, figs 32; pl. 7, figs 36–41.
2016. *Tintinnopsella carpathica* Murgeanu et Filipescu; Maalaoui and Zargouni, p. 58, fig. 4.8, 9.
2017. *Tintinnopsella carpathica* Murgeanu et Filipescu; Kietzmann, p. 160, fig. 5.20.
2017. *Tintinnopsella carpathica* Murgeanu et Filipescu; Petrova *et al*., p. 90, figs 6.14–6.17; 8.22–8.25.
2018. *Tintinnopsella carpathica* Murgeanu et Filipescu; Kowal-Kasprzyk, p. 42, fig. 10K–M.
2019. *Tintinnopsella carpathica* Murgeanu et Filipescu; Petrova *et al*., p. 70, fig. 8.7–8.17.
2022. *Tintinnopsella carpathica* Murgeanu et Filipescu; Ölveczká and Reháková, p. 56, fig. 10.23.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KNA1 (1 specimen in the matrix of bioclast-lithoclastic rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KNA4 (1 specimen in the matrix of bioclast-lithoclastic rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KNB1 (5 specimens in the matrix of calpionellid wackestone from Kruhel Wielki Klippe, Text-fig. 5), sample KNC6 (1 specimen in the matrix of bioclast-lithoclastic rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KN41 (1 specimen in the matrix of poorly-washed rudstone pebble from debris), sample KRE2 (1 specimen in a clast of bioclast-lithoclast floatstone from debris), sample KRG27 (1 specimen in the matrix of bioclast-lithoclast wackestone pebble from debris), sample KS1 (1 specimen in an oncoid of oncoid wackestone pebble from debris); Huwniki – sample H22A (2 specimens in a peloid packstone clast of bioclast-debris-cement rudstone pebble from debris).

DESCRIPTION: The hyaline lorica is bell-shaped or calicular, widest in the middle part. The aboral part is conical or semicircular, often with a caudal appendage. The aperture is wide, and the collar is strongly outwardly deflected, almost perpendicular to the lorica. The studied specimens measure 60–64 µm in length and 45–50 µm in width.

OCCURRENCE: Uppermost Jurassic to lowermost Cretaceous; *Remanei* to upper Berriasian *Darderi* Subzone in SE France (Lodowski *et al.* 2025), *Remanei–Elliptica* subzones in the Western Carpathians (Geroch and Morycowa 1966; Borza 1969; Nowak 1980; Borza and Michalík 1986; Ciborowski and Kołodziej 2001; Olszewska *et al*. 2008, 2011; Kowal-Kasprzyk 2018; Ölveczká and Reháková 2022), and Spain (Colom 1948); *Remanei* to Valanginian *Major* subzones in the western Balkanides (Lakova *et al.* 1997, 1999; Lakova and Petrova 2013; Petrova *et al.* 2019), and the Southern Carpathians (Murgeanu and Filipescu 1933; Petrova *et al.* 2017); *Remanei* to *Alpina* subzones in the Maghrebides (Benzaggagh *et al.* 2010; Maalaoui and Zargouni 2016), *Remanei* Subzone in Chile (Kietzmann *et al.* 2022), and SW Argentina (Kietzmann 2017).

Genus *Crassicollaria* Remane, 1962

TYPE SPECIES: *Crassicollaria brevis* Remane, 1962.

Crassicollaria intermedia (Durand Delga, 1957)
(Text-fig. 11M–O)

1957. *Calpionella intermedia*; Durand Delga, p. 167, fig. 1C; pl. 1, figs 2–4.
1963. *Crassicollaria intermedia* (Durand Delga); Remane, p. 23, fig. 9, 17q–t; pl. 2, figs 19–35; pl. 5, fig. 7.
1966. *Crassicollaria intermedia* (Durand Delga); Geroch and Morycowa, p. 296, pl. 24, figs 4–6.
1968. *Crassicollaria intermedia* (Durand Delga); Morycowa, p. 19, pl. 9, fig. 5.
1969. *Crassicollaria intermedia* (Durand Delga); Borza, pp. 88, 89, pl. 74, figs 1–16.
1980. *Crassicollaria intermedia* (Durand Delga); Nowak, p. 336, pl. 92, fig. 2v.
1986. *Crassicollaria intermedia* (Durand Delga); Borza and Michalík, p. 149, pl. 3, figs 1–3.
2001. *Crassicollaria intermedia* (Durand Delga); Ciborowski and Kołodziej, p. 346, fig. 2.2.
2001. *Crassicollaria intermedia* (Durand Delga); Olszewska and Wieczorek, p. 220, fig. 8.2.
2005. *Crassicollaria intermedia* (Durand Delga); Olszewska, pl. 1, p. 27, fig. 13.
2005. *Crassicollaria intermedia* (Durand Delga); Pszczółkowski *et al.*, p. 7, fig. 7E.
2006. *Crassicollaria intermedia* (Durand Delga); Boughdiri *et al.*, p. 1253, fig. 4.7.
2007. *Crassicollaria intermedia* (Durand Delga); Andreini *et al.*, pl. 1, p. 183, figs 28, 29.
2008. *Crassicollaria intermedia* (Durand Delga); Olszewska *et al*., p. 45, pl. 1, fig. 13.
2009. *Crassicollaria intermedia* (Durand Delga); Benzaggagh *et al.*, p. 12, fig. 9.13–9.16.
2010. *Crassicollaria intermedia* (Durand Delga); Pszczółkowski and Myczyński, p. 232, fig. 13.2.
2011. *Crassicollaria intermedia* (Durand Delga); Olszewska *et al.*, p. 25, figs 30K, 36E.
2013. *Crassicollaria intermedia* (Durand Delga); Lakova and Petrova, p. 208, pl. 1, figs 32, 33; pl. 5, figs 44–46.
2015. *Crassicollaria intermedia* (Durand Delga); Benzaggagh *et al.*, p. 259, fig. 5H–J.
2016. *Crassicollaria intermedia* (Durand Delga); Michalík *et al.*, p. 328, fig. 8F.
2017. *Crassicollaria intermedia* (Durand Delga); Kietzmann, pp. 159, 160, fig. 5.17, 5.18.
2018. *Crassicollaria intermedia* (Durand Delga); Carević *et al.*, p. 311, figs 6.24, 7.1–7.5.
2018. *Crassicollaria intermedia* (Durand Delga); Kowal-Kasprzyk, p. 42, fig. 10F.
2019. *Crassicollaria intermedia* (Durand Delga); Petrova *et al.*, p. 70, fig. 7.7–7.12.
2020. *Crassicollaria intermedia* (Durand Delga); López-Martínez *et al.*, p. 583, fig. 5A.
2022. *Crassicollaria intermedia* (Durand Delga); Ölveczká and Reháková, p. 56, figs 6.19, 10.10.
2024. *Crassicollaria intermedia* (Durand Delga); Rožič and Reháková, p. 15, fig. 5C.
2024. *Crassicollaria intermedia* (Durand Delga); Touansa *et al.*, p. 7, fig. 4H.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KNA02 (2 specimens in a peloid packstone clast in coral-sponge-debris rudstone from Kruhel Wielki Klippe, Text-fig. 5), samples KNC0, KNC1, KNC3 (9 specimens in the matrix and clasts in bioclast-lithoclast rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KND1 (2 specimens in a peloid packstone clast from Rapacz Conglomerate, Text-fig. 5), sample KRG21 (2 specimens in a peloid packstone clast in bioclast-debris-cement rudstone pebble from debris, Text-fig. 5), sample KS2 (1 specimen in a peloid packstone clast from Rapacz Conglomerate, Text-fig. 5); Grochowski Stream I – sample PZFB (1 specimen in a peloid packstone clast from Rapacz Conglomerate, Text-fig. 9).

DESCRIPTION: An elongated hyaline lorica, more or less elliptical or cylindrical in longitudinal section. The longest lorica among the representatives of the genus *Crassicollaria* studied herein are 80–100 µm in length and 35–45 µm in width. The lorica walls are parallel or slightly taper towards the aboral pole. At the oral pole, up to the swelling, the lorica walls diverge into a short collar. The aboral end is conical and extends into a caudal appendage.

REMARKS: The oral side is similar to that of *Crassicollaria brevis*.

OCCURRENCE: Uppermost Jurassic; *Crassicollaria* Zone in the Western Carpathians (Geroch and Morycowa 1966; Morycowa 1968; Borza 1969; Nowak 1980; Ciborowski and Kołodziej 2001; Olszewska and Wieczorek 2001; Olszewska 2005; Olszewska *et al.* 2005; Michalík *et al.* 2016; Kowal-Kasprzyk 2018), SE Alps (Rožič and Reháková 2024), southern Italy (Andreini *et al.* 2007), northern Italy (Houša *et al.* 2004), western Balkanides (Lakova *et al.* 1999; Lakova and Petrova 2013; Carević *et al.* 2018), SE France (Remane 1963; Wimbledon *et al.* 2013; Granier *et al.* 2023; Lodowski *et al.* 2025), Maghrebides (Durand Delga 1957; Benzaggagh and Atrops 1995; Boughdiri *et al.* 2006; Benzaggagh *et al.* 2009, 2015), Mexico (López-Martínez *et al.* 2015) and SW Argentina (Kietzmann 2017). Occasionally noted in the lowermost Cretaceous *Alpina* Subzone in Cuba (Pszczółkowski *et al.* 2005), the Western Carpathians (Ölveczká and Reháková 2022), and in the Maghrebides (Touansa *et al.* 2024).

Crassicollaria brevis Remane, 1962
(Text-fig. 11P–S)

1962. *Crassicollaria brevis* n. sp.; Remane, p. 16, figs 19–26, 35.
1969. *Crassicollaria brevis* Remane; Borza, p. 88, pl. 73, figs 1-16.
1980. *Crassicollaria brevis* Remane; Nowak, p. 335, pl. 92, fig. 1.
2001. *Crassicollaria brevis* Remane; Ciborowski and Kołodziej, p. 346, fig. 2.4.
2001. *Crassicollaria brevis* Remane; Olszewska and Wieczorek, p. 220, fig. 8.1.
2005. *Crassicollaria brevis* Remane; Olszewska, p. 27, pl. 1, fig. 12.
2006. *Crassicollaria brevis* Remane; Grabowski and Pszczółkowski, pp. 402, 417, fig. 7F.
2011. *Crassicollaria brevis* Remane; Olszewska *et al.*, p. 25, fig. 36H.
2013. *Crassicollaria brevis* Remane; Lakova and Petrova, p. 209, pl. 2, figs 2, 3; pl. 6, figs 18, 19.
2016. *Crassicollaria brevis* Remane; Hoedemaeker *et al.*, p. 190, pl. 20, figs A, B.
2016. *Crassicollaria brevis* Remane; Michalík *et al.*, p. 328, fig. 8H.
2018. *Crassicollaria brevis* Remane; Kowal-Kasprzyk, p. 42, fig. 10B.
2019. *Crassicollaria brevis* Remane; Petrova *et al*., p. 70, fig. 7.1–7.6.
2022. *Crassicollaria brevis* Remane; Ölveczká and Reháková, p. 56, figs 6.24, 10.11.
2024. *Crassicollaria brevis* Remane; Touansa *et al.*, p. 7, fig. 4K–M.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KNA02 (1 specimen in a clast of oncoid wackestone in coral-sponge-debris rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KNB1 (2 specimens in the matrix of calpionellid wackestone from Kruhel Wielki Klippe, Text-fig. 5), sample KNC6 (3 specimens in clasts of calpionellid wackestone in rudstone bioclast-lithoclast rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KNG3 (1 specimen in a clast of bioclastic-peloidal packstone from Rapacz Conglomerate, Text-fig. 5), sample KRE (2 specimens in a clast in bioclast-lithoclast floatstone), sample KS2 (1 specimen in a peloid packstone clast from Rapacz Conglomerate, Text-fig. 5); Grochowski Stream I – sample PZFC (1 specimen in a peloid packstone clast in a bioclast-debris-cement rudstone pebble from debris).

DESCRIPTION: A conical, short hyaline lorica, widest at the oral side near the swelling. The loricae of the observed specimens are 57–70 µm in length and 38–50 in width. The aboral zone is sharp, sometimes with a caudal appendage. The short cylindrical collar is significantly deflected outwards.

OCCURRENCE: Uppermost Jurassic; *Crassicollaria* Zone, most common in the lower *Massutiniana* Subzone (*Brevis* Subzone of Reháková (1995)) in the Western Carpathians (Borza 1969; Nowak 1980; Ciborowski and Kołodziej 2001; Olszewska and Wieczorek 2001; Olszewska 2005; Grabowski and Pszczółkowski 2006; Olszewska *et al.* 2011; Michalík *et al.* 2016; Kowal-Kasprzyk 2018; Ölveczká and Reháková 2022), western Balkanides (Lakova and Petrova 2013; Carević *et al.* 2018; Petrova *et al.* 2019), Maghrebides (Touansa *et al.* 2024), SE Spain (Hoedemaeker *et al.* 2016), and Mexico (López-Martínez *et al.* 2013a, 2015). Occasionally occurs in the lowermost Cretaceous *Alpina* Subzone in Cuba (Pszczółkowski *et al.* 2005), SE France (Wimbledon *et al.* 2020; Granier *et al.* 2023), and northern Italy (Petrova *et al.* 2025).

Crassicollaria colomi Doben, 1963
(Text-fig. 11T, U)

1963. *Crassicollaria colomi* n. sp.; Doben, p. 37, pl. 5, figs 13–18.
1969. *Crassicollaria colomi* Doben; Borza, p. 91, pl. 74, figs 1–16.
2011. *Crassicollaria colomi* Doben; Olszewska *et al.*, p. 62, fig. 36D.
2013. *Crassicollaria colomi* Doben; Lakova and Petrova, pp. 210, 214, pl. 2, figs 6, 7; pl. 6, figs 30, 31.
2013b. *Crassicollaria colomi* Doben; López-Martínez *et al.*, p. 144, fig. 3E.
2016. *Crassicollaria colomi* Doben; Hoedemaeker *et al.*, p. 190, pl. 20, fig. C.
2016. *Crassicollaria colomi* Doben; Michalík *et al.*, p. 328, fig. 8I.
2018. *Crassicollaria colomi* Doben; Kowal-Kasprzyk, p. 42, fig. 10C–D.
2019. *Crassicollaria colomi* Doben; Petrova *et al.*, p. 70, fig. 7.19–7.24.
2020b. *Crassicollaria colomi* Doben; Wimbledon *et al.*, p. 129, fig. 11I.
2022. *Crassicollaria colomi* Doben; Ölveczká and Reháková, p. 56, figs 6.23, 10.13.
2024. *Crassicollaria colomi* Doben; Touansa *et al.*, p. 7, fig. 4Q–R.
2024. *Crassicollaria colomi* Doben; Rožič and Reháková, p. 15, fig. 5D.

MATERIAL AND SAMPLES: Wapielnica Hill – samples KNC1 and KNC6 (3 specimens in clasts of bioclast-lithoclast rudstone from Kruhel Wielki Klippe, Text-fig. 5).

DESCRIPTION: A narrow and long conical hyaline lorica, widest near the oral pole. Lorica measures 72–83 µm in length and 35–42 µm in width. The aboral side is sharp, and the caudal appendage is present. Above the distinct swelling occurs an outwardly deflected collar.

OCCURRENCE: Uppermost Jurassic; *Crassicollaria* Zone, most common in the upper *Massutiniana* (*Colomi* Subzone of Pop (1994)). Known from the Western Carpathians (Borza 1969; Olszewska *et al.* 2011; Michalík *et al.* 2016; Kowal-Kasprzyk 2018; Ölveczká and Reháková 2022), western Balkanides (Lakova *et al.* 1999; Lakova and Petrova 2013; Petrova *et al.* 2019), Alps (Doben 1963; Rožič and Reháková 2024), SE Spain (Hoedemaeker *et al.* 2016), SE France (Lodowski *et al.* 2025), Maghrebides (Touansa *et al.* 2024), and Mexico (López-Martínez *et al.* 2013a, 2015). Occasionally, in the lowermost Cretaceous *Alpina* Subzone in the Western Balkanides (Lakova and Petrova 2013; Wimbledon *et al.* 2020b; Petrova *et al.* 2025).

Crassicollaria parvula Remane, 1962
(Text-fig. 11V)

1962. *Crassicollaria parvula* n. sp.; Remane, p. 19, figs 36–46.
1966. *Crassicollaria parvula* Remane; Geroch and Morycowa, p. 296, pl. 24, figs 2, 3.
1968. *Crassicollaria parvula* Remane; Morycowa, p. 21, pl. 9, fig. 6.
1969. *Crassicollaria parvula* Remane; Borza, pp. 90, 91, pl. 1–16, 76.
1980. *Crassicollaria parvula* Remane; Nowak, p. 336, pl. 92, fig. 4.
1986. *Crassicollaria parvula* Remane; Borza and Michalík, p. 149, pl. 3, figs 12, 13.
1993. *Crassicollaria parvula* Remane; Michalík *et al.*, p. 164, pl. 2, fig. 2.
2001. *Crassicollaria parvula* Remane; Olszewska and Wieczorek, p. 227, fig. 6.2.
2005. *Crassicollaria parvula* Remane; Olszewska, p. 27, pl. 1, fig. 14.
2011. *Crassicollaria parvula* Remane; Olszewska *et al.*, p. 8, fig. 30I.
2013. *Crassicollaria parvula* Remane; Lakova and Petrova, pp. 209, 210, pl. 2, figs 4, 5; pl. 5, fig. 49; pl. 6, figs 20–29.
2013a. *Crassicollaria parvula* Remane; López-Martínez *et al.*, p. 144, fig. 3D.

2016. *Crassicollaria parvula* Remane; Hoedemaeker *et al.*, p. 190, pl. 20, figs G–I.
2016. *Crassicollaria parvula* Remane; Maalaoui and Zargouni, pp. 47, 58, fig. 4.7.
2017. *Crassicollaria parvula* Remane; Petrova *et al.*, p. 90, fig. 6.10, 6.11.
2018. *Crassicollaria parvula* Remane; Kowal-Kasprzyk, p. 42, fig. 10I.
2018. *Crassicollaria parvula* Remane; Carević *et al.*, pp. 309, 311, fig. 6.6, 6.7.
2019. *Crassicollaria parvula* Remane; Petrova *et al.*, p. 70, fig. 7.25–7.30.
2022. *Crassicollaria parvula* Remane; Ölveczká and Reháková, p. 56, figs 6.22, 10.9.
2024. *Crassicollaria parvula* Remane; Touansa *et al.*, p. 7, fig. 4J–S.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KNB1 (over a dozen specimens in the matrix of calpionellid wackestone from Kruhel Wielki Klippe, Text-fig. 5), sample KNC4 (6 specimens in the matrix and clasts of bioclast-lithoclast rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KN4 (3 specimens in a mudstone clast in poorly-washed rudstone pebble from debris), sample KRG103 (2 specimens in the matrix of poorly washed rudstone pebble from debris); Grochowski Stream I – sample PZFA (2 specimens in a peloid packstone clast in Rapacz Conglomerate, Text-fig. 9).

DESCRIPTION: Elliptical hyaline lorica with a conical aboral pole. Up to the swelling, the lorica has a straight, parabolic transition into the short collar. The specimens studied are 60–80 µm in length and approximately 40–50 µm in width.

OCCURRENCE: Uppermost Jurassic to lowermost Cretaceous; *Crassicollaria* to Valanginian *Calpionellopsis* Zone; most common in the upper *Massutiniana* (*Colomi* Subzone of Pop (1994)) and *Alpina* subzones in the Western Carpathians (Geroch and Morycowa 1966; Morycowa 1968; Borza 1969; Nowak 1980; Borza and Michalík 1986; Michalík 1993; Olszewska and Wieczorek 2001; Olszewska 2005; Olszewska *et al.* 2011; Kowal-Kasprzyk 2018; Ölveczká and Reháková 2022), Southern Carpathians (Petrova *et al.* 2017), Western Balkanides (Lakova and Petrova 2013; Grabowski *et al.* 2016; Carević *et al.* 2018; Petrova *et al.* 2019), SE France (Granier *et al.* 2023; Lodowski *et al.* 2025), SE Spain (Hoedemaeker *et al.* 2016), Maghrebides (Benzaggagh and Atrops 1995; Benzaggagh *et al.* 2009; Maalaoui and Zargouni 2016; Touansa *et al.* 2024), and Mexico (López-Martínez *et al.* 2013a).

Crassicollaria massutiniana (Colom, 1948)
(Text-fig. 11W)

1948. *Calpionella massutiniana* n. sp.; Colom, p. 243, pl. 11, fig. 45.
1969. *Crassicollaria massutiniana* (Colom); Borza, p. 90, pl. 75, figs 5–16.
1980. *Crassicollaria massutiniana* (Colom); Nowak, p. 337, pl. 92, fig. 3.
1986. *Crassicollaria massutiniana* (Colom); Borza and Michalík, p. 149, pl. 3, figs 9–11.
2006. *Crassicollaria massutiniana* (Colom); Grabowski and Pszczółkowski, pp. 402, 417, fig. 7E.
2011. *Crassicollaria massutiniana* (Colom); Reháková *et al.*, p. 74, pl. 8, fig. 3.
2013. *Crassicollaria massutiniana* (Colom); Lakova and Petrova, p. 209, pl. 2, fig. 1; pl. 5, figs 47, 48; pl. 6, figs 15–17.
2016. *Crassicollaria massutiniana* (Colom); Hoedemaeker *et al.*, p. 190, pl. 20, figs D–F.
2016. *Crassicollaria massutiniana* (Colom); Michalík *et al.*, p. 328, fig. 8G.
2017. *Crassicollaria massutiniana* (Colom); Kietzmann, p. 160, fig. 5.19.
2017. *Crassicollaria massutiniana* (Colom); Petrova *et al.*, p. 90, fig. 8.5.
2018. *Crassicollaria massutiniana* (Colom); Carević *et al.*, pp. 309, 311, fig. 6.8–6.11.
2018. *Crassicollaria massutiniana* (Colom); Kowal-Kasprzyk, p. 42, fig. 10G, 10H.
2019. *Crassicollaria massutiniana* (Colom); Petrova *et al.*, p. 70, fig. 7.13–7.18.
2020b. *Crassicollaria massutiniana* (Colom); Wimbledon *et al.*, p. 131, fig. 11F.
2022 *Crassicollaria massutiniana* (Colom); Ölveczká and Reháková, p. 56, fig. 6.21.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KRG103 (1 specimen in the matrix of poorly-washed rudstone pebble from debris).

DESCRIPTION: Elongated and widely ellipsoidal hyaline lorica. The observed specimen is 80 µm in length and 48 µm in width. The lorica is widest in the oral pole near the poorly preserved swelling. The upper part of the lorica walls is almost parallel, while the aboral pole is slightly rounded. The collar is short and cylindrical.

OCCURRENCE: Uppermost Jurassic; most common in the upper part of the *Crassicollaria* Zone (*Massutiniana* Subzone). Known from the Western Carpathians (Borza 1969; Nowak 1980; Borza and Michalík 1986; Grabowski and Pszczółkowski 2006; Reháková *et al.* 2011; Michalík 2016; Kowal-Kasprzyk 2018; Svobodová *et al.* 2019; Ölveczká and Reháková 2022), Southern Carpathians (Petrova *et al.* 2017), Alps (Doben 1963), western Balkanides (Lakova *et al.* 1999; Carević *et al.* 2018; Petrova *et al.* 2019), SE France (Wimbledon *et al.* 2020b; Lodowski *et al.* 2025), SE Spain (Hoedemaeker *et al.* 2016), Maghrebides (Benzaggagh *et al.* 2009), Balearic Islands (Colom 1948), and SW Argentina (Kietzmann 2017). Occasionally occurs in the lowermost Cretaceous lowermost *Alpina* Subzone in the western Balkanides (Lakova and Petrova 2013; Petrova *et al.* 2025) and in the *Calpionella*–upper Berriasian *Calpionellopsis* Zone in the Maghrebides (Maalaoui and Zargouni 2016).

Genus *Calpionella* Lorenz, 1902

TYPE SPECIES: *Calpionella alpina* Lorenz, 1902.

Calpionella alpina Lorenz, 1902
(Text-fig. 11X, Y)

1902. *Calpionella alpina* n. sp; Lorenz, p. 60, pl. 9, fig. 1.
1966. *Calpionella alpina* Lorenz; Geroch and Morycowa, p. 296, pl. 24, fig. 1.
1969. *Calpionella alpina* Lorenz; Borza, pp. 82–85, pl. 70, figs 13–16; pl. 71, figs 1–16.
1980. *Calpionella alpina* Lorenz; Nowak, p. 335, pl. 91, fig. 3.
1986. *Calpionella alpina* Lorenz; Borza and Michalík, p. 149, pl. 3, figs 14–16.
1993. *Calpionella alpina* Lorenz; Michalík *et al.*, p. 164, pl. 5, fig. 2.
1994. *Calpionella alpina* Lorenz; Adatte *et al*., p. 47 pl. 1, figs 1–3.
2001. *Calpionella alpina* Lorenz; Ciborowski and Kołodziej, p. 346, fig. 2.3, 2.6–2.9.
2001. *Calpionella alpina* Lorenz; Olszewska and Wieczorek, p. 220, figs 6.1, 7.6.
2005. *Calpionella alpina* Lorenz; Olszewska, p. 28, pl. 1, fig. 5.
2006. *Calpionella alpina* Lorenz; Grabowski and Pszczółkowski, pp. 402, 417, fig. 7D.
2007. *Calpionella alpina* Lorenz; Andreini *et al.*, pp. 183–185, pl. 1, figs 10–13.
2008. *Calpionella alpina* Lorenz; Olszewska *et al.*, p. 45, fig 7b.
2011. *Calpionella alpina* Lorenz; Olszewska *et al.*, p. 25, figs 28N, 30J, 36I.
2013. *Calpionella alpina* Lorenz; Lakova and Petrova, p. 209, 210, 214, 215, pl. 2, figs 12–16; pl. 5, fig. 52; pl. 6, figs 3–7.
2013a. *Calpionella alpina* Lorenz; López-Martínez *et al*., p. 144, fig. 3I.
2015. *Calpionella alpina* Lorenz; López-Martínez *et al.*, pp. 583–587, fig. 7C–D.
2016. *Calpionella alpina* Lorenz; Hoedemaeker *et al.*, p. 190, pl. 22, figs A, B.
2016. *Calpionella alpina* Lorenz; Maalaoui and Zargouni, p. 58, fig. 4.1–4.3.
2016. *Calpionella alpina* Lorenz; Michalík *et al.*, p. 328, fig. 8J.
2017. *Calpionella alpina* Lorenz; Petrova *et al*., p. 90, figs 6.1–6.3, 8.11–8.13.
2018. *Calpionella alpina* Lorenz; Kowal-Kasprzyk, p. 41, fig. 10O–Q, S–T.
2018. *Calpionella alpina* Lorenz; Carević *et al.*, p. 311, fig. 6.12–6.23.
2019. *Calpionella alpina* Lorenz; Petrova *et al*., p. 70, fig. 6.11–6.24.
2022. *Calpionella alpina* Lorenz; Ölveczká and Reháková, p. 56, figs 6.25, 10.12.
2023. *Calpionella alpina* Lorenz; Granier *et al.*, pp. 7–10, fig. 6AC–AE, AO, AP.
2024. *Calpionella alpina* Lorenz; Touansa *et al.*, p. 7, fig. 4T–U.

MATERIAL AND SAMPLES: Wapielnica Hil – sample KNB1 (over a dozen specimens in matrix of calpionellid wackestone from Kruhel Wielki Klippe, Text-fig. 5), samples KNC5, KNC6 (over a dozen specimens in clasts of bioclast-lithoclast rudstone from Kruhel Wielki Klippe, Text-fig. 5), sample KNG3 (2 specimens in a clast of bioclastic-peloidal packstone in Rapacz Conglomerate, Text-fig. 5), sample KN4 (7 specimens in the matrix of poorly-washed rudstone pebble from debris), sample KN41 (5 specimens in the matrix of poorly-washed rudstone pebble from debris), sample KRE (4 specimens in a clast in bioclast-lithoclastic floatstone pebble from debris), sample KRG21 (5 specimens in a clast in bioclast-lithoclastic rudstone pebble from debris), sample KRG22 (4 specimens in a peloid packstone clast in bioclast-lithoclastic rudstone from debris), sample KRG23 (7 specimens in clast of calpionellid wackestone in bioclast-lithoclastic rudstone pebble from debris), sample KRG27 (6 specimens in matrix in bioclast peloidal wackestone pebble from debris), sample KRG31 (1 specimen in clast of peloid packstone in bioclast-lithoclast rudstone pebble from debris), sample KRG35 (4 specimens in clasts in coral-sponge-debris rudstone pebble from debris), sample KRG103 (1 specimen in clasts in poorly-washed rudstone pebble from debris); Huwniki – sample H22A (1 specimen in peloid packstone clast in bioclast-debris-cement rudstone pebble from debris).

DESCRIPTION: Rounded or slightly ellipsoidal hyaline lorica. The oral pole is composed of a cylindrical collar, and the aboral pole is rounded. The loricae of the observed specimens are 40–70 µm in length and 35–70 µm in width.

OCCURRENCE: Uppermost Jurassic *Crassicollaria* Zone to upper Berriasian *Calpionellopsis* Zone. Known from the Western Carpathians (Geroch and Morycowa 1966; Borza 1969; Nowak 1980; Borza and Michalík 1986; Michalík *et al.* 1993; Ciborowski and Kołodziej 2001; Olszewska and Wieczorek 2001; Olszewska 2005; Grabowski and Pszczółkowski 2006; Olszewska *et al.* 2008, 2011; Michalík *et al.* 2016; Kowal-Kasprzyk 2018; Ölveczká and Reháková 2022), Southern Carpathians (Petrova *et al.* 2017), western Balkanides (Lakova *et al.* 1997; Lakova and Petrova 2013; Carević *et al.* 2018; Petrova *et al.* 2019), SE France (Granier *et al.* 2020; Lodowski *et al.* 2025), SE Spain (Hoedemaeker *et al.* 2016), southern Italy (Andreini *et al.* 2007), Maghrebides (Benzaggagh and Atrops 1995; Benzaggagh *et al.* 2009; Maalaoui and Zargouni 2016; Touansa *et al.* 2024), Cuba (Pszczółkowski 2005; Pszczółkowski and Myczyński 2010), Mexico (Adatte *et al.* 1994; López-Martínez *et al.* 2013a, 2015), and Argentina (Kietzmann 2017).

Calpionella grandalpina Nagy, 1986
(Text-fig. 11Z, AA)

1986. *Calpionella grandalpina* n. sp.; Nagy, pp. 57, 58, pl. 1, fig. 3.
1999. *Calpionella grandalpina* Nagy; Lakova *et al.*, p. 165, pl. 1, fig. 7.
2011. *Calpionella grandalpina* Nagy; Olszewska *et al.*, p. 18.
2013. *Calpionella grandalpina* Nagy; Lakova and Petrova, pp. 209, 214, pl. 2, figs 8, 9; pl. 5, figs 50, 51, 53, 54; pl. 6, fig. 1.
2016. *Calpionella grandalpina* Nagy; Michalík *et al.*, p. 328, fig. 8K.
2017. *Calpionella grandalpina*; Petrova *et al.*, p. 90, fig. 8.10.
2018. *Calpionella* '*grandalpina*'; Kowal-Kasprzyk, p. 42, fig. 10Q.
2019. *Calpionella* grandalpina; Petrova *et al.*, p. 70, fig. 6.1–6.5.
2022. *Calpionella grandalpina* Nagy; Ölveczká and Reháková, p. 56, fig. 10.14.
2025. *Calpionella grandalpina* Nagy; Lodowski *et al.*, p. 7, pl. 2, fig. 2.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KRG27 (2 specimens in the matrix of bioclast-peloidal wackestone pebble from debris), sample KRG31 (2 specimens in clast of peloid packstone in bioclast-lithoclastic rudstone pebble from debris).

DESCRIPTION: The observed specimens measure 70–78 µm in length and 55–62 µm in width. The lorica is more or less elliptical, with the maximum width in its upper part. The oral side is medium-sized. The collar is parallel and slightly thickened at the end.

OCCURRENCE: Known from the uppermost Jurassic *Massutiniana* Subzone in the Carpathians (Olszewska *et al.* 2011; Reháková *et al.* 2011; Michalík *et al.* 2016; Kowal-Kasprzyk 2018; Svobodová *et al.* 2019), Southern Carpathians (Petrova *et al.* 2017), western Balkanides (Lakova and Petrova 2013; Petrova *et al.* 2019), and SE France (Lodowski *et al.* 2025); occasionally found in the lowermost Cretaceous *Alpina* Subzone in Hungary (Nagy 1986) and *Remaniella* Subzone in the Western Carpathians (Ölveczká and Reháková 2022).

Calpionella elliptalpina Nagy, 1986
(Text-fig. 11AB)

1986. *Calpionella elliptalpina* n. sp.; Nagy, p. 58, pl. 1, fig. 4.
1999. *Calpionella elliptalpina* Nagy; Lakova *et al.*, p. 165, pl. 1, fig. 8.
2005. *Calpionella elliptalpina* Nagy; Olszewska, pp. 28, 29, pl. 1, fig. 4.
2011. *Calpionella elliptalpina* Nagy; Olszewska *et al.*, p. 19, fig. 28M.
2013. *Calpionella elliptalpina* Nagy; Lakova and Petrova, p. 209, pl. 2, figs 10, 11; pl. 6, fig. 2.
2013a. *Calpionella elliptalpina* Nagy; López-Martínez *et al.*, p. 144, fig. 3J.
2018. *Calpionella* '*elliptalpina*'; Kowal-Kasprzyk, p. 41, fig. 10R.
2019. *Calpionella elliptalpina* Nagy; Petrova *et al.*, p. 70, fig. 6.6–6.10
2022. *Calpionella elliptalpina* Nagy; Ölveczká and Reháková, p. 56, fig. 10.16.
2023. *Calpionella elliptalpina* Nagy; Granier *et al.*, pp. 9, 10, fig. 6AJ, AK.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KNB1 (1 specimen in matrix of calpionellid wackestone from Kruhel Wielki Klippe, Text-fig. 5).

DESCRIPTION: The hyaline lorica is elongated with a medium oral opening. The identified specimen is 70 µm long and 47 µm wide; the ellipticity of the lorica is 1.21. The lorica reaches the maximum width around the shoulders. The aboral side is slightly rounded, and the collar is straight and parallel.

OCCURRENCE: Uppermost Jurassic; most frequent in the *Massutiniana* Subzone in the Western Carpathians (Olszewska 2005; Olszewska *et al.* 2011; Kowal-Kasprzyk 2018; Svobodová *et al.* 2019), Southern Carpathians (Petrova *et al.* 2017), western Balkanides (Lakova *et al.* 1999; Lakova and Petrova 2013; Petrova *et al.* 2019), Hungary (Nagy 1986), SE France (Granier *et al.* 2023; Lodowski *et al.* 2025), and Mexico (López-Martínez *et al.* 2013a). According to Olszewska *et al.* (2011) and Ölveczká and Reháková (2022), also found in the lower part of the lowermost Cretaceous *Calpionella* Zone in the Western Carpathians.

Calpionella elliptica Cadisch, 1932
(Text-fig. 11AC)

1932. *Calpionella elliptica* n. sp.; Cadisch, p. 259, figs 3.10, 3.11, 3.17, 3.25.
1969. *Calpionella elliptica* Cadisch; Borza, pp. 85–87, pl. 72, figs 1–15.
1986. *Calpionella elliptica* Cadisch; Borza and Michalík, p. 149, pl. 4, figs 1, 2.
1994. *Calpionella elliptica* Cadisch; Adatte *et al*., p. 47, pl. 1, fig. 4.
2005. *Calpionella elliptica* Cadisch; Olszewska, p. 29, pl. 1, fig. 6.
2006. *Calpionella elliptica* Cadisch; Grabowski and Pszczółkowski, pp. 402, 417, fig. 7G.
2008. *Calpionella elliptica* Cadisch; Olszewska *et al.*, p. 45, fig. 7c.
2011. *Calpionella elliptica* Cadisch; Olszewska *et al.*, p. 8, fig. 11B.
2013. *Calpionella elliptica* Cadisch; Lakova and Petrova, p. 221, pl. 2, figs 36, 37; pl. 3, figs 1, 2; pl. 6, fig. 14.
2013a. *Calpionella elliptica* Cadisch; López-Martínez *et al.*, p. 150, fig. 6C.
2016. *Calpionella elliptica* Cadisch; Maalaoui and Zargouni, p. 58, fig. 4.4–4.6.
2016. *Calpionella elliptica* Cadisch; Michalík *et al.*, p. 328, fig. 9B, 9C.
2017. *Calpionella elliptica* Cadisch; Petrova *et al.*, p. 90, figs 6.6, 6.7, 8.17, 8.18.
2020b. *Calpionella elliptica* Cadisch; Wimbledon *et al.*, p. 131, fig. 11S.
2024. *Calpionella elliptica* Cadisch; Rožič and Reháková, p. 15, fig. 5I.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KN41 (1 specimen incorporated into the annelid tube in the matrix of poorly-washed rudstone pebble from debris).

DESCRIPTION: The hyaline lorica is large and ellipsoidal. The identified specimen measures 77.5 µm in length and 43 µm in width; the ellipticity of the lorica is 1.39. The collar is short, straight and cylindrical-shaped. The aperture is narrow, and the aboral side is rounded.

OCCURRENCE: Lowermost Cretaceous; *Calpionella*–upper Berriasian *Calpionellopsis* zones, most common in the *Elliptica* Subzone in the Western Carpathians (Borza 1969, Borza and Michalík 1986; Olszewska 2005; Grabowski and Pszczółkowski 2006; Olszewska *et al.* 2008, 2011; Michalík *et al.* 2016; Kowal-Kasprzyk 2018; Svobodová *et al.* 2019), Southern Carpathians (Petrova *et al.* 2017), western Balkanides (Lakova *et al.* 1999; Lakova and Petrova 2013), Hungary (Nagy 1986), Southern Alps (Rožič and Reháková 2024), SE France (Wimbledon *et al.* 2020b; Lodowski *et al.* 2025), Maghrebides (Maalaoui and Zargouni 2016), and Mexico (Adatte 1994; López-Martínez *et al.* 2013a).

Genus *Remaniella* Catalano, 1965

TYPE SPECIES: *Tintinnopsella cadischiana* Colom, 1948.

Remaniella catalanoi Pop, 1996
(Text-fig. 11AD)

1996. *Remaniella catalanoi* n. sp.; Pop, p. 320, figs 10–15.
1997. *Remaniella catalanoi* Pop; Grün and Blau, pl. 1, figs 13, 14.
1998. *Remaniella catalanoi* Pop; Reháková, p. 446, pl. 1, figs 3–5.
2007. *Remaniella catalanoi* Pop; Andreini *et al.*, p. 191, pl. 1, figs 32a, b; pl. 2, figs 4a, b.
2009. *Remaniella catalanoi* Pop; Reháková *et al.*, p. 353, pl. 2, fig. 8.

2013. *Remaniella catalanoi* Pop; Lakova and Petrova, p. 221, pl. 6, fig. 55.
2016. *Remaniella catalanoi* Pop; Maalaoui and Zargouni, p. 58, fig. 4.16.
2017. *Remaniella catalanoi* Pop; Petrova *et al.*, p. 90, fig. 6.26.
2020b. *Remaniella catalanoi* Pop; Wimbledon *et al.*, p. 131, fig. 11N.
2022. *Remaniella catalanoi* Pop; Ölveczká and Reháková, p. 56, fig. 10.15.
2024. *Remaniella catalanoi* Pop; Rožič and Reháková, p. 15, fig. 5M.
2025. *Remaniella catalanoi* Pop; Lodowski *et al.*, pl. 2, fig. 12.

MATERIAL AND SAMPLES: Wapielnica Hill – sample KN4 (1 specimen in intraclast in poorly-washed rudstone pebble from debris)

DESCRIPTION: The hyaline lorica is bell-shaped to slightly ovoidal with a conical aboral pole ended by a short caudal appendage. The identified specimen measures 70 µm in length and 45 µm in width. It is bell-shaped to slightly ovoidal with a conical aboral pole ended by a short caudal appendage. The collar consists of two unequal circumoral rings.

OCCURRENCE: Lowermost Cretaceous; *Calpionella*–upper Valanginian *Tintinopsella* Zone, most common in the *Elliptica* Subzone in the Western Balkanides (Lakova and Petrova 2013), Western Carpathians (Reháková 1998; Ölveczká and Reháková 2022), Southern Carpathians (Pop 1996; Petrova *et al.* 2017), Southern Alps (Rožič and Reháková 2024), Northern Alps (Reháková *et al.* 2009), Maghrebides (Maalaoui and Zargouni 2016), and *Calpionella* Zone in Italy (Andreini *et al.* 2007) and SE France (Wimbledon *et al.* 2020b). There is also evidence that the species occurs in the upper part of the uppermost Jurassic *Crassicollaria* Zone of the Southern Alps in Italy (Grün and Blau 1997).

CALPIONELLID BIOSTRATIGRAPHY

The biostratigraphic analysis confirms the presence of three calpionellid zones (*Chitinoidella*, *Crassicollaria* and *Calpionella*), and six subzones (*Dobeni*, *Boneti*, *Remanei*, *Massutiniana*, *Alpina*, and *Elliptica*) spanning the Jurassic/Cretaceous boundary, based on material from 15 representative samples (Text-fig. 12). Besides, 2 samples were assigned to the *Boneti* Subzone based on the occurrence of *Chitinoidella* sp., whereas 12 samples contained taxa characteristic of the *Crassicollaria* Zone (*Crassicollaria intermedia*, *Cr. brevis*, *Cr. colomi*, and *Calpionella grandalpina*). A total of 8 samples, containing *C. alpina*, *Crassicollaria parvula* and *Tintinnopsella carpathica,* were dated to the uppermost Tithonian–Berriasian, but their precise age could not be determined. Calpionellids found in the remaining 13 samples were strongly recrystallised, hindering their precise taxonomy. The lack of the rare genus representing the narrow *Praetintinnopsella* Zone is noted. There is no data to confirm the presence of the *Remaniella* Subzone; the *Alpina* Subzone was confirmed in only one sample. No deposits younger than the *Elliptica* Subzone were found.

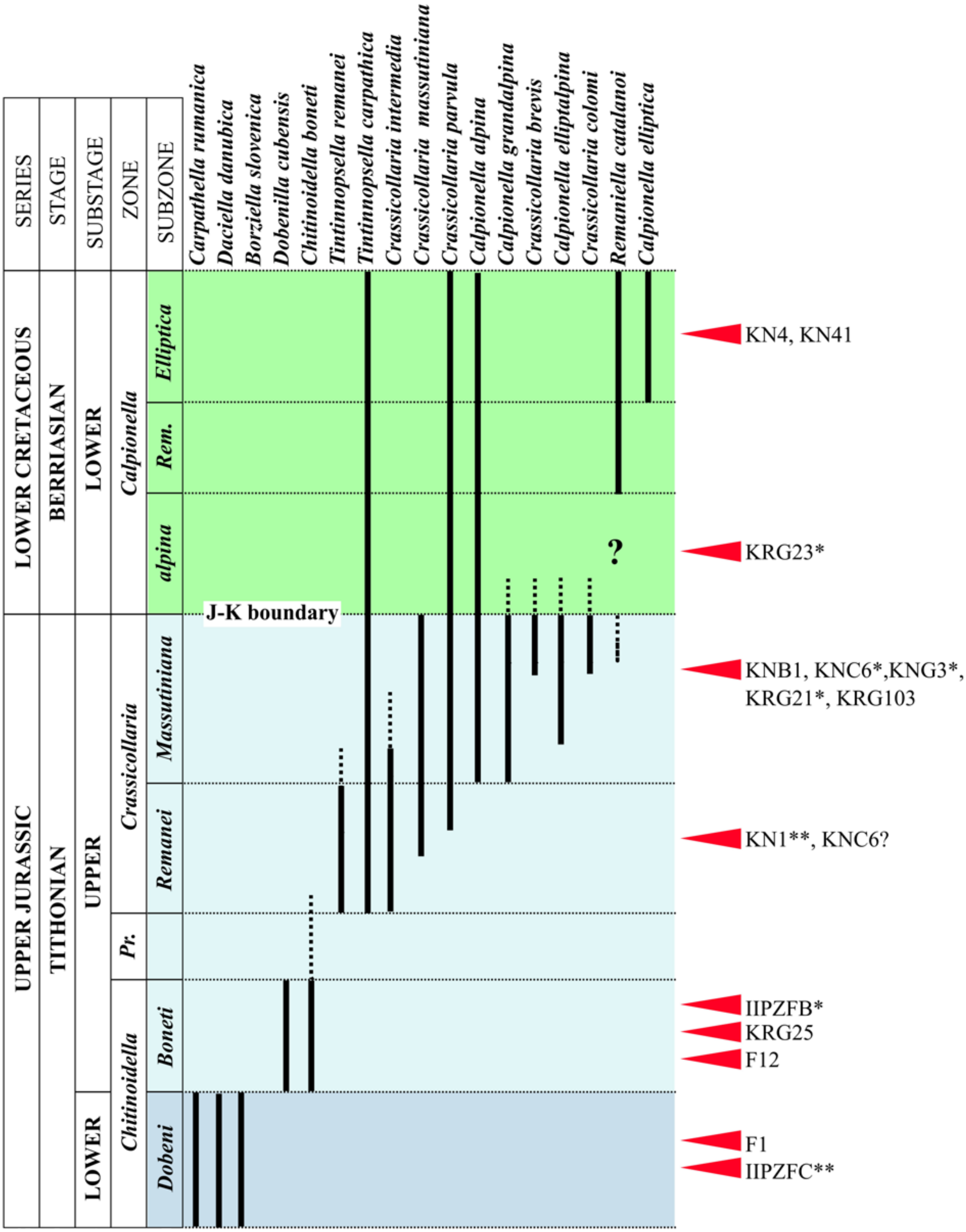
***Chitinoidella* Zone**

The *Chitinoidella* Zone was introduced by Enay and Geyssant (1975) and subsequently defined by Grandesso (1977). The base of this zone is marked by the first occurrence of specimens belonging to the Family Chitinoidellidae. The upper boundary was established based on the almost entire disappearance of chitinoidellids and the first specimens with partly hyaline lorica. The subdivision of the *Chitinoidella* Zone is based on the classic studies by Borza (1984), who distinguished two subzones based on the variability in chitinoidellid sizes. Recently, Benzaggagh (2021) subdivided the Chitinoidellidae into two subfamilies: the Dobeninae, which are typical of the *Dobeni* Subzone and the Bonetinae, which are typical of the *Boneti* Subzone.

Dobeni Subzone

The *Dobeni* Subzone was defined by Borza (1984) and named after *Chitinoidella dobeni* Borza, 1984, based on the assemblage of small chitinoidellids, including: *Chitinoidella colomi* Borza, 1984, *Ch. slovenica* Borza, 1984, and *Ch. tithonica* Borza, 1984, which had been recognised in the 'middle' Tithonian of the Western Carpathians. The base of this subzone coincides with the base of the *Chitinoidella* Zone, and it ends with the first occurrence of significantly larger specimens.

In the studied material, the *Dobeni* Subzone is confirmed by the assemblage composed of *Carpathella rumanica* and *Borziella slovenica* found in sample F1 collected from Iwanowa Góra, and by *Daciella danubica* identified in a clast of Rapacz Conglomerate collected in the Grochowski Stream exposure (sample IIPZFC).



Text-fig. 12. Ranges of chitinoidellids and calpionellids collected in the study area, stratigraphic positions of 15 representative samples are shown with red arrows on the right side of the scheme. Explanations: * – assemblage found in clasts of Štramberk-type rudstone; ** – assemblage identified in clasts of Upper Cretaceous Rapacz Conglomerate; dashed lines – occasional occurrence. Abbreviations: *Pr.* – *Praetinntinopsella*; *Rem.* – *Remaniella*.

Boneti **Subzone**

The *Boneti* Subzone was originally defined by Borza (1984) as an interval dominated by larger chitinoidellids, represented by: *Chitinoidella boneti*, *Ch. bermudezi*, and *Dobeniella cubensis*. In the recently proposed systematics of the chitinoidellids, the first occurrence of *Bonetilla praeboneti* (Benzaggagh, 2021) marks the base of the *Boneti* Subzone (Benzaggagh 2021). Its top corresponds to the first occurrence of *Praetintinnopsella andrusovi* Borza, 1969, characterised by a mixed organic-hyaline lorica (Ölveczká *et al.* 2024).

This subzone is documented in the studied material by the following taxa: *D. cubensis* found in fenestral bindstones from Kruhel Wielki Quarry (sample KRG25), *Ch. boneti* occurring in clasts of the Štramberk-type limestone in Rapacz Conglomerate collected in the Grochowce Stream II exposure (sample IIPZFB), and in coated grainstones from Iwanowa Góra (sample F12). One exotic rudstone sample (KRG106) from Kruhel Wielki Quarry was assigned to this subzone based on the occurrence of *Chitinoidella* sp.

Crassicollaria **Zone**

The *Crassicollaria* Zone was defined by Allemann *et al.* (1971) as an interval characterised by the predominance of *Crassicollaria* spp. It corresponds strictly to Zone 'A' distinguished by Remane (1971). According to Allemann *et al.* (1971), the base of the *Crassicollaria* Zone is marked by the appearance of calpionellids with fully hyaline loricae (first occurrence of a small variety of *Tintinnopsella carpathica*), and ends with the increase in the abundance of *Calpionella alpina* specimens. In the zonation by Lakova and Petrova (2013), the *Crassicollaria* Zone is subdivided into two subzones: *Remanei* and *Massutiniana*.

Remanei **Subzone**

The *Remanei* Subzone was introduced by Remane *et al.* (1986) as an equivalent of Subzone 'A1' of Remane (1971). Its name derives from the species *Tintinnopsella remanei*, the most characteristic taxon of this interval. The base of the subzone corresponds to the base of the *Crassicollaria* Zone, and the top of this zone is marked by the appearance of a large form of *Calpionella*. In the zonation of Lakova and Petrova (2013), the subzone begins with simultaneous first occurrences of *T. remanei* and a small variety of *T. carpathica*. The first occurrence of *Calpionella grandalpina* marks the top of the *Remanei* Subzone (Lakova and Petrova 2013).

In the studied material, the *Remanei* Subzone was confirmed in two samples collected in Kruhel Wielki Quarry based on the occurrence of an assemblage containing small, poorly preserved calpionellids with fully-hyaline loricae, which co-occurs with *Chitinoidella* spp. (KN1), and presumably in a redeposited clast in sample KNC6 based on the presence of *T. remanei*.

Massutiniana **Subzone**

The *Massutiniana* Subzone was proposed by Lakova (1993) and corresponds to subzones 'A2' and 'A3' of Remane (1971), as well as the *Intermedia* Subzone of Remane *et al.* (1986), and the *Intermedia* and *Colomi* subzones of Pop (1994, 1997) and Ölveczká and Reháková (2022). The lower boundary of the *Massutiniana* Subzone is defined by the first occurrence of *Calpionella grandalpina*, and the upper boundary – by the base of the lowermost Cretaceous *Calpionella* Zone. Lakova and Petrova (2013) noted that the last occurrence of *Calpionella elliptalpina* coincides with the end of this subzone. During the *Massutiniana* Subzone (Remane *et al.* 1986; Lakova 1993; Lakova and Petrova 2013), crassicollarians reached their maximum diversity and abundance; however, in its upper part, representatives of the genus *Calpionella* (*C. alpina*, *C. grandalpina* and *C. elliptalpina*) dominate over those of the genus *Crassicollaria*.

In the studied material, the *Massutiniana* Subzone is identified based on the rich assemblage of calpionellids represented by *C. alpina*, including its large forms (*C. grandalpina*, *C. elliptalpina*), as well as *Cr. brevis*, *Cr. parvula*, *Cr. massutiniana*, and *T. carpathica*. This subzone is undoubtedly confirmed in five samples (KNB1, KNC6, KNG3, KRG21, and KRG103) collected from Kruhel Wielki Quarry.

Calpionella **Zone**

The *Calpionella* Zone was defined by Allemann *et al.* (1971) based on the predominance of the genus *Calpionella*, which was successively replaced by *T. carpathica* in the upper part of the zone. In general, it is equivalent to zones 'B' and 'C' proposed by Remane (1971). The base of the zone is established based on the 'explosion' of small morphotypes of *C. alpina*. The upper boundary of this zone is defined by the first occurrence of *Calpionellopsis simplex* Colom, 1939.

Alpina Subzone

The *Alpina* Subzone was introduced by Pop (1974) and corresponds to the lower part of Zone 'B' as defined by Remane (1971). The base of this subzone is marked by the acme of small forms of *C. alpina* and ends with the first occurrence of representatives of the genus *Remaniella*. This subzone is characterised by a significant predominance of *C. alpina* and the acme of *Cr. parvula*.

In the studied samples, the presence of the *Alpina* Subzone is confirmed based on calpionellid assemblages comprising numerous small forms of *C. alpina*, as well as *T. carpathica*, and rare *Cr. colomi* found in Kruhel Wielki Quarry (sample KRG23).

Elliptica Subzone

The *Elliptica* Subzone was introduced by Catalano and Liguori (1971). According to Pop (1974), this zone begins with the first occurrence of *Calpionella elliptica* and ends with the appearance of *Calionellopsis simplex*.

In the present study, this subzone is identified based on an assemblage represented by: *C. elliptica*, a small variety of *Calpionella alpina*, and *Remaniella catalanoi* found in Kruhel Wielki Quarry (samples KN4 and KN41).

DISCUSSION

The collected material contains the most diverse calpionellid assemblage recorded in this region (Text-fig. 12). It comprises eighteen taxa, including eight (*Carpathella rumanica*, *Daciella danubica*, *Borziella slovenica*, *Dobeniella cubensis*, *Chitinoidella boneti*, *Tintinnopsella remanei*, *Calpionella grandalpina*, and *Remaniella catalanoi*) documented for the first time in this part of the Skole Nappe. The studied taxa were recognised across various facies types; the highest abundances, however, were observed in the slope (lithoclastic rudstone and floatstone) and shelf facies (calpionellid wackestone).

During the study of the exotic material from the Skole Nappe, some obstacles were encountered, including: a) relative scarcity of biota, b) lack of preserved stratigraphic successions, necessary to track changes in calpionellid assemblages, and c) absence of pelagic deposits, which are often rich in calpionellids. Consequently, the analysis of the entire succession is unachievable, and only a small portion of the ancient carbonate platform can be analysed.

A valid calpionellid zonation for the Western Carpathians deposits, including exotics from the Polish Outer Carpathians, was introduced by Reháková (1995) and modified by Reháková and Michalík (1997). However, due to difficulties in recognising the *Brevis* and *Colomi* subzones, the present study follows the standard zonation by Lakova and Petrova (2013), which introduces the *Massutiniana* Subzone within the upper part of the *Crassicollaria* Zone. Besides this modification, both zonations are based on the same bioevents and index fossils.

The late Tithonian–Berriasian age of the Štramberk-type limestone exotics from the vicinity of Kruhel Wielki has been established by numerous studies. The dating of selected uppermost Jurassic to lowermost Cretaceous exotics from the Gruszowa-Prałkowce Thrust Sheet was based on both microfaunal (Morycowa 1968; Ciborowski and Kołodziej 2001) and macrofaunal taxa (Wójcik 1914). Morycowa (1964), and Geroch and Morycowa (1966) conducted the first stratigraphic investigation based on calpionellids. They determined five species from the detrital limestone in Kruhel Wielki: *Crassicolaria parvula*, *Cr. intermedia*, *Calpionella alpina*, *C. elliptica*, and *Tintinnopsella carpathica*. The preliminary conclusions were presented in a conference fieldtrip guide (Morycowa 1988), where unpublished results were discussed. The additional inventory of calpionellids comprises the following taxa: *Crassicolaria massutiniana*, *Remaniella cadischiana*, and *Calpionellites darderi*. Some uncertain chitinoidellids were also found (Morycowa 1988); their poor preservation, however, prevented the documentation of the *Chitinoidella* Zone in the study area. It is also important to note that a few poorly preserved Valanginian specimens of *C. darderi* were identified in the exotic grey marls occurring in clasts of Rapacz Conglomerate (Morycowa 1988). Based on studies of exotics from Kruhel Wielki Quarry (Wapielnica Hill), Morycowa recognised calpionellid zones A–D *sensu* Remane (1971). Ciborowski and Kołodziej (2001), based on the occurrence of *Crassicollaria intermedia* and an unknown calpionellid assemblage with fully hyaline lorica in the coral-bearing limestone from Wapielnica Hill site, interpreted these deposits as representing the *Remanei* Subzone (upper Tithonian). Nevertheless, this specimen has also been documented from the *Massutiniana* Subzone (e.g., Lakova and Petrova 2013) and therefore, a younger age of this facies cannot be excluded. Additionally, Olszewska *et al.* (2011) documented representatives of *Calpionella alpina*, *Crassicollaria brevis*, *Cr. intermedia*, *Cr. colomi*, *Tintinnopsella carpathica*, *T. longa* Colom, 1939, and *T. subacuta* Colom, 1948 from exotics collected in the vicinity of Przemyśl (Kruhel Zone *sensu* Olszewska *et al.* 2011).

The oldest specimens found in this study are chitinoidellids represented by *Carpathella rumanica* and *Daciella danubica*. Specimens of both taxa were identified in peloidal-bioclastic grainstone (samples F1 and IIPZFC) representing inner platform facies zones. In general, specimens attributable to the *Dobeni* Subzone are rare and poorly preserved in the study material, as noted by Kowal-Kasprzyk (2018) for the Silesian and Sub-Silesian Nappes. Specimens representing the *Boneti* Subzone were identified in grainstones and various lithoclasts in detrital limestones (lithoclast rudstone/floatstone) typical of the slope and platform deposits (samples F12, PZKA and IIPZFB). In one sample of Rapacz Conglomerate collected in Kruhel Wielki Quarry (sample KN1), chitinoidellids co-occurred with poorly preserved specimens bearing hyaline lorica, indicating the lowermost part of the *Remanei* Subzone. Single *Tintinnopsella remanei* in some clasts of Štramberk-type limestone rudstones and floatstones, as well as Rapacz Conglomerate, is consistent with assignment to this interval.

The best-preserved and most abundant inventory of calpionellids was found in samples collected from detrital (sample KNC6) and pelitic limestone (sample KNB1) within blocks and, occasionally, from exotic pebbles in Kruhel Wielki Quarry (samples KNG3, KRG21 and KRG103). The assemblage indicating the *Massutiniana* Subzone was identified in this material, and it represents the most complete microfossil record found in the study area. Calpionellids were identified both in lithoclasts and in the matrix of the detrital limestones. Predominance of well-preserved specimens was observed in wackestones, which additionally contained bioclasts represented by sponge spicules, rare ostracods and radiolarians (lower part of the KNB olistolith, Text-fig. 5).

The identification of the *Alpina* Subzone is hindered by the lack of continuous sections and the limited number of specimens in the assemblage (compared to pelagic sediments); nevertheless, the *Alpina* Subzone was confirmed in a few calpionellid wackestone lithoclasts in rudstones (KRG23), based on the predominance of small specimens of *Calpionella alpina* that co-occur with *Crassicollaria parvula* and rarely with *Cr. colomi*. The youngest sediments are represented by grey lithoclast-sponge rudstones, in which a calpionellid assemblage indicating the *Elliptica* Subzone was found. It is represented by an assemblage composed of *Calpionella elliptica*, *Tintinnopsella carpathica* and *Remaniella catalanoi*. This subzone was confirmed in only two samples – KN4 and KN41 (grey exotic pebble; Wapielnica Hill). This interval is rare among exotics from the Polish Outer Carpathians, as reported by Kowal-Kasprzyk (2018).

The absence of younger deposits might be due to a decline in sedimentation on the Štramberk-type platform, which was flooded in the Valanginian (Hoffmann and Kołodziej 2008; Hoffmann *et al.* 2021). Rare calpionellids indicating the Lower Cretaceous *Calpionellopsis* and *Calpionellites* zones, documented by Morycowa (1988), were found in pelagic deposits, which may reflect a further stage in the evolution of the Carpathian Basins after the disappearance of Štramberk-type platforms.

Based on the documentation discussed herein, the uppermost 'middle' Tithonian–early Berriasian age of the Jurassic to lowest Cretaceous exotics from the Gruszowa-Prałkowce Thrust Sheet can be confirmed. These results are consistent with the studies conducted in the western sector of the Polish Outer Carpathians (Kowal-Kasprzyk 2018; Hoffmann *et al.* 2021). Based solely on the studied material, it can be inferred that the Štramberk-type platform developed at least from the late 'middle' Tithonian to the end of the early Berriasian. Moreover, the gradual disintegration of the platform that occurred during this time is inferred from the coeval calpionellids found in both lithoclasts and matrix. The presence of calpionellids in the shallow-water facies of the carbonate platform may indicate the absence of a true barrier and a connection with open marine waters.

CONCLUSIONS

- A relatively rich inventory of calpionellids was found in exotic rocks previously dated at least to the late Tithonian. Eighteen taxa were recognised, of which eight were documented for the first time in the area: *Carpathella rumanica*, *Daciella danubica*, *Borziella slovenica*, *Dobeniella cubensis*, *Chitinoidella boneti*, *Tintinnopsella remanei*, *Calpionella grandalpina*, and *Remaniella catalanoi*.
- The biostratigraphic analysis confirmed the presence of three calpionellid zones (*Chitinoidella*, *Crassicollaria*, and *Calpionella*) and six subzones (sensu Lakova and Petrova 2013): *Dobeni*, *Boneti*, *Remanei*, *Massutiniana*, *Alpina*, and *Elliptica*, spanning the uppermost Jurassic to lowermost Cretaceous.
- The *Remanei* Subzone of the *Crassicollaria* Zone and the *Calpionella* Zone were identified based on the analysis of clasts found in detrital limestones. The largest exotic blocks, referred to in the litera-

ture as the Kruhel Wielki Klippe, have been dated to the *Massutiniana* Subzone of the *Crassicollaria* Zone.

- The oldest specimens representing the *Dobeni* and *Boneti* subzones were recorded sporadically in the oolite shoals and intraplatform facies. The most abundant assemblage of the uppermost Tithonian (*Massutiniana* Subzone) and lowermost Berriasian specimens (*Alpina* Subzone) was observed in calpionellid wackestones representing slope and open shelf facies zones. The *Elliptica* Subzone is noted in the matrix and intraclasts of poorly-washed rudstone. All samples with calpionellids contained bioclasts and microfacies features characteristic of the Štramberk-type limestone.

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APPENDIX 1

List of samples collected during this study with localities and type of exotic limestone.

Sample	Outcrop	Type of exotic limestones
KNA01	Kruhel Wielki Quarry	Klippe
KNA02	Kruhel Wielki Quarry	Klippe
KNA1	Kruhel Wielki Quarry	Klippe
KNA2	Kruhel Wielki Quarry	Klippe
KNA3	Kruhel Wielki Quarry	Klippe
KNA4	Kruhel Wielki Quarry	Klippe
KNB01	Kruhel Wielki Quarry	Klippe
KNB02	Kruhel Wielki Quarry	Klippe
KNB1	Kruhel Wielki Quarry	Klippe
KNB2	Kruhel Wielki Quarry	Klippe
KNC0	Kruhel Wielki Quarry	Klippe
KNC1	Kruhel Wielki Quarry	Klippe
KNC2	Kruhel Wielki Quarry	Klippe
KNC3	Kruhel Wielki Quarry	Klippe
KNC4	Kruhel Wielki Quarry	Klippe
KNC5	Kruhel Wielki Quarry	Klippe
KNC6	Kruhel Wielki Quarry	Klippe
KNE1	Kruhel Wielki Quarry	Klippe
KNE2	Kruhel Wielki Quarry	Klippe
KNH1	Kruhel Wielki Quarry	Klippe
KNH2	Kruhel Wielki Quarry	Klippe
KNH3	Kruhel Wielki Quarry	Klippe
KRG20	Kruhel Wielki Quarry	Pebble from debris
KRG21	Kruhel Wielki Quarry	Pebble from debris
KRG22	Kruhel Wielki Quarry	Pebble from debris
KRG23	Kruhel Wielki Quarry	Pebble from debris
KRG24	Kruhel Wielki Quarry	Pebble from debris
KRG25	Kruhel Wielki Quarry	Pebble from debris
KRG26	Kruhel Wielki Quarry	Pebble from debris
KRG27	Kruhel Wielki Quarry	Pebble from debris
KRG28	Kruhel Wielki Quarry	Pebble from debris
KRG29	Kruhel Wielki Quarry	Pebble from debris
KRG30	Kruhel Wielki Quarry	Pebble from debris
KRG31	Kruhel Wielki Quarry	Pebble from debris
KRG32	Kruhel Wielki Quarry	Pebble from debris
KRG33	Kruhel Wielki Quarry	Pebble from debris
KRG34	Kruhel Wielki Quarry	Pebble from debris
KRG35	Kruhel Wielki Quarry	Pebble from debris
KRG36	Kruhel Wielki Quarry	Pebble from debris
KRG37	Kruhel Wielki Quarry	Pebble from debris
KRG102	Kruhel Wielki Quarry	Pebble from debris
KRG103	Kruhel Wielki Quarry	Pebble from debris
KRG104	Kruhel Wielki Quarry	Pebble from debris
KRG105	Kruhel Wielki Quarry	Pebble from debris
KRG106	Kruhel Wielki Quarry	Pebble from debris
KRG300	Kruhel Wielki Quarry	Pebble from debris
KRG301	Kruhel Wielki Quarry	Pebble from debris
KRG302	Kruhel Wielki Quarry	Pebble from debris
KRG303	Kruhel Wielki Quarry	Pebble from debris
KRG304	Kruhel Wielki Quarry	Pebble from debris
KRG305	Kruhel Wielki Quarry	Pebble from debris
KRG306	Kruhel Wielki Quarry	Pebble from debris
KRG307	Kruhel Wielki Quarry	Pebble from debris
KRG308	Kruhel Wielki Quarry	Pebble from debris
KRG309	Kruhel Wielki Quarry	Pebble from debris
KRG310	Kruhel Wielki Quarry	Pebble from debris
KRE	Kruhel Wielki Quarry	Pebble from debris
KS1	Kruhel Wielki Quarry	Pebble from debris
KN1	Kruhel Wielki Quarry	Rapacz Conglomerate (block from debris)
KN2	Kruhel Wielki Quarry	Pebble from debris
KN3	Kruhel Wielki Quarry	Pebble from debris
KN4	Kruhel Wielki Quarry	Pebble from debris
KN41	Kruhel Wielki Quarry	Pebble from debris
KN42	Kruhel Wielki Quarry	Pebble from debris
KRS20	Kruhel Wielki Quarry	Pebble from debris
KSA1	Kruhel Wielki Quarry	Rapacz Conglomerate
KSA2	Kruhel Wielki Quarry	Rapacz Conglomerate
KSA3	Kruhel Wielki Quarry	Rapacz Conglomerate
KND1	Kruhel Wielki Quarry	Rapacz Conglomerate
KND2	Kruhel Wielki Quarry	Rapacz Conglomerate
KNG1	Kruhel Wielki Quarry	Rapacz Conglomerate
KNG2	Kruhel Wielki Quarry	Rapacz Conglomerate
KNG3	Kruhel Wielki Quarry	Rapacz Conglomerate
KNG4	Kruhel Wielki Quarry	Rapacz Conglomerate
F1	Iwanowa Góra	Pebble from olistostrome
F12	Iwanowa Góra	Pebble from olistostrome
F2	Iwanowa Góra	Pebble from olistostrome
PZFA	Grochowski Stream I	Rapacz Conglomerate
PZFB	Grochowski Stream I	Rapacz Conglomerate
PZFC	Grochowski Stream I	Pebble from debris
IIPZFA	Grochowski Stream II	Pebble from debris
IIPZFB	Grochowski Stream II	Rapacz Conglomerate
IIPZFC	Grochowski Stream II	Rapacz Conglomerate
IIPZFD	Grochowski Stream II	Rapacz Conglomerate
IIPZFE	Grochowski Stream II	Rapacz Conglomerate
PFZ1A	Leśny Stream	Klippe
PFZ1B	Leśny Stream	Rapacz Conglomerate
PFZ1C	Leśny Stream	Rapacz Conglomerate
PFZ1D	Leśny Stream	Rapacz Conglomerate
PR	Prałkowce I	Rapacz Conglomerate
PR6A	Prałkowce I	Rapacz Conglomerate
PR6B	Prałkowce II	Rapacz Conglomerate
PZKA	Błońce Stream	Rapacz Conglomerate
PZKB	Błońce Stream	Pebble from debris
PZKC	Błońce Stream	Pebble from debris
PZKD	Błońce Stream	Pebble from olistostrome
W1	Błonie Stream	Conglomerate
W15A	Błonie Stream	Pebble from olistostrome
W15B	Błonie Stream	Pebble from olistostrome
HEW1	Huszczyn Stream	Rapacz Conglomerate
HE9	Huszczyn Stream	Pebble from debris
H10	Huszczyn Stream	Pebble from debris
MK2	Gruszowski Stream	Pebble from debris
MK3	Gruszowski Stream	Pebble from debris
MK4	Gruszowski Stream	Pebble from debris
MK9	Gruszowski Stream	Pebble from debris
H22	Huwniki	Pebble from olistostrome

APPENDIX 2

List of chitinoidellid and calpionellid taxa mentioned in this paper.

Borziella slovenica (Borza, 1969)
Carpathella rumanica Pop, 1998
Chitinoidella boneti Doben, 1963
Chitinoidella sp.
Daciella danubica Pop, 1998
Dobeniella cubensis (Furazola-Bermúdez, 1965)
Calpionella alpina Lorenz, 1902
Calpionella elliptalpina Nagy, 1986
Calpionella elliptica Cadisch, 1932
Calpionella grandalpina Nagy, 1986
Crassicollaria brevis Remane, 1962
Crassicollaria colomi Doben, 1963
Crassicollaria intermedia (Durand-Delga, 1957)
Crassicollaria massutiniana (Colom, 1948)
Crassicollaria parvula Remane, 1962
Remaniella catalanoi Pop, 1996
Tintinnopsella carpathica (Murgeanu and Filipescu, 1933)
Tintinnopsella remanei Borza, 1969