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Ordovician trilobite-bearing erratic boulders from northern Poland: lithology, assemblages and stratigraphic assignment

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This study provides the first regionally consistent dataset on the lithology, trilobite assemblages and stratigraphic assignment of Ordovician erratic boulders from northern Poland, based on systematically documented field observations. In contrast to previous locality-based studies, it integrates lithological, taxonomic and stratigraphic data to assess the regional variability of erratic assemblages across an east-west transect. A total of 56 erratic boulders containing 27 identified trilobite species-level taxa were collected from exposures located in northern Poland within the maximum extent of the Pomeranian Phase of the Weichselian Glaciation. The assemblages are dominated by Middle and Upper Ordovician taxa, particularly Sandbian forms. Lithologically, the erratics consist mainly of pelitic (micritic) and bioclastic limestones corresponding to open-shelf carbonate facies known from Baltoscandia. Distinct regional variation is observed across northern Poland. Upper Ordovician erratics dominate in the eastern sector, whereas the western part of the study area shows a more equivalent proportion of Middle and Upper Ordovician material. This pattern broadly corresponds to regional trends observed elsewhere in the southern Baltic region. This study fills a regional gap by integrating lithological, taxonomic and stratigraphic data for Ordovician trilobite-bearing erratics from northern Poland, providing a basis for comparison with Baltoscandian source successions and other erratic assemblages in the southern Baltic region.

Key words: Ordovician, trilobite, glacial erratics, Baltoscandia, biostratigraphy, northern Poland.

INTRODUCTION

In northern Poland, sedimentary erratic boulders containing Paleozoic fossils are common components of Pleistocene glacial and fluvioglacial deposits. Such erratics have long been recognized as an important archive for reconstructing the provenance of glacial material and the geological structure of source areas within Baltoscandia (e.g., Woźniak et al., 2009; Hall and Boeckel, 2020; Górska-Zabielska et al., 2021). They include a wide range of carbonate rocks bearing fossil assemblages of various stratigraphic ages and facies, among which trilobites, although not abundant, are of particular stratigraphic value when well-preserved.

The first reports of fossil-bearing erratics from northern Poland date back to the nineteenth century (Roemer, 1858; Jentzsch, 1880; Kiesow, 1884). Early studies focused primarily on the identification of fossil taxa and the lithological classification of erratics, enabling broad interpretations of their Scandinavian source regions (Noetling, 1883; Pompeckj, 1890). These studies provided an important foundation for both academic research and fossil collecting. Despite this long tradition, systematic studies of Paleozoic fossil-bearing erratics in Poland remain limited. More recent investigations have generally concentrated on individual localities or selected fossil groups (e.g., Mierzejewski, 1978; Chrząstek and Pluta, 2017; Borowski, 2021; Kowalewska, 2023), leaving broader regional patterns insufficiently documented.

Ordovician carbonate erratics are of particular interest because their fossil content, especially trilobites, allows a rela-

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tively precise biostratigraphic assignment and correlation with well-established Ordovician successions in Baltoscandia. Although Ordovician trilobites are extensively documented from *in situ* exposures in Scandinavia, their occurrence in glacial erratics provides complementary information on the distribution of eroded source rocks and the lithological diversity of Ordovician successions represented within the glacial deposits of Central Europe.

This study:

- identifies trilobite taxa,
- characterizes the lithology of trilobite-bearing erratic boulders,
- assesses their spatial distribution within glacial depositional settings of northern Poland.

It provides a regionally coherent dataset based on systematically documented trilobite-bearing erratics. Although the material does not allow for fully quantitative analyses, it illustrates the potential of such erratics for future, more comprehensive studies of Paleozoic erratic distribution, provenance patterns, and glacial transport processes in northern Europe.

GEOLOGICAL SETTING

Ordovician rocks are widely distributed across Baltoscandia and the East Baltic region, forming one of the most extensive Lower Paleozoic carbonate successions in northern Europe. They are exposed along the Baltic Klint, particularly within its North Estonian segment, extend offshore beneath the Baltic Sea, and reappear on the island of Öland (Fig. 1). Additional Ordovician successions crop out in central and southern Sweden (e.g., Dalarna, Uppland), in parts of Norway (Oslo Region), and locally on Bornholm Island. Southwards, the Ordovician strata dip beneath the younger sedimentary cover and reach depths of several hundred metres in northern Poland, increasing to several kilometres in the vicinity of the Teisseyre-Tornquist Zone (Paškevičius, 1997; Modliński and Podhalańska, 2010).

Based on sedimentological and palaeontological criteria, five major confacies belts can be distinguished: the Oslo, Scanian, central Baltoscandian, central Lithuanian, and north Estonian belts (Jaanusson, 1995). These belts formed a broad west-east gradient, ranging from deeper-water graptolitic shales in the Scanian confacies, through lithologically diverse limestones and marls of the central Baltoscandian confacies, to shallow-water carbonate and mixed carbonate-siliciclastic deposits of the north Estonian confacies. Despite local environmental fluctuations, the overall spatial configuration of these confacies remained relatively stable throughout much of the Ordovician.

Early Ordovician sedimentation (Tremadocian–Floian) was marked by strong facies contrasts across the basin. Shallow-water terrigenous and mixed sediments prevailed in the

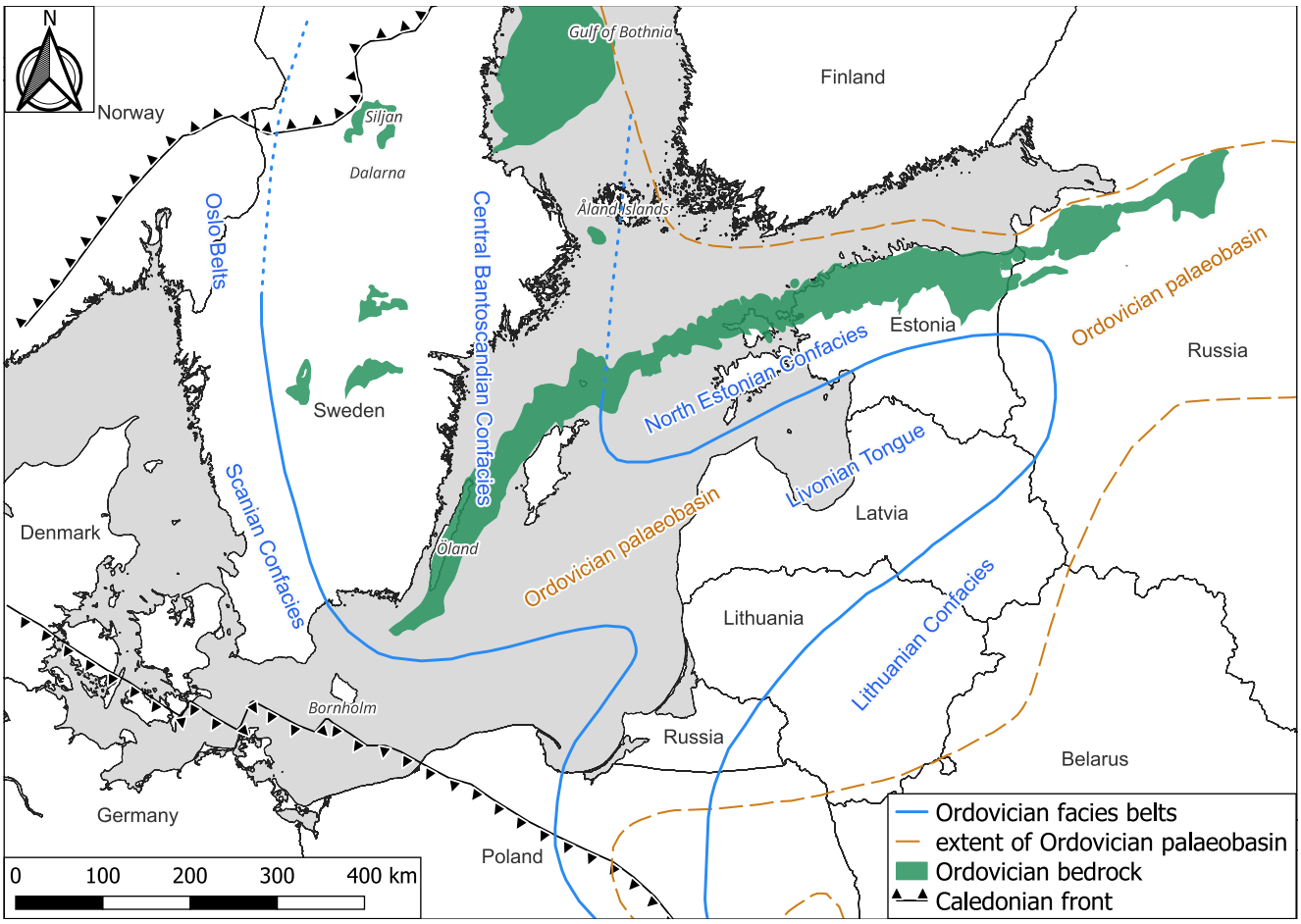

Fig. 1. Map of the Ordovician confacies of Baltoscandia in relation to the Ordovician bedrock (after Jaanusson, 1995, modified)

eastern part of Baltoscandia, whereas limestones, marls and deeper-water shales accumulated in the central and western areas, including present-day Sweden and the Oslo region (Pärnaste, 2006).

In the Middle Ordovician, a major marine transgression resulted in the widespread development of carbonate sedimentation across the broad, low-relief epicontinental shelf. Limestones of this interval are typically characterized by a microcrystalline matrix with abundant skeletal debris, including trilobites, echinoderms, brachiopods and bryozoans, reflecting well-oxygenated shelf environments under temperate climatic conditions (Hints et al., 1989; Nestor et al., 2007).

Late Ordovician sedimentation was associated with increased carbonate production and higher sedimentation rates, leading to a total thickness that commonly exceeds that of the combined Lower and Middle Ordovician succession. During this interval, shallow-water carbonate platforms developed widely and locally hosted biohermal buildups with corals and stromatoporoids, particularly during the Sandbian and Katian (Jaanusson, 1972; Meidla, 2014; Nielsen et al., 2023).

Ordovician carbonate rocks from these Baltoscandian successions occur widely as sedimentary erratic boulders within the Quaternary glacial and fluvioglacial deposits of northern Poland. Transported southwards by the Scandinavian ice sheets during successive Pleistocene glaciations, these erratics provide an indirect record of Ordovician lithologies and fossil assemblages derived mainly from the well-established outcrops in Baltoscandia, including Estonia, Sweden and the Baltic Sea region.

MATERIAL AND METHODS

Field investigations were conducted in northern Poland within areas affected by the Weichselian Glaciation, with particular focus on the maximum extent of the Pomeranian Phase. The study targeted glacial and glaciofluvial deposits, including end moraines, push moraines, dead-ice moraines and ice-contact deposits. Sampling sites were selected based on the presence of accessible natural or artificial exposures, such as gravel pits, sand pits, construction excavations, and coastal outcrops. Potential localities were initially identified using satellite imagery and geological maps and were subsequently verified during field visits. In total, 115 sites distributed across five study areas were examined (Fig. 2). These areas represent various parts of northern Poland along a west-east transect and encompass a variety of geomorphological settings related to the Pomeranian Phase ice-sheet margin.

Fieldwork was conducted mainly between September and October 2023. At each site, exposed erratic boulders were inspected, with particular attention to carbonate boulders, which are less common than crystalline erratics in these deposits. Only boulders containing visible fossil remains, especially trilobites, were collected, whereas fossil-free carbonate erratics were not sampled systematically.

Ordovician trilobite-bearing erratics described in this study were collected from 31 localities. In the remaining sites investigated (84 localities), no Ordovician trilobites were found (Fig. 2). In addition, 14 specimens originating from a large

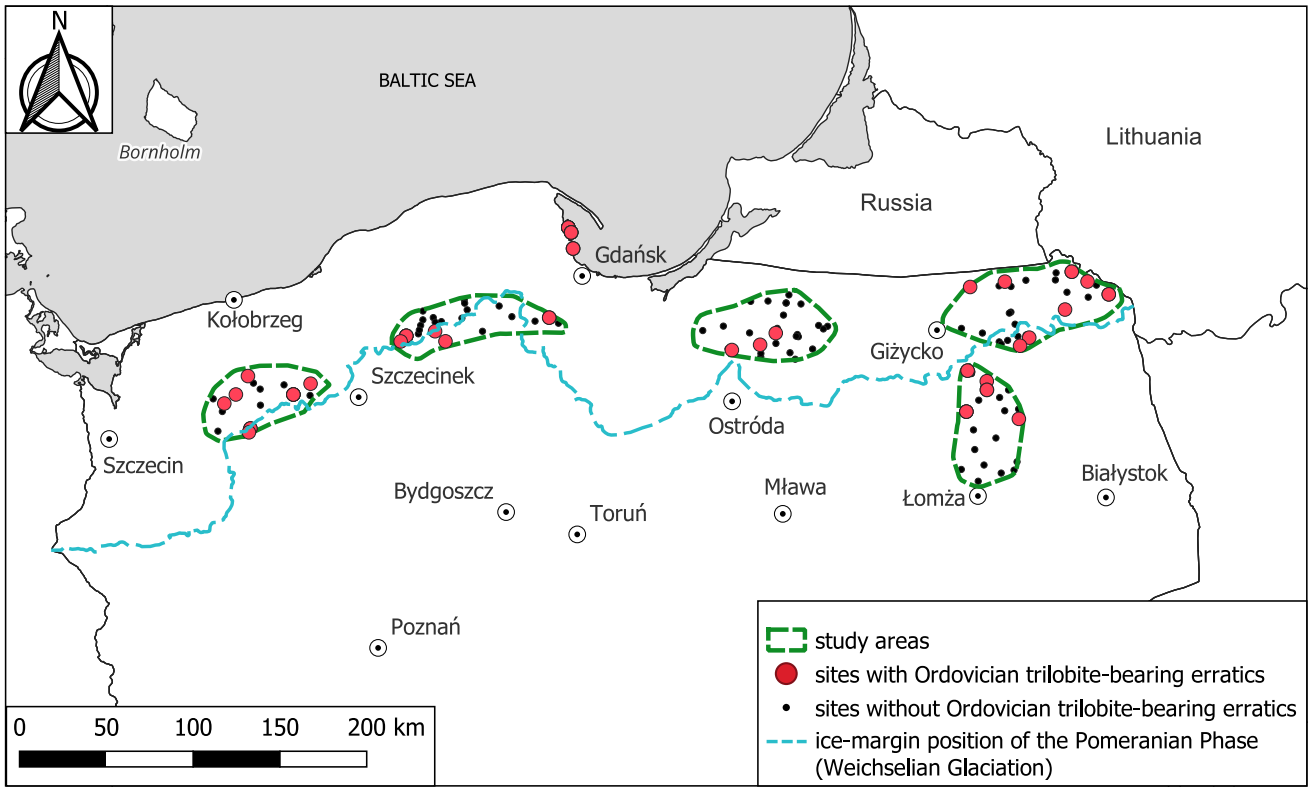

Fig. 2. Location of trilobite-bearing erratics in northern Poland in relation to the ice sheet margin position of the Pomeranian Phase of the Weichselian Glaciation (after Marks, 2012, modified)

private collection of one of the authors (Bartosz Glinka), collected mainly from the Baltic Sea coast near Gdynia, were included in the study. These specimens represent selected examples from a much larger collection and were not used for quantitative spatial analyses.

In total, 56 Ordovician erratic boulders containing identifiable trilobite faunas were examined. A detailed inventory of all Ordovician trilobite-bearing erratic boulders analysed, including repository numbers, locality data, lithological characteristics, depositional settings, and stratigraphic assignments, is provided in Appendix 1.

Most trilobite specimens required mechanical preparation to enable reliable taxonomic identification. Fossil preparation was carried out using a pneumatic air scribe (modified Chicago CP9361) and manual preparation tools. All specimens were photographed after coating with ammonium chloride sublimate, a standard technique used to enhance surface contrast and reveal fine morphological details. Photographs were taken using a Pixel smartphone camera in macro mode. Minor adjustments to brightness and contrast were applied to ensure visual consistency.

Taxonomic identification and stratigraphic interpretation were based on published literature and comparisons with material from *in situ* Ordovician sections in Baltoscandia. Information on stratigraphic ranges and geographic distribution of taxa was supplemented using the Global Biodiversity Information Facility (GBIF) database and relevant palaeontological studies.

Most illustrated specimens have been deposited in the Geological Museum of the Polish Geological Institute – National Research Institute (collection MUZ.PIG.1846.II.1–26). One specimen remains housed in the private collection of one of the authors (Bartosz Glinka).

RESULTS

LITHOLOGY AND PRESERVATION OF ORDOVICIAN ERRATIC BOULDERS

The Ordovician trilobite-bearing erratic boulders collected in northern Poland are composed predominantly of carbonate rocks representing a range of micritic/pelitic and bioclastic limestones. The lithological terms used here are based mainly on macroscopic observations and refer to facies varieties known from Baltoscandian Ordovician erratics rather than to a formal microfacies classification. Most boulders are grey to dark grey in colour, although light grey, grey-brown, red and locally red-green varieties also occur. This lithological variability reflects the diversity of Ordovician carbonate facies known from Baltoscandia.

Middle Ordovician erratics are typically represented by grey pelitic (micritic, carbonate-mud-rich) limestones and fine- to medium-grained bioclastic limestones, commonly corresponding to the orthoceratite-type facies. Red and yellow-red pelitic limestones, locally enriched in glauconite, also occur within this interval. These lithologies frequently contain diverse trilobite assemblages accompanied by brachiopods and other shelly fauna, indicating deposition in well-oxygenated shelf environments.

Upper Ordovician erratic boulders display somewhat greater lithological diversity. Most erratics consist of grey pelitic (micritic) limestones, locally with a bioclastic component, corresponding to open-shelf carbonate facies. Within the Sandbian interval, many trilobite-bearing erratics represent Macrourus-type pelitic limestones (grey Sandbian pelitic limestones in traditional erratic terminology), locally with a bioclastic component, and their silicified diagenetic equivalents traditionally referred to as Backsteinkalk. A small number of erratics represent more distinctive lithologies, including grey-brown oolitic limestones interpreted as equivalents of shallow-water carbonate facies known from the Aseri Stage (mid-Darriwilian), as well as limestones enriched in kukersite, an organic-rich oil shale, which are readily identifiable by their characteristic brownish colouration.

The state of preservation of the erratic boulders varies considerably. Many specimens show evidence of surface weathering, of fracturing or abrasion related to glacial transport, and of post-depositional processes. Some limestones have haematite-filled cavities or show strong weathering that locally obscures the primary textures. Nevertheless, a substantial proportion of the erratic boulders preserves the original sedimentary fabrics and fossil content sufficiently well to allow reliable lithological characterization and taxonomic identification of the trilobite remains.

Overall, the lithological diversity recorded among the Ordovician erratic boulders reflects a broad spectrum of carbonate facies known from Baltoscandia. Representative lithologies are illustrated in Figure 3. A detailed inventory of the lithological types, together with locality information and associated trilobite taxa, is provided in Appendix 1.

TRILOBITE ASSEMBLAGES

The Ordovician trilobite assemblages recorded in the erratic boulders studied comprise a taxonomically diverse but unevenly represented fauna. In total, 27 trilobite species-level taxa were identified (Appendix 1). The assemblages are dominated by representatives of the families Asaphidae and Chasmopinae, which together constitute the most frequently encountered trilobite groups in the material studied. Other families, including the Illaenidae, Cheiruridae and Phacopidae, occur less commonly and are typically represented by single specimens or only a few erratics.

Asaphid trilobites are widely distributed across the study area and occur in a broad range of lithological types, including pelitic (micritic) limestones and fine- to medium-grained bioclastic limestones. The genus *Asaphus* is particularly common and is represented by several species, as well as numerous specimens identified only to generic level. Asaphid trilobites constitute a characteristic component of Baltoscandian Ordovician faunas and have been widely documented in previous studies (e.g., Pärnaste and Bergström, 2013). Chasmopine trilobites, including representatives of *Chasmops*, *Bolbochasmops*, *Oculichasmops* and related genera, form another major component of the assemblages and are especially frequent in pelitic (micritic) limestones, locally with a bioclastic component. These taxa are also well-documented in Baltoscandian successions (e.g., McNamara, 1980; Rõõmusoks, 1998).

Illaenid trilobites occur sporadically but are taxonomically diverse, including *Illaenus* and related genera. These trilobites are typically preserved as disarticulated or fragmentary remains, although locally better-preserved specimens were also recorded. Cheirurid and phacopid trilobites are rare and are represented mainly by isolated cephala or incomplete exoskeletons, reflecting both their lower abundance and variable preservation.

The state of preservation of the trilobite specimens varies considerably between the individual erratics. Many specimens

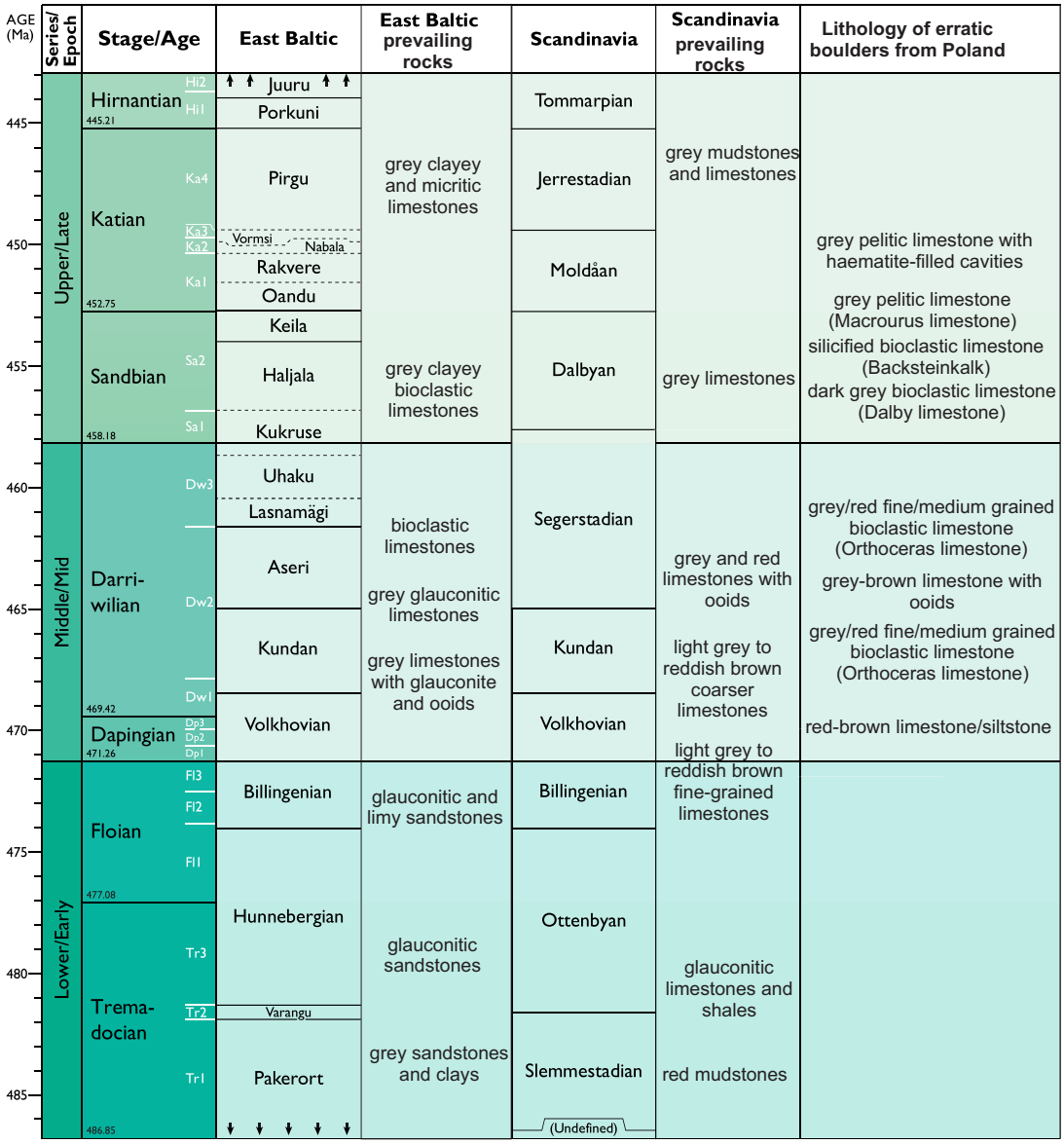

Fig. 3. Correlation of the Ordovician regional stages for Scandinavia and the east Baltic with the general lithology of the rocks (Hadding, 1958; Nestor et al., 2007; Nielsen et al., 2023; Ebbestad, 2023)

are fragmentary and commonly represented by isolated cephala, pygidia or thoracic segments. Articulated or nearly complete exoskeletons are rare but occur in a few cases. In some specimens, features interpreted as possible moults or associated skeletal remains were observed. Despite variable preservation, diagnostic morphological characters are commonly retained, allowing reliable taxonomic identification in most cases.

Overall, the trilobite assemblages documented in the Ordovician erratic boulders represent a broad spectrum of taxa typical of Baltoscandian Ordovician carbonate successions. Although the material does not permit quantitative palaeoecological analyses, it provides a representative overview of the taxonomic composition of trilobite faunas preserved in glacial erratics from northern Poland.

STRATIGRAPHIC ASSIGNMENT OF THE TRILOBITE-BEARING ERRATICS

The stratigraphic assignment of the Ordovician trilobite-bearing erratic boulders is based primarily on biostratigraphic evidence provided by the trilobite taxa identified. Age assignments rely chiefly on trilobite taxonomic identifications, whereas lithological characteristics are treated as supplementary evidence. Owing to the glacial origin of the material and the variable state of fossil preservation, stratigraphic interpretations are made conservatively and refer to broad regional chronostratigraphic intervals. The resulting stratigraphic assignments and their relative frequencies are summarized in Figure 4.

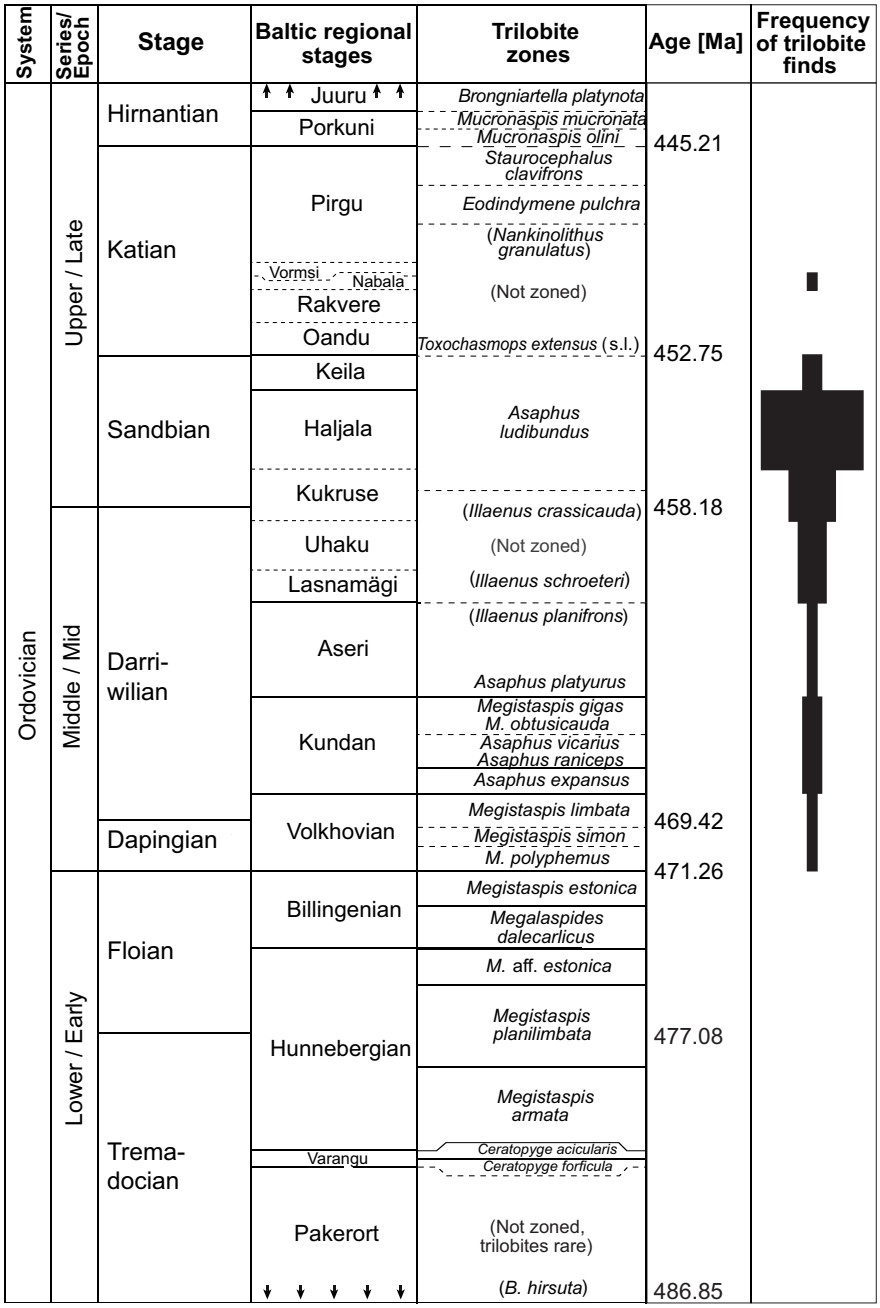

Fig. 4. Ordovician trilobite biozonation after Nielsen et al. (2023) with the stratigraphic position of the trilobite-bearing erratic boulders from northern Poland and their relative frequency in the stratigraphic intervals identified

The erratic boulders studied span the Middle and Upper Ordovician. The oldest trilobite-bearing erratic identified in this study yields an assemblage characteristic of the Volkhovian Regional Stage, corresponding to the Dapingian. This assemblage includes *Nileus exarmatus*, *Megistaspis limbata* and *Niobe* (*Niobella*) *imparilimbata* (Fig. 5), taxa well-documented from Middle Ordovician successions of Baltoscandia (Nielsen, 1995). In addition to trilobites, several brachiopods belonging to the superfamily Orthoidea (Woodward, 1852), as well as small (1–2 mm) representatives of the order Acrotretida (Kühn, 1949), were observed (Fig. 5).

Middle Ordovician erratics attributable to the Darriwilian (regional Kundan-Uhaku interval) are more common and are indicated by the occurrence of such species as *Asaphus bottnicus*, *A. pseudornatus*, *Hoplolichas tricuspidata*, *Pseudoasaphus tecticaudatus* and *Illaenus incisus* (Fig. 6). These assemblages are typical of shallow to moderately deep shelf environments widely developed across Baltoscandia during the Middle Ordovician. In several cases, stratigraphic assignment remains relatively broad owing to the fragmentary preservation or the presence of taxa with long stratigraphic ranges.

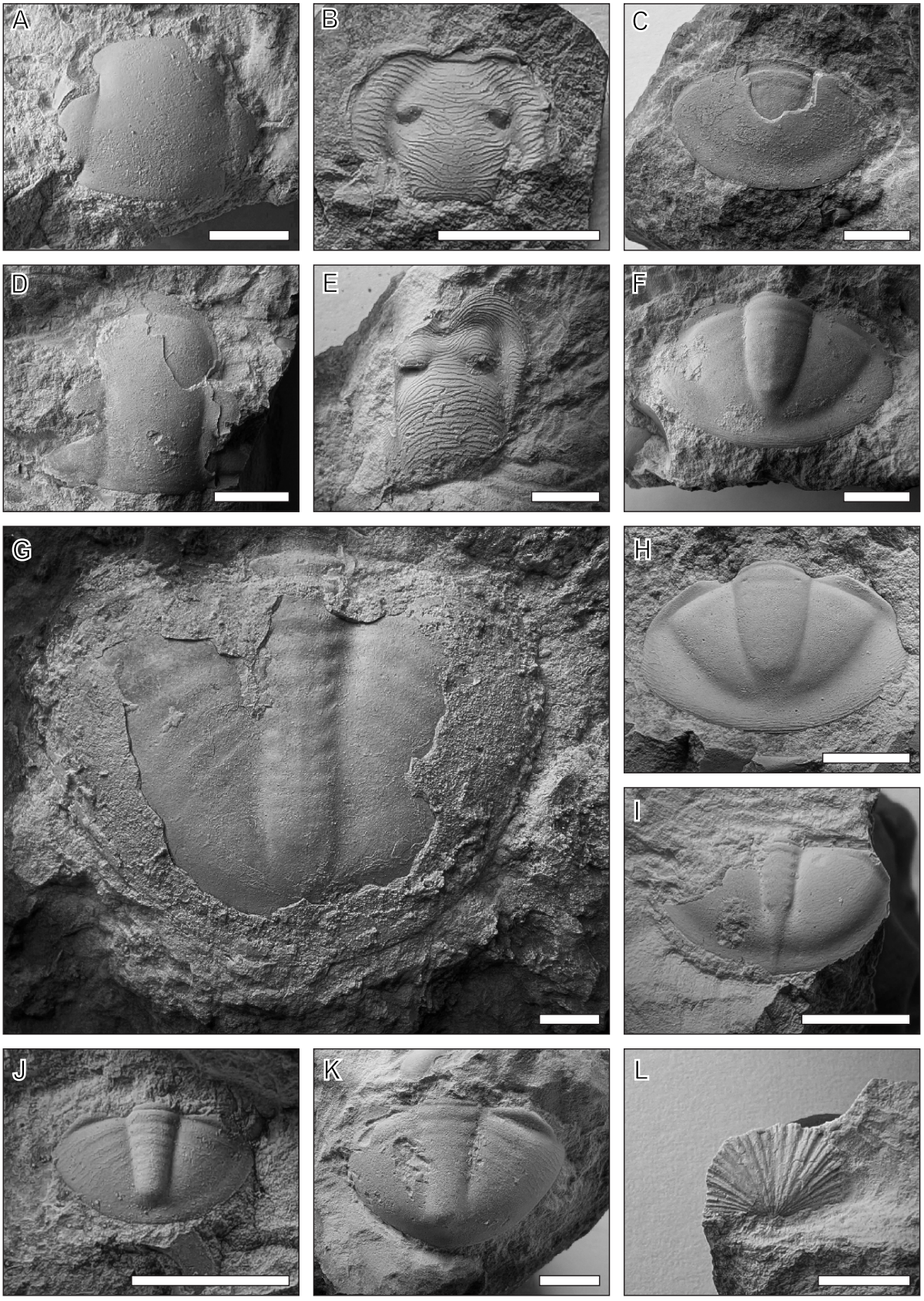

Fig. 5. Trilobites from an Ordovician (Volkhovian) boulder from the western part of Poland (Czarnkowie, Świdwin District)

A–C – *Nileus exarmatus* (Tjernvik, 1956), MUZ.PIG.1846.II.1.1-4; **D–F** – *Niobe (Niobella) imparilimbata* (Bohlin, 1955), MUZ.PIG.1846.II.1.6-8; **G** – *Megistaspis limbata* (Jaanusson, 1956), MUZ.PIG.1846.II.1.5; **H** – *Niobe (Niobella)* sp. (*N. imparilimbata* ?), MUZ.PIG.1846.II.1.9; **I** – *Raymondaspis* sp. (Přibyl, 1949), MUZ.PIG.1846.II.1.12; **J, K** – *Asaphus* cf. *lepidurus* (Brongniart, 1822), MUZ.PIG.1846.II.1.10-11; **L** – Orthoidea (Woodward, 1852), indet. Scale bars = 5 mm

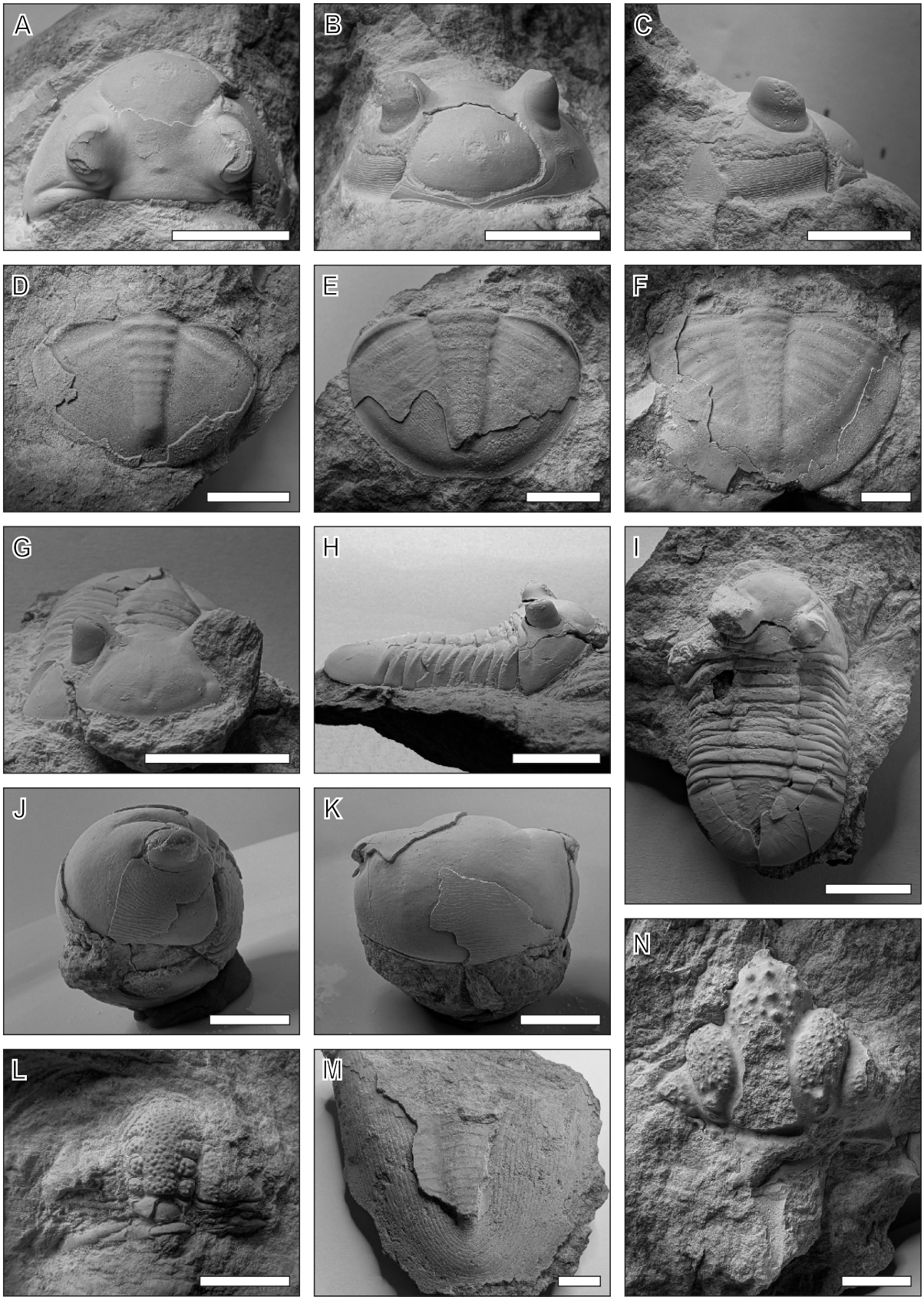

Fig. 6. Trilobites from Middle Ordovician (Kundan-Uhaku) erratic boulders from northern Poland (A–C – Redłowo, Gdynia District; D, F – Mechelinki, Puck District; E, L, M – Monety, Pisz District; G–I – Zdedy, Ełk District; J–K – Kaliszki, Pisz District; N – Niedźwiedzkie, Olecko District)

A–C – *Asaphus pseudornatus* (Jaanusson V., 1953), MUZ.PIG.1846.II.6; **D** – *Asaphus* sp. (Brongniart, 1822); MUZ.PIG.1846.II.8; **E** – *Megistaspis* sp. (Jaanusson V., 1956), MUZ.PIG.1846.II.7; **F** – *Megistaspis* sp. (Jaanusson V., 1956). MUZ.PIG.1846.II.10; **G–I** – *Asaphus bottnicus* (Jaanusson V., 1953), MUZ.PIG.1846.II.3; **J, K** – *Illaenus* cf. *incisus* (Jaanusson, 1957); MUZ.PIG.1846.II.9; **L** – *Paraceraurus* cf. *exsul* (Männil, 1958), MUZ.PIG.1846.II.2; **M** – *Pseudoasaphus tecticaudatus* (Steinhardt, 1874), MUZ.PIG.1846.II.4; **N** – *Hoplolichas tricuspidata* (Beyrich, 1846), MUZ.PIG.1846.II.5. Scale bars = 1 cm

Upper Ordovician erratics constitute the largest proportion of the studied material. Most erratic boulders can be assigned to the Sandbian, as indicated by the frequent occurrence of chasmopine species, including *Chasmops tallinnensis, Ch. odini*, *Bolbochasmops emarginatus*, *Oculichasmops tumidus*, *O. muticus* (Fig. 7) and *Scopelochasmops nebeni*. Additional taxa, such as *Estoniops maennili*, *E. exilis*, *Keilopyge laevigata* and *Leiolichas illaenoides*, further support a Sandbian age for the majority of the assemblages.

A smaller number of erratic boulders represent the Sandbian-early Katian transition or can be attributed to the Katian. They include assemblages containing *Hemisphaerocoryphe pseudohemicranium* and *Erratencrinurus* cf. *praecapricornu*, occurring in pelitic limestones with distinctive preservational features, such as haematite-filled cavities (Fig. 7). These erratics represent the youngest Ordovician material recognized in the dataset (Krueger, 2013).

Erratic boulders containing trilobite specimens identified only to generic level were assigned conservatively to broader stratigraphic intervals. Despite these limitations, the combined biostratigraphic evidence indicates that the trilobite-bearing erratics from northern Poland predominantly represent Middle and Upper Ordovician successions, with a clear dominance of Sandbian-age assemblages.

DISCUSSION

RELATIONSHIPS BETWEEN LITHOLOGY AND TRILOBITE ASSEMBLAGES

The material analysed indicates recurring associations between the lithologies recorded and trilobite assemblages within the Ordovician erratic boulders. The dataset is restricted to fossil-bearing specimens and therefore does not represent the full spectrum of Ordovician carbonate lithologies present in glacial deposits. Nevertheless, several lithology-taxon associations can be recognized.

Most trilobite assemblages are preserved in pelitic (micritic) limestones, locally with a bioclastic component, which constitute the dominant lithological type among the erratic boulders studied. These lithologies host a wide range of taxa, including representatives of the Asaphidae, Chasmopinae and Illaenidae. Asaphid trilobites occur across nearly the entire range of recorded lithologies, from pelitic (micritic) limestones to more bioclastic varieties, reflecting their broad ecological tolerance within Ordovician carbonate shelf environments.

Middle Ordovician trilobites, particularly representatives of the Asaphidae, are most commonly associated with grey pelitic (micritic) limestones and fine- to medium-grained bioclastic limestones corresponding to orthoceratite-type facies. These lithologies typically yield relatively diverse trilobite assemblages accompanied by brachiopods and other shelly fossils, suggesting deposition in open-shelf carbonate settings.

Upper Ordovician assemblages dominated by chasmopine trilobites are predominantly found in grey pelitic (micritic) limestones, locally with a bioclastic component, reflecting comparable shallow-shelf carbonate environments. Within the Sandbian interval, two closely related lithological types are recognized: non-silicified pelitic limestones traditionally referred to as Macrourus-type facies, and their silicified equivalents commonly described as Backsteinkalk. In the material studied, the characteristic Sandbian trilobite *Bolbochasmops emarginatus* occurs in both non-silicified pelitic limestones and strongly indurated, partially silicified Backsteinkalk-type boulders. The occurrence of *Bolbochasmops emarginatus* in both lithologies supports their assignment to the Sandbian interval.

The available data do not permit precise stratigraphic differentiation between the silicified Backsteinkalk-type boulders and non-silicified Macrourus-type pelitic limestones. Their occurrence within Sandbian trilobite assemblages, including those with *Bolbochasmops emarginatus*, is consistent with the common interpretation that Backsteinkalk represents a silicified, diagenetically modified variant within the Sandbian carbonate succession rather than a separate chronostratigraphic unit (e.g., Keulen and Rhebergen, 2017).

Overall, the relationships observed between the lithology and the trilobite assemblages in the Ordovician erratic boulders from northern Poland broadly correspond to patterns documented in *in situ* Baltoscandian successions. At the same time, the glacial origin of the material and the selective preservation of the fossil-bearing erratics impose limitations on detailed palaeoecological interpretation. Accordingly, the lithology-fauna relationships discussed here should be regarded as qualitative observations that complement the taxonomic and stratigraphic framework described in this study, rather than as a basis for quantitative palaeoecological analysis.

REGIONAL DISTRIBUTION OF ORDOVICIAN ERRATICS

Field observations indicate that Ordovician trilobite-bearing erratics occur most frequently in end and dead-ice moraines, whereas in some areas intensive sediment reworking results in a low abundance or absence of Paleozoic sedimentary erratics. These geomorphological controls provide an important context for understanding the spatial variability of the material studied.

Within this sedimentological context, the regional distribution of the Ordovician trilobite-bearing erratic boulders in northern Poland shows a clear spatial differentiation. Although erratics containing identifiable Ordovician trilobite faunas occur across the entire study area, their frequency, lithological composition and stratigraphic representation vary between the western, central and eastern sectors. A gradual east-west differentiation is evident in the stratigraphic composition of the erratics. In the eastern sector of the study area, Upper Ordovician boulders clearly dominate, accounting for approximately two-thirds of the trilobite-bearing Ordovician erratics analysed, whereas Middle Ordovician rocks constitute roughly one-third. In contrast, the western sector shows a more even distribution, with Middle and Upper Ordovician trilobite-bearing erratics occurring in broadly comparable proportions, each representing approximately half of the material analysed.

This pattern broadly corresponds to regional trends documented elsewhere in the southern Baltic area. Long-term studies from northern Germany demonstrate a higher proportion of Middle (and locally Lower) Ordovician erratics within the trilobite-bearing assemblages (Schöning, 2017). By comparison, data from Belarus indicate a predominance of Upper Ordovician forms and a markedly lower representation of Middle Ordovician trilobites (Zaika and Krylov, 2017). Taken together, these observations suggest a regional gradient in the stratigraphic composition of Ordovician erratics across the southern Baltic region, with an increasing relative contribution of older Ordovician material towards the west.

A comparable spatial contrast is also visible in lithological terms. Reddish orthoceratite limestones are relatively common in the western part of the study area, whereas they were not

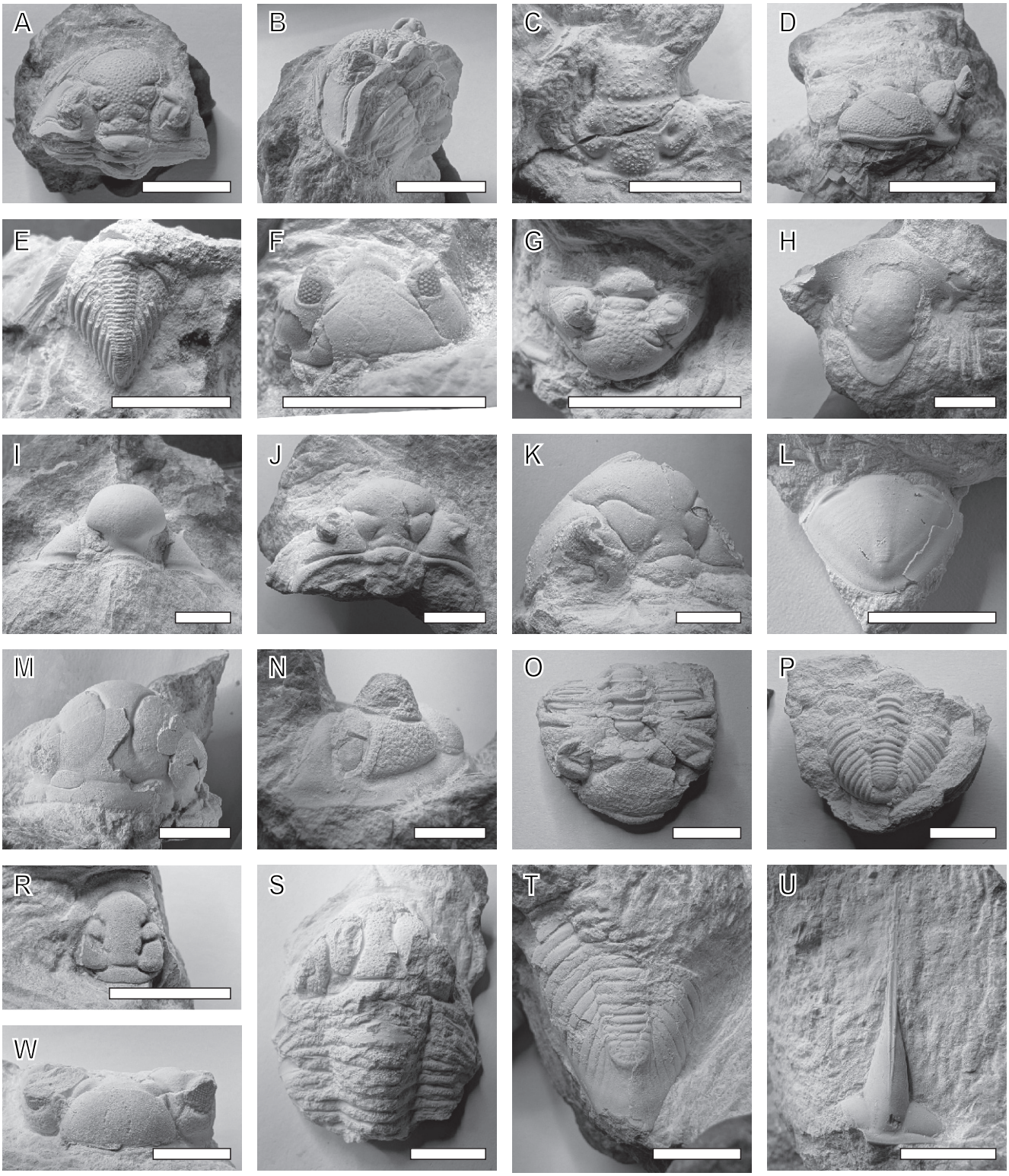

Fig. 7. Trilobites from Upper Ordovician erratic boulders from northern Poland (A, B, O, P – Czarnkowie, Świdwin District; C – Baranowo, Suwałki District; D – Kaliszki, Pisz District; E, L – Klony, Olsztyn District; F, G – Krzywólka, Suwałki District; H, K, M, N, T – Klępczewo, Świdwin District; I – Mechelinki, Puck District; J – Wiłkopedzie, Sejny District; R – Woliczno, Drawsko Pomorskie District; S – Kolniszki, Gołdap District; U – Chlebowo, Bytów District; W – Kamieńskie, Pisz District)

A, B – *Estoniops maennili* (Jaanusson et Ramsköld, 1993), MUZ.PIG.1846.II.12; **C** – *Apianurus kuckersianus* (Schmidt, 1885), MUZ.PIG.1846.II.15; **D** – *Bolbochasmops emarginatus* (Schmidt, 1881), MUZ.PIG.1846.II.22; **E** – *Erratencrinurus* cf. *praecapricornu* (Krueger, 2004), MUZ.PIG.1846.II.24.1; **F, G** – *Keilopyge laevigata* (Schmidt, 1881), MUZ.PIG.1846.II.17; **H, K, T** – *Toxochasmops (Schmidtops) proavus* (Rõõmusoks, 1998): H – hypostome, MUZ.PIG.1846.II.18; K – part of cephalon, MUZ.PIG.1846.II.19; T – pygidium, MUZ.PIG.1846.II.20; **I** – *Hemisphaerocoryphe pseudohemicranium* (Nieszkowski, 1859), priv. coll. Glinka B.; **J** – *Chasmops tallinnensis* (Öpik, 1937), MUZ.PIG.1846.II.16; **L** – *Achatella nabalaensis* (Krueger, 2017), MUZ.PIG.1846.II.24.2; **M** – *Leiolichas illaenoides* (Nieszkowski, 1857), MUZ.PIG.1846.II.21; **N** – *Oculichasmops muticus* (Schmidt, 1881), MUZ.PIG.1846.II.14; **O, P** – *Oculichasmops muticus* (Schmidt, 1881), MUZ.PIG.1846.II.11; **R** – *Pharostoma* sp. (Hawle et Corda, 1847), MUZ.PIG.1846.II.23; **S** – *Otarozoum eichwaldi* (Nieszkowski, 1857), MUZ.PIG.1846.II.25. **U** – *Lonchodomas rostratus* (Sars, 1835), MUZ.PIG.1846.II.13; **W** – *Chasmops odini* (Eichwald, 1840), MUZ.PIG.1846.II.26. Scale bars = 1 cm

identified in the eastern and northeastern sectors, despite extensive field investigations. This distribution is interpreted here as an observational pattern and may reflect differences in source-rock availability and glacial transport pathways affecting particular sectors of northern Poland.

Regional differentiation is further reflected in the taxonomic composition of the Middle Ordovician assemblages. Within this interval, trilobites of the family Asaphidae form a prominent component of the fauna. Two species, *Asaphus bottnicus* and *A. pseudornatus*, were identified among the erratics studied. Both species were distinguished based on consistent differences in cephalic morphology, following published diagnoses (Jaanusson, 1953a, b). Notably, these taxa were originally described exclusively from erratics collected in the Uppsala region and the Åland Islands in the southern Gulf of Bothnia (Jaanusson, 1953b). Their occurrence in northern Poland is therefore consistent with previously documented distributions in glacial erratics and may indicate a connection with source areas in the northern Baltic region.

An additional example is provided by the oldest trilobite-bearing erratic identified in the study, which yields a Volkhovian (Dapingian) assemblage including *Nileus exarmatus*, *Megistaspis limbata* and *Niobe* (*Niobella*) *imparilimbata*. Comparable faunal associations have been reported from Ordovician successions and erratic boulders in northern Öland, central Sweden (Dalarna region) and the southern Gulf of Bothnia (e.g., Bohlin and Jaanusson, 1955; Tjernvik, 1956). The presence of this assemblage in northern Poland is thus consistent with its known regional distribution within Baltoscandia, while remaining descriptive in the absence of independent provenance constraints.

CONCLUSIONS

This study documents 56 Ordovician trilobite-bearing erratic boulders collected from northern Poland and provides a systematic overview of their lithology, trilobite assemblages and stratigraphic assignment. The material comprises 27 trilobite species-level taxa and represents predominantly Middle and Upper Ordovician intervals.

The erratic boulders analysed consist mainly of pelitic (micritic) limestones and fine- to medium-grained bioclastic limestones corresponding to the open-shelf carbonate facies known from Baltoscandia. A relationship between lithology and trilobite assemblages is evident, particularly within the Sandbian interval, where both non-silicified pelitic limestones and silicified Backsteinkalk-type boulders yield comparable trilobite faunas, including *Bolbochasmops emarginatus*. The available evidence suggests that these lithological variants represent non-silicified and silicified diagenetic variants within the same general stratigraphic interval rather than distinct chronostratigraphic units.

A marked regional differentiation is observed across the study area. In the eastern sector, Upper Ordovician erratic boulders clearly dominate, whereas in western Poland the proportions of Middle and Upper Ordovician boulders are more equal. This pattern broadly corresponds to regional trends documented in northern Germany and eastern parts of the Baltic region. The variability observed likely reflects differences in the distribution and glacial accessibility of Ordovician source rocks in Baltoscandia.

Although the dataset is restricted to fossil-bearing erratics and does not constitute a fully quantitative survey of all Paleozoic boulders, it provides a coherent descriptive framework for assessing regional variability in the Ordovician erratics of northern Poland. The results demonstrate the usefulness of trilobite-bearing erratics as indicators of stratigraphic affiliation and facies relationships within the Baltoscandian Ordovician succession and provide a basis for future, more comprehensive regional analyses.

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APPENDIX 1

List of Ordovician trilobite-bearing erratic boulders from northern Poland

Sample ID	Figure number	Museum Catalogue No.	Locality	Latitude	Longitude	Depositional environment	Simplified lithological description	Trilobite taxa	Global stratigraphic series and stage	Notes*
1-1	Fig. 7J	MUZ.PIG.1846.II.16	Wiłkopedzie	54.180485	23.298468	dead-ice moraine	grey pelitic to slightly silty limestone	*Chasmops tallinnensis*	Upper Ordovician (Sandbian)	
1-2	–	–	Wiłkopedzie	54.180485	23.298468	dead-ice moraine	grey pelitic limestone	*Asaphus* sp.	Upper Ordovician (Sandbian)	
1-3	Fig. 7C	MUZ.PIG.1846.II.15	Baranowo	54.308505	22.98400	end moraine	grey pelitic limestone	*Apianurus kuckersianus*; *Bolbochasmops emarginatus*	Upper Ordovician (Sandbian)	
1-4	–	–	Baranowo	54.308505	22.98400	end moraine	grey pelitic limestone	*Illaenus* sp.	Upper Ordovician (Sandbian)	co-occurring with rare *Ischadites* sponge
1-5	Fig. 6N	MUZ.PIG.1846.II.5	Niedźwiedzkie	53.979788	22.57848	push moraine	grey pelitic to bioclastic limestone	*Hoplolichas tricuspidata*; *Pseudasaphus tecticaudatus*; *Chasmops* sp.	Middle Ordovician (Darriwilian)	
1-6	Fig. 7S	MUZ.PIG.1846.II.25	Kolniszki	54.275301	22.38856	end moraine	grey pelitic limestone	*Otarozoum eichwaldi*	Upper Ordovician (Sandbian)	
1-7	Fig. 7F-G	MUZ.PIG.1846.II.17	Krzywólka	54.11516	22.90596	glaciofluvial deposit	grey-brown pelitic bioclastic limestone	*Keilopyge laevigata*; *Asaphus* sp.	Upper Ordovician (Sandbian–lower Katian)	
1-8	–	-	Kulsze	54.25598	22.07940	push moraine	grey-brown oolitic limestone	*Illaenus* sp.	Middle Ordovician (Darriwilian)	
1-9	–	–	Żyrwiny	54.253289	23.118097	dead-ice moraine	grey-brown pelitic limestone	*Asaphus* sp.; *Chasmops* sp.	Upper Ordovician (Sandbian)	
2-1	Fig. 6G-I	MUZ.PIG.1846.II.3	Zdedy	53.765082	22.188759	end moraine	grey pelitic to fine-grained limestone	*Asaphus bottnicus*	Middle Ordovician (Darriwilian)	well-preserved specimen
2-2	–	–	Kamieńskie	53.823988	22.025172	end moraine	grey pelitic limestone	*Oculichasmops tumidus*	Upper Ordovician (Sandbian)	
2-3	–	–	Kamieńskie	53.823988	22.025172	end moraine	grey pelitic to slightly silty limestone	*Chasmops odini*	Upper Ordovician (Sandbian)	
2-4	Fig. 6L Fig. 6M Fig. 6E	MUZ.PIG.1846.II.2 MUZ.PIG.1846.II.4 MUZ.PIG.1846.II.7	Monety	53.720022	22.186495	end moraine	grey fine-grained to bioclastic limestone	*Asaphus* sp.; *Hoplolichas* sp.; *Megistaspis* sp.; *Pseudoasaphus tecticaudatus*; *Paraceraurus* cf. exsul	Middle Ordovician (Darriwilian)	
2-5	–	–	Monety	53.720022	22.186495	end moraine	grey pelitic limestone	*Asaphus* sp.; *Chasmops* sp.	Upper Ordovician (Sandbian)	
2-6	–	–	Łosewo	53.56249	22.452826	end moraine	grey pelitic limestone	*Estoniops exilis*	Upper Ordovician (Sandbian)	
2-7	–	–	Kaliszki	53.612164	21.999388	end moraine	grey pelitic to slightly fine-grained limestone	*Oculichasmops sakalensis*; *Illaenus* sp.	Upper Ordovician (Sandbian)	
2-8	Fig. 7D	MUZ.PIG.1846.II.22	Kaliszki	53.612164	21.999388	end moraine	grey-brown pelitic limestone	*Bolbochasmops emarginatus*; *Asaphus* sp.; *Illaenus* sp.	Upper Ordovician (Sandbian)	
2-9	Fig. 6J-K	MUZ.PIG.1846.II.9	Kaliszki	53.612164	21.999388	end moraine	grey pelitic limestone	*Illaenus* cf. *incisus*; *Lonchodomas* sp.	Middle Ordovician (Darriwilian)	
3-1	Fig. 7E Fig. 7L	MUZ.PIG.1846.II.24.1 MUZ.PIG.1846.II.24.2	Klony	53.989921	20.213338	glacial deposit	grey pelitic limestone with haematite-filled cavities	*Erratencrinurus* cf. *praecapricornu*; *Achatella nabalaensis*; *Isotelus* cf. *remigium*	Upper Ordovician (Katian)	weathered and fractured erratic
3-2	–	–	Gronowo	54.048976	20.352752	dead-ice moraine	grey pelitic bioclastic limestone	*Asaphus* sp.	Middle Ordovician (Darriwilian)	

3-3	–	–	Niebrzydowo Wielkie	53.965127	19.964495	push moraine	grey pelitic limestone	*Lonchodomas* sp.	Middle Ordovician (Darriwilian)	smooth, slightly lustrous fracture surfaces
4-1	–	–	Skryte	54.054856	17.35396	glaciofluvial deposit	grey pelitic limestone	*Chasmops* sp.	Upper Ordovician (Sandbian)	
4-2	–	–	Smołdziny	54.003946	17.447347	glaciofluvial deposit	light grey to brown pelitic limestone	*Chasmops* sp.	Upper Ordovician (Sandbian)	
4-3	Fig. 7U	MUZ.PIG.1846.II.13	Chlebowo	53.99758	17.053725	glacial deposit	dark grey pelitic limestone	*Lonchodomas* sp.	Upper Ordovician (Sandbian)	Dalby Limestone type
4-4	–	–	Nowy Wiec	54.134901	18.357351	ice-contact deposit	grey-green pelitic limestone	*Asaphus* sp.	Middle Ordovician (Darriwilian)	
4-5	–	–	Nowy Wiec	54.134901	18.357351	ice-contact deposit	grey-green pelitic limestone	*Stenopareia* sp.	Upper Ordovician (Sandbian)	
4-6	–	–	Dolsko	54.027247	17.101491	dead-ice moraine	grey medium-grained bioclastic limestone	*Illaenus* sp.; *Paraceraurus* sp.	Middle Ordovician (Darriwilian)	
4-7	–	–	Dolsko	54.027247	17.101491	dead-ice moraine	grey-green pelitic limestone	*Scopelochasmops nebeni*	Upper Ordovician (Sandbian)	
4-8	–	–	Dolsko	54.027247	17.101491	dead-ice moraine	grey pelitic limestone	*Asaphus* sp.; *Illaenus* sp.	Middle Ordovician (Darriwilian)	
4-9	–	–	Dolsko	54.027247	17.101491	dead-ice moraine	grey pelitic limestone	*Asaphus* sp.	Middle Ordovician (Darriwilian)	
5-1	Fig. 5	MUZ.PIG.1846.II.1.1–12	Czarnkowie	53.704102	16.130179	end moraine	dark red pelitic to silty limestone	*Nileus exarmatus*; *Niobe* (*Niobella*) *imparilimbata*; *Niobella* sp. (cf. *N. imparilimbata*); *Megistaspis limbata*; *Asaphus* cf. *lepidurus*; *Raymondaspis* sp.	Middle Ordovician (Dapingian)	
5-10	–	–	Woliczno	53.498539	15.758013	end moraine	grey pelitic limestone with brachiopods	*Chasmops* sp.	Upper Ordovician (Sandbian)	
5-11	–	–	Jankowo	53.51885	15.769381	end moraine	dark grey fine-grained limestone	*Illaenus* sp.	Middle Ordovician (Darriwilian)	
5-12	–	–	Jankowo	53.51885	15.769381	end moraine	grey pelitic limestone	*Chasmops* sp.	Upper Ordovician (Sandbian)	
5-2	–	–	Czarnkowie	53.704102	16.130179	end moraine	yellow-red pelitic limestone	*Asaphus* sp.	Middle Ordovician (Darriwilian)	
5-3	Fig. 7A-B	MUZ.PIG.1846.II.12	Czarnkowie	53.704102	16.130179	end moraine	grey pelitic limestone	*Estoniops maennili*	Upper Ordovician (early Katian)	
5-4	Fig. 7O-P	MUZ.PIG.1846.II.11	Czarnkowie	53.704102	16.130179	end moraine	grey-green pelitic limestone	*Oculichasmops muticus*; *Asaphus* sp.	Upper Ordovician (Sandbian)	strongly weathered
5-5	–	–	Prusinowo	53.691178	15.629437	glaciofluvial deposit	grey fine-grained silicified limestone	*Bolbochasmops emarginatus*	Upper Ordovician (Sandbian)	very dense, strongly silicified limestone
5-6	–	–	Zachełmie	53.641683	15.532396	glaciofluvial deposit	red-green pelitic limestone	*Asaphus* sp.; *Illaenus* sp.	Middle Ordovician (Darriwilian)	
5-7	–	–	Piaski	53.76368	16.276726	dead-ice moraine	grey-green fine-grained limestone	*Asaphus* sp.; *Illaenus* sp.	Middle Ordovician (Darriwilian)	
5-8	Fig. 7N Fig. 7H,K,T Fig. 7M	MUZ.PIG.1846.II.14; MUZ.PIG.1846.II.II.18–20 MUZ.PIG.1846.II.II.21	Klępczewo	53.789374	15.727158	ice-contact deposit	light grey bioclastic limestone with local yellow, clay-rich patches	*Toxochasmops proavus*; *Oculichasmops muticus*; *Leiolichas illaenoides*; *Chasmops* sp.; *Asaphus* sp.	Upper Ordovician (Sandbian)	well-preserved trilobite specimens
5-9	Fig. 7R	MUZ.PIG.1846.II.23	Woliczno	53.498539	15.758013	end moraine	grey pelitic limestone	*Chasmops* sp.; *Pharostoma* sp.	Upper Ordovician (Sandbian)	
A1	–	–	Redłowo	54.493638	18.564117	glacial deposit	red-green medium-grained limestone with glauconite	*Asaphus* sp.	Middle Ordovician (Darriwilian)	

A2	Fig. 6A-C	MUZ.PIG.1846.II.6	Redłowo	54.493638	18.564117	glacial deposit	light grey pelitic limestone	*Asaphus pseudornatus*	Upper Ordovician (Sandbian)	well-preserved trilobite specimen
A3	–	–	Redłowo	54.493638	18.564117	glacial deposit	grey-green medium-grained limestone with glauconite	*Asaphus* sp.; *Illaenus* sp.	Middle Ordovician (Darriwilian)	
A4	–	–	Babie Doły	54.576956	18.546006	glacial deposit	grey pelitic limestone	*Megistaspis* sp.	Middle Ordovician (Darriwilian)	
A5	–	–	Babie Doły	54.576956	18.546006	glacial deposit	grey pelitic limestone	*Asaphus* sp.	Middle Ordovician (Darriwilian)	
A6	–	–	Babie Doły	54.576956	18.546006	glacial deposit	grey bioclastic limestone	*Asaphus* sp.	Upper Ordovician (Sandbian)	
A7	–	–	Babie Doły	54.576956	18.546006	glacial deposit	grey bioclastic limestone	*Asaphus* sp.	Middle Ordovician (Darriwilian)	
A8	Fig. 6D	MUZ.PIG.1846.II.8	Mechelinki	54.602711	18.520037	ice-contact deposit	red fine-grained limestone	*Asaphus* sp.	Middle Ordovician (Darriwilian)	
A9	–	–	Mechelinki	54.602711	18.520037	ice-contact deposit	grey pelitic limestone	*Chasmops* sp.	Upper Ordovician (Sandbian)	
A10	–	–	Mechelinki	54.602711	18.520037	glacial deposit	reddish limestone enriched in kukersite	*Apianurus kuckersianus*; *Estoniops exilis*	Upper Ordovician (Sandbian)	rare kukersite-bearing erratic
A11	–	–	Babie Doły	54.576956	18.546006	glacial deposit	grey-brown bioclastic limestone	*Paraceraurus* sp.	Middle Ordovician (Darriwilian)	
A12	Fig. 7I	–	Mechelinki	54.602711	18.520037	ice-contact deposit	grey pelitic limestone	*Hemisphaerocoryphe pseudohemicranium*	Upper Ordovician (Sandbian)	specimen from private collection
A13	Fig. 6F	MUZ.PIG.1846.II.10	Mechelinki	54.602711	18.520037	glacial deposit	red pelitic limestone	*Megistaspis* sp.	Middle Ordovician (Darriwilian)	
A14	–	–	Mechelinki	54.602711	18.520037	ice-contact deposit	grey bioclastic limestone	*Paraceraurus* sp.	Middle Ordovician (Darriwilian)	

* Notes include brief remarks on preservation, lithological features and fossil occurrence based on macroscopic observations.