SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

JERZY DZIK and ANDRZEJ PISERA

Dzik, J. and Pisera, A. 1994. Sedimentation and fossils of the Mójcza Limestone. — *In:* J. Dzik, E. Olempska, and A. Pisera 1994. Ordovician carbonate platform ecosystem of the Holy Cross Mountains. *Palaeontologia Polonica* **53**, 5–41.

On the south Polish pre-Caledonian Małopolska microcontinent, after its complete peneplanation in the Late Arenig, deposition of the extremely stratigraphically condensed Mójcza Limestone Formation continued during the whole mid-Ordovician. The formation, 8 meters thick, is composed of biosparites (grainstones to packstones), sandy at the base, and contains dispersed ferruginous ooids. The global regressive eustatic event in the Late Llanvirn has its expression in a hiatus of locally varying duration, depending on the thickness of the sediment cover removed by submarine erosion. The basal Caradoc transgression is expressed by faunistic changes in the central part of the area, suggestive of a warming of the climate, but in marginal parts it initiated deposition of the fine clastic Zalesie Formation. This facies appeared in the type section of the Mójcza Limestone not before the Latest Caradoc. Possible influences of the Gondwana late Ordovician glaciations are recorded in faunal changes within the Mójcza Limestone and the Zalesie Formation. Late Ashgill regression seems to be the cause of the reappearance of carbonates or coarse clastics close to the top of the Ordovician, even in deeper parts of the area.

Key words: Ordovician, paleogeography, stratigraphy, Poland.

Jerzy Dzik and Andrzej Pisera, Instytut Paleobiologii PAN, Aleja Żwirki i Wigury 93, 02-089 Warszawa, Poland. *Revised version received 5th June, 1993.*

CONTENTS

INTRODUCTION

The Ordovician of the Holy Cross Mountains is of special interest because of its crucial paleogeographic location. This area represents the margin and the only exposed part of the subsurface Małopolska Massif. In the pre-Caledonian epoch it is considered to have formed, together with the Upper Silesia Massif, a separate microcontinent (DZIK 1978, 1990) located between Baltica and the mid-European Variscan massifs of Gondwanan affinities. Although faunal assemblages in the Holy Cross Mountains Ordovician are generally Baltic, there were also influences of the Celtic province faunas of Wales, the Armorican Massif and the Sudetes, as well as of the cold-water Gondwana faunas of Thuringia and the Moldanubicum (DZIK 1990).

Our interests are mostly focused on the highly fossiliferous and stratigraphically condensed carbonate rocks of the area, the Mójcza Limestone Formation. Its distribution in time and space is reviewed below and the type locality section is described in detail. This introductory contribution, containing also a review of macrofossils, is followed in the volume by separate descriptive papers presenting the results of more detailed studies of the major groups of fossils represented in the Mójcza Limestone. Although the formation does not represent a carbonate platform in the strict sense (see WILSON 1975), being representative of rather deeper and colder water environment, we use this term because of the extensive occurrence of carbonate deposits over wide areas of the submerged Małopolska microcontinent.

Acknowledgements. — We are thankful to Dr. Wiesław BEDNARCZYK (Institute of Geological Sciences of the Polish Academy of Sciences, Warsaw) for his highly critical comments on the manuscript of this paper. Special thanks are due to Dr. Richard A. FORTEY (The Natural History Museum, London) for his thorough review of this paper, several useful suggestions concerning eustatic and paleobiogeographic interpretations, and for improving the English language of the text. Dr. David A.T. HARPER (University College, Galway, Ireland) has also read the manuscript. Mrs. Grażyna DZIEWIŃSKA took photographs of macrofossils.

FACIES DISTRIBUTION IN THE ORDOVICIAN OF THE HOLY CROSS MOUNTAINS

The Ordovician rocks in the Holy Cross Mountains are generally poorly exposed and there are only a few localities where a significant part of the Ordovician rock column can be studied without special excavations (Text-fig. 1). Because of the complicated tectonics and inadequate descriptions (in the "pre-conodont epoch"), data from several boreholes, drilled in the 50's, that reached the Ordovician, are of limited importance. However, even considering this scarce evidence, it is clear that within the area three facies belts can be recognized.

The earliest known outcrops of the Ordovician represent the central belt, extending from Kielce at WNW to Sandomierz at ESE, named the "Kielce facies region" by CZARNOCKI (1928). It is characterized by a coarsely clastic lower part of the system, a strongly condensed carbonate middle part and a thin marly cover at its top. The clastic lower part, traditionally called the Bukówka Sandstone, owing to its thickness and resistance to erosion represents the best exposed part of the Ordovician in the Holy Cross Mountains, and is known from several exposures (BEDNARCZYK 1971). Close to Sandomierz it crops out in the quarry at Międzygórz (Pl. 4; SAMSONOWICZ 1916; TOMCZYK 1954). Initially the strata were considered there to be Devonian in age (ZEUSCHNER 1869), which is understandable in that they are overturned and the sandstones apparently rest on the Silurian graptolite shales. At this locality, stratigraphically below the Bukówka Sandstone, a thick sequence of conglomerates and dark glauconitic sandstones (Międzygórz Beds) occurs, while near Kielce this part of the sequence corresponds to sandstones with only a thin layer (at the most 0.6 m, the Biesak quarry) of a basal conglomerate (CZARNOCKI 1928; BEDNARCZYK 1964). In the Bukówka quarry a thin intercalation of marly limestones separating the two Early Ordovician formations was formerly exposed (CZARNOCKI 1928). The Bukówka Sandstone in all its complete exposures is overlain by the Mójcza Limestone. It was first reported by ZEUSCHNER (1869) from Międzygórz and identified as Ordovician in its type locality by GÜRICH (1901).

The Mójcza Limestone (Pl. 1), is about 8 m in thickness in Mójcza, and is strongly sandy close to its base, with rare glauconite grains contributing to the clastic fraction there, higher up it becomes organodetrital, with grains coated with phosphatic envelopes, and contains ferruginous ooids (Pl. 2). This lithology continues above the bentonite layer (RYKA and TOMCZYK 1959) occurring in its middle part (Pl. 3). About 3.9 m above the bentonite, it is replaced by argillaceous limestones with marls interbedded (Pl. 3). In the Międzygórz quarry (Pl. 4) the Mójcza Limestone is dolomitized.

The argillaceous limestones and marls with Ashgill conodonts topping the section at Mójcza represent a subsequent lithologic unit, the Zalesie Formation, which is better developed in the second facies belt, following the Kielce one from the South. The best exposure of the Ordovician in this area is that at Zalesie Nowe near Łagów (Text-figs 1–2) but more or less fragmentary parts of the system are known also from several other localities in the Łagów area. CZARNOCKI (1928) coined the term "Łagów facies region" from the name of this town. The Early Ordovician is dominated there, not by coarse clastics, but by mudstones interbedded with chalcedonites. At Zalesie, the Ordovician starts with a thin layer of pebbles, a few centimeters in thickness, overlain by about three meters of shales, and then mudstones and chalcedonites about 4.5 m thick (CZARNOCKI 1928). In a nearby locality, Chojnów Dół, a few centimeters thick clay intercalation occurs just above the conglomerate bed, which contains an assemblage of conodonts corresponding to that in the chalcedonite from Wysoczki. In both these localities sandstones closely similar to the Bukówka Sandstone occur above the mudstones. The borehole Mokradle in the area (BEDNARCZYK *et al.* 1966) revealed that, as in Bukówka, these two formations are separated by a carbonate intercalation (Text-fig. 3). Above the Bukówka Sandstone at Zalesie the Mójcza Limestone occurs (now its outcrop being covered by debris) but it passes into marls and shales much earlier stratigraphically than at Mójcza or Międzygórz. The transition from carbonate to fine clastic sedimentation in the borehole Mokradle happens immediately above a bentonite layer, possibly correlatable with that at Mójcza. Conodont samples from a borehole drilled in the proximity of the Zalesie exposure indicate that the marly part of the section corresponds in age to the upper half of the Mójcza Limestone in its type locality (DZIK 1994a). This fine clastic sequence represents the type section of the Zalesie Formation. Carbonate sedimentation was re-established for a brief time close to the top of the Ordovician. These are marly dolomites with a typical Ashgill assemblage of conodonts. Terminal Ordovician strata may possibly be represented by graptolite shales of the basal Bardo beds, because the earliest Silurian graptolite *Akidograptus acuminatus* has been found a few meters above the base of the shales (KIELAN 1960).

The Łagów facies region represents an area of evidently deeper sedimentation than in the Kielce region, and more distant from the source area of coarse clastics. The sea was even deeper towards the west where at Brzeziny, not far to the south from Mójcza, almost the whole Ordovician is represented by graptolite shales (TOMCZYK and TURNAU-MORAWSKA 1964). Sandstones occur there only in the lowermost part of the section, and the time equivalents of both the Międzygórz beds and the Bukówka Sandstone are developed as fine clastic rocks known as the Brzeziny beds. It seems that an interval here with abundant chamosite ooids, with a few intercalations of limestones, may correspond to the Mójcza Limestone. It deserves recognition as a separate lithologic unit. However, it was split by TOMCZYK and TURNAU-MORAWSKA (1964) between their upper Brzeziny beds and lower Morawica shales on the basis of proposed age, rather than lithology. Above, there are the exclusively graptolite Morawica shales (TOMCZYK and TURNAU-MORAWSKA 1964). In this respect the Brzeziny section resembles a third facies belt, the northern one, named the "Łysogóry facies region" by TOMCZYK (*in* TOMCZYK and TURNAU-MORAWSKA 1967), as it is best exposed along the northern slope of the Łysogóry range. It differs profoundly from the disscussed above in its complete lack of coarse clastics in the Early Ordovician, resembling in this respect rather marginal sections of the East European Platform (see Text-fig. 2).

The Early Ordovician in the Jeleniów borehole IG 2 in the Łysogóry range seems to be restricted to a few meters of clayey shales in a sedimentary continuity with the underlaying Late Cambrian shales (BIERNAT and TOMCZYKOWA 1968). A sequence of less than 1.5 m of limestones intercalated with shales (containing *Glyptograptus*) seems to be an equivalent of the chamosite iron horizon at Brzeziny. Above the limestones there is a relatively thick sequence of shales (about 150 m), with thin limestone intercalations (*Nemagraptus* occurs in its lower part). These fine clastic strata resemble the Zalesie Formation in the Łagów region and show a similar subdivision. The Jeleniów beds are represented mostly by graptolite shales. The Wólka beds (mostly mudstones) appear above.

FOSSILS AND STRATIGRAPHY OF THE HOLY CROSS MOUNTAINS ORDOVICIAN

Fossils from the sandstones quarried in Bukówka near Kielce were known already to Karl Ferdinand ROEMER (1866), who defined the allegedly Devonian species *Orthis kielcensis*, the most common Bukówka orthid. This age misidentification was not followed by HEMPEL (1867) and the evidence for the Ordovician age was first presented by MICHALSKI (1883: p. 121), who synonymised *O. kielcensis* with Baltic *Orthis moneta* and also identified several other brachiopods indicative of the Ordovician age of the formation. First illustrations of some of these fossils were provided by GÜRICH (1901), who based his descriptions on the collection of Ing. Stanisław KONTKIEWICZ.

A fauna of inarticulate brachiopods with *Thysanotos siluricus* from the Międzygórz beds was interpreted as Tremadoc in age (BEDNARCZYK 1964, 1971) but the discovery of apparently Arenig chitinozoans in a shale pebble from the conglomerate at the Międzygórz quarry (CHLEBOWSKI and SZANIAWSKI 1974) suggests a post-Tremadoc age for the clastic sequence in the Kielce facies region.

The Bukówka Sandstone contains an assemblage of articulate brachiopods (Pl. 6) of generally Baltic appearance (MICHALSKI 1883; BEDNARCZYK 1964), with *Antigonambonites planus*, *Lycophoria nucella*, *Orthambonites calligramma*, *Productorthis obtusa*, and, possibly Baltic as well, *Orthis kielcensis* (ROEMER, 1866). A characteristic member of the assemblage is the large bellerophontid *Modestospira polonica* (GÜRICH, 1896) (Pl. 6: 10–13). These fossils are clearly of Arenig age but do not enable more precise dating.

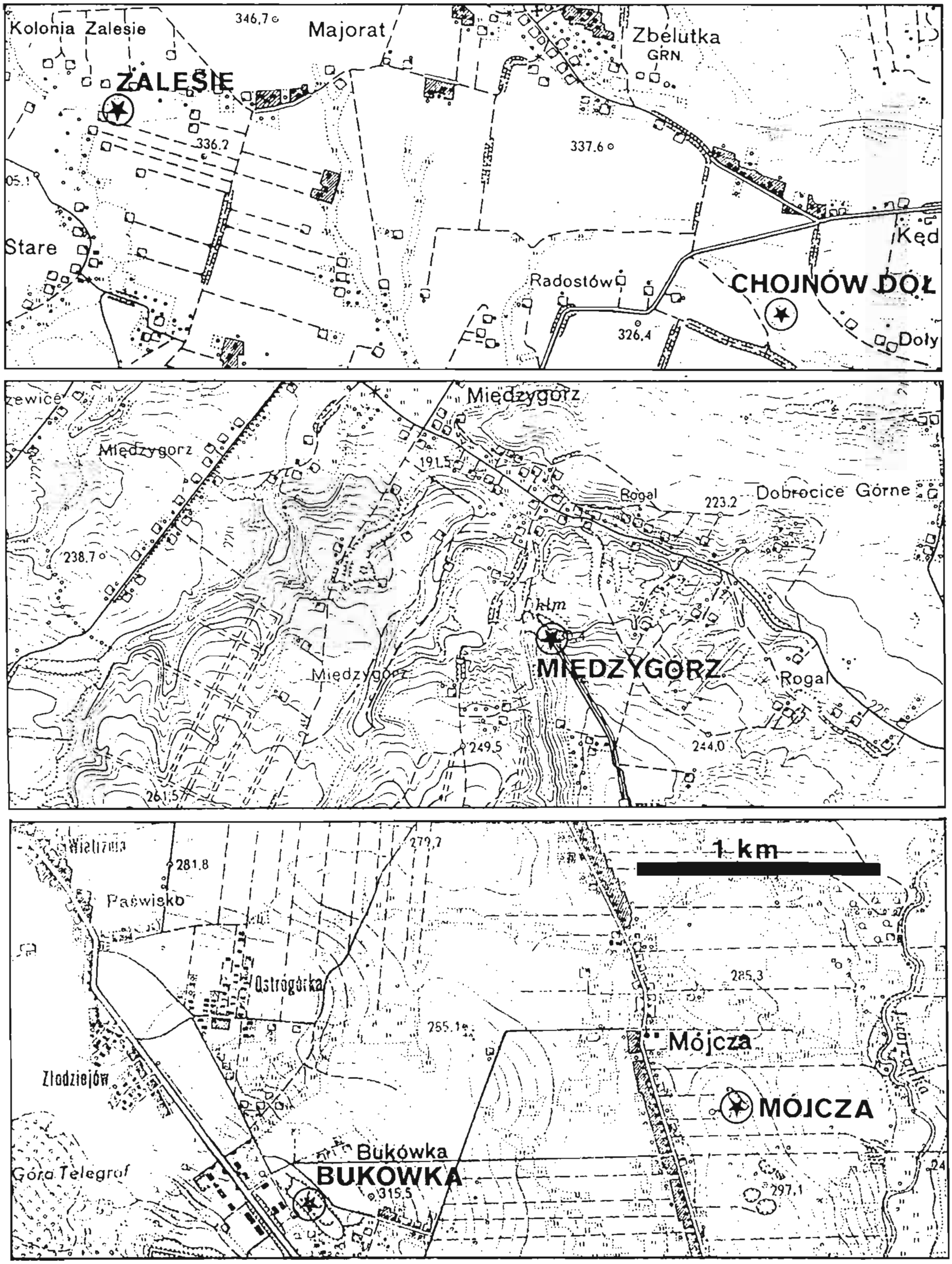


Fig. 1.
Location of the five most important localities of the Ordovician in the Holy Cross Mountains, Poland.

At Mójcza, the transitional zone of sandstones with originally calcitic matrix and irregular limestone bands (in outcrops usually decalcified) abounds in fossils representing an assemblage similar to that of the underlying strata (Pl. 7), except for the absence of *Modestospira*. The dominant species, instead of *A. planus*, is *O. kielcensis* (see Pl. 7: 4–10). The inarticulate brachiopod assemblage described by BEDNARCZYK and BIERNAT (1978) from the limestone intercalations within the Bukówka Sandstone apparently represents this zone as being transitional with the Mójcza Limestone. Conodonts from the same samples suggest an age close to the base of the Mójcza Limestone (DZIK 1990: p. 2).

Macrofossils occur abundantly only in the lower part of the Mójcza Limestone in its type locality, where two bedding planes are crowded with orthids and trilobite carapaces (Pls 7–8; CZARNOCKI and SAMSONOWICZ 1913; BEDNARCZYK 1964, 1966b). Close to the bentonite layer a bedding surface occurs with rare endoceratid nautiloid phragmocones, preserved fragmentarily, with dorsal sides missing and the conchs overturned with venters upside (DZIK 1985: Pl. 4: 9). Above the bentonite, macrofossils are extremely rare although some cystoid thecae are known from this part of the section.

In the Międzygórz quarry (Pl. 5), the Mójcza limestone contains poorly preserved orthoceratid phragmocones in its upper Ashgill part. Neither the base nor the top of the formation can be studied there but it seems, on the basis of the occurrence of the nautiloid *Cyclolituites* (DZIK 1984: Pl. 38: 3–4) and an enigmatic monoplacophoran(?) mollusc (known from Mójcza section, too; see Pl. 6: 14) that carbonate sedimentation was established there slightly later than near Kielce.

Abundant conodonts (SPASOV and TELLER 1962; BEDNARCZYK 1971; DZIK 1978, 1990, 1994a) allow precise subdivision and time correlation of the Mójcza Limestone in all the sections where they have been studied. In the type locality, the formation covers the time span from the end of Arenig to the end of Caradoc (perhaps even early Ashgill), being thus extremely condensed even in its non-bedded central part.

In another facies region, located southward, chalcedonites cropping out near Wysoczki contain graptolites described by KOZŁOWSKI in his classic monograph (1948), brachiopods (BIERNAT 1973), acritarchs (GÓRKA 1969), and conodonts (SZANIAWSKI 1980); all these fossils were extracted by means of hydrofluoric acid. The conodonts indicate the age as late Tremadoc (*Paltodus deltifer* Zone).

Conodonts have also been found in a glauconitic sand layer within the basal part of the mudstone-chalcedonite series in Chojnów Dół, about 1.5 m above the conglomerate (Pl. 9: 1–12), as well as in the chalcedonites (SZANIAWSKI 1980). The Bukówka Sandstone and Mójcza Limestone are developed in Zalesie Nowe, being of lower thickness and covering less time than in Międzygórz or Kielce (CZARNOCKI 1928). In a borehole located nearby (CHLEBOWSKI 1976), Caradoc shales with marly intercalations were documented by conodonts. Therefore, although any Late Caradoc and Early Ashgill strata are not proven to occur in this section, there is still no need to assume a hiatus between the Early Ordovician and Late Ashgill, as proposed by KIELAN (1960). The marls with *Dalmanitina (Mucronaspis)*, occurring close to the top of the Ordovician in Zalesie Nowe, contain a diverse assemblage of trilobites (KIELAN 1960) and brachiopods (TEMPLE 1965).

Fossils from the northern Łysogóry facies region had been collected already in the late nineteenth century by Stanisław KONTKIEWICZ. A pelagic trilobite *Cyclopyge* found by KONTKIEWICZ in Pobroszyn near Opatów was described by GÜRICH (1901) as *Aeglina kontkiewiczi*. The mudstones of the Wólka Beds contain abundant trilobites and brachiopods (KIELAN 1960; COCKS 1988; COCKS and RONG 1988).

SPATIAL DISTRIBUTION OF THE MÓJCZA LIMESTONE FACIES

Outside the Holy Cross Mountains the Ordovician is known in south-eastern Poland exclusively from deep boreholes. Within the Małopolska Massif the development of the Ordovician closely follows that of the Holy Cross Mountains (Text-fig. 2). Close to the north-eastern end of the Massif, near Lubaczów, in Uszkowce 1 and 4 boreholes, at least 20 m, and not more than 30 m, of early Ordovician sandstones occur above the Cambrian shales (the boundary is not represented in the core). One of the

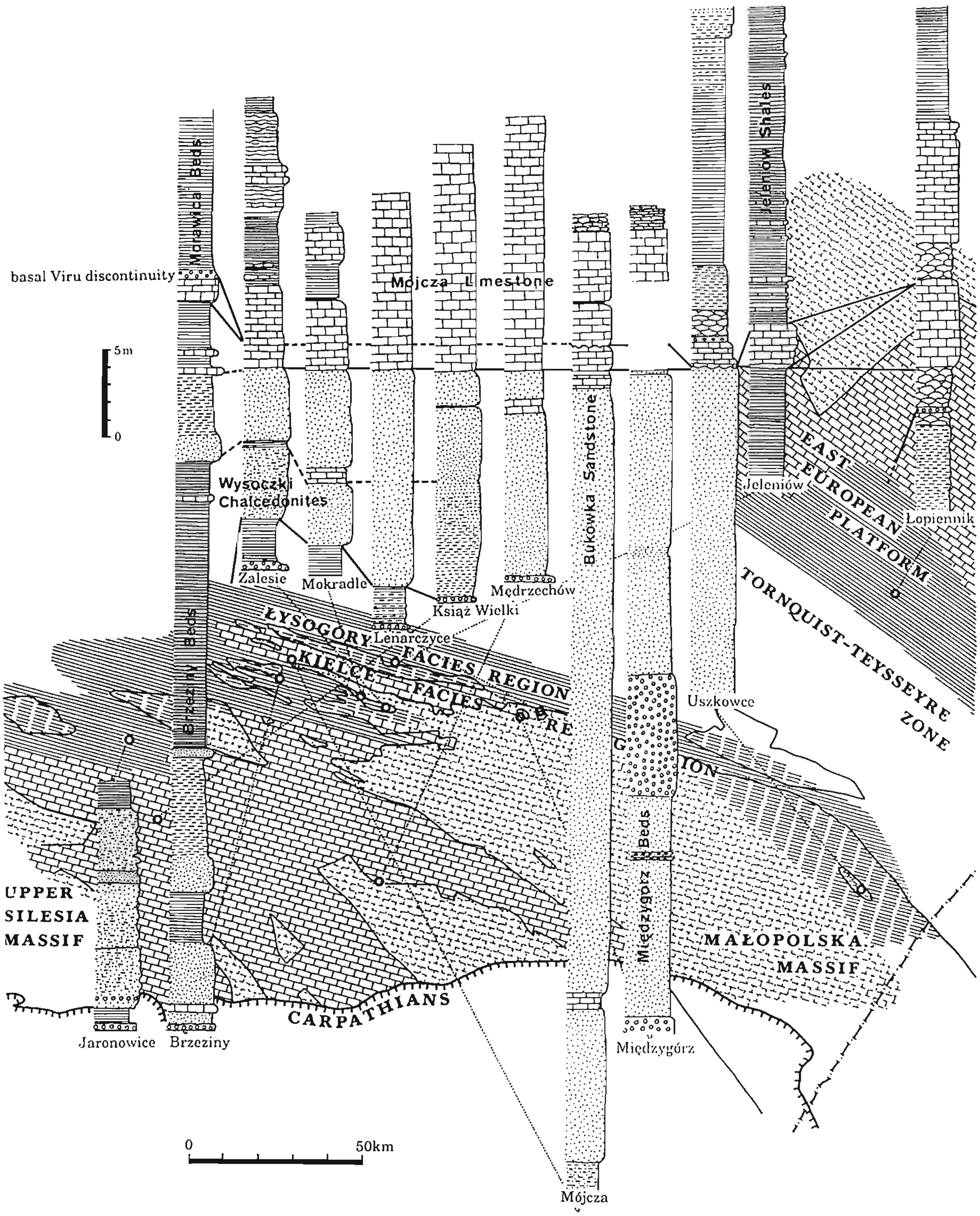


Fig. 2.
Rock columns from the most important localities of the Ordovician in south-eastern Poland superimposed on the distribution map of facies and tectonic units. Brick-like pattern indicates carbonates in the Middle Ordovician, hatchuring argillites, broken lines in later eroded areas. Data from TOMCZYK and TURNAU-MORAWSKA (1967), MODLIŃSKI (1984) and other sources (see text).

shale intercalations at a depth 1139.6 m in the borehole Uszkowce 1 contains dissepimentous dendrograptid rhabdosomes (TOMCZYK 1962) used to support the Tremadoc age for the strata. In fact, a younger age cannot be excluded, as there is no evidence that these dendroids represent the planktonic *Rhabdinopora* and not the long-ranging benthic *Dictyonema*. A discontinuity with pebbles separates the sandstone sequence from the limestones overlying it. It seems possible that the discontinuity corresponds to that in Mójcza, being different in that the erosion removed there all the limestone cover and cut deeper into the sandstones. There is no more than 1.5 m of the limestones and about 4.5 m of marls and mudstones with ferruginous ooids in borehole Uszkowce 1, and above there are only graptolite shales until close to the end of the Ordovician, when a shallowing event(?) is recorded by mudstones with gravel intercalations (TOMCZYK 1962). As often happens with borehole cores, estimations of real thicknesses are not necessarily reliable. The presence of not less than 9 m (and perhaps up to 12 m) of limestones and marls only about 2 km to NW in the borehole Uszkowce 4, may thus be accountable to an error in coring. In any case, the thickness of the limestone is similar to that in Mójcza or Zalesie.

A similarly developed Ordovician is reported from near the southern margin of the Massif, at Mędrzechów near Tarnów, as well as in its center, in the Książ Wielki IG 1 borehole (JURKIEWICZ 1974). A conglomerate bed initiated there the deposition of about 14 m of sandstones (with *Isograptus* in the middle part) that pass continuously into limestones with phosphorite concretions, which again may indicate a stratigraphic condensation and perhaps the presence of the same discontinuity as in Mójcza. Dolomitized organodetrital limestones in the Książ Wielki IG 1 borehole reach 13 m in thickness and contain the conodont *Scabbardella* in its lower half (BEDNARCZYK *in* JURKIEWICZ 1974). A somewhat different section was recorded in the Jaronowice IG 1 borehole located further to the NW. Above a thin basal conglomerate follow shales about 1 m thick layer. Then, a bed of pebbles marks the base of a 12 m thick series of sandstones and mudstones with glauconite in the basal part and shale intercalations. This resembles rather the Łagów facies region than the Kielce one. Graptolite shales, reported to be Silurian in age, cover this sequence directly (JURKIEWICZ 1974). It remains uncertain whether most of the Ordovician is missing there because of the effect of tectonics or of pre-Silurian erosion.

The major carbonate platform of the Baltic region, known from several deep boreholes in NE Poland (MODLIŃSKI 1973, 1982, 1984) is separated by a belt of presumably deep-water deposits (now hidden under a thick cover of the Late Paleozoic and Mesozoic) from the Holy Cross Mountains area. Sequences there are closely similar to those in the Baltic outcrops, being different from these of the Małopolska Massif in the absence of any thick post-Tremadoc, Early Ordovician clastic sequences. The borehole Łopiennik IG 1, located at the margin of the East European Platform is the nearest one to the Małopolska Massif (MODLIŃSKI 1984). Above a 48 m thick series of mudstones of Tremadoc age (with carbonate concretions in 2.5 m thick shales close to the top) a conglomerate bed occurs there, and above it there are no coarse clastics. The time equivalents of the Międzygórz conglomerates and the Bukówka Sandstone are represented in this borehole by argillaceous and biodetrital limestones. The Caradoc is entirely graptolite shales, but in other boreholes, towards the center of the Platform, they are replaced by argillaceous limestones. The whole Ordovician in these areas is thus represented by carbonates, as the Tremadoc mudstones do not occur there.

Coarse clastics seem also to be missing at the Upper Silesia Massif where, in several boreholes in the Myszków area, limestone sequences of remarkable (but not precisely determined) thickness have been reported (PIEKARSKI and SIEWNIAK-WITRUK 1974). These limestones contain the same conodont assemblages as the Mójcza Limestone. Although it remains unclear whether there was any direct connection between the area of carbonate sedimentation of the Małopolska and the Upper Silesia Massifs, their biogeographic proximity is not in doubt (DZIK 1990). In the Upper Silesia Massif the distribution of facies was evidently as complex as in the Holy Cross Mountains. This is shown by another core from the borehole BM 152, located about twenty kilometers further to the west, where the Ordovician is represented by at least 100 m of fine clastics with rare sandstone and limestone intercalations and possibly 60 m of carbonates and 30 m of sandstones of unknown age above. Conodonts are reported from a limestone bed in the middle of the shaly part of the section which, if correctly determined, are definitely Middle Ordovician in age (SIEWNIAK-MADEJ and JEZIOROWSKA *in* GŁADYSZ *et al.* 1990) the age determination being consistent with the distribution of acritarchs in the section (GŁADYSZ *et al.* 1990).

The Ordovician of the Sudetes is totally different. Near Rzeszówek in the Kaczawa Hills, a flysch-like sequence contains sideritic beds with conodonts of the Welsh type (BARANOWSKI and URBANEK 1972; DZIK 1990). This curious distribution of conodont faunas is probably because of completely different location of the south Polish massifs during the Proterozoic to Early Paleozoic.

PALEOGEOGRAPHY OF THE AREA

As has been reviewed above, all the boreholes from the Małopolska Massif that are complete enough to ensure a reliable record invariably contain a stratigraphically condensed organodetrital limestone sequence above much thicker sandstones and below graptolite shales, or at least marls. It is thus clear that the whole Massif was an area of carbonate sedimentation during the Middle Ordovician (at least during the Llanvirn and Llandeilo, in central parts also the Caradoc). Despite the high stratigraphic condensation this limestone rock unit is surprisingly uniform lithologically over the whole area and, judging from the results of conodont studies in some sections, shows a good representation of geological time apart from one large gap in its lower part. This could hardly be possible if any part of the Małopolska Massif was elevated and exposed to erosion during the sedimentation of the limestone series. It seems thus that the whole surface of the Massif was already peneplained in the Early Ordovician and then submerged (a kind of extensive Tiefschwelle of German geologists), and separated from any surrounding sources of clastics by a deeper sea. This can thus be called, with some reservation, a carbonate platform.

The Early Ordovician erosion at the NE margin of the Massif deposited a thick sequence of conglomerates (Międzygórz Beds) which were traditionally associated with the destruction of the Sandomirian (late Cambrian) orogen. The quartz pebbles in the upper part of the Międzygórz conglomerates, as well as in corresponding strata in Koziel, indicate the presence of a yet unrecognized crystalline source in the Małopolska Massif. However, among pebbles there are also pieces of Early Ordovician clays that could hardly be deposited immediately after an orogeny in the area. Either thus there was a post-Tremadoc orogeny (which is rather unlikely) or there had been quite another erosional event, which resulted in peneplanation of the Małopolska Massif before the Early Ordovician clays have developed. The former can be definitely excluded because the late Tremadoc conodonts date the Wysoczki Chalcedonite and the glauconitic sand immediately above the basal conglomerate which rests on folded Cambrian strata in the Łagów area. There were thus several eustatic episodes of erosion in the Holy Cross Mountains before the deposition of the Bukówka Sandstone. Their dating is an interesting question.

The Międzygórz conglomerate itself may have originated, as suggested by the presence of allegedly Arenig chitinozoans (CHLEBOWSKI and SZANIAWSKI 1974), at the beginning of the worldwide Late Arenig regression (FORTEY 1984), possibly glacially controlled (see ERDTMANN 1986), and most probably is an effect of a local debris flow. The end of this long regressive epoch seems to correspond to the development of the Šárka Shales in Bohemia, iron ores in Thuringia, and also the beginning of the Mójcza Limestone sedimentation in the Małopolska Massif.

The erosion immediately preceding the basal Ordovician conglomerate of the Łagów region perhaps corresponds with the eustatic fall that is marked in the Baltic black shale successions by the *Ceratopyge* Limestone intercalation (see FORTEY 1984). The glauconitic sand with conodonts would then indicate the beginning of the following transgression, with the chalcedonites developed at its maximum. The *Ceratopyge* event is still unlikely to be the major cause for the peneplanation of the Małopolska Massif. The question to be answered is where the sediment removed from the Sandomirian orogen were deposited? Evidently, they must have been located far outside the Łagów region; such an extent of the peneplained area suggests an extraordinary fall in the sea level. Possibly, this was the topmost Cambrian *Acerocare* regression (Lange Ranch Eustatic Event of MILLER 1984; see discussion in BRYANT and SMITH 1990) of worldwide significance. Glacial deposits of similar age from Argentina and Bolivia indicate its possible cause. If this was really the case, the Sandomirian orogeny preceded the base of the Tremadoc.

In the southern part of the Małopolska Massif only a thin cover of sandstones is represented. They are completely missing in the northernmost Łysogóry facies region, where the Cambrian-Ordovician transition is continuous in shaly facies (TOMCZYKOWA 1968). There is thus no influence of any of the erosion events that resulted in the destruction of the Sandomirides. This is evidence of a tectonic origin for the present geographic proximity of the Kielce and Łysogóry facies regions.

The Upper Silesia Massif was probably already accreted to the Małopolska Massif in the Ordovician. Now these areas are separated by a belt of strongly folded early Paleozoic rocks (BUKOWY 1984). It is difficult to trace distribution of facies during the Ordovician in the area. The shallow furrow of the Łagów facies region presumably represents a remnant of an area earlier separating the two tectonic subunits: the Kielce region of the Holy Cross Mountains and the Jędrzejów Massif. It gaped towards the NW where a deepening is indicated by the predominance of graptolite shales in the Brzeziny section (Jaronowice may possibly belong there, too).

Whether the carbonate platform of the Małopolska Massif had a connection with the Upper Silesia Massif or not, their close proximity is clearly shown by the similarity of conodont faunas. The apparent lack of any coarse clastics in the Myszków area seems to be consistent with a general trend in their distribution. Their share of the Ordovician rock column decreases towards the south, with increasing distance from the source area of the Sandomirian orogen. The Ordovician of the SW margin of the East European Platform (MODLIŃSKI 1982, 1984) resembles in many respects that of the Małopolska Massif but this may be due to the influence of the same eustatic factors in the same climatic zone. The conodonts from Mójcza and the boreholes Lesieniec 1, Gałajny 2, Niwa and others are generally similar to each other, with a degree of similarity comparable to that of the South China Yangtze region. However, the ostracodes (OLEMPSKA 1994) and other groups of the benthos from strata above the Bukówka Sandstone are basically different from coeval Baltic assemblages. This is consistent with the distribution of facies, which indicates separation of the Małopolska Massif from the East European Platform by a belt of deep-sea, possibly oceanic, sediments (MODLIŃSKI 1982; DADLEZ 1987). There is no direct continuity between the carbonate platforms of these areas.

Even more profound is the difference in facies and faunas between the Baltic-like Ordovician of the Małopolska-Upper Silesia area and the Sudetes. These were probably microcontinents located in different climatic zones, separated by an ocean, and they have been unified not earlier than the Variscan orogeny. Limestones are missing in the Sudetic Ordovician but it is not yet clear whether it belongs to the same tectonic unit at that time as Thuringia and the Moldanubicum, where in the Late Ordovician glacial deposits (dropstones) are reported.

It may be concluded that the southern Polish massifs represent a separate pre-Caledonian Małopolska microcontinent (DZIK 1978, 1983). It was coherent enough to allow, after a long history of clastic sedimentation, stable and monotonous carbonate sedimentation during almost thirty million years, and over the whole area of its peneplained surface. There is no evidence of any tectonic activity in this area during the Ordovician. The Sandomirian orogeny had probably taken place before the Tremadoc. The presence of reworked shales with possibly early Arenig fossils in the Międzygórz conglomerate (CHLEBOWSKI and SZANIAWSKI 1974) is presumably a result of one of the eustatic drops in the sea level, which also resulted in removal of Tremadoc sediments from most of the East European Platform (LENDZION *et al.* 1979). The sedimentary gap close to the base of the Mójcza Limestone was evidently an effect of submarine erosion, resulting perhaps also in an increased supply of ferruginous ooids to the deeper parts of the basin. Its eustatic nature is shown by its wide geographic extension, because it is also known in many regions far away from the Małopolska Massif.

No generally accepted reconstruction of the Ordovician paleogeography of the central Europe is yet available. Without a provisional hypothesis concerning the distribution of the central European massifs little progress in understanding the geological and biological evolution of the pre-Caledonian Europe can be achieved. For the purposes of the present paper a modification is proposed of the model that has been steadily improved over the last decade (COCKS and FORTEY 1982) (Text-fig. 3). Its geological framework is based on the paleomagnetic data from the major land areas of the Ordovician

Fig. 3.
Tentative paleogeographic position of the discussed continents and terranes in the Llandeilo time (brick pattern indicates epicontinental seas with dominant limestone sedimentation, in hachured regions only clastics are known).

(VAN DER VOO 1989; LEWANDOWSKI 1987, 1992) and the current models of the development of the orogens in between.

For the Caledonides the model of PICKERING *et al.* (1988) is accepted here, except for the following alterations:

(1) In the Trondheim area in the Norwegian Caledonides a terrane with strong Midcontinent, that is equatorial, faunal affinities occurs. Conodont faunas from there are totally dissimilar to the coeval Baltic ones (BERGSTRÖM 1979). At least the northernmost nappes of the Norwegian Caledonides belonged thus to North America. This means that the volcanic arcs now incorporated into the Caledonides originated in connection with Laurentia and the subduction zone was in between.

(2) The presence of the cold-water *Hamarodus* fauna throughout almost the whole Late Ordovician of the Baltic region (BERGSTRÖM 1971; SWEET and BERGSTRÖM 1984), which in England and Wales occurs only temporarily in the Middle Ashgill (ORCHARD 1980), strongly testifies against the Ashgill time of the closure of the Iapetus in its Baltic part.

(3) It seems doubtful whether the TORNQUIST-TEYSSEYRE lineament was a great shear zone (DADLEZ 1982). The Małopolska Massif, located outside the lineament shows too close faunistic similarities with the adjacent areas on the East European Platform during the whole Ordovician. A minor (some 350 km) displacement, proposed by PEGRUM (1984) to fit pre-Variscan structures on both sides of the lineament, cannot be rejected but may not be necessary.

(4) A significant dislocation may correspond, rather, with the lineament separating the Kielce and Łysogóry regions of the Holy Cross Mountains. Paleomagnetic data from the Łysogóry region show the same apparent polar wander path as the Baltic area but the Kielce region was quite outboard from it until the Devonian (LEWANDOWSKI 1992). To fit data from both areas a position of the Kielce region (and thus the Małopolska Massif) close to Crimea in the Tremadoc is proposed, followed its gradual migration to its present position. Before the Late Cambrian migration of the Massif it was not connected with that of Baltica at all, perhaps it rather followed Gondwana.

A prerequisite of any reliable reconstruction of the pre Caledonian paleogeography must be, obviously, a properly made pre-Variscan map of mid-European tectonic units. Here evidence seems even more equivocal but provisionally the model of NEUGEBAUER (1989) may be accepted. Necessary changes refer to:

(1) Except for a brief cooling period in the Middle Ashgill (Rawtheyan) when the *Hamarodus* fauna appeared in Wales and England these areas had, at least since the base of the Caradoc, conodont faunas of close Midcontinent affinities. It seems thus unlikely that Avalonia was then in proximity to Gondwana as suggested by trilobite faunas. It may be of some importance in considering this disparity, that the conodonts and trilobites not only represent different ecologic groups (which alone may give different results; see FORTEY and MELLISH 1992) but their biogeographic analyses were performed on different (species *versus* generic) levels.

(2) Even less likely is an equatorial position of Baltica in the Middle Ordovician because of the basic dissimilarity of its faunas to those of the equatorial regions of that time (Midcontinent, Siberia, north China) except for brief incursions, presumably corresponding to periodic warmings (see DZIK 1983).

The resulting map (Text-fig. 2) accepts NEUGEBAUER's (1989) proposal that the Mediterranean massifs developed along the margin of Gondwana as island arcs, although for us the position of Meseta from the pre-Atlantic epoch seems more justified than that assumed by NEUGEBAUER. The paleomagnetic evidence (LEWANDOWSKI 1987, 1992) indicates also that the Małopolska microcontinent followed Gondwana in its drift across the south pole during the Cambrian and Early Ordovician. In the Arenig it was located at the latitude of about 60° S, reaching the latitude of 10° S in the Late Silurian. At least until the Early Ordovician Baltica did not change significantly in its latitudinal position but, as the biogeographic differences between its and the Armorican (and those located at similar latitudes) faunas suggest, their longitudinal position differed significantly. The simplest interpretation of this trifold biogeographic pattern (DZIK 1990) is to assume that Baltica was drifting from the east towards the Gondwana island arcs, reaching the Małopolska island at the beginning of the Ordovician. The Sandomirian orogeny might possibly be a result of the accretion, which was not completed until the Late Devonian, when the depression separating the Małopolska Massif from the East European Platform was finally filled with sediments and consolidated.

Of some interest in this respect is the Ordovician in the Hardangervidda area, west of the Oslo graben in Norway which, like the Małopolska sections, was located next to the typically Baltic Ordovician sequences, and differs from them in the presence of coarse clastics in the Early Ordovician. In Hardangervidda, the 100–150 m thick Arenig Holberg Quarzite formation is covered with 5–6 m of limestones of the Bjørnaskalle Formation, followed by fine clastics of the Solnut Formation. The sandstones, as in the Holy Cross Mountains, contain the *Antigonambonites* brachiopod fauna (BRUTON *et al.* 1984). One may surmise that this metamorphosed paraautochthonous unit might represent another segment of the same island arc accreted to the Baltica continent.

Subsequent paths of migration of the Małopolska Massif and the East European Platform were concerted, and they moved, together with Gondwana, towards equatorially situated Laurentia. This profound change of latitude is well shown by the appearance of coral-stromatoporoid reefs in the Baltic area, first in its Norwegian part. The northward drift of the most southerly situated Małopolska

Massif was not fast enough to reach subtropical regions and develop warm-water ecosystems before the Late Ordovician glacial period. Limestones with corals appear there, as in the Sudetes, beginning from the Late Silurian. The sequence of events in the western part of Iapetus proposed by PICKERING *et al.* (1988) requires perhaps a slight delay of the final closure, just to avoid problems with the presence of the *Hamarodus* fauna in Armorica and its absence in the Midcontinent.

It follows from the proposed paleogeographic position of the Małopolska Massif during the Ordovician, that it was located close to the western margin of a continent in relatively high latitudes. This was the position at which intense phosphatization of sediments could be expected.

LITHOLOGICAL UNITS OF THE ORDOVICIAN IN THE MAŁOPOLSKA MASSIF

To avoid misunderstandings that may result from a different usage of the traditional lithostratigraphic names a brief synopsis of each one used in this volume are given below.

WYSOCZKI CHALCEDONITE FORMATION

Type section. — Wysoczki near Bogoria (SAMSONOWICZ *in* KOZŁOWSKI 1948).

Base. — At the basal Ordovician conglomerate. The basal part of the formation is best exposed in Chojnów Dół.

Lithology. — Mostly mudstones with cherty intercalations.

Top. — At the base of the massive sandstones with inarticulate brachiopods. Best exposed at Zalesie Nowe.

Distribution. — Confined to the Łagów facies region.

Age. — Conodonts from the clay immediately above the conglomerate, from the glauconitic sandstone about 1.5 m above (Pl. 9: 10), as well as from the chalcedonites in Chojnów Dół, but also from Wysoczki (SZANIAWSKI 1980) unequivocally indicate the Late Tremadoc age of the whole formation.

The term "Wysoczki chalcedonites" has been widely used since publication of KOZŁOWSKI's monograph (1948) so there is no need to replace it with other poorly defined terms. The Zbilutka beds of BEDNARCZYK (1964) had the original meaning of a chronostratigraphic rather than lithostratigraphic unit and the term was finally dropped by the author himself (BEDNARCZYK 1971). In fact, chalcedonites constitute only a fraction of the formation, which consists mostly of mudstones and thin bedded sandstones, but they are its most characteristic element.

MIĘDZYGÓRZ FORMATION

Type section. — Międzygórz quarry near Sandomierz (Pl. 5; Text-figs 1–2). The most detailed description of the locality given in TOMCZYK (1954).

Base. — At the change to thick-bedded dark glauconitic sandstones with inarticulate brachiopods. Well exposed only in Zalesie Nowe.

Lithology. — Thick bedded conglomerates and dark glauconitic sandstones.

Top. — At the transition to the light coloured orthid sandstones. In other outcrops it corresponds to the appearance of a limestone intercalation (CZARNOCKI 1928) or perhaps even shales (see TOMCZYK and TURNAU-MORAWSKA 1964).

Distribution. — Best developed thick conglomerates and dark sandstones with glauconite are exposed in the Międzygórz quarry. In the remaining outcrops in the Kielce and Łagów facies regions the formation is represented by sandstones with inarticulate brachiopods and glauconite.

Age. — The presence of chitinozoans in clay pebbles within the main conglomerates in Międzygórz (CHLEBOWSKI and SZANIAWSKI 1974) suggests a post-Tremadoc age for the formation, most probably the Early Arenig. In a thin intercalation of such clay 2.4 m below the top of the conglomerate benthic graptolites occur.

The unit was recognized by CZARNOCKI (1928) as the "glauconitic sandstone with *Obolus siluricus* and *Acrothele ceratopygarum*". In the type locality the name was introduced by SAMSONOWICZ in 1916 (according to TOMCZYK 1954) for a coarse clastic series at the base of the Ordovician. The Koziel beds of BEDNARCZYK (1964) may also belong there. Fossils have been illustrated in BEDNARCZYK (1964), SZANIAWSKI and CHLEBOWSKI (1974).

BUKÓWKA SANDSTONE FORMATION

Type section. — Bukówka quarry in Kielce (Text-figs 1–2).

Base. — At the base of the limestones with "*Orthis* cf. *Christianiae*" of CZARNOCKI (1928) in the type locality.

Lithology. — Thick and medium bedded light fossiliferous sandstones.

Top. — At the base of the thick-bedded sandy limestone of the Mójcza Limestone Formation (now exposed only in Mójcza but reported in other outcrops and boreholes).

Distribution. — Known in the whole Kielce and Łagów facies regions, also in the subsurface of the Małopolska Massif.

Age. — The whole Bukówka Sandstone is rather uniform faunistically (CZARNOCKI 1928); conodonts from the limestone intercalations suggest Late Volkhovian age (DZIK 1990).

Identified as a rock unit by ROEMER (1866), dated by MICHALSKI (1883). CZARNOCKI (1928) recognized it in the whole Holy Cross Mountains area as the "*Orthis* Sandstone". Fossils listed by him indicate a basic similarity of the faunal assemblages of both sandstones and the limestone beds at their base. BEDNARCZYK (1971) gave it the rank of "beds" within his chronostratigraphically understood Dyminy "formation". Fossils illustrated by GÜRICH (1901), YOCHELSON (1962), BEDNARCZYK (1964), DZIK (1985).

MÓJCZA LIMESTONE FORMATION

Type section. — A small quarry on the Skała hill near Mójcza, Kielce (Pl. 1; Text-figs 1–2, 4).

Base. — At the transition from the decalcified topmost strata of the Bukówka Sandstone to sandy limestones, 4.5 m below the bentonite in the type section.

Lithology. — Thick bedded organodetrital limestones with phosphate-coated grains and ferruginous ooids.

Top. — At the transition from the organodetrital limestone with ferruginous ooids to argillaceous limestones and marls; in the type section 3.5 m above the bentonite.

Distribution. — Known from the whole Kielce facies region and from the Łagów area in the Holy Cross Mountains, as well as from the subsurface of the Małopolska Massif. In the Brzeziny area it may correspond to the chamosite series developed between the Brzeziny beds and the Morawica shales (see TOMCZYK and TURNAU-MORAWSKA 1964).

Age. — The stratigraphic range of the formation is precisely determined only in the type section where its base is dated as the top of the Arenig (early Kundan, *Amorphognathus variabilis* Zone) while the top as the latest Caradoc (*A. superbus* Zone). At Międzygórz its base is presumably younger but the transition to the overlying marly Zalesie Formation (Ashgill), highly condensed stratigraphically in this section, is somewhat obliterated by a dolomitization. In the sections of the Łagów facies zone the change from limestones to shales had already happened by the Early Caradoc but at present this cannot be precisely determined in the outcrops. Even less data are available for the Brzeziny area and the Łysogóry facies region where carbonates seem to be even more restricted in time, judging from graptolites. The strata with ferruginous ooids in the Brzeziny boreholes were split by TOMCZYK and TURNAU-MORAWSKA (1964) between the upper Brzeziny beds and lower Morawica shales.

The organodetrital limestones included in the formation were identified by GÜRICH (1901) in the type locality, but they were noticed even earlier at Międzygórz by ZEUSCHNER (1869). Macrofossils are illustrated in GÜRICH (1901), CZARNOCKI and SAMSONOWICZ (1913), BEDNARCZYK (1964), and

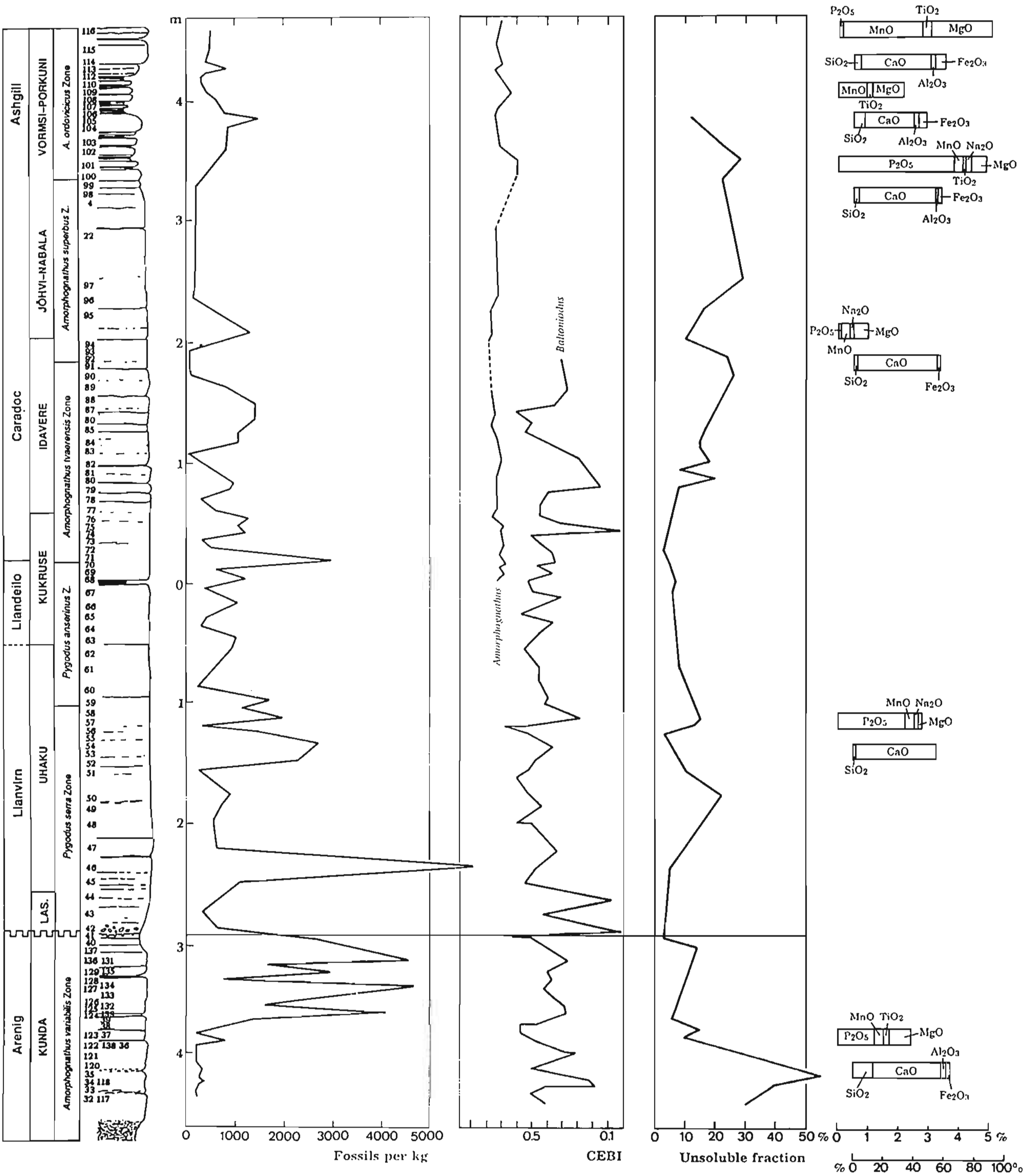


Fig. 4.
Position of samples in the section of the Mójcza Limestone in Mójcza, frequency of phosphatic and phosphatized fossils per kilogram of the rock, plot of the conodont elements balancing index (CEBI), content of insoluble (in a weak acetic acid) residue in the rock, and its chemical composition.

DZIK (1985). Conodonts were studied by SPASOV and TELLER (1962), BEDNARCZYK (1971), BERGSTRÖM (1971) and DZIK (1976, 1978, 1990, 1994a).

ZALESIE FORMATION

Type section. — The ravine section at Zalesie Nowe near Łagów (Text-figs 1–2).

Base. — At the change from the dolomitized Mójcza Limestone to marls and shales (not exposed now and inferred from description by CZARNOCKI 1928).

Lithology. — Thin bedded marls, shales, and argillaceous limestones.

Top. — At the base of the black Silurian (possibly latest Ordovician) graptolite shales of the Bardo beds.

Distribution. — The formation is well developed in the Łagów facies regions. We include in it not only the topmost fossiliferous mudstones with a Late Ashgill trilobite fauna (KIELAN 1956) but all argillaceous strata above the dolomitized Mójcza Limestone in the Zalesie Nowe section. In the vicinities of Kielce it seems to be represented only by a thin cover of marls and at Międzygórz by thin bedded dolomites and lightly coloured shales.

Age. — Varies strongly. In the areas of its typical development the base seems to correspond to the *Nemagraptus gracilis* transgressive eustatic event (the base of Caradoc). The *Dalmanitina (Mucronaspis)* trilobite assemblage occurs close to the top of the formation (KIELAN 1956). At Mójcza it did not appear earlier than in the Ashgill. The strata had been recognized by CZARNOCKI (1928) in the type area.

In the Łysogóry region argillaceous strata developed above some limestone intercalations, possibly corresponding facially to the Mójcza Limestone, show similar subdivision to that in the Łagów area although are of much higher thickness. Their lower part is represented by graptolite shales of the Jeleniów beds. Above, mudstones, marls and/or dolomites of the Wólka beds occur. They contain Early Ashgill trilobite assemblages in the lower part, the upper one being unfossiliferous and thus of uncertain age (KIELAN 1956).

The latest Ordovician *Glyptograptus persculptus* Zone may possibly be represented in the basal Bardo beds of the Łagów area (see KIELAN 1960).

Macrofossils from the Zalesie Formation and corresponding strata in the Łysogóry region were described by KIELAN (1960), TEMPLE (1965), and COCKS and RONG (1988).

LITHOLOGICAL CHARACTERISTICS AND SEDIMENTARY HISTORY OF THE MÓJCZA LIMESTONE

There is a continuous transition from the Bukówka Sandstone (Text-fig. 4; Pl. 2: 1) to the Mójcza Limestone in the type locality. In the lowermost part of the section the rock changes from carbonate sandstones (Pl. 2: 3) to a sandy limestone (Pl. 2: 2, 4) (strongly recrystallized biosparites). Quartz grains in these beds are 0.1–0.2 mm in size, well sorted and poorly rounded. In these respects they are similar to those in the Bukówka Sandstone, thus probably from the same source. The quantity of quartz grains diminishes slowly, although irregularly (see Pl. 2: 2), and above the sample MA-45 no quartz has been identified in thin sections. There is only one horizon, about 1.5 meters from the base of the section, with phosphorite pebbles (extraclasts of the earliest Ordovician or Cambrian; Pl. 2: 6) burrows (Pl. 2: 5–6) and perhaps erosional pockets representing a sedimentary discontinuity (perhaps with some submarine erosion) with a few conodont subzones missing there (DZIK 1990). The rest of the section shows a surprising continuity of sedimentation on the macroscale, an observation supported by conodont studies, showing no deep reworking or clearly mixed assemblages.

In the lower and upper parts of the section there is distinct bedding, with particular beds from about 20 cm at the base to over 50 cm (and poorly developed) in the middle, near the bentonite layer. The central portion of the section, both above and below the bentonite layer (samples 60–67, 68–75), as well at the top of the section (samples 96–98) shows very poor bedding (Pl. 1), despite the fact that it is also strongly condensed, as indicated by conodonts. The absence of bedding indicates intense bioturbation (and continuity of sedimentation under very stable conditions) but some examples of sudden appearance and disappearance of species within assemblages at different levels suggests that

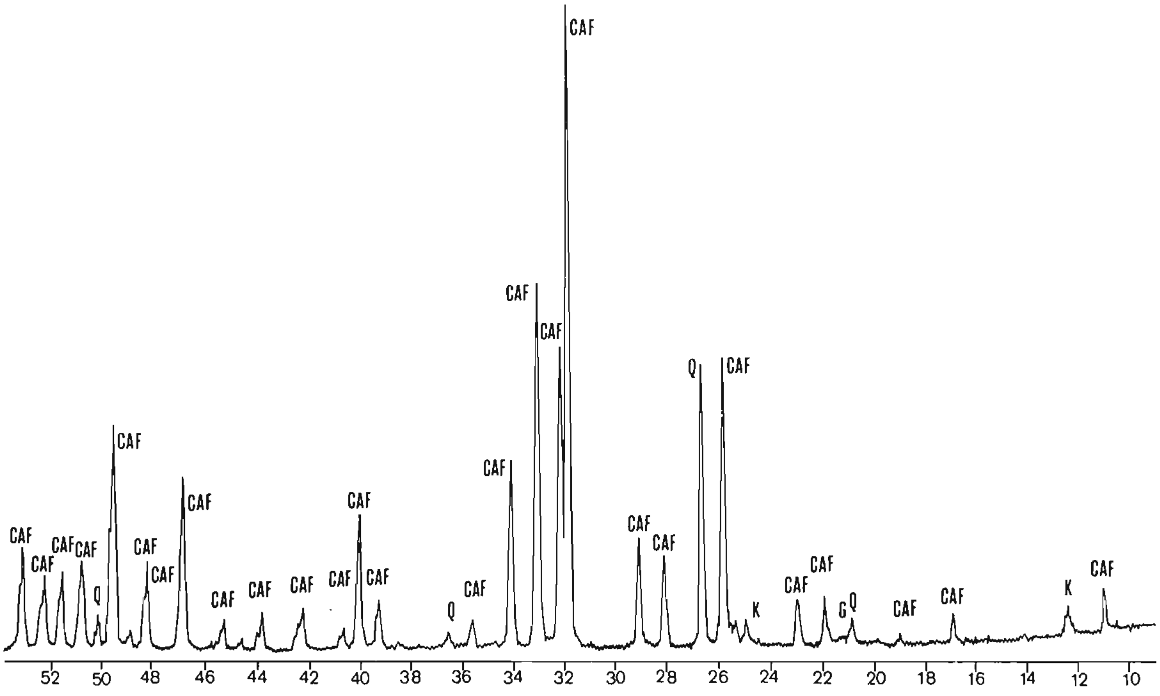


Fig. 5.
X-ray diffractogram of the phosphatic envelopes (residue after dissolving in a weak acetic acid) from the Mójcza Limestone; CAF – carbonate fluoroapatite, Q – quartz, G – glauconite, K – kaolinite.

the depth of reworking was rather shallow, apparently less than the thickness of a standard sample. At the microscale (thin section) there are, however, common traces of bioturbation, small discontinuities, or laminations shown by a rapid change in grain size.

The lithological character of the most of the section is monotonous (Pl. 3: 1–6) and may be described as strongly recrystallized biosparites, biomicrosparites and sometimes poorly washed biosparites (packstones to grainstones). The dominant bioclasts are (in various proportion) ostracodes, echinoderm ossicles (dominating in the central and upper part of the Mójcza Limestone), trilobite and brachiopod fragments (dominant at the bottom in sandy limestones), and other unrecognizable small organic detritus. Bioclasts are very small as a rule (0.4–0.5 mm on average, but reaching up to 2–3 mm; exceptionally up to 5 mm) being represented only by fragments of skeletons. Larger fossils are known to occur only exceptionally (except in the lowermost part of the section) and are associated with bedding planes; most probably they are of tempestitic origin. Small bioclasts often show microborings (OLEMPSKA 1986). Although the rock is now a biosparite, it must have once contained a considerable amount of carbonate mud, because an important part of the present sparite is of neomorphic origin; some samples still contain micrite patches.

The most characteristic inorganic components of the Mójcza Limestone are ferruginous ooids (TURNAU-MORAWSKA 1961; ŁĄCKA 1990). The size of the ooids is rather uniform, varying from 1.5 to 2 mm in diameter (Pl. 3: 5–6). They are unevenly distributed and even in neighbouring beds may be either common or very rare. Within a bed their distribution is also uneven. When common, the ooids usually occur in patches, most probably an effect of bioturbation. According to ŁĄCKA (1990) the ooids consist of kaolinite, illite/smectite, quartz and carbonate fluoroapatite (Text-fig. 5), but the kaolinite-goethite-quartz association is a product of primary chlorite weathering.

Ooids (usually 1.5–2 mm in diameter) developed round bioclasts occur as low as in the sample MA-42, but they are common only above the bentonite layer, which more or less coincides with the paleontologically established *Nemagraptus gracilis* transgression. The ooids are very numerous at the top of the Mójcza Limestone (samples MA-80, 84, 93, 96, and especially 99). The appearance of the ooids thus seems to be controlled by delivery of iron to the basin, either in connection with the vulcanism documented by the bentonite, and/or transgression washing out iron from the land. Unfortunately, the genesis of ferruginous ooids is still debated, and seems to be not limited to any specific palaeoenvironment (see YOUNG and TAYLOR 1989) but generally interpreted as a product of early diagenesis of superficial sediments in a sediment starved marine environment, while ironstones seem to be associated with a high see level (YOUNG 1992). The calcareous sandstones and sandy limestones at the bottom contain sporadic chlorite grains. Ordovician iron ooids are widespread in the world (see YOUNG and TAYLOR 1989; YOUNG 1992) and common also in the Baltic region (see SUTERSSON 1986, 1988a, b, 1989), but occur usually as discrete ironstone beds.

Above the Mójcza Limestone there is a unit of about 1.5 m of brown and yellow argillaceous, well-bedded limestones, interbedded with calcareous shales (Zalesie Formation). They are heavily impregnated with iron oxides (and perhaps some manganese oxides are also present) of a late diagenetic origin. The change from the underlying Mójcza Limestone is sudden. The argillaceous limestones contain no echinoderms, and fragments of trilobites and ostracodes are the only clasts recognizable in thin sections (Pl. 4: 1–3, 5). Similar to the Mójcza Limestone below, they contain no recognizable macrofossils, only small fragments. No phosphatic envelopes have been recognized around them. These rocks may be classified as biomicrites (sparse to dense) or biomicrosparites (Pl. 4: 1–6). They contain no ooids but some cauliflower-like structures (Pl. 4: 4, 6), up to 6 mm in diameter, consisting of goethite; calcite and kaolinite (but no CFA) have been found. The switch from the ooid to "cauliflower" formation was probably caused by changes in the hydrodynamic bottom energy, the cauliflower structures forming when the bottom energy was very low.

The pattern of the distribution of insoluble residue (left after dissolving the rock in a weak acetic acid) is generally rather simple. In the lower part of the section, where calcareous sandstones and sandy limestones occur, the residue is greatest (Text-fig. 4) and the quartz content is responsible for this. In the rest of the section it varies, higher values being identified in horizons where most of the fossils are covered with phosphatic envelopes (carbonate fluoroapatite is resistant to dissolving in acetic acid) and with a high content of ferruginous ooids. The argillaceous limestones above the Mójcza Limestone also show increased content of the acid-resitant residue but there it is connected with a high clay content. The distribution of the residue in the main part of the Mójcza Limestone does not show any clear pattern, as a result of the varying degree of phosphatization. If this is really the case, then a lower content of residue (i.e. phosphatized bioclasts and ooids) may indicate a higher sedimentation rate, a hypothesis that is supported by frequent association of a less pronounced bedding with a lower content of residue.

Geochemical analyses of six bulk samples (Text-fig. 5), representative of the formation lithological variability, have been carried out by Dr. Bożena ŁĄCKA (Institute of Geological Sciences of the Polish Academy of Sciences). The pattern revealed is rather simple, the lower part of the section shows high content of SiO_2 (quartz) as well as Fe_2O_3, Al_2O_3, MnO and TiO_2. This is an expression of the detrital quartz and abundant iron hydroxides and oxides. The main part of the Mójcza Limestone is characterized by a very low content of SiO_2 and relatively high content of Na_2O, typical of limestones, variation in P_2O_5 content is clearly caused by variations in phosphatic envelopes of fossils and the number of ooids (especially in the sample MA-99). The high content of MgO in the marly limestone atop the Mójcza Limestone is clearly a result of the higher clay content, as no dolomitization has been observed. The elevated contents of MnO in these rocks is most probably an effect of late diagenetic impregnations with manganese minerals.

The sedimentary environment of the Mójcza Limestone is rather difficult to interpret. Only one major section is available (strong dolomitization in Międzygórz hampers any reliable analysis), which is strangely homogeneous and lacking any sedimentary structures. As follows from the paleontological data, the section is only about 8 meters thick and represents most of the Ordovician, and thus must be extremely condensed. Such condensation should result in numerous discontinuities, which in the Mójcza Limestone are lacking (with apparent one exception). Even the bedding is poorly expressed and the lithology changes gradually, mostly being homogeneous.

The only explanation for these peculiarities we can offer is deposition in an extremely stable environment with a very slow (although not necessarily uniform) sedimentation rate, coupled with homogenization of the sediment by very shallow bioturbation. Another characteristic feature of the formation is the absence (or at least rarity) of entire macrofossils. A plausible explanation is that they were destroyed during prolonged periods of exposure on the sea bottom. Bioerosion is well documented in Mójcza (OLEMPSKA 1986). Such exposure is also necessary for the origin of phosphatic envelopes. Considering the abundance of well-sorted small bioclasts (both disarticulated and broken fragments) one might suppose that the bioclasts were winnowed. Nevertheless, the real influence of these factors is far from being clear. Almost all identifiable specimens of the molluscs, brachiopods and trilobites from the Mójcza Limestone represent early ontogenetic stages. In the abundant detritus of double-walled bryozoans, with the ability of strong secondary thickening of colony branches, fragments of mature colonies are missing. The Mójcza communities were thus of a very high juvenile mortality rate. At least in the case of the bryozoans the lack of exposed larger hard objects that could be colonized by larvae was a factor increasing the juvenile mortality (DZIK 1994b). This testifies against winnowing; apparently the bottom was permanently covered with a fine calcareous mud. If any large bottom organisms, and consequently macrofossils, were originally missing, some special factors which prohibited benthic life had to be involved, and these are difficult to find.

The distribution of quartz and other nonbioclastic material clearly indicates a separation of the Mójcza area from the source of clastics, so that most of the time (samples MA-42 up to MA-99) it was far removed from shore in an open sea. The clay material suddenly appearing in the limestones on top of the Mójcza Limestone was also deposited in low bottom energy conditions (as follows from the lithology). Possibly the slightly increased delivery of clastics was caused by Ashgill glaciations (see HAMBREY 1985).

The most important fossils with originally phosphatic skeletons in the Mójcza Limestone are pelagic conodonts and possibly benthic or epiplanktonic acrotretacean brachiopods. It would not be safe to assume that the biological productivity of the conodonts was stable during the sedimentation of the entire Mójcza Limestone, and that their distribution was controlled solely by the sedimentation rate (Text-fig. 4). Obviously, also a stable sedimentation rate would hardly be acceptable. Anyway, it may be meaningful that the frequency of conodont elements varies from 500 to 1000 per kilogram through most of the section, increasing strongly only about 0.8 m below the discontinuity surface, at 0.7 m above the discontinuity, and at the beginning of the *Nemagraptus gracilis* transgression. The first two events can be explained by changes in the sedimentation rate (see above), the latter one was probably an effect of real increase in biological productivity (as sedimentary features rather suggest increase in sedimentation rate there), perhaps associated with the global warming of the climate.

There is another peculiarity in the distribution of conodont elements that strictly depends on sedimentary conditions. It is now well established that because of different hydrodynamic properties of different element types within the same apparatus conodont samples are usually rich in the robust platform element types (**sp–oz**), while the remaining delicate elements are numerically underrepresented. This feature is usually called the "degree of unbalancing of samples". The ratio of platform and remaining elements for any apparatus species, called here "Conodont Elements Balance Index" (CEBI), can be used to estimate the hydrodynamic energy at the sea bottom and the degree of reworking of sediment. A high ratio means a high energy environment with strong winnowing, the value 3.75 (perhaps 2.83 in some balognathids) would correspond to the conditions when all the element types have the same chance of preservation, while lower values would indicate a transfer of gracile elements from outside.

At first sight the oscillations in the CEBI values seem to be random, being mostly an effect of the sampling error and irregularities in the sedimentary process (Text-fig. 4). When compared with the rock lithology some patterns can be revealed. In most cases the unbalancing dramatically increases just below any discontinuity (bedding) surface and suddenly drops at the base of the succeeding bed. Such a change clearly took place at the two bedding planes with abundant macrofossils close to the base of the Mójcza Formation and at the basal Viru discontinuity surface. This can be interpreted as an expression of increased winnowing preceding the development of a discontinuity (or just a bedding surface), and an increase in sedimentation rate at the beginning of a new cycle. A decrease in winnowing seems to be also responsible for changes at the beginning of the *Nemagraptus gracilis* transgressive event, when both *Baltoniodus* and *Amorphognathus* samples are rich in delicate ramiform elements.

Significant enrichment in the delicate ramiform elements has been observed in some samples of *Baltoniodus* (Text-fig. 4). This phenomenon, being associated with the macrofossil-rich horizons and interpreted as an indication of a transport of fine sediment from the outside, supports their interpretation as tempestitic in origin.

The most common kinds of phosphatized fossils in the Mójcza Limestone are ostracode valves (originally calcitic), echinoderm ossicles (originally high magnesium calcite), and mollusc conchs (originally aragonitic). Usually they are preserved as phosphatic linings of external and internal surfaces (see Pl. 10); rarely the whole shell is replaced with calcium phosphate, and this usually happens with aragonitic fossils. As revealed by X-ray and SEM analyses, in all cases these linings are composed of extremely fine-grained and poorly crystalline carbonate fluoroapatite. The envelopes may cover previously broken bioclasts but no bioclasts with broken envelopes have been identified.

FAUNAL CHANGES AT THE BASE OF THE MÓJCZA LIMESTONE

The two groups of fossils that can be studied at the transition between the Bukówka Sandstone and the Mójcza Limestone are trilobites and articulate brachiopods. Within the Bukówka Sandstone an assemblage composed of several articulate brachiopod species, a single species of bellerophontid mollusc, and rare trilobites continues from close to the base up to the strata transitional to the Mójcza Limestone. In these transitional, originally calcareous sandstones, the bellerophontid and *Antigonambonites planus* are missing, or rare, while the remaining species, with *Orthis kielcensis* dominating, occur in abundance (Pl. 7: 10). Within the Mójcza Limestone itself only two bedding planes close to the base contain macrofossils, and are covered with numerous orthid shells and trilobite carapaces. Although some trilobite species typical of the Bukówka Sandstone continue their presence in this assemblage, the dominating orthids and trilobites are different. This is not a result of evolutionary change but rather a change in the environment. The conodonts from the limestone intercalations in the Bukówka Sandstone and the basal Mójcza Limestone are virtually the same.

In this chapter the distribution of these two most important groups of benthic organisms is reviewed not only on the basis of macrofossils collected in the transition strata and close to the base of the limestone series, but also on phosphatized fragments of juvenile specimens occurring within the Mójcza Limestone. The present contribution is only a preliminary review and these fossils definitely require more specialist approach than we are now able to offer. Some comments on sponges and receptaculitids, which may be of some importance in reconstructing the environment of sedimentation, are also added.

THE TRILOBITE BED FOSSILS

Trilobites provided the basis for the first dating of the Mójcza Limestone by GÜRICH (1901) and CZARNOCKI and SAMSONOWICZ (1913). BEDNARCZYK (1964, 1966a, b) described several species from many outcrops of the Bukówka Sandstone as well as from the Mójcza Limestone. Several species cited from these strata have never been illustrated and the original specimens were destroyed during World War II. This review is based on specimens kindly lent by Dr. Wiesław BEDNARCZYK (the collection, taken by him from the Warsaw University to the Institute of Geological Sciences of the Polish Academy of Sciences, is abbreviated WB) and on our new collections.

Cybele sp. n.
(Pl. 8: 1–3; Text-fig. 6a)

A cranidium occurring in the same piece of rock as a specimen of *Cheirurus* WB M.4, certainly derived from the trilobite bed close to the base of the Mójcza Limestone, differs from specimens of the coeval Baltic *C. bellatula* (DALMAN, 1827) in the position of eyes, which are more posteriorly located in the Mójcza specimen (see OWEN and TRIPP 1988), resembling in this respect rather

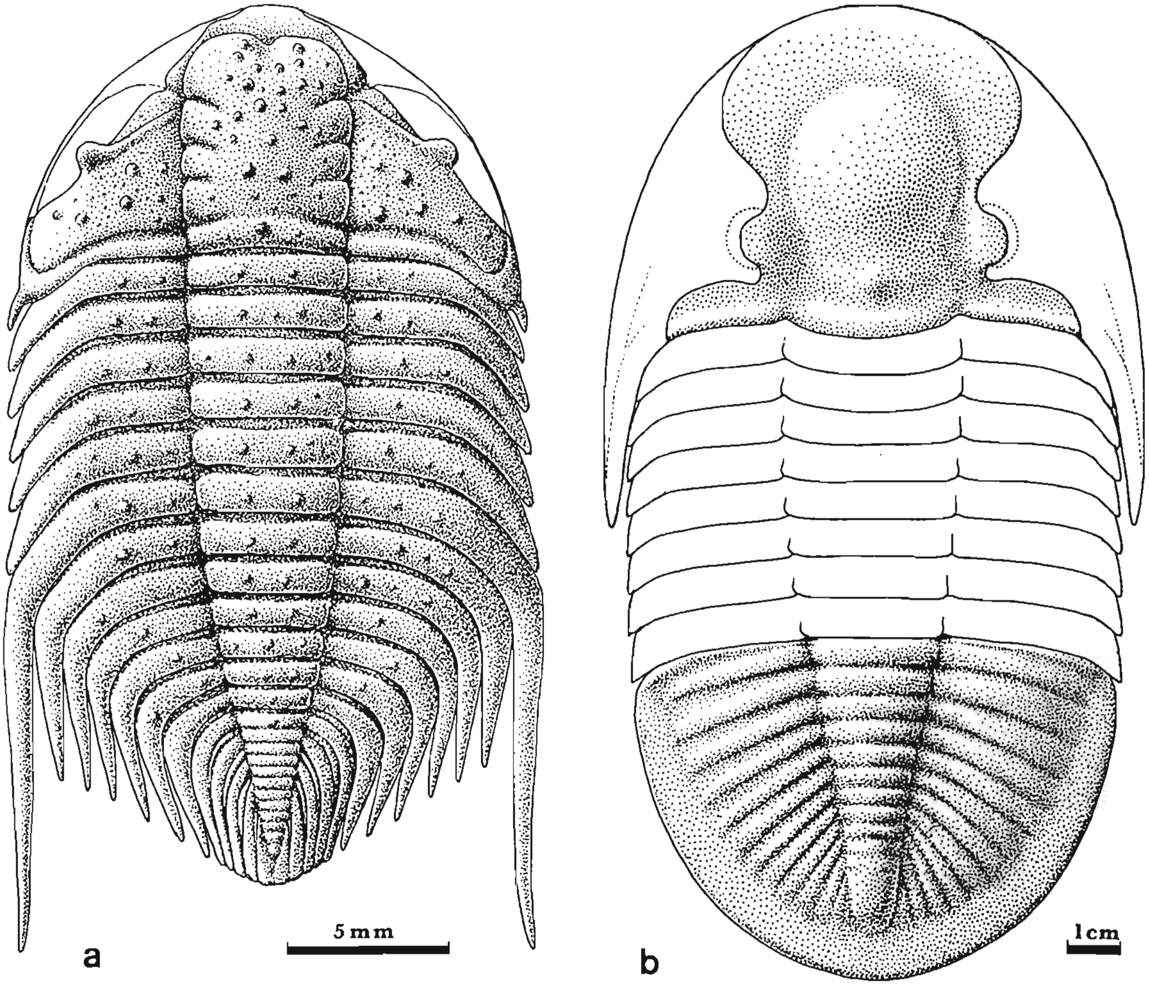


Fig. 6.
Reconstruction of carapaces of the most typical and best known trilobite species from the trilobite bed in Mójcza. **a.** *Cybele* sp. n. **b.** *Basilicus* sp. n.

Cybelurus or *Atractopyge*, and in less regular tuberculation. The anterior margin of the cranidium is broken and it is not clear of what size was the anteriorly directed spatulate process, so typical of the Baltic species. The cheeks sharply point ventrally in front of the eyes, the furrows in the middle of the preocular area reach the tips of the resulting triangular areas. A fragmentary pygidium and almost complete thorax, with one enlarged segment and its spine-like pleurae elongated up to the posterior end of the thorax, were found in decalcified calcareous sandstones of the transitional strata (Pl. 1: 2, 3). Fragments of phosphatized juvenile carapaces occur in the sample MA-35 taken from the trilobite bed. One of them shows the presence of a small genal spine.

Cyrtometopus polonicus (CZARNOCKI *et* SAMSONOWICZ, 1913)
(Pl. 8: 16–18)

The species is relatively common in the trilobite bed but all the studied specimens have their genal spines broken and the pygidium remains unknown. Therefore, although no difference in cephalic morphology between it and Baltic *C. clavifrons* (DALMAN, 1826) has been identified, the name introduced by CZARNOCKI and SAMSONOWICZ (1913) is provisionally preserved until specimens with diagnostic characters preserved are found.

Calyptaulax sp. n.
(Pl. 8: 14–15)

The single cephalon described by BEDNARCZYK (1964) as *Zeliszkella* probably belongs to the same species as the two pygidia attributed by him to *Pterygometopus*. They all occurr in the same kind of rock, almost certainly the trilobite bed and their outlines fit well, the cephalon being quite dissimilar to that of *Zeliszkella*. A rather thin-walled cephalon makes it different from all the described Baltic species of *Pterygometopus*. A weakly convex anterior glabellar lobe and eyes approaching the glabella anteriorly suggest a proximity to *Calyptaulax*, the genus known from the Baltic region, England, and the Laurentian part of Scotland, Northern Ireland (CLARKSON and TRIPP 1982), and Newfoundland (WHITTINGTON 1965). Baltic *C. trigonocephals* (SCHMIDT, 1881) may be close to the Mójcza species, still being more *Pterygometopus*-like. The morphology of coeval Gondwanan forms (see HAMMANN 1974) suggests that the Mójcza species may be related to them. Its appearance in Małopolska precedes post-Kundan isolation of the Baltic lineage that subsequently radiated into the Chasmopinae (see MCNAMARA 1980; LUDVIGSEN and CHATTERTON 1982).

Illaenus polonicus GÜRICH, 1901
(Pl. 8: 4–7)

GÜRICH (1901) erected the species on the basis of a juvenile specimen illustrated only from lateral side. It was probably lost during World War II, at least we were not able to trace it in the collection of the Wrocław University. The most numerous trilobites in the trilobite bed belong to *Illaenus* and it is rather likely that they belong to the GÜRICH's species. The Baltic species closest in time and morphology are *I. sarsi* JAANUSSON, 1954 and (only slightly younger) *I. aduncus* JAANUSSON, 1957. The duplicature of the pygidium is wider in the Mójcza specimens. It covers more than half of the pygidial lower surface and does not have any incision at the midline. *I. wahlenbergi* (EICHWALD, 1825) is Late Kundan in age (JAANUSSON 1954, 1957) but without knowing the exact morphology of its pygidial duplicature, the only non-generalized feature observable in the Mójcza material, we are not able to decide what is the degree of relationship. Similar forms of the genus are also known from Turkey (i.a. DEAN 1973).

Protostygina(?) sp.
(Pl. 8: 20)

A single incomplete pygidium, much shorter than associated pygidia of *Illaenus* represents this genus, which we are not able to determine more precisely.

Nileus sp.
(Pl. 8: 19)

The cranidium identified by BEDNARCZYK (1966: Pl. 2: 2) as belonging to *Illaenus polonicus* and the pygidium (BEDNARCZYK 1966: Text-fig. 2, Pl. 2: 8) described as "gen. et sp. indet." represent a nileid species in the trilobite bed of the Mójcza Limestone. The genus is known also from the whole Bukówka Sandstone (BEDNARCZYK 1964). Although the specimens seem identical with the coeval Baltic *N. armadillo* (DALMAN, 1827) we hesitate to identify them specifically because several closely related forms are known also from other regions (e.g. SCHRANK 1972).

Basilicus sp. n.
(Pl. 8: 9–13; Text-fig. 6b)

This is the most typical species of the trilobite bed, many large pygidia of it always being visible on its exposed surface. Its Welsh affinities were recognized by CZARNOCKI and SAMSONOWICZ (1913) but subsequently questioned by BEDNARCZYK (1964) although he attributed to this genus some poorly preserved, probably conspecific specimens from the Bukówka Sandstone at Koziel in the Łagów facies region, possibly from strata coeval to the base of the Mójcza Limestone. He suggested relationships

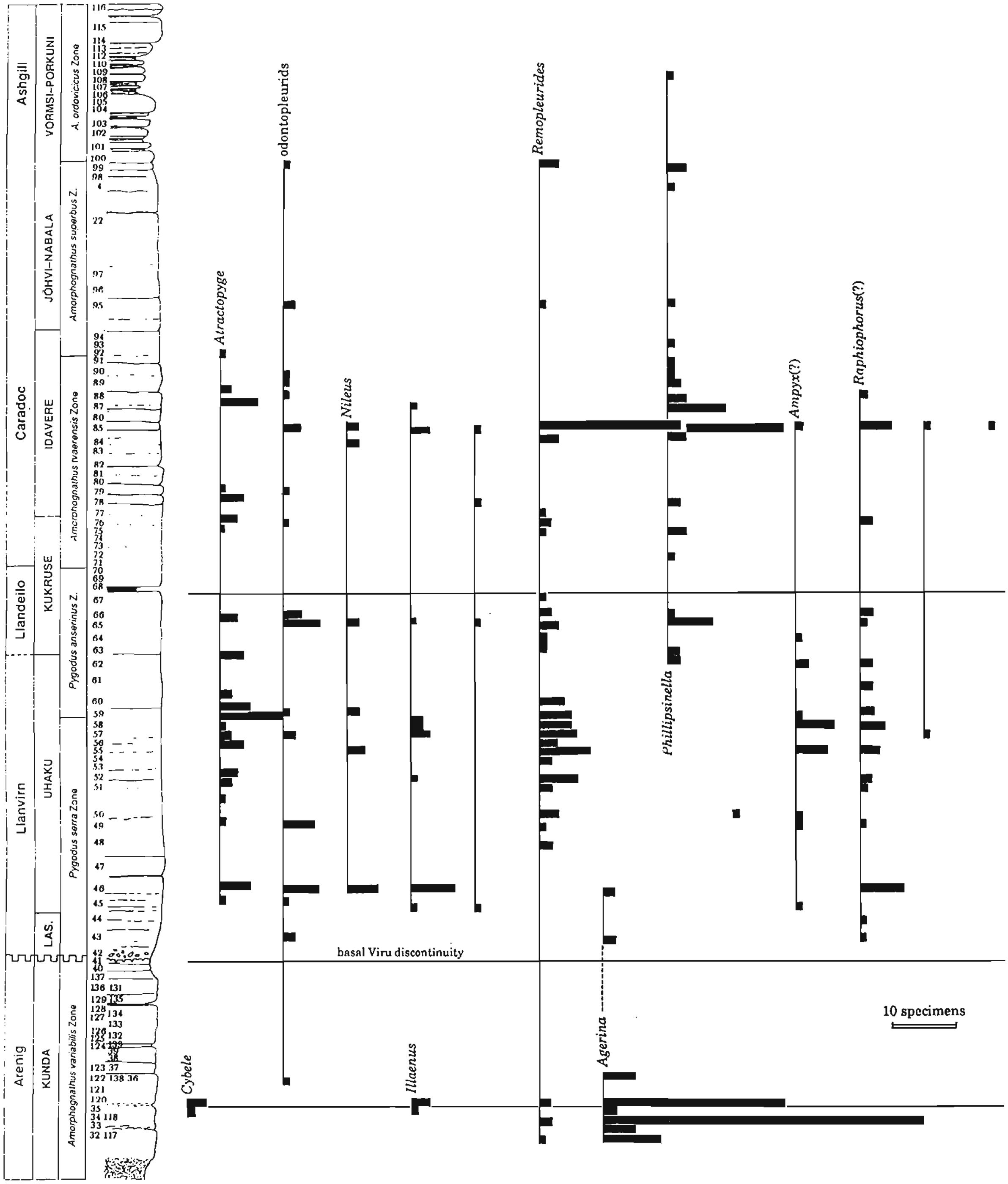


Fig. 7.
Distribution of phosphatized trilobite carapaces in the section of the Mójcza Limestone at Mójcza. Number of specimens per sample shown by bars.

to the Baltic *Pseudoptychopyge* instead. This seems unlikely; the single known cranidium which belongs with previously known pygidia is of an appearance rather unlike Baltic forms. Although it resembles some primitive species of *Megistaspis*, in anterior view the contour of its glabella is almost semicircular, being similar in this respect to specimens from the Llandeilo of Wales interpreted by FORTEY (1980: Fig. 7) as juveniles of the type species, *Basilicus tyrannus* (MURCHISON, 1839). The

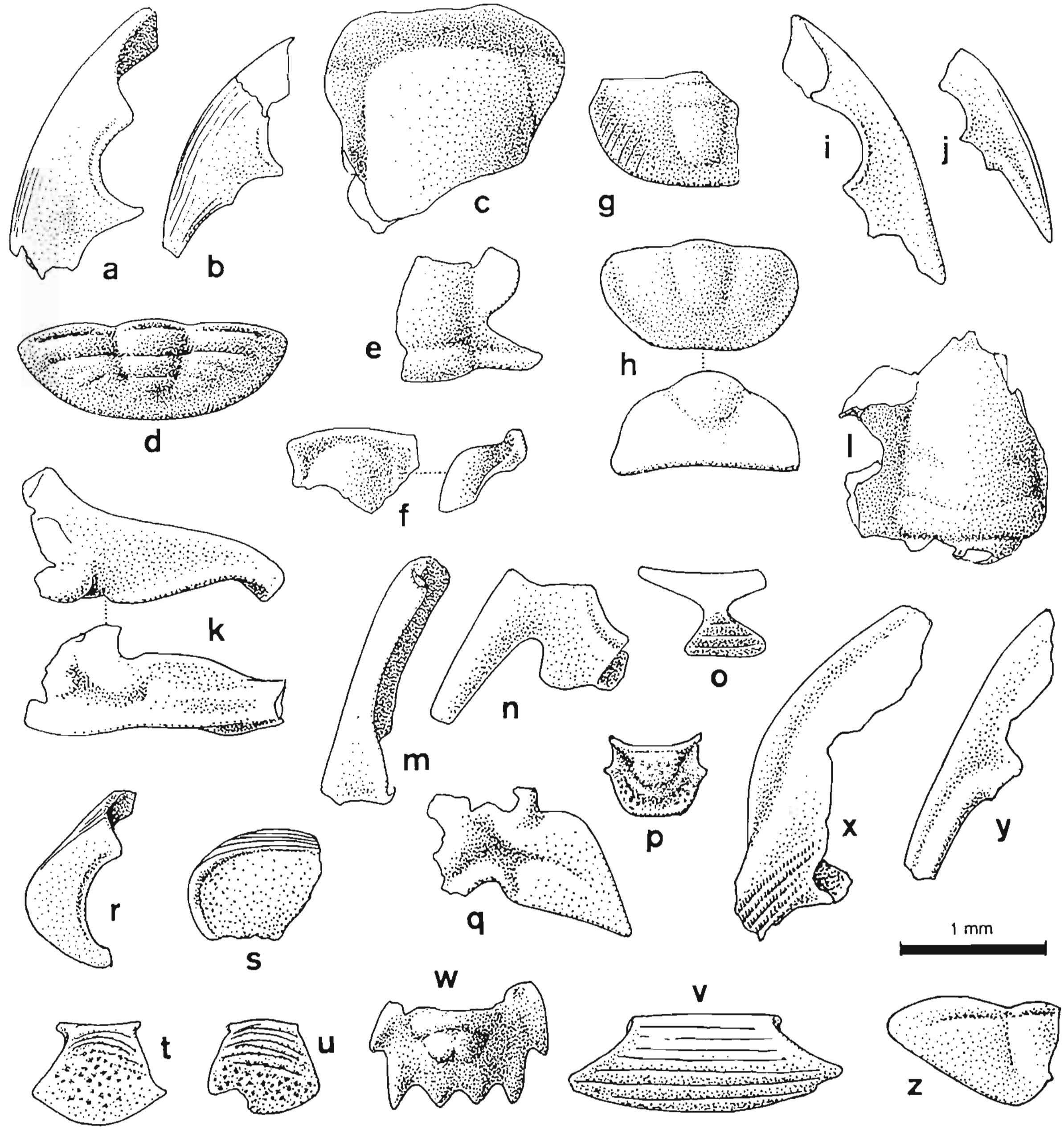


Fig. 8.
Phosphatized trilobite remnants from the Mójcza Limestone section at Mójcza. **a–f**. *Agerina* sp.; a–b, cheeks, sample MA-34; c, glabella, sample MA-118; d–e, pygidium and glabella, sample MA-120; f, juvenile glabella, same sample. **g–j**, **t–u**. *Phillipsinella* sp.; g–j, pygidia and cheeks, sample MA-5; t, u, rostral plates, samples MA-65 and 85. **k**. Gen. et sp. indet, pleura, sample MA-85. **l**. Proetid? gen et sp. indet; cranidium, sample MA-5. **m–q**, **w**. Remopleurid gen. et sp. indet.; m, cheek, sample MA-120; n, cheek, sample MA-85; o, rostral plate, sample MA-120; p, hypostome, sample MA-55; q, thoracic pleura, sample MA-77; w, pygidium, sample MA-43. **r**. *Nileus* sp. (cf. *N. platys stigmatus* SCHRANK, 1972); cheek, sample MA-46. **v**. *Illaenus*(?) sp.; rostral plate, sample MA-43. **x**. Raphiophorid gen. et sp. indet.; genal spine, sample MA-65. **y–z**. *Ampyx* sp.; y, genal spine, sample MA-85; z, pygidium, sample MA-58.

Mójcza species being much older, at the latest Arenig in age, and may be ancestral to the Welsh lineage. An even more primitive member of the genus, perhaps a little older than the Mójcza species, is *Basilicus mckeei* ROSS, 1970, known from the Antelope Valley Limestone of Nevada (ROSS 1970) and possibly represented also in the Goldwyer Formation of the Canning Basin, Australia (LEGG 1976).

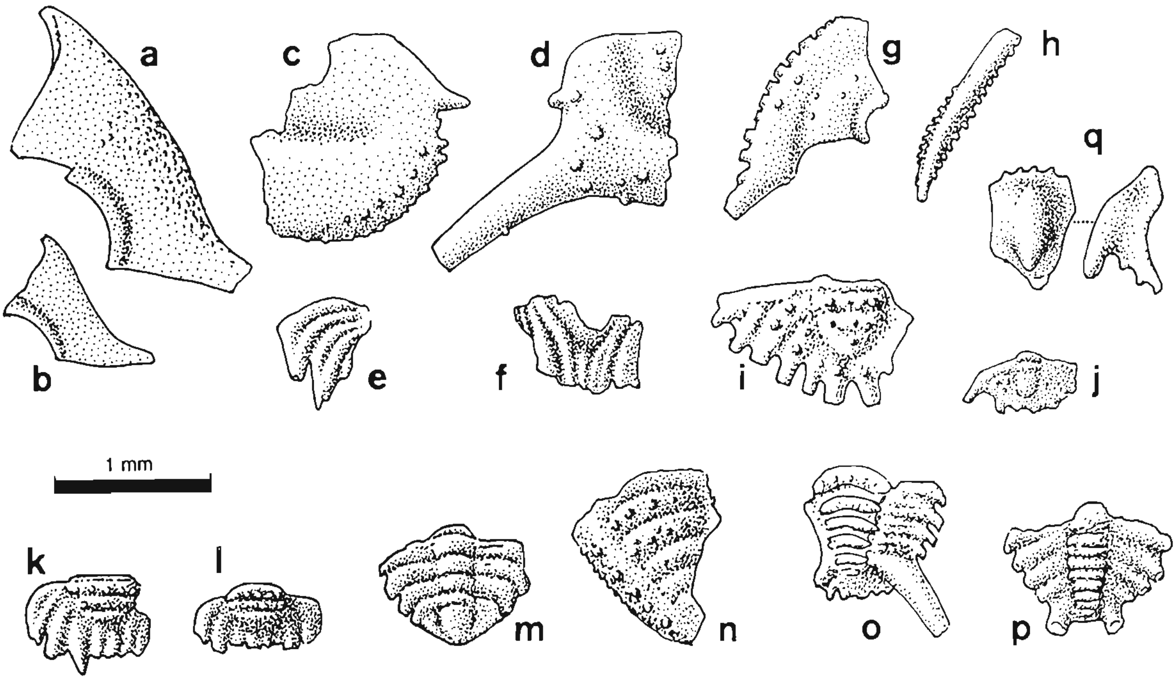


Fig. 9.
Phosphatized trilobite remnants from the Mójcza Limestone section at Mójcza. **a–f**. *Atractopyge* sp.; a–b, cheeks, sample MA-45; c–d, thoracic pleurae, samples MA-65 and 87; e–f, pygidia, samples MA-45 and 46. **g–j**, **q**. Odontopleurid gen. et sp. indet.; g, cheek, sample MA-65; h, pygidial spine, sample MA-36; i–j, pygidia, samples MA-85 and 78; q, larval cranidium, sample MA-58. **k–l**. *Cheirurus*(?) sp.; pygidia, sample MA-84. **m**. Gen. et sp. indet.; larval thorax, sample MA-62. **n**. *Dimeropyge* sp.; pygidium, sample MA-50. **o–p**. Gen. et sp. indet.; pygidia, samples MA-30 and 84.

Agerina pamphylica DEAN, 1973
(Pl. 8: 21)

Somewhat surprisingly, the trilobite assemblage closest in composition to that of the Mójcza trilobite bed occurs in the Sobova limestone in the Taurus Mountains, Turkey (DEAN 1973). Except for *Cybele*, all the remaining Mójcza species seem to have at least close relatives in the Sobova assemblage. This species seems to be especially important as it, being known from only a single specimen among the macrofossils, is the most numerous among phosphatized trilobites in the Kundan part of the Mójcza Limestone (Text-fig. 8), being unknown from coeval strata of the Baltic area.

DISTRIBUTION OF PHOSPHATIZED TRILOBITE REMAINS
(Text-figs 8–10)

Phosphatized trilobite carapaces occur frequently in the proximity of the trilobite bed in Mójcza and they are represented by the same species that are known as macrofossils, except for the largest *Basilicus*, which has probably little chance of preservation as identifiable carapace fragments. Minute specimens of *Agerina* are the most common in the phosphatic debris (Pl. 10: 6–7). Fragments of *Remopleurides* carapaces, unknown from macrofossil remnants, also occur here (Pl. 10: 9). The strata between the trilobite bed and the discontinuity surface are almost barren of phosphatized trilobite carapaces and an assemblage that appears about a half meter above the discontinuity differs from the basal one in the lack of *Agerina* (a few pygidia similar to *A. pamphylica* but with more pronounced segmentation have been found immediately above the discontinuity surface). Instead, at least two genera of the raphiophorids are represented there, one with a spine quadrangular in cross section (perhaps *Ampyx*), and another with very characteristic ornamentation composed of obliquely arranged rows of tubercles (Pl. 10: 11). In the Llandeilo, *Phillipsinella* becomes a common species in the

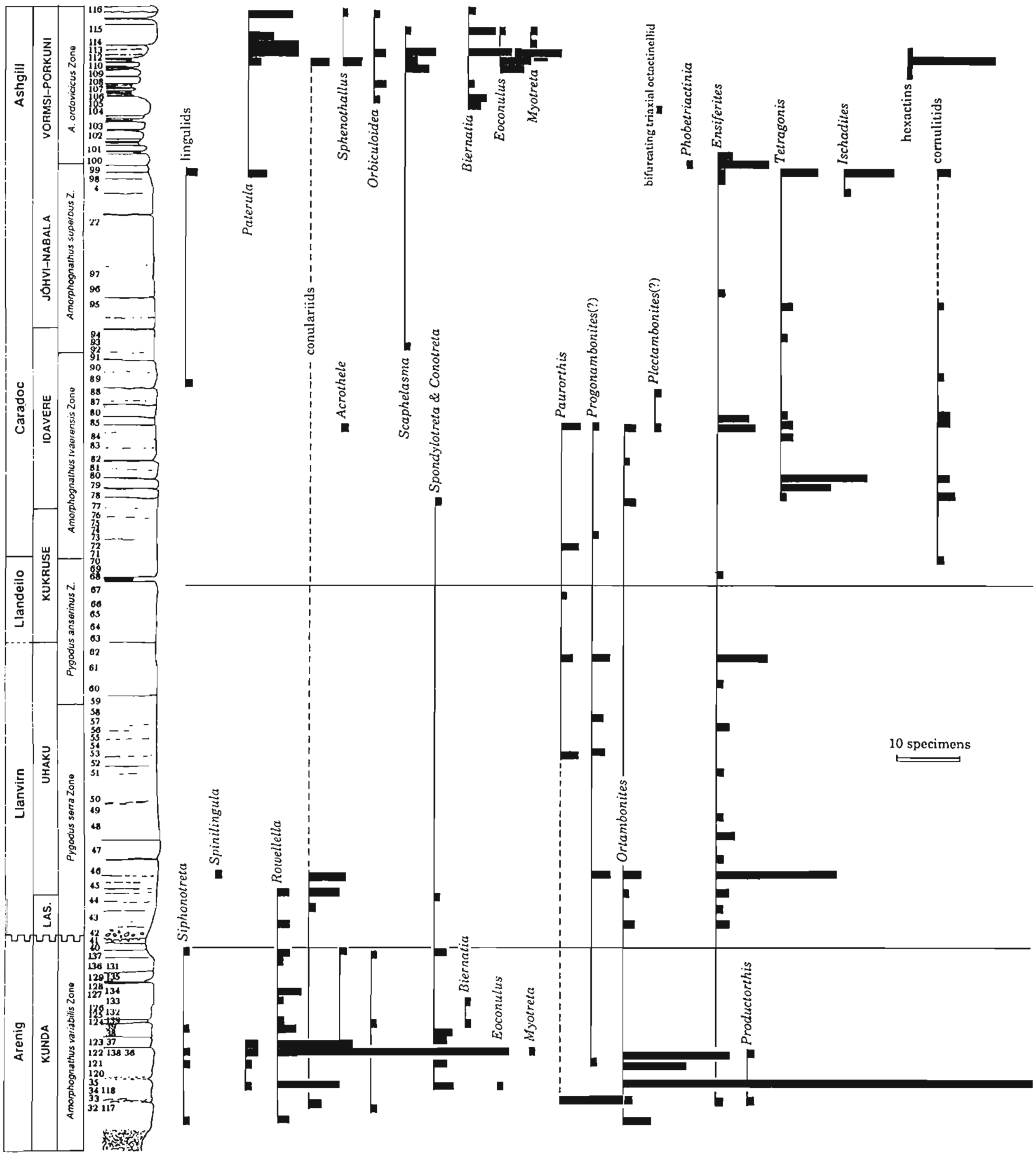


Fig. 10.
Distribution of phosphatic acrotretid, phosphatized articulate brachiopod shells, calcitic and phosphatized octactinellid sponge, phosphatized and siliceous hexactinellid sponges, and phosphatized aragonitic receptaculite meroms in the section of the Mójcza Limestone at Mójcza.

assemblage (Pl. 10: 8, 13). It continues up to the top of the section, and from the Late Caradoc it remains the only recognizable trilobite form in the Mójcza Limestone. The pattern of the trilobite distribution does not show any major changes in the type of assemblage, but this may be a limitation of fragmentary preservation.

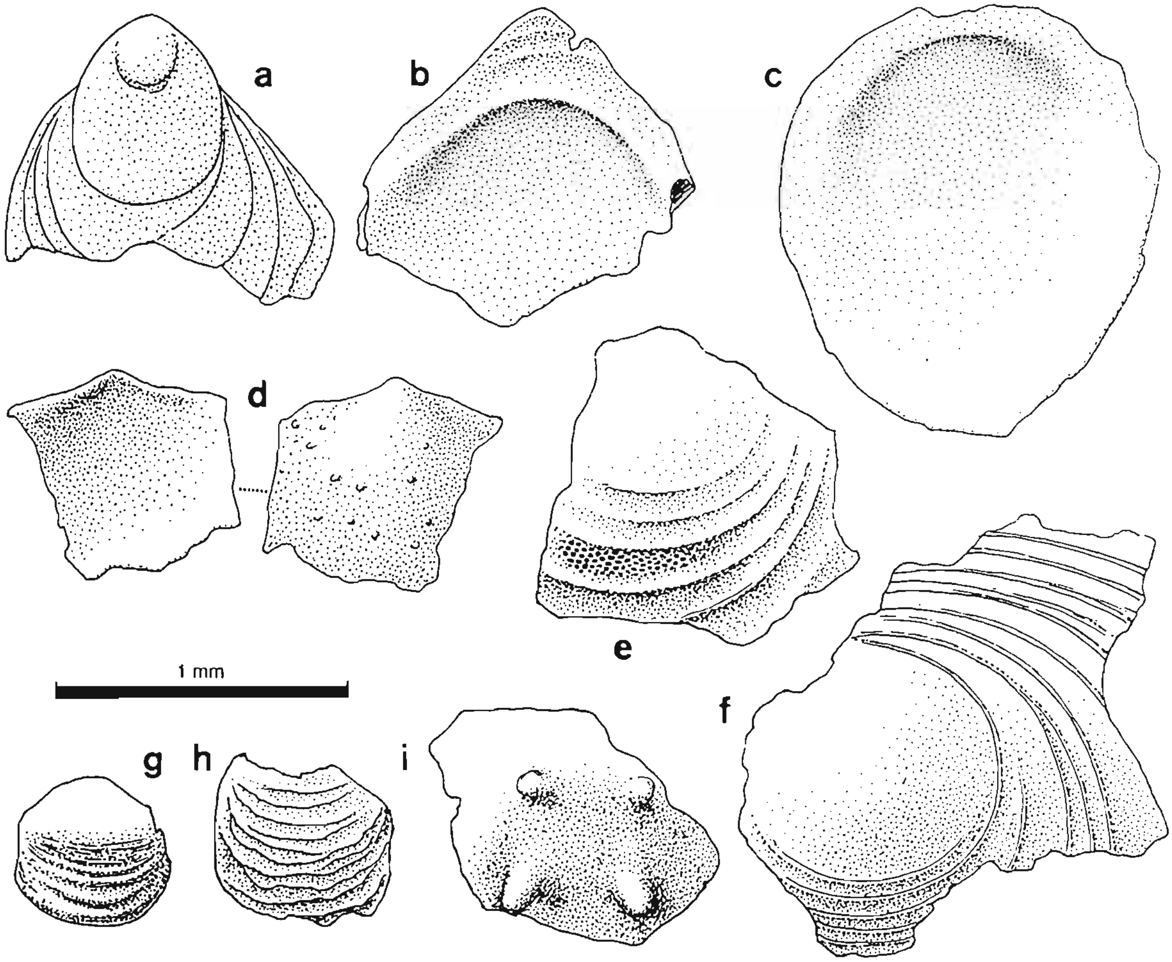


Fig. 11.
Inarticulate brachiopods from the Mójcza Limestone section at Mójcza. **a–b**. Lingulid gen. et sp. indet.; samples MA-89 and 99. **c**. *Paterula* sp.; sample MA-112. **d**. *Acanthambonia* or *Siphonotreta* sp.; sample MA-117. **e**. Gen. et sp. indet.; sample MA-40. **f**. *Orbiculoidea* sp.; sample MA-2. **g–h**. *Rowellella* sp.; samples MA-128 and 120. **i**. *Acrothele* sp.; sample MA-5.

BRACHIOPODS
(Text-figs 11–14)

Originally phosphatic benthic fossils show a rather strange pattern of distribution in the Mójcza section, being restricted to the basal (Kundan and possibly Lasnamägian) and the topmost (Ashgill) parts of the section. This applies to both the acrotretid brachiopods and tubular problematica (conulariids and *Sphenothallus* with its attachment discs "*Phosphannulus*").

Phosphatic inarticulate brachiopods were diverse in the Early Ordovician of the Holy Cross Mountains. BIERNAT (1973) described some fifteen species from the Wysoczki Chalcedonite and eleven species are present in the topmost Bukówka Sandstone (BEDNARCZYK and BIERNAT 1978). Possibly all of them occur also in the basal Mójcza Limestone, although the fragmentary preservation of the shells does not allow us to distinguish more than seven undoubtedly distinct morphologic types of phosphatic inarticulate brachiopods. Among them the most common are shells of *Rowellella* (represented by typical *R. distincta* BEDNARCZYK *et* BIERNAT, 1978 and an associated gibbose smoother form) and generalized acrotretids probably representing *Spondylotreta* and/or *Conotreta*. The Ashgill assemblage, known from Mójcza, Międzygórz, and Zalesie sections, is different, being dominated by *Paterula*, *Eoconulus*, and *Biernatia*.

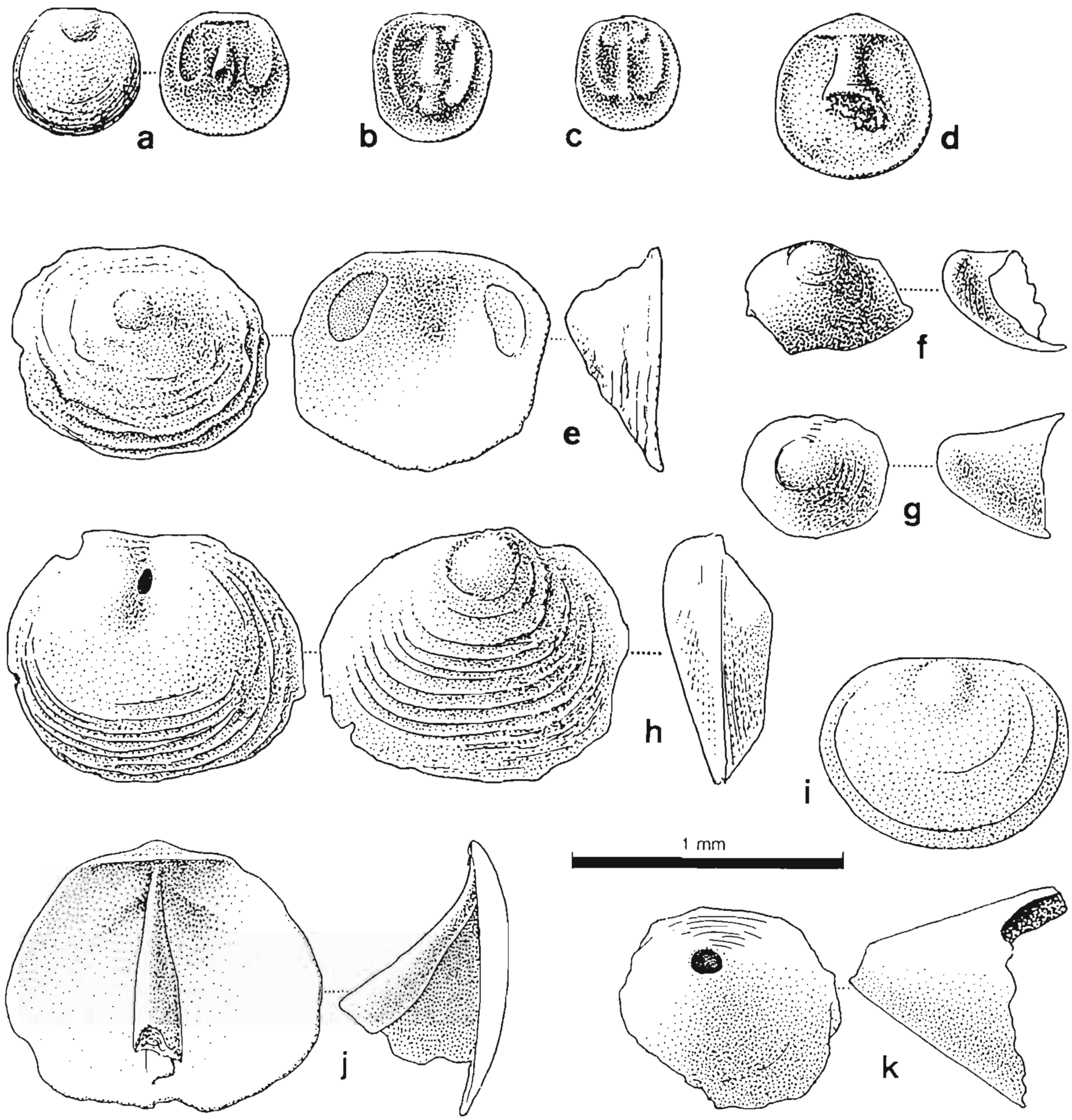


Fig. 12.
Acrotretid brachiopods from the Mójcza Limestone section at Mójcza. **a–d**. Gen. et sp. indet.; samples MA-36, 120, 37, and 38, respectively. **e**. *Eoconulus* sp.; sample MA-111. **f–g**. *Myotreta* sp.; samples MA-37 and 114. **h**. *Scaphelasma* sp.; sample MA-111. **i**, **k**. *Spondylotreta* sp.; samples MA-120 and 37. **j**. *Biernatia* sp.; sample MA-116.

Phosphatic linings of calcitic shells of the articulate brachiopods (Text-fig. 14; Pl. 9: 18–19) occur throughout the lower two-thirds of the Mójcza section, up to the Early Caradoc. Juvenile shells are difficult to determine but it seems that the same groups are represented throughout the range. These groups are punctate enteletaceans (at least in the basal zone *Paurorthis* seems to be present), rare, irregularly ornamented shells resembling *Progonambonites* and an orthid, at these early ontogenetic stages dissimilar to any genus known to us, but possibly conspecific with *Orthambonites* occurring close to the base of the Mójcza Limestone as macrofossils. The bedding surface preceding that of the trilobite bed is covered with numerous shells of *Orthambonites* possibly conspecific with *O. calligramma* (Pl. 2: 17–18) and with rare lamellose shells probably belonging to *Progonambonites*. The only lineage that appears much later, in the middle of the Caradoc, is a strophomenid, perhaps

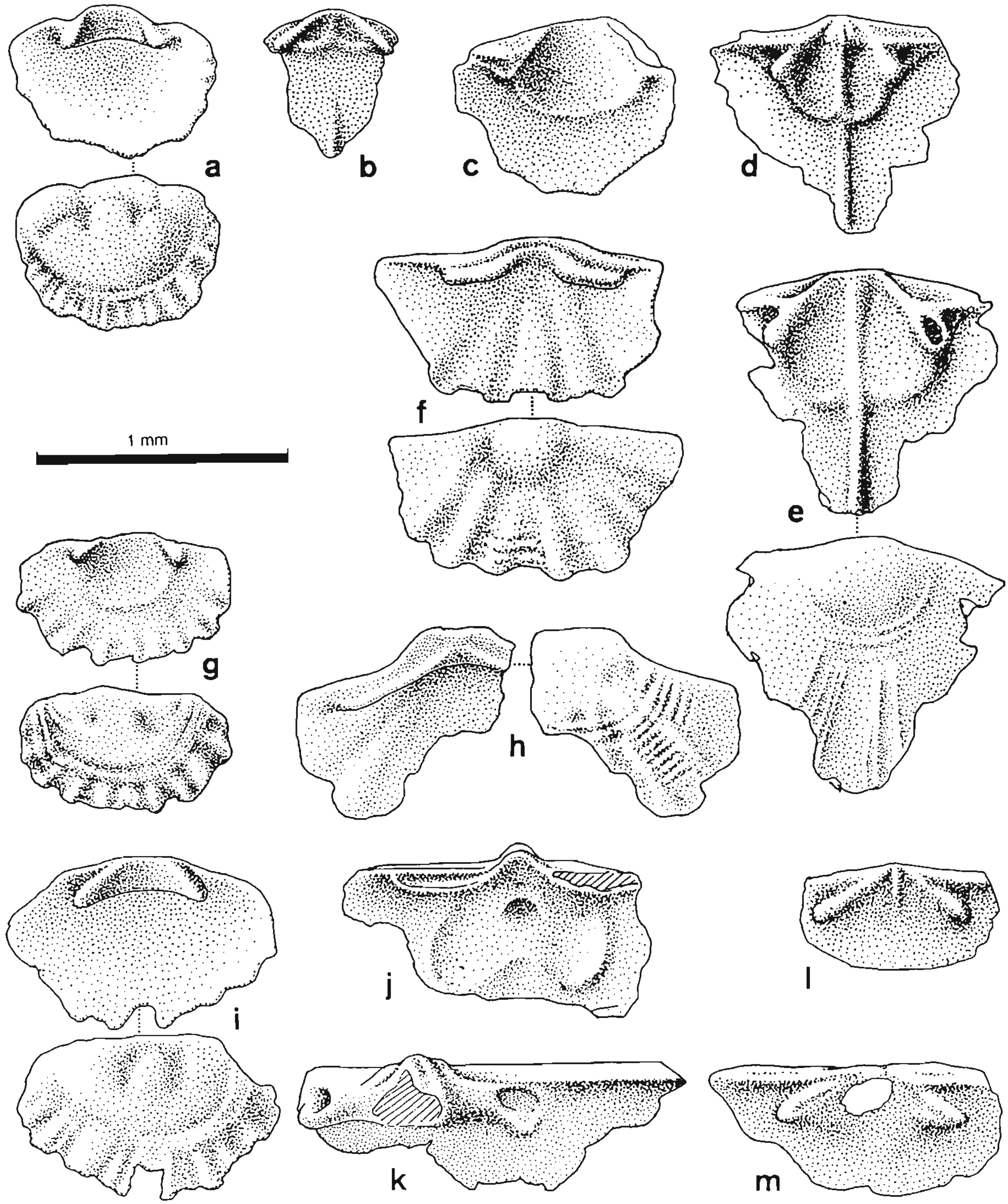


Fig. 13.
Phosphatized articulate brachiopods from the Mójcza Limestone section at Mójcza. **a–e**. *Orhambonites* sp.; a–b, sample MA-120; c–e, samples MA-34, 43, and 85. **f–h**. *Progonambonites*(?) sp.; samples MA-85, 46 and 36. **i**. *Paurorthis* sp.; sample MA-118. **j–k**. *Plectambonites*(?) sp.; sample MA-5. **l–m**. *Productorthis* sp.; samples MA-37 and 34.

congeneric with *Plectambonites*. The Mójcza phosphatized brachiopods frequently represent the earliest larval stages, otherwise almost unknown in the Early Paleozoic, and are therefore of great interest. Their proper taxonomic identification requires, nevertheless, more experience with well preserved Ordovician material than we have.

SPONGES
(including the receptaculites)
(Text-figs 11, 15–16)

A pattern of distribution similar to phosphatic remnants is shown by originally siliceous hexactinellid spicules. They occur only in the basal part of the section, there very rare being, and more abundantly in the Ashgill. This may be a preservational artifact, as only in the types of rocks occurring close to the base and the top of the section in Mójcza the content of silica is high enough to prevent the early diagenetic dissolution of opal.

Along with the articulate brachiopods, the octactinellid sponges represent another group of originally calcitic fossils. Their spicules are preserved both as sparitic calcite remnants (especially in higher parts of the section; Pl. 9: 16) and phosphatic linings (Pl. 9: 17). The same mode of preservation is typical also of rare tubular fossils, at least partially belonging to the cornulitids (Pl. 10: 4–5). Both fragments of large longitudinally striated and annulated *Ancientia*-like tubes and minute *Cornulitozoon*-like tubes have been found.

AGE CORRELATION OF THE MÓJCZA LIMESTONE

In face of the complete absence of any organic-walled fossils, conodonts remain the only reliable source for dating of the formation. They show close Baltic similarities, which allows a quite precise correlation with the Baltic region, but several immigrations of lineages foreign to the Baltic area also enable time correlation with the North American Midcontinent. The basis for the correlation was reviewed in Dzik (1978, 1990) and the factual evidence is presented in this volume. The zonation applied there is generally that of Bergström (1971) with some units defined in slightly different ways, but without changes in their ranges.

EVENT BIOZONATION OF THE MÓJCZA LIMESTONE

The dominating pattern of the faunal evolution of the conodonts (see Dzik 1994a) as well as the ostracodes (see Olempska 1994) within the Mójcza Limestone is a gradual, more or less continuous replacement of one lineage by another. In the basal part of the section this is expressed, for instance, by a gradual disappearance of the *Phragmodus* and *Lenodus* conodont lineages associated with increased contribution of simple-cone species of the genera *Protopanderodus* and *Cornuodus*. Generally it corresponds to an increase in diversity of the assemblage.

The only single abrupt environmental change is that at the discontinuity surface itself, but it is not, surprisingly, connected with any significant reconstitution of the conodont fauna.

Above the discontinuity surface the diversity index of conodonts remains rather stable up to the base of the Caradoc. In the basal part of this stable interval the assemblage is gradually enriched with an introduction of *Panderodus* (generally believed to be a shallow-, warm-water conodont), a somewhat irregular increase in contribution of *Sagittodontina*, and subsequent introduction of *Scabbardella* (a cold- and deep-water form that seems to replace *Panderodus*) and *Complexodus* (an exotic South Chinese element).

No significant faunal change was caused by the bentonite deposition. It seems that this event of volcanic activity had no direct influence on the organic life in the Małopolska area. We are not able to correlate the Mójcza bentonite bed with any other in the Baltic area, although a few thin beds are known to occur there in the *P. anserinus* Zone, or to indicate the source of the volcanic ash. If the conodont dating is correct the Mójcza bentonite is significantly older than the Big Bentonite of the Middle Caradoc age, developed on both sides of Iapetus ocean (Huff *et al.* 1992), but not in Mójcza.

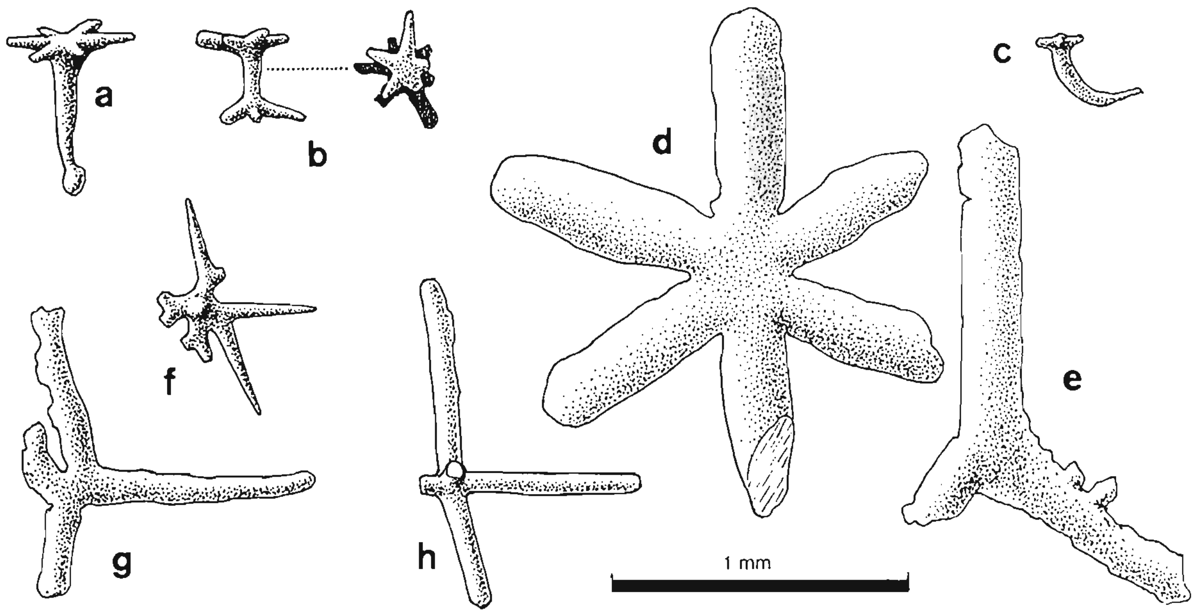


Fig. 14.
Octactinellid calcitic sponge spicules (a–g) and siliceous hexactinellid spicules replaced with iron minerals (h). **a–e**. *Ensiferites* sp.; a, calcitic juvenile spicule, sample MA-26; b–c, calcitic juvenile spicules, sample MA-101; d, calcitic spicule head with phosphatic coating, sample MA-10; e, calcitic spicule root, sample MA-96. **f**. Bifurcating triaxial spicule, possibly octactinellid rootlet, sample MA-105. **g**. *Phobetriactinia* sp.; calcitic, sample MA-100. **h**. Hexactin replaced with goethite, sample MA-22.

A profound drop in the diversity of the conodonts, associated with a remarkable increase in productivity of *Amorphognathus*, took place during the sedimentation of approximately 1 m of rock above the bentonite. It seems highly probable that this corresponds to the incursion of *A. tvaerensis* into the Baltic area and North American Midcontinent. Such a shift in the geographic distribution of the lineage may possibly be an expression of those climatic transformations that resulted in the global rise of the sea level during the graptolite *Nemagraptus gracilis* Zone (FINNEY and BERGSTRÖM 1985). In the slightly deeper Łagów facies region the sedimentation changed in effect from calcareous to fine clastic. The event does not correspond to any change in evolutionary rates within the *Amorphognathus* lineage (DZIK 1990). Although the conodont assemblage was profoundly rebuilt at that time, no significant morphologic transformation took place. It is therefore of much interest to observe that in the Welsh, sections along with the development of the transgression, a contribution of *Sagittodontina kielcensis* (="*Prioniodus deani*" of SAVAGE and BASSETT 1985; see DZIK 1990), the only cold-water Gondwanan conodont species in those assemblages, decreased from about 20 per cent to 1 per cent, and finally disappeared. This indicates that the *N. gracilis* transgression was connected with warming of the climate or with northward movement of the Avalonian microcontinent. It thus seems reasonable to suggests that the rise of sea level resulted from melting of the Gondwana ice cover.

The most profound faunal change in the whole section, at the level of about 2 m above the bentonite (DZIK 1994a: Text-fig. 1), has no expression in the sedimentary regime. *Amorphognathus* almost totally disappeared then but, after a brief time during which the strange Welsh simple-cone *Strachanognathus* dominated the assemblage, another Welsh form, *Rhodesognathus*, appeared and became numerous. This level corresponds roughly to the *A. tvaerensis* – *A. superbus* evolutionary transition (DZIK 1990) and may be coeval with the base of the *A. superbus* Zone elsewhere in the world. Whether this is an effect of a sudden cooling and a brief warm period following immediately after, cannot be proven without quantitative evidence from other regions.

For the upper part of the Mójcza section a gradual, almost linear, increase in relative productivity of *Scabbardella* is characteristic. *Scabbardella altipes* becames the dominant conodont species close to the top of the section. The introduction of *Rhodesognathus*, mentioned above, introduced a tem-

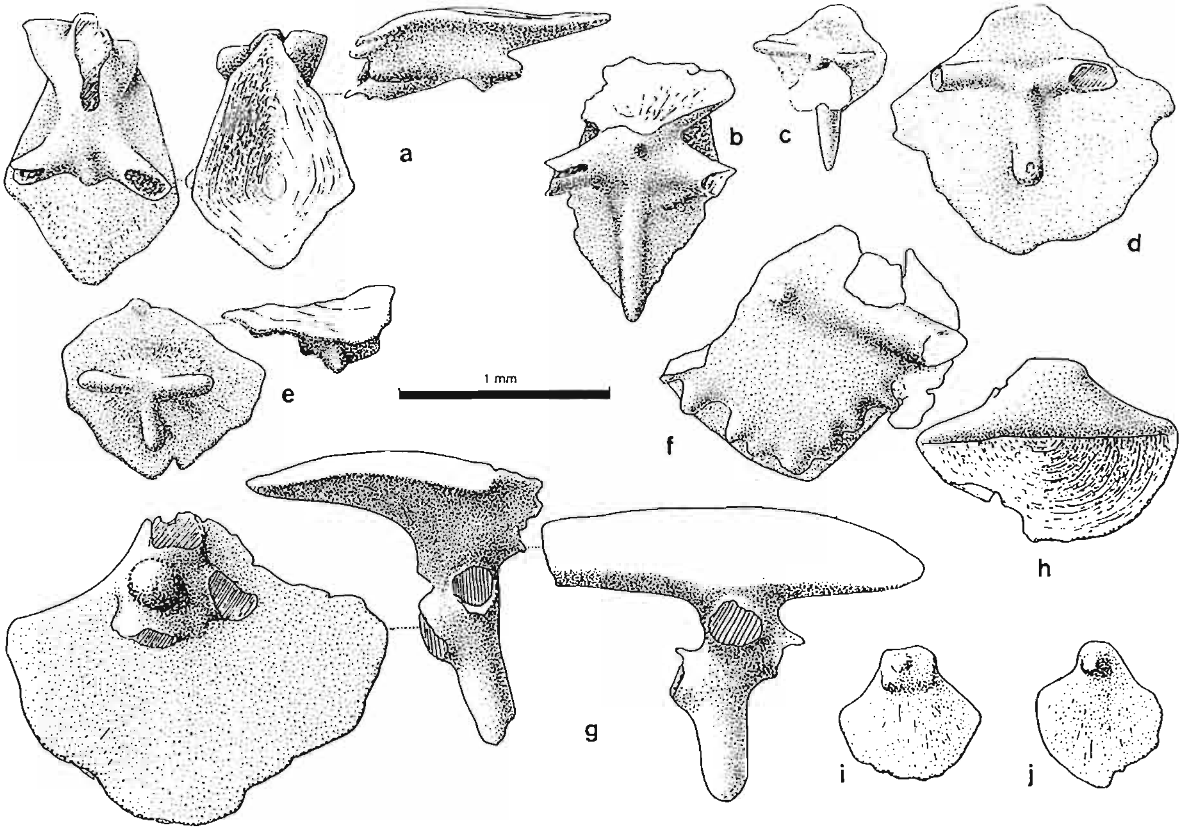


Fig. 15.
Phosphatized receptaculitid meroms. **a–f**. *Ischadites*(?) sp.; a, e, sample MA-4, b–d, f, sample MA-99. **g–j**. *Tetragonis* sp.; g–h, sample MA-85; i–j, sample MA-99.

porary disturbance in the general pattern. Its disappearance was associated with a suddenly high proportion of *Scabbardella*. After some time the pre-*Rhodesognathus* status was reestablished and the domination of *Scabbardella* slowly increased. As *Scabbardella* was almost certainly a cool-water form, this may be interpreted as the evidence for a brief warm epoch (introduction of *Strachanognathus* and then *Rhodesognathus*) that was followed by a sudden cooling and reestablishent of conditions typical of the Late Ordovician. Another member of the *Scabbardella* assemblage was *Hamarodus*, similar to it in having a very deep basal cavity, a feature probably typical of most of the cold-water conodont species of the Ordovician (DZIK and DRYGANT 1986). *Hamarodus* significantly increased its contribution to the assemblage three times, which corresponded to a change from clastic to calcareous (marly) sediments. The first increase was also associated with a brief appearance of *Icriodella*, a warm-water Welsh to Midcontinent faunal element. This may be coeval with the level in the Baltic region sections where several exotic, Welsh forms occur, namely "*Aphelognathus*" *rhodesi*, *Icriodella* and *Belodina* (see DZIK 1983). At Mójcza, the *Icriodella* incursion corresponds to the last layer of the continuous limestone series, especially rich in ferruginous ooids. Above it, there are only marls and clays of the Zalesie Formation. Perhaps this change in facies corresponds to the *Tretaspis* (Fjäcka) Shale sedimentation that separated the reef-like Kullsberg Limestone of the Late Caradoc from the Late Ashgill Boda Limestone in the Dalarna region of Sweden (JUX and MANZE 1979). Another possible expression of a later peak in this cold epoch may be the temporary replacement of Midcontinent-like assemblages with the *Hamarodus* fauna in England and Wales during the Middle Ashgill (Rawtheyan). Any precise independent correlation markers are missing in this interval, so this supposition must remain speculative. In any case it seems that *Hamarodus* was a relatively less strictly cold-water species than *Scabbardella* and that these are the events of a temporary warming (interglacials?).

Higher up in the Zalesie Formation another important event is connected with the reappearance of calcareous sedimentation. This seems to correspond in time to the Hirnantian shallowing, although precise dating is not possible with the conodonts available, and the *Mucronaspis* fauna is known only from marls above the dolomites, in the topmost part of the Zalesie Formation (KIELAN 1960).

The Late Ordovician history of sedimentation on the Małopolska microcontinent seems to be controlled by the development of the glacial cover in Gondwana. The most precisely dated Late Ordovician glaciomarine rocks, those in the Tindouf Basin of Morocco, are of Hirnantian age (DESTOMBES 1981; HAMBREY 1985). The presence of the Pakhis Tillite Formation below the glaciomarine Cedarberg Formation with *Mucronaspis* trilobites in South Africa suggests an earlier age for the beginning of glaciation in Gondwana (COCKS and FORTEY 1986). In Thuringia, the varve-like Lederschiefer with dropstones occur above the Kalbank that contains conodonts not older than late *A. superbus* Zone, possibly *A. ordovicicus* Zone (taxonomic identification of the zonal species relies on a single element, which may be atypical or may belong to associated species of *Rhodesognathus*; DZIK 1990). The boulders from the Lederschiefer contain diverse fauna of echinoderms, sponges, receptaculites, bryozoans, and ostracodes (BLUMENSTENGEL 1965). Only three specimens of phacopid trilobites, more or less deformed and worn, are known from these supposed dropstones. They were the basis of establishing three separate species by STRUVE (1959, 1962): *Volkops volki* STRUVE, 1959, *Dalmanitina (D.) wagneri* STRUVE, 1962, and *D. (Thuringiaspis) osiris* STRUVE, 1962. Closely similar specimens described as *Andreaspis phacopoides* STRUVE, 1962 were found in the Andreasteich-Quarzite in Hessen. Actually, according to COCKS and FORTEY (1986) the genus *Thuringiaspis* may be synonymous with the genus *Mucronaspis*, species of which are widespread members of the latest Ordovician faunas, also in Poland (see KIELAN 1960). The appearance of Thuringia cold-water fauna is thus not so different from that of the Holy Cross Mountains, not only in regard to the conodonts (DZIK 1990). One may infer that the end of sedimentation of the Kalkbank of the Gräfenthaler Beds and the Mójcza Limestone marks the beginning of the same cold epoch in the Late Ordovician.

A similar occurrence of latest Caradoc limestone dropstones in rhytmic Ashgill clastics is known also from the Empozada Formation near Mendoza, Argentina. The conodont assemblage recovered from the dropstones (GALLARDO *et al.* 1988) is virtually identical with that from coeval warm-water faunal incursion in the Baltic area (DZIK 1983). Several bentonite layers occur in thick (up to 5 meters) complexes within the Zalesie Formation in its type area (see CHLEBOWSKI 1976).

THE MÓJCZA EUSTATIC DISCONTINUITY

At the discontinuity at Mójcza, a significant amount of time is missing, corresponding to the Late Kundan, Aserian, and at least Early Lasnamägian (DZIK 1990). The real time of non-deposition seems to have been shorter because reworked specimens of Late Kundan to Aserian *Baltoniodus medius* suggest the former presence of sediments of this age. Moreover, in boreholes located in the marginal part of the East European Platform (Gałajny 1, Lesieniec 1) a similar time gap has, characteristically, only its upper boundary strictly coeval, whereas the base is of a different age in each place. It seems probable that the hiatus resulted from submarine erosion during an eustatic fall in the sea level during the *Eoplacognathus reclinatus* and/or *E. robustus* Subzones. Depending on local factors the erosion removed more (like at Mójcza) or less (like at Lesieniec) of the sediment. Exactly the same pattern is shown by the basal Viru discontinuity surface in the Baltic area (HOLMER 1983). Thus, in Kinnekulle the Early Uhakuan (possibly latest Lasnamägian) beds rest directly on the latest Kundan while in Billingen the very thin early Aserian Vikarby Limestone and Lasnamägian Skövde Limestone occur in between. In Wales (MCKERROW 1979) and China (CHEN 1988) the same event is represented by the terminal Llanvirn regression. The gap at Mójcza corresponds thus to a global eustatic event of some correlative value.

REFERENCES

BARANOWSKI, W. and URBANEK, Z. 1972. Ordovician conodonts from the epimetamorphic complex from Rzeszówek in the Kaczawa Mts, Sudetes. — *Bulletin de l'Academie Polonaise des Sciences, Séries des Sciences de la Terre* **20**, 211–21.

BARNES, C.R. 1984. Early Ordovician eustatic events in Canada. — *In*: D.L. Brunton (ed.) *Aspects of the Ordovician System*, 51–63. Universitetsforlaget, Oslo.

BARNES, C.R. and WILLIAMS, S.H. 1988. Conodonts from the Ordovician-Silurian boundary stratotype, Dob'Linn, Scotland. — *Bulletin of the British Museum (Natural History), Geology* **43**, 31–49.

BEDNARCZYK, W. 1962. Dolny ordowik okolic wsi Koziel w Górach Świętokrzyskich. — *In:* E. Passendorfer (ed.) *Księga pamiątkowa ku czci Profesora Jana Samsonowicza*, 149–170. Wydawnictwa Geologiczne, Warszawa.

BEDNARCZYK, W. 1964. Stratygrafia i fauna tremadoku i arenigu (oelandianu) regionu kieleckiego Gór Świętokrzyskich. — *Biuletyn Geologiczny Uniwersytetu Warszawskiego* **4**, 3–127, 188–197.

BEDNARCZYK, W. 1966a. Litologia dolnego ordowiku (elandu) w regionie kieleckim Gór Świętokrzyskich. — *Biuletyn Geologiczny Uniwersytetu Warszawskiego* **8**, 4–53.

BEDNARCZYK, W. 1966b. Stratygrafia wapieni z Mójczy pod Kielcami, Góry Świętokrzyskie. — *Acta Geologica Polonica* **16**, 107–123.

BEDNARCZYK, W. 1971. Stratigraphy and palaeogeography of the Ordovician in the Holy Cross Mts. — *Acta Geologica Polonica* **21**, 574–616.

BEDNARCZYK, W. and BIERNAT, G. 1978. Inarticulate brachiopods from the Lower Ordovician of the Holy Cross Mountains, Poland. — *Acta Palaeontologica Polonica* **23**, 293–313.

BEDNARCZYK, W., CHLEBOWSKI, R., and KOWALCZEWSKI Z. 1966. Utwory ordowiku w synklinie bardziańskiej. — *Kwartalnik Geologiczny* **10**, 705–723.

BERGSTRÖM, S.M. 1971. Conodont biostratigraphy of the Middle to Upper Ordovician of Europe and eastern North America. — *The Geological Society of America Memoir* **127**, 83–157.

BERGSTRÖM, S.M. 1979. Whiterockian (Ordovician) conodonts from the Hølonda Limestone of the Trondheim Region, Norwegian Caledonides. — *Norsk Geologisk Tidsskrift* **59**, 295–307.

BERGSTRÖM, S.M. 1988. Conodont biostratigraphy of the Uppermost Ordovician and Lowermost Silurian. — *Bulletin of the British Museum (Natural History), Geology* **43**, 325–343.

BIERNAT, G. 1973. Ordovician inarticulate brachiopods from Poland and Estonia. — *Palaeontologia Polonica* **28**, 1–116.

BIERNAT, G. and TOMCZYKOWA, E. 1968. On the Upper Cambrian *Lingulella* Salter (Brachiopoda) from the Holy Cross Mountains, Poland. — *Acta Palaeontologica Polonica* **13**, 159–177.

BLUMENSTENGEL, H. 1965. Zur Ostrakodenfauna eines Kalkgerölls aus dem Thüringer Lederschiefer (Ordovizium). — *Freiberger Forschungshefte* **C182**, 63–78.

BRENCHLEY, P.J. 1988. Environmental changes close to the Ordovician-Silurian boundary. — *Bulletin of the British Museum (Natural History), Geology* **43**, 377–385.

BRUTON, D.L., HARPER, D.A.T., GUNBY, I., and NATERSTAD, J. 1984. Cambrian and Ordovician fossils from the Hardengervidda Group, Haukelifjell, southern Norway. — *Norsk Geologisk Tidsskrift* **64**, 313–324.

BRYANT, I.D. and SMITH, M.P. 1990. A composite tectonic-eustatic origin for shelf sandstones at the Cambrian-Ordovician boundary in North Greenland. — *Journal of the Geological Society, London* **147**, 795–809.

BUKOWY, S. 1984. Struktury waryscyjskie regionu śląsko-krakowskiego. — *Prace Naukowe Uniwersytetu Śląskiego* **691**, 1–73.

CHEN, J.-y. 1988. Ordovician changes of sea level. — *New Mexico Bureau of Mines and Mineral Resources Memoir* **44**, 387–404.

CHLEBOWSKI, R. 1971. Petrografia utworów ordowiku rejonu synkliny bardziańskiej w południowej części Gór Świętokrzyskich. — *Archiwum Mineralogiczne* **29**, 193–304.

CHLEBOWSKI, R. 1976. Studium petrograficzne skał tufogenicznych starszego paleozoiku Gór Świętokrzyskich. — *Archiwum Mineralogiczne* **34**, 69–134.

CHLEBOWSKI, R. and SZANIAWSKI, H. 1974. Chitinozoa from the Ordovician conglomerate at Międzygórz in the Holy Cross Mts. — *Acta Geologica Polonica* **24**, 221–230.

CLARKSON, E.N.K. and TRIPP, R.P. 1982. The Ordovician trilobite *Calyptaulax brongniarti* (Portlock).— *Transactions of the Royal Society of Edinburgh: Earth Sciences* **72**, 287–294.

COCKS, L.R.M. 1988. Brachiopods across the Ordovician-Silurian boundary. — *Bulletin of the British Museum (Natural History), Geology* **43**, 311–315.

COCKS, L.R.M. and FORTEY, R.A. 1986. New evidence on the South African Lower Palaeozoic: age and fossils reviewed. — *Geological Magazine* **123**, 437–444.

COCKS, L.R.M. and RONG, J-y. 1988. A review of the Lower Ordovician *Foliomena* brachiopod fauna with a new data from China, Wales, and Poland. — *Palaeontology* **31**, 53–67.

CZARNOCKI, J. 1928. Profil dolnego i górnego ordowiku w Zalesiu pod Łagowem w porównaniu z ordowikiem innych miejscowości środkowej części Gór Świętokrzyskich. — *Sprawozdania Państwowego Instytutu Geologicznego* **4**, 555–568.

CZARNOCKI, J. and SAMSONOWICZ, J. 1913. Drobny przyczynek do znajomości syluru Gór Kielecko-Sandomierskich. — *Sprawozdania z posiedzeń Towarzystwa Naukowego Warszawskiego, Wydział III* **6**, 487–491.

DADLEZ, R. 1982. Tektonika permo-mezozoiku a głębokie rozłamy strefy Teysseyre'a-Tornquista na terenie Polski. — *Kwartalnik Geologiczny* **26**, 273–284.

DADLEZ, R. 1986. Ewolucja basenów fanerozoicznych wzdłuż strefy Teysseyre'a-Tornquista. — *Kwartalnik Geologiczny* **31**, 263–278.

DEAN, W.T. 1973. The Lower Palaeozoic stratigraphy and faunas of the Taurus Mountains near Beysehir, Turkey. III. The trilobites of the Sobova Formation (Lower Ordovician). — *Bulletin of the British Museum Natural History, Geology* **24**, 281–348.

DESTOMBES, I. 1981. Himantian (Upper Ordovician) tillites on the north flank of the Rindonf Basin, Anti-atlas, Maroco. — *In:* M.J. Hambrey and W.B. Harland (eds) *Earth's Pre-Pleistocene Glacial Record*, 84-88. Cambridge University Press, Cambridge.

DZIK, J. 1976. Remarks on the evolution of Ordovician conodonts. — *Acta Palaeontologica Polonica* **21**, 395–455.

DZIK, J. 1978. Conodont biostratigraphy and paleogeographical relations of the Mójcza Limestone (Holy Cross Mts, Poland). — *Acta Palaeontologica Polonica* **23**, 51–72.

DZIK, J. 1983. Relationships between Ordovician Baltic and North American Midcontinent conodont faunas. — *Fossils and Strata* **15**, 59–83.

DZIK, J. 1984. Phylogeny of the Nautiloidea. — *Palaeontologia Polonica* **45**, 1–219.

DZIK, J. 1990. Conodont evolution in high latitudes of the Ordovician. — *Courier Forschungsinstitut Senckenberg* **117**, 1–28.

DZIK, J. 1994a. Conodonts of the Mójcza Limestone. — *In:* J. Dzik, E. Olempska, and A. Pisera Ordovician carbonate platform ecosystem of the Holy Cross Mountains. *Palaeontologia Polonica* **53**, 43–128.

DZIK, J. 1994b. Bryozoa of the Mójcza Limestone. — *In:* J. Dzik, E. Olempska, and A. Pisera Ordovician carbonate platform ecosystem of the Holy Cross Mountains. *Palaeontologia Polonica* **53**, 253–282.

DZIK, J. and DRYGANT, D. 1986. The apparatus of panderodontid conodonts. — *Lethaia* **19**, 133–141.

ERDTMANN, B.-D. 1986. Early Ordovician eustatic cycles and their bearing on punctuations in early nematophorid (planktic) graptolite evolution. — *In:* O. Walliser (ed.) *Global Bio-Events. Lecture Notes in Earth Sciences Vol.* 8, 139–152. Springer.

FINNEY, S.C. and BERGSTRÖM, S.M. 1985. Regional contemporaneity of eustatic subsidence and tectonic events in the Middle-Upper Ordovician of the Appalachians and Quachita Orogens and the southern Oklahoma Aulacogen. — *The Geological Society of America Abstracts with Programs* 1985, 583 (78003).

FLAJS, G. and SCHÖNLAUB, H.P. 1976. Die biostratigraphische Gliederung des Altpaläozoikums am Polster bei Eisenerz (Nordliche Grauwakenzone, Österreich). — *Verhandlungen der Geologisches Bundes Anstalt* **2**, 257–303.

FORTEY, R.A. 1980. *Basilicus tyrannus* (MURCHISON) and the glabellar structure of asaphid trilobites. — *Bulletin of the British Museum Natural History (Geology)* **34**, 255–264.

FORTEY, R.A. 1984. Global earlier Ordovician transgressions and regressions and their biological implications.— *In:* Bruton, D.L. (ed.) *Aspects of the Ordovician System, 37–50. Universitetsforlaget, Oslo.*

FORTEY, R.A. and MELLISH, C.J.T. 1992. Are some fossils better than others for inferring palaeogeography? The early Ordovician of the North Atlantic region as an example. — *Terra Nova*, 210–216.

GALLARDO, G., HEREDIA, S., and MALDONALDO, A. 1988. Depositos carbonaticos aloctonos, miembro superior de la Formacian Empozada, Ordovicico superior de la Precordillera de Mendoza, Argentina. — *V Congreso Geologico Chileno, Santiago* **IA**, 37–53.

GŁADYSZ, J., JACHOWICZ, M., and PIEKARSKI, K. 1990. Akritarchy paleozoiczne z okolic Siewierza (północne obrzeżenie GZW). — *Kwartalnik Geologiczny* **34**, 4, 623–646.

GÓRKA, H. 1969. Microorganismes de l'Ordovicien de Pologne. — *Palaeontologia Polonica* **22**, 1–102.

GÜRICH, G. 1901. Nachträge zum Paleozoicum in polnischen Mittelgebirge. — *Neues Jahrbuch für Geologie und Paläontologie, Beilage Band* **13**, 331–387.

HAMBREY, M.J. 1985. The Late Ordovician - Early Silurian Glacial Period. — *Palaeogeography, Palaeoclimatology, Palaeoecology* **51**, 273–289.

HAMMANN, W. 1974. Phacopina and Cheirurina (Trilobita) aus dem Ordovizium von Spanien. — *Senckenbergiana lethaea* **55**, 1–151.

HEMPEL, J. 1867. Description geologique des environs de Kielce, de Chenciny et de Malogoszcz. — *Annales des Mines Série III* **12**, 141–183.

HOLMER, L. 1983. Lower Viruan disconformity surfaces in central Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **105**, 29–42.

HUFF, W.D., BERGSTRÖM, S.M., and KOLATA, D.R. 1992. Gigantic Ordovician volcanic ash fall in North America and Europe: biological, tectonomagnetic, and event-stratigraphic significance. — *Geology* **20**, 875–878.

JAANUSSON, V. 1954. Zur Morphologie und Taxonomie der Illaeniden. — *Arkiv für Mineralogi och Geologi* **1**, 545–583.

JAANUSSON, V. 1957. Unterordovizische Illaeniden aus Skandinavien. Mit Bemerkungen über die Korrelation des Unterordoviziums. — *Bulletin of the Geological Institution of the University of Uppsala* **37**, 79–166.
JURKIEWICZ, H. 1975. Budowa geologiczna podłoża mezozoiku centralnej części niecki miechowskiej. — *Biuletyn Instytutu Geologicznego* **283**, 5–150.
JUX, U. and MANZE, U. 1979. Glazialeustatisch gesteuerte Sedimentationsabläufe auf dem kaledonischen Schelf (Mittelschweden) an der Wende Ordovizium-Silur. — *Neues Jahrbuch für Geologie und Paläontologie Monatshefte* **1979**, 155–180.
KIELAN, Z. 1956. Stratygrafia górnego ordowiku w Górach Świętokrzyskich. — *Acta Geologica Polonica* **6**, 253–271.
KIELAN, Z. 1960. Upper Ordovician trilobites from Poland and some related forms from Bohemia and Scandinavia. — *Palaeontologia Polonica* **11**, 1–198.
KOZŁOWSKI, R. 1948. Les graptolites et quelques nouveaux groupes d'animaux de Tremadoc de la Pologne. — *Palaeontologia Polonica* **3**, 1–235.
LEGG, D.P. 1976. Ordovician trilobites and graptolites from the Canning Basin, Western Australia. — *Geologica et Palaeontologica* **10**, 1–58.
LENDZION, K., MODLIŃSKI, Z., and SZYMAŃSKI, B. 1979. Tremadok Lubelszczyzny. — *Kwartalnik geologiczny* **23**, 713–726.
LEWANDOWSKI, M. 1987. Results of the preliminary paleomagnetic investigations of some Lower Paleozoic rocks from the Holy Cross Mts (Poland). — *Kwartalnik geologiczny* **31**, 543–556.
LEWANDOWSKI, M. 1992. Paleomagnetic evidences for dextral strike-slip displacement of the southern block of Holy Cross Mts along the East Eauropean Platform border during Variscan orogeny and its continental scale geotectonic implications. — *III Biennian Meeting, Smolenice 1992.*
LUDVIGSEN, R. and CHATTERTON, B.D.E. 1982. Ordovician Pterygometopidae (Trilobita) of North America. — *Canadian Journal of Earth Sciences* **19**, 2179–2208.
ŁĄCKA, B. 1990. Mineralogy of the Ordovician ferruginous coated grains (the Holy Cross Mountains and Northern Poland). — *Archiwum Mineralogiczne* **45**, 79–92.
MCKERROW, W.S. 1979. Ordovician and Silurian changes in sea level. — *Journal of the Geological Society of London* **136**, 137–145.
MCNAMARA, K. 1980. Evolutionary trends and their functional significance in chasmopine trilobites. — *Lethaia* **13**, 61–78.
MICHALSKI, 1883. Krótkie sprawozdanie z badań geologicznych w guberni kieleckiej. — *Pamiętnik fizjograficzny* **3**.
MILLER, J.F. 1984. Cambrian and earliest Ordovician conodont evolution, biofacies and provincionalism. — *Geological Society of America, Special Paper* **196**, 43–68.
MODLIŃSKI, Z. 1973. Stratygrafia i rozwój ordowiku w północno-wschodniej Polsce. — *Prace Instytutu Geologicznego* **72**, 7–64.
MODLIŃSKI, Z. 1982. Rozwój litofacjalny i paleotektoniczny ordowiku na obszarze platformy prekambryjskiej w Polsce. — *Prace Instytutu Geologicznego* **102**, 1–66.
MODLIŃSKI, Z. 1984. Stratygrafia potremadockich osadów ordowiku Lubelszczyzny. — *Kwartalnik geologiczny* **28**, 1–16.
NEUGEBAUER, J. 1989. The Iapetus model: a plate tectonic concept for the Variscan belt of Europe. — *Tectonophysics* **169**, 229–256.
NORDLUND, U. 1989. Genesis of phosphatic hardground in the Lower Ordovician of northern Öland, Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **111**, 101–192.
OLEMPSKA, E. 1986. Endolithic microorganisms in Ordovician ostracod valves. — *Acta Palaeontologica Polonica* **31**, 229–236.
OLEMPSKA, E. 1988. *Mojczella*, a new genus of of Ostracoda from the Ordovician of the Świętokrzyskie Mts., Poland. — *Acta Palaeontologica Polonica* **33**, 135–144.
OLEMPSKA, E. 1989. Gradual evolutionary transformations of ontogeny in an Ordovician ostracod lineage. — *Lethaia* **22**, 159–163.
OLEMPSKA, E. 1994. Ostracodes of the Mójcza Limestone. — *In:* J. Dzik, E. Olempska, and A. Pisera Ordovician carbonate platform ecosystem of the Holy Cross Mountains. *Palaeontologia Polonica* **53**, 129–212.
ORCHARD, M.J. 1980. Upper Ordovician conodonts from England and Wales. — *Geologica et Palaeontologica* **14**, 9–44.
OWEN, A.W. and TRIPP, R.P. 1988. Two cybeline trilobites from the Ordovician of Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **110**, 279–288.
PEGRUM, R.M. 1984. The extension of the Tornquist Zone in the Norwegian North Sea. — *Norsk Geologisk Tidsskrift* **64**, 39–68.
PICKERING, K.T., BASSETT, M.G., and SIVETER, D.J. 1988. Late Ordovician-early Silurian destruction of the Iapetus Ocean: Newfoundland, British Isles and Scandinavia – a discussion. — *Transactions of the Royal Society of Edinburgh* **79**, 361–382.
PIEKARSKI, K. and SIEWNIAK-WITRUK, A. 1974. O występowaniu ordowiku w okolicach Mrzygłodu. — *Przegląd Geologiczny* **22**, 647–650.

ROEMER, F. 1866. Geognostische Beobachtungen in Polnischen Mittelgebirge. — *Zeitschrift der Deutsche geologische Gesellschaft* **18**, 667–690.

RONG, J.-y. and HARPER, D.A.T. 1988. A global synthesis of the latest Ordovician Hirnantian brachiopod faunas.— *Transactions of the Royal Society of Edinburgh* **79**, 383–402.

ROSS, R.J.jr. 1970. Ordovician brachiopods, trilobites, and stratigraphy in eastern and central Nevada. — *Geological Survey Professional Paper* **639**, 1–103.

RYKA, W. and TOMCZYK, H. 1959. Bentonity w osadach staropaleozoicznych Gór Świętokrzyskich. — *Kwartalnik geologiczny* **3**, 689–711.

SAMSONOWICZ, J. 1916. Kambr i kambro-sylur Gór Świętokrzyskich. — *Sprawozdania z posiedzenia Towarzystwa Naukowego Warszawskiego* **9**, 319–358.

SCHRANK, E. 1972. *Nileus*-Arten (Trilobita) aus Geschieben des Tremadoc bis tieferen Caradoc. *Berichte der deutsche Gesellschaft der Geologische Wissenschaften, A Geologie und Paläontologie* **17**, 351–375.

SPASOV, C. and TELLER, L. (Спасов, Х. и Теллер, Л.) 1963. Конодонты от ордовикските варовицы при с. Муйча в Górach Świętokrzyskich, Польша. — *Трудове върху геологские на България* **5**, 75–83.

STRUVE, W. 1959. *Volkops volki* n. g., n. sp., ein Phacopinae aus dem deutschen Ordovizium. — *Senckenbergiana lethaea* **40**, 29–45.

STRUVE, W. 1962. Einige Trilobiten aus dem Ordovizium von Hessen und Thuringen. — *Senckenbergiana lethaea* **43**, 151–180.

STURESSON, U. 1986. Lower Ordovician ooids in northern Öland, Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **108**, 331–348.

STURESSON, U. 1988a. Chemical composition of Lower Ordovician ooids from northern Öland, Sweden, and their sedimentary host matrix. — *Geologiska Föreningens i Stockholm Förhandlingar* **110**, 29–38.

STURESSON, U. 1988b. Lower Ordovician ferriferous ooids from the Siljan District, Sweden. — *Bulletin of the Geological Institutions of the University of Uppsala, N.S.* **12**, 109–121. Uppsala.

STURESSON, U. 1989. Coated grains in Lower Viruan limestones in Västergötland, central Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **111**, 273–284.

SZANIAWSKI, H. 1980. Conodonts from the Tremadocian chalcedony beds, Holy Cross Mountains (Poland). — *Acta Palaeontologica Polonica* **25**, 101–121.

TEMPLE, J.T. 1965. Upper Ordovician brachiopods from Poland and Britain. — *Acta Palaeontologica Polonica* **10**, 379–450.

TOMCZYK, H. 1954. Stratygrafia gotlandu niecki międzygórskiej w Górach Świętokrzyskich na podstawie fauny z łupków graptolitowych. — *Biuletyn Instytutu Geologicznego* **93**, 1–66.

TOMCZYK, H. 1962. Stratygrafia osadów staropaleozoicznych z wiercenia w Uszkowcach koło Lubaczowa. — *In:* E. Passendorfer (ed.) *Księga Pamiątkowa ku czci Profesora Jana Samsonowicza* 123–148, Wydawnictwa Geologiczne, Warszawa.

TOMCZYK, H. and TURNAU-MORAWSKA, M. 1964. Stratygrafia i petrografia ordowiku Brzezin koło Morawicy w Górach Świętokrzyskich. — *Acta Geologica Polonica* **14**, 501–546.

TOMCZYK, H. and TURNAU-MORAWSKA, M. 1967. Zagadnienie stratygrafii i sedymentacji ordowiku Łysogór w nawiązaniu do niektórych profilów obszaru południowego. — *Acta Geologica Polonica* **17**, 1–46.

TOMCZYKOWA, E. 1968. Stratygrafia osadów najwyższego kambru w Górach Świętokrzyskich. — *Prace Instytutu Geologicznego* **54**, 1–85.

TURNAU-MORAWSKA, M. 1961. Charakterystyka petrograficzna ordowiku w Mójczy koło Kielc w porównaniu z równowiekowymi osadami innych obszarów Polski. — *Kwartalnik geologiczny* **5**, 775–787.

VAN DER VOO, R.1988. Paleozoic paleogeography of North America, Gondwana, and intervening displaced terranes: Comparisons of paleomagnetism with paleoclimatology and biogeographical patterns. *Bulletin of the Geological Society of America* **100**, 311–324.

WHITTINGTON, 1965. Table Head trilobites. — *Bulletin of the Museum of Comparative Zoology Harvard University* **132**, 275–442.

WILSON, J.L. 1975. *Carbonate facies in Geological History*, 1–471. Springer, New York.

YOCHELSON, E.L. 1964. *Modestospira*, a new Ordovician gastropod. — *Journal of Paleontology* **38**, 891–898.

YOUNG, T. P. 1992. Ooidal ironstones from Ordovician Gondwana: a review. — *Palaeogeography, Palaeoclimatology, Palaeoecology* **99**, 321–348.

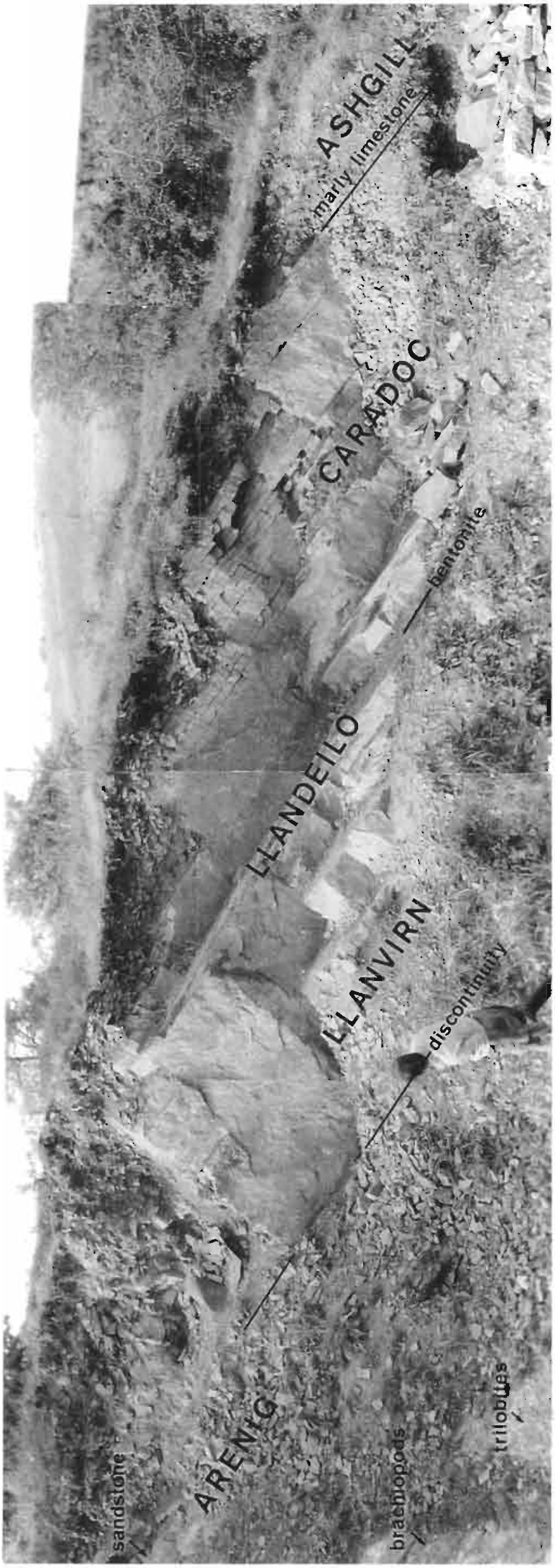
YOUNG, T. P. and TAYLOR, W.E.G. (eds) 1989. Phanerozoic ironstones. — *Geological Society Special Publication* **46**, 1–251.

ZEUSCHNER, L. 1869. Über die neuentdeckte Silurformation von Kleczanow. — *Zeitschrift der Deutsche geologische Gesselschaft* **21**, 257–262.

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 1

Fig. 1. Exposure of the type section of the Mójcza Limestone at the Skała hill at Mójcza, Kielce. View from the south.


ASHGILL
marly limestone
CARADOC
bentonite
LLANDEILO
LLANVIRN
discontinuity
ARENIG
sandstone
brachiopods
trilobites

Palaeontologia Polonica, No. 53, 1994

PLATE 2

Petrography of the rocks from the basal part of the Mójcza Limestone in the type section at Mójcza.

Fig. 1. The Bukówka sandstone, dark patches are iron hydroxides; × 10.

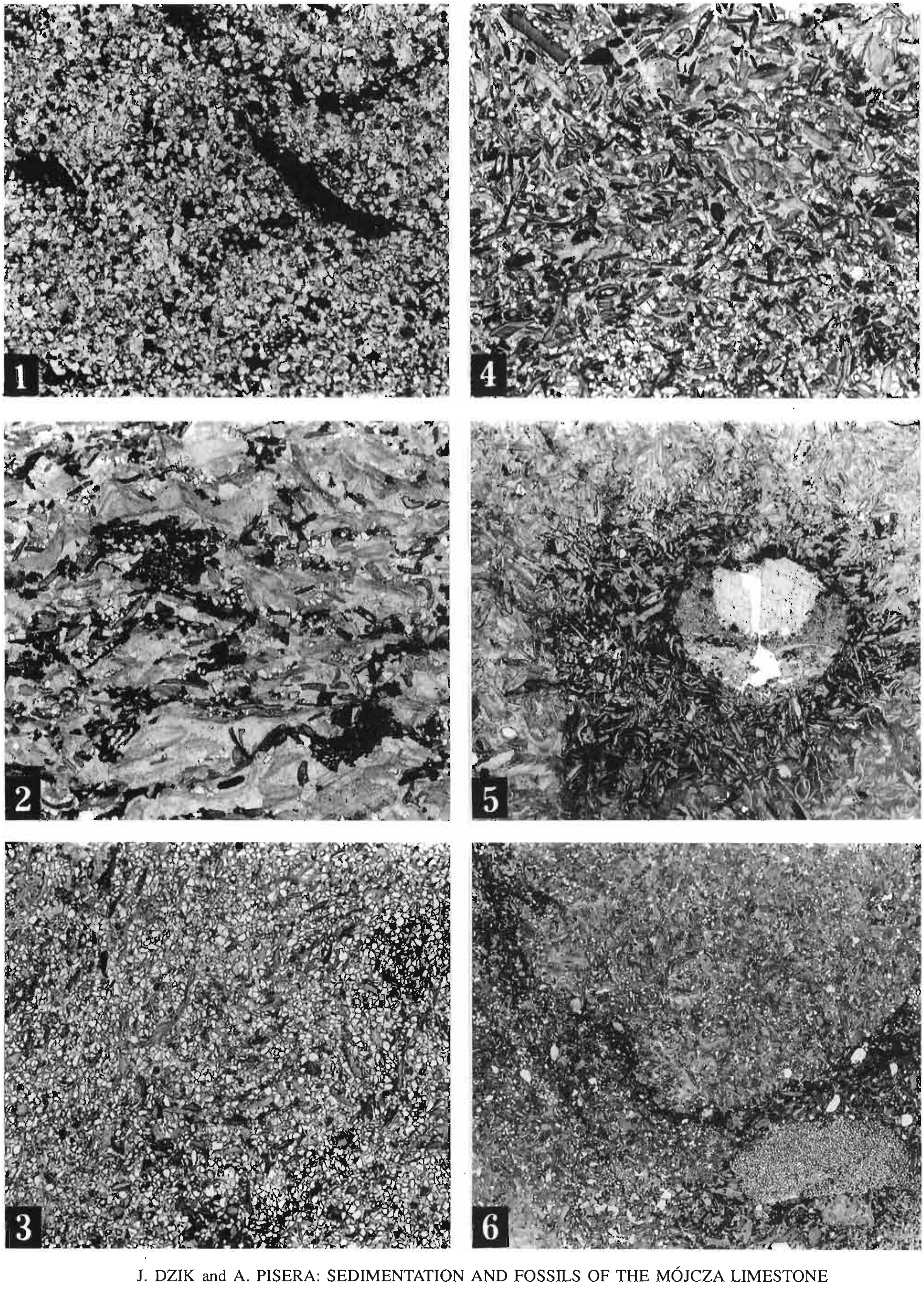
Fig. 2. Sandy brachiopod biosparite, sampe·MA-32; black patches are iron hydroxides; × 10.

Fig. 3. Calcareous sandstone (compare size of the quartz grains in this sample and the Bukówka sandstone) with bioclast (mostly fragments of brachiopd shells), MA-36; × 10.

Fig. 4. Sandy trilobite-brachiopod biosparite; note irregular distribution of quartz (more abundant in lower part), MA-37; × 10.

Fig. 5. Biosparite with preserved burrow (infilled with sparite) surrounded by a helo of iron oxides and hydroxides, MA-41 (just below the discontinuity surface); × 10.

Fig. 6. Sandy biosparite; upper parts shows a fraction of large irregular ?burrow with a helo of iron oxides and hydroxides, in the lower corner extraclasts of phosphorite; MA-42 (discontinuity zone); × 6.



J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 3

Petrography of the rocks from the middle part of the Mójcza Limestone in the type section at Mójcza.

Fig. 1. Biomicrosparite to biosparite (grainstone) with numerous fragments of trilobites, sample MA-45; × 10.

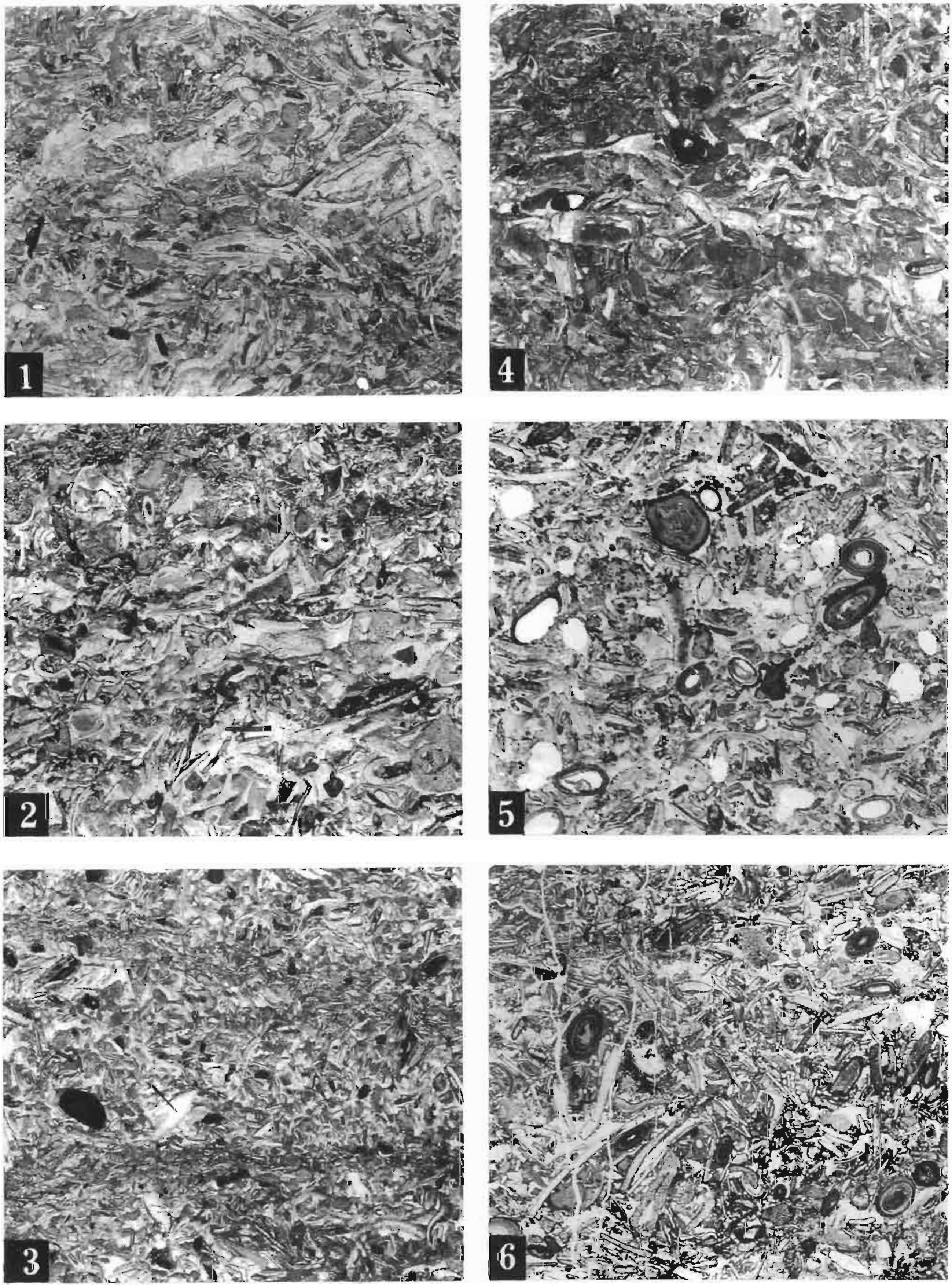
Fig. 2. Echinoderm-trilobite biosparite, MA-66; × 10.

Fig. 3. Biomicrosparite showing some lamination (lower part); ferruginous ooid black, MA-70; × 10.

Fig. 4. Poorly sorted trilobite-echinoderm biomicrosparite, ferruginous ooids black, MA-79; × 10.

Fig. 5. Echinoderm-trilobite biosparite with numerous ferruginous ooids (dark and white) occuring in patches, MA-92; × 10.

Fig. 6. Trilobite-echinoderm biosparite (bioclasts not well sorted) and common patchily distributed ferruginous ooids (dark), MA-99; × 10.


1
4
2
5
3
6

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 4

Petrography of the rocks from the upper part of the type section at Mójcza (Zalesie Formation).

Fig. 1. Ostracode-trilobite biomicrosparite, some cauliflower structures are also present (upper left corner and middle right), MA-101; × 10.

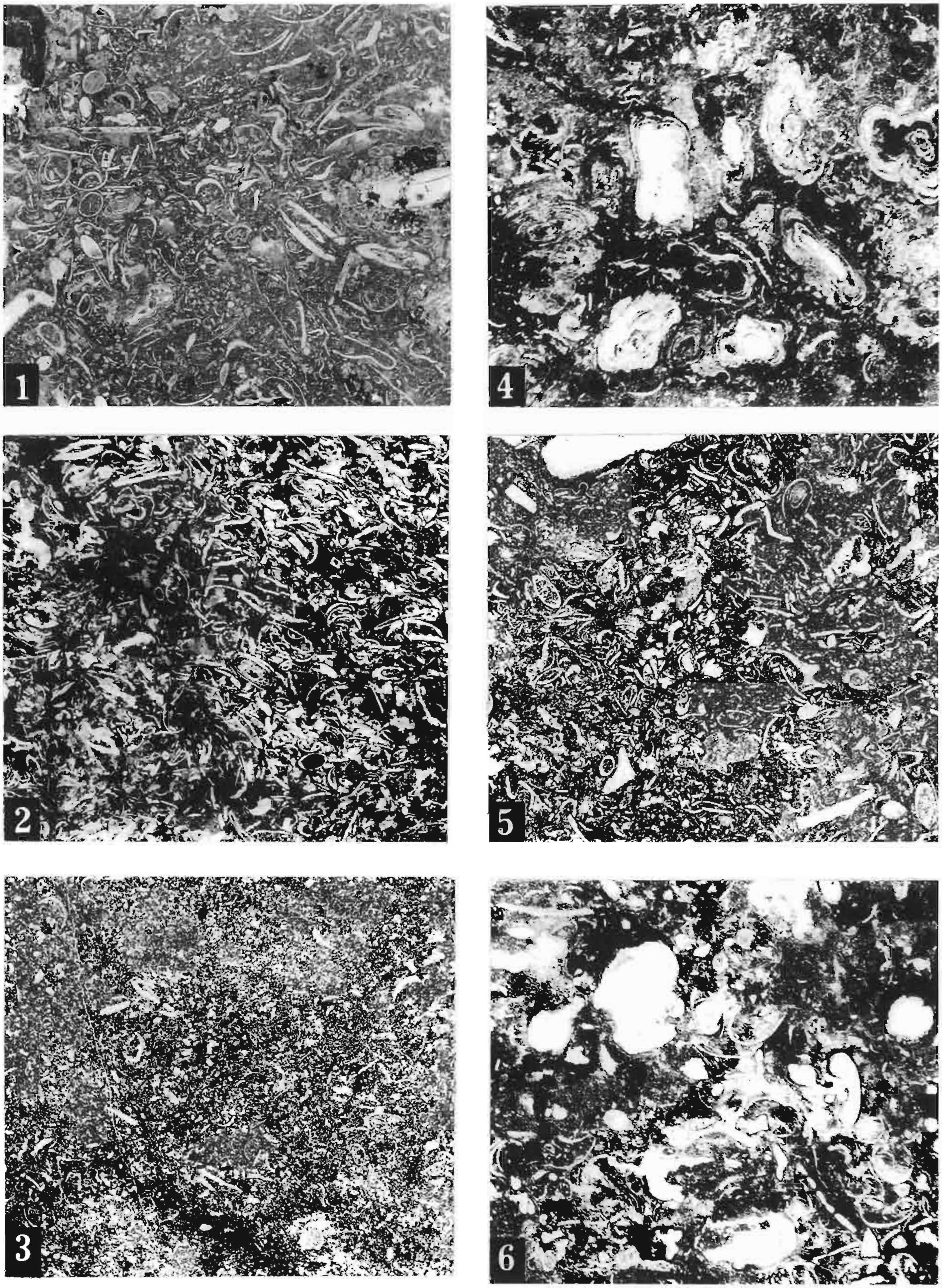
Fig. 2. Dense ostracod biomicrite, MA-106; × 10.

Fig. 3. Sparse biomicrosparite, MA-108; × 10.

Fig. 4. Biomicrite with numerous cauliflower structures, MA-113; × 10.

Fig. 5. Ostracode-trilobite biomicrite, MA-114, × 10.

Fig. 6. Biomicrite with numerous cauliflower structures (white and grey), MA-116 × 10.

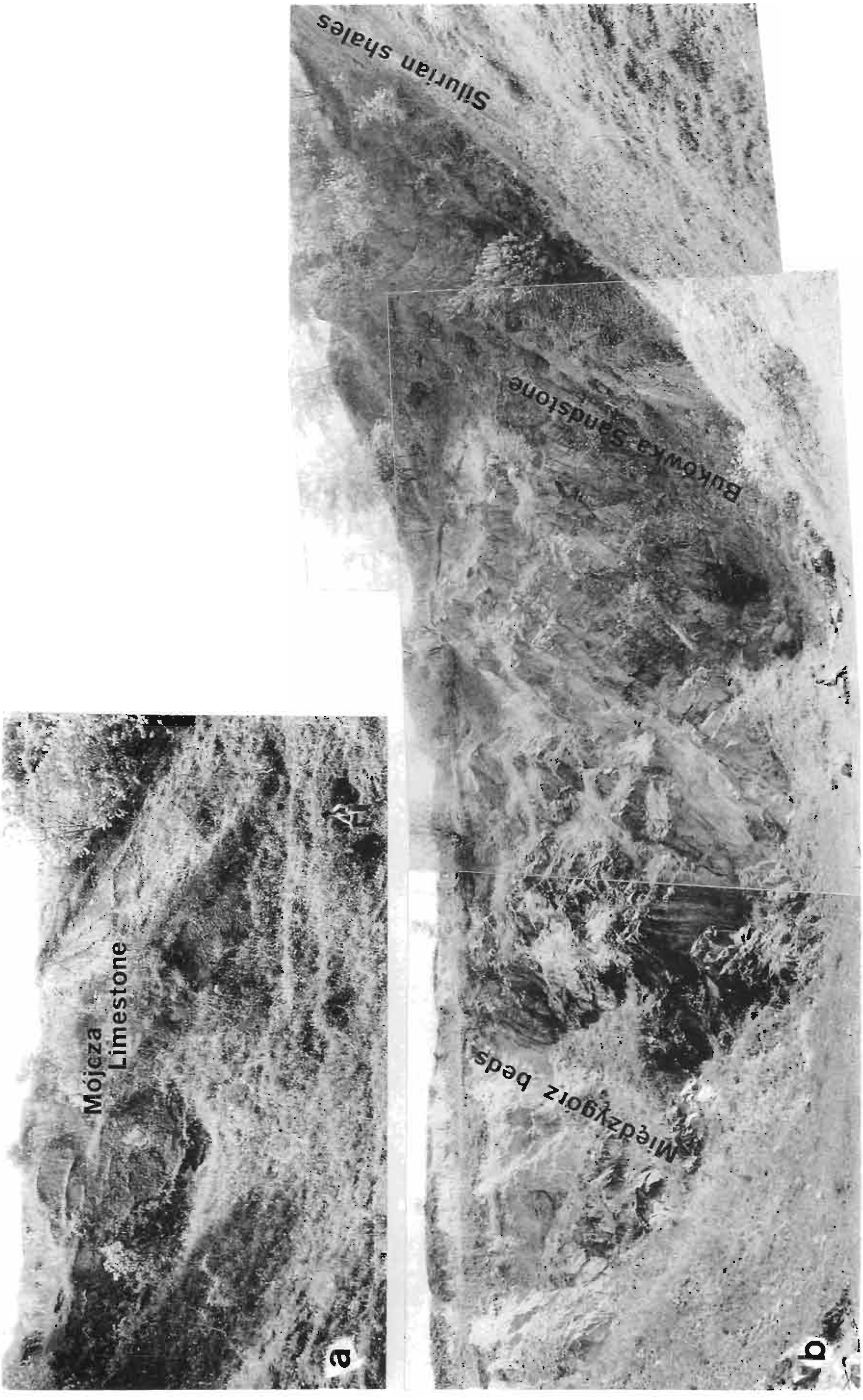


J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 5

Fig. 1. The quarry at Międzygórz near Sandomierz, the north side with the Mójcza Limestone exposed (a) and the main western wall (b).



J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 6

Articulate brachiopods and molluscs from the Bukówka sandstone and the Mójcza Limestone.

Antigonambonites planus (PANDER, 1830) 8

Late Volkhovian (Arenig) Bukówka Sandstone, Holy Cross Mountains, latex cast; × 2.

Figs 1–3, 6–8. ZPAL 21/047, 048, 045, 049, 046; Mójcza.
Figs 4–5, 9. ZPAL 21/086, IG 8.II.189; ZPAL 21/087; Międzygórz.

Modestospira polonica (GÜRICH, 1896) 8

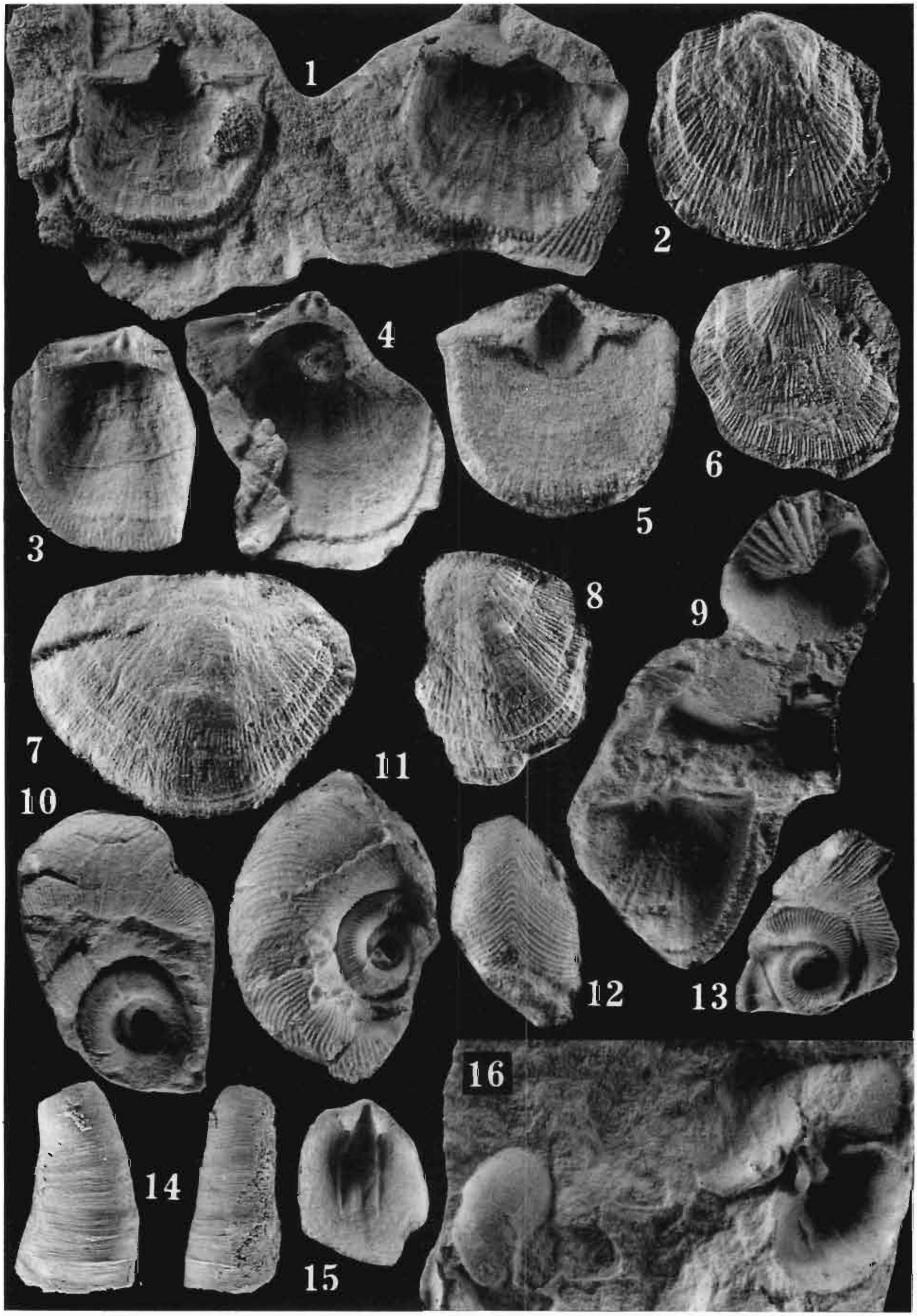
Figs 10–13. Late Volkhovian (Arenig), Bukówka Sandstone, Mójcza, latex casts, ZPAL 21/041, 042, 043, 044; × 2.

"*Hypseloconus*" sp. 224

Fig. 14. Early Kundan (Arenig), Mójcza Limestone basal part, Mójcza, latex casts, ZPAL 21/069, lateral and anterior (?) views × 2.

Lycophoria nucella (DALMAN, 1827) 8

Figs 15–16. Late Volkhovian (Arenig), Bukówka Sandstone, Mójcza, latex casts, ZPAL 21/059, 060; × 2.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 7

Articulate brachiopods from the topmost strata of the Bukówka Sandstone (Figs 1–16) (partially silicified specimens, except for the specimen at Figs 9, 15–16, which are latex casts from Międzygórz) from Mójcza and the basal part of the Mójcza limestone (Figs 17–18); × 2.

Productorthis obtusa (PANDER, 1830) 8

Figs 1–3. ZPAL 21/065, 066, 067.

Orthis kielcensis ROEMER, 1866 8

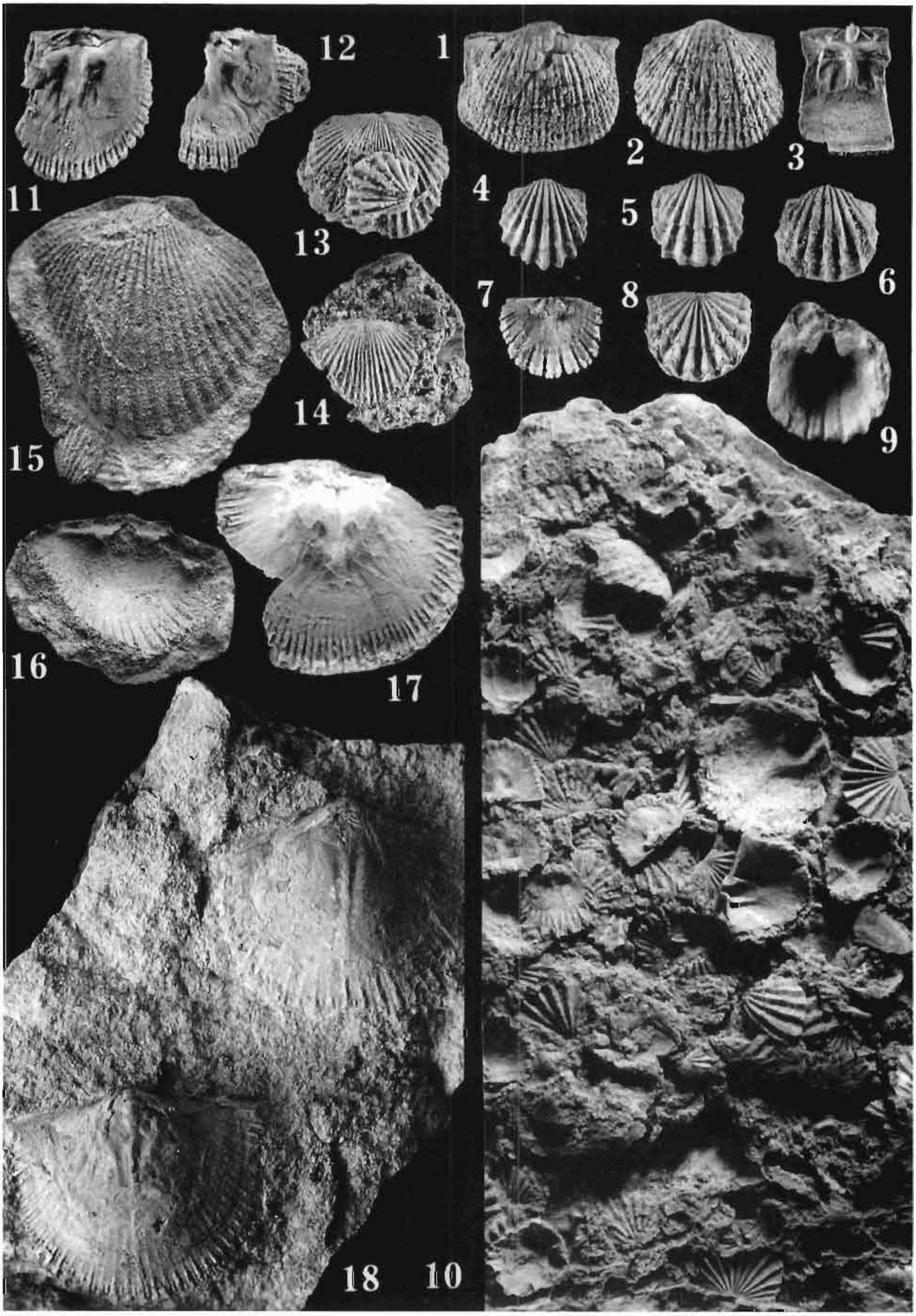
Figs 4–10. ZPAL 21/077, 075, 079, 080, 078, 091, UWR 168s.

Orthambonites calligramma (DALMAN, 1827) 8

Figs 11–14. ZPAL 21/072, 074, 073, 071, Mójcza.

Figs 15–16. IG 8.II.189, Międzygórz.

Figs 17–18. ZPAL 21/023, 031, Mójcza.



11
12
1
2
3
4
5
6
7
8
9
13
14
15
16
17
18
10

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 8

Trilobites from the base of the Mójcza Limestone and the topmost strata of the Bukówka Sandstone.

Cybele sp. n. 24

Fig. 1. Cranidium WB B.M/4, trilobite bed, coll. W. BEDNARCZYK.; × 2.
Fig. 2. Plasticine cast of pygidium ZPAL 21/053, uppermost Bukówka Sandstone, Mójcza; × 2.
Fig. 3. Juvenile thorax ZPAL 21/051, transition to the Mójcza Limestone, Mójcza, coll. Z. KIELAN; × 2.

Illaenus polonicus GÜRICH, 1901 26

Figs 4, 6. Cranidia WB B.M/12,14, trilobite bed; × 1.
Fig. 5. Pygidium WB B.M/11, trilobite bed; × 1.
Fig. 7. Pygidium ZPAL 21/003, trilobite bed; × 1.

Basilicus sp. n. 26

Fig. 8. Cranidium ZPAL 21/018, trilobite bed; × 1.
Figs 9, 11–13. Pygidia WB B.M/1,3,2,16, trilobite bed; coll. W. BEDNARCZYK; × 1.
Fig. 10. Pygidium ZPAL 21/019, trilobite bed, latex cast; × 1.

Calyptaulax sp. aff. *C. trigonocephala* (SCHMIDT, 1881) 26

Fig. 14. Cephalon WB B.M/15, trilobite bed, coll. W. BEDNARCZYK; × 2.
Fig. 15. Pygidium WB B.M/8, trilobite bed, coll. W. BEDNARCZYK; × 2.

Cyrtometopus polonicus (CZARNOCKI *et* SAMSONOWICZ, 1913) 25

Figs. 16–17. Cranidia WB B.M/4,6, trilobite bed, coll. W. BEDNARCZYK; × 1.
Fig. 18. Cranidium ZPAL, trilobite bed, × 1.

Nileus sp. [cf. *N. armadillo* (DALMAN, 1827)] 26

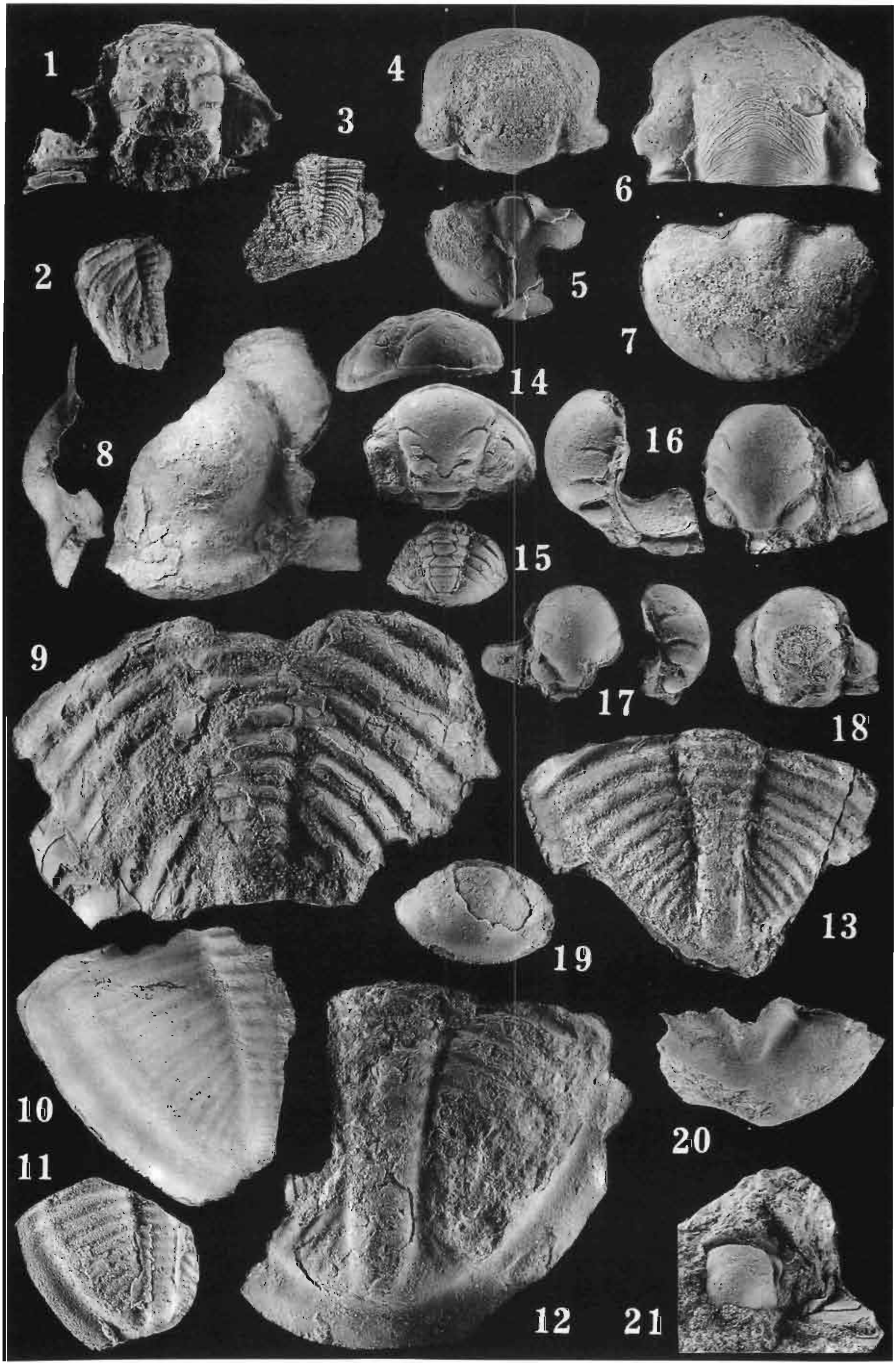
Fig. 19. Pygidium WB B.M/10, trilobite bed, coll. W. BEDNARCZYK; × 2.

Protostygina(?) sp. 26

Fig. 20. Pygidium WB B.M/13, trilobite bed, coll. W. BEDNARCZYK; × 1.

Agerina pamphylica DEAN, 1973 29

Fig. 21. Cranidium WB B.M/10, trilobite bed, block with *Nileus* sp., coll. W. BEDNARCZYK; × 2.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 9

Conodonts from the basal Ordovician strata at Chojnów Dół near Łagów; all × 75.

Drepanoistodus deltifer pristinus (VIIRA, 1970) 10

Figs 1–5. Elements ne ZPAL CVI/722, 724, 725, 727, 728.

Figs 6–10, 12. Unidentified element types ZPAL VI/729, 726, 730–732.

Nericodus(?) sp. 10

Fig. 11. ZPAL CVI/733.

Paraconodonts from the Mójcza Limestone at Mójcza; both × 75.

Westergaardodina bicuspidata MÜLLER, 1959 53

Fig. 13. Specimen ZPAL CVI/734, sample MA-124.

Fig. 14. Specimen ZPAL CVI/723, sample MA-41.

Preservation of sponge spicules and brachiopod shells in the Mójcza Limestone; all approximately × 50.

Fig. 15. Hexactinellid spicule with the original siliceous skeleton replaced with goetite, sample MA-111.

Fig. 16. *Ensiferites* sp., octactinellid spicule with the original calcitic skeleton preserved, sample MA-26.

Fig. 17. *Ensiferites* sp., phosphatic coating of spicule, sample MA-20.

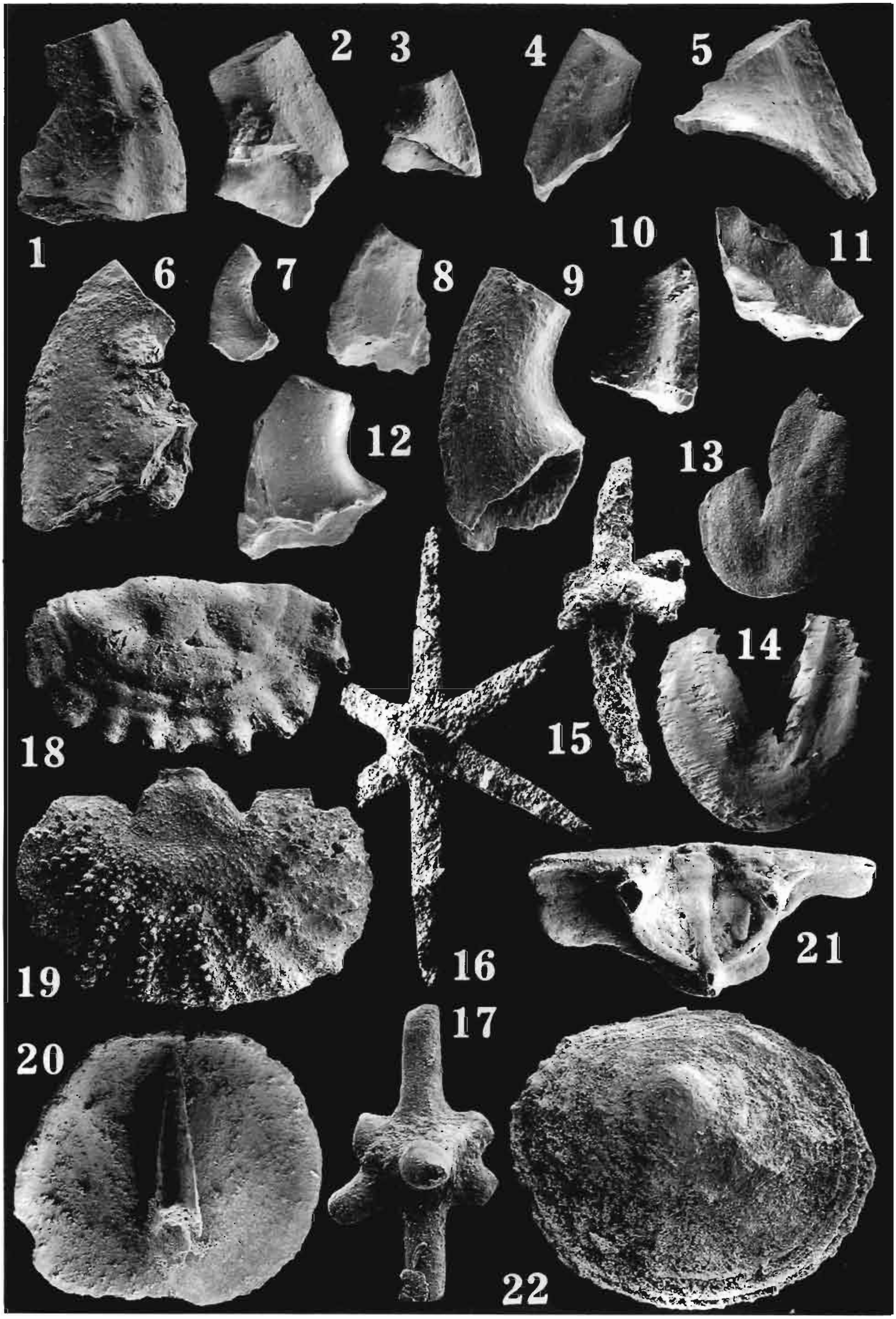
Fig. 18. *Progonambonites* sp., early postlarval shell with phosphatic coating from sample MA-46 (see also Text-fig. 13g).

Fig. 19. *Paurorthis* sp., phosphatic nucleus of juvenile specimen with articulated shells, sample MA-67.

Fig. 20. *Biernatia* sp., original phosphatic shell preserved, sample MA-116 (see also Text-fig. 12j).

Fig. 21. *Orthambonites* sp., shell fragment covered with phosphate, sample MA-46.

Fig. 22. *Eoconulus* sp.; original phosphatic shell preserved, sample MA-111.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 10

Trilobites, cornulitids and conulariids from the Mójcza Limestone; all × 50.

Fig. 1. *Nileus* sp., cheek with phosphatic coating, sample MA-46 (see also Text-fig. 8r).

Fig. 2. *Illaenus*(?) sp., rostral plate with phosphatic coating, sample MA-43 (see also Text-fig. 8v).

Fig. 3. Remopleurid gen. et sp. indet., hypostome with phosphatic coating, sample MA-55 (see also Text-fig. 8p).

Fig. 4. Cornulitid gen. et sp. indet., phosphatic nucleus of originally calcitic tube, sample MA-78.

Fig. 5. Cornulitid gen. et sp. indet., originally calcitic tubewith phosphatic coating, sample MA-85.

Fig. 6. *Agerina* sp., glabella with phosphatic coating, sample MA-118 (see also Text-fig. 8c).

Fig. 7. *Agerina* sp., pygidium with phosphatic coating, sample MA-120.

Fig. 8. *Phillipsinella* sp., rostral plate with phosphatic coating, sample MA-85 (see also Text-fig. 8u).

Fig. 9. Remopleurid gen. et sp. indet., pygidium with phosphatic coating, sample MA-43 (see also Text-fig. 8w).

Fig. 10. Proetid? gen et sp. indet; cranidium, sample MA-5 (see also Text-fig. 8l).

Fig. 11. Raphiophorid gen. et sp. indet.; phosphate coated fragment of genal spine, sample MA-46.

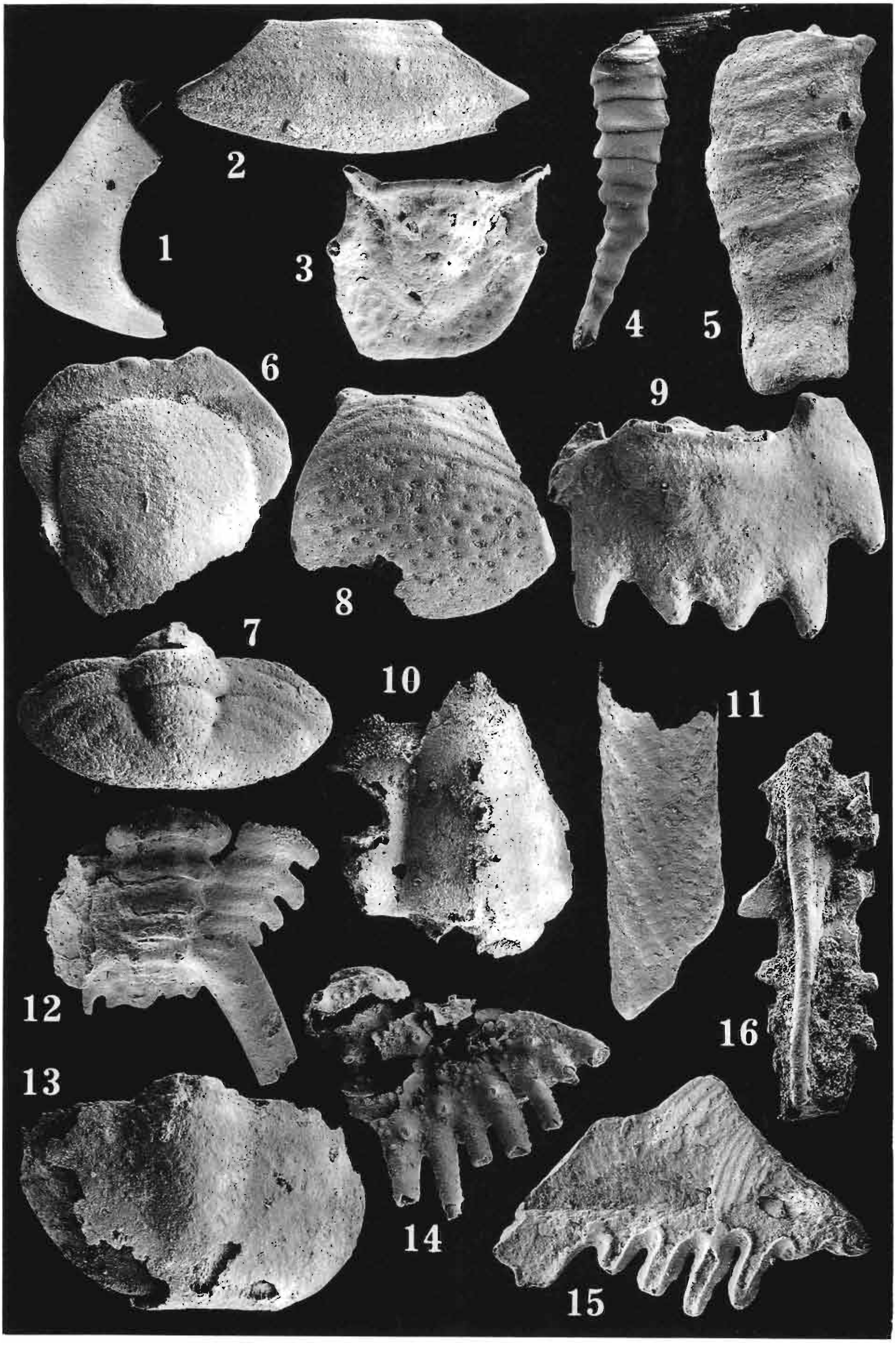
Fig. 12. Gen. et sp. indet.; phosphatic nucleus of pygidium, sample MA-30 (see also Text-fig. 8o).

Fig. 13. *Phillipsinella* sp., pygidium with partly exfoliated phosphatic coating, sample MA-5.

Fig. 14. Odontopleurid gen. et sp. indet., phosphatic coating of pygidium crushed when mounted on SEM stub, sample MA-57.

Fig. 15. *Plumulites*(?), phosphatized lateral sclerite?, sample MA-5.

Fig. 16. Conulariid gen. et sp. indet., fragment of test with medial inner rib, sample MA-111.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PALAEONTOLOGIA POLONICA — No. 53, 1994

ORDOVICIAN CARBONATE PLATFORM ECOSYSTEM OF THE HOLY CROSS MOUNTAINS

(EKOSYSTEM ORDOWICKIEJ PLATFORMY WĘGLANOWEJ GÓR ŚWIĘTOKRZYSKICH)

by

JERZY DZIK, EWA OLEMPSKA, and ANDRZEJ PISERA

(WITH 104 TEXT-FIGURES AND 67 PLATES)

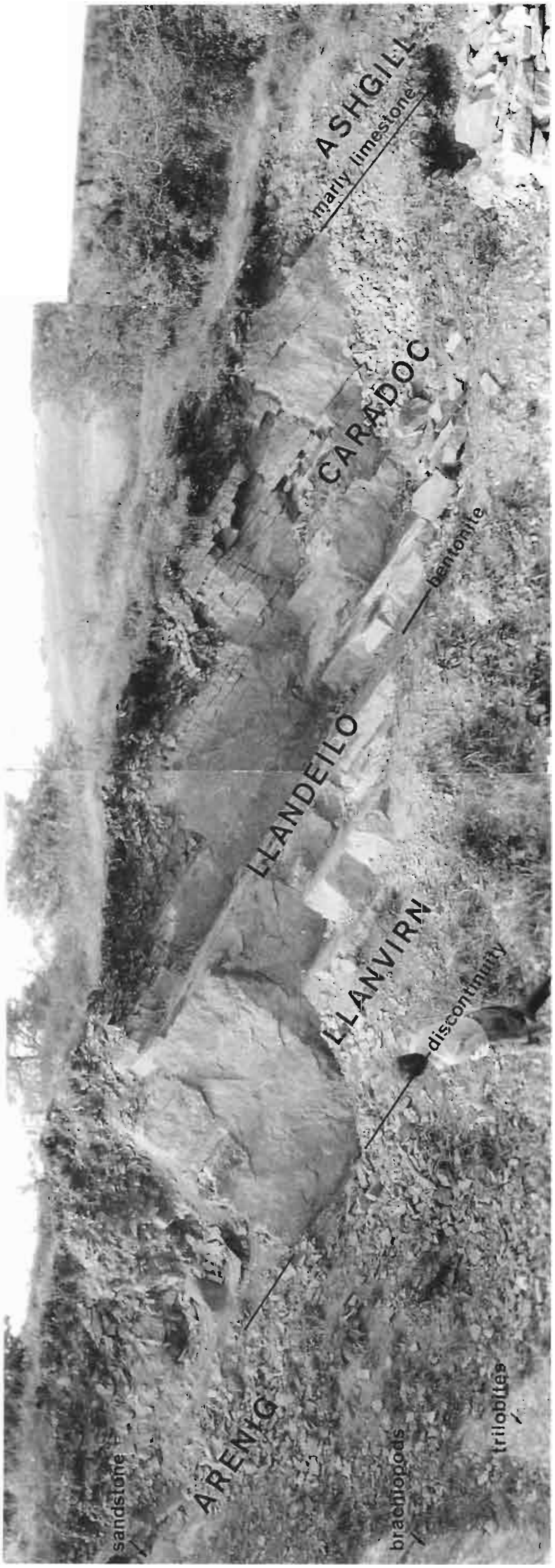
PART 2. PLATES

WARSZAWA 1994
INSTYTUT PALEOBIOLOGII PAN im. ROMANA KOZŁOWSKIEGO

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 1

Fig. 1. Exposure of the type section of the Mójcza Limestone at the Skała hill at Mójcza, Kielce. View from the south.


ASHGILL
marly limestone
CARADOC
bentonite
LLANDEILO
LLANVIRN
discontinuity
ARENIG
sandstone
brachiopods
trilobites

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 2

Petrography of the rocks from the basal part of the Mójcza Limestone in the type section at Mójcza.

Fig. 1. The Bukówka sandstone, dark patches are iron hydroxides; × 10.

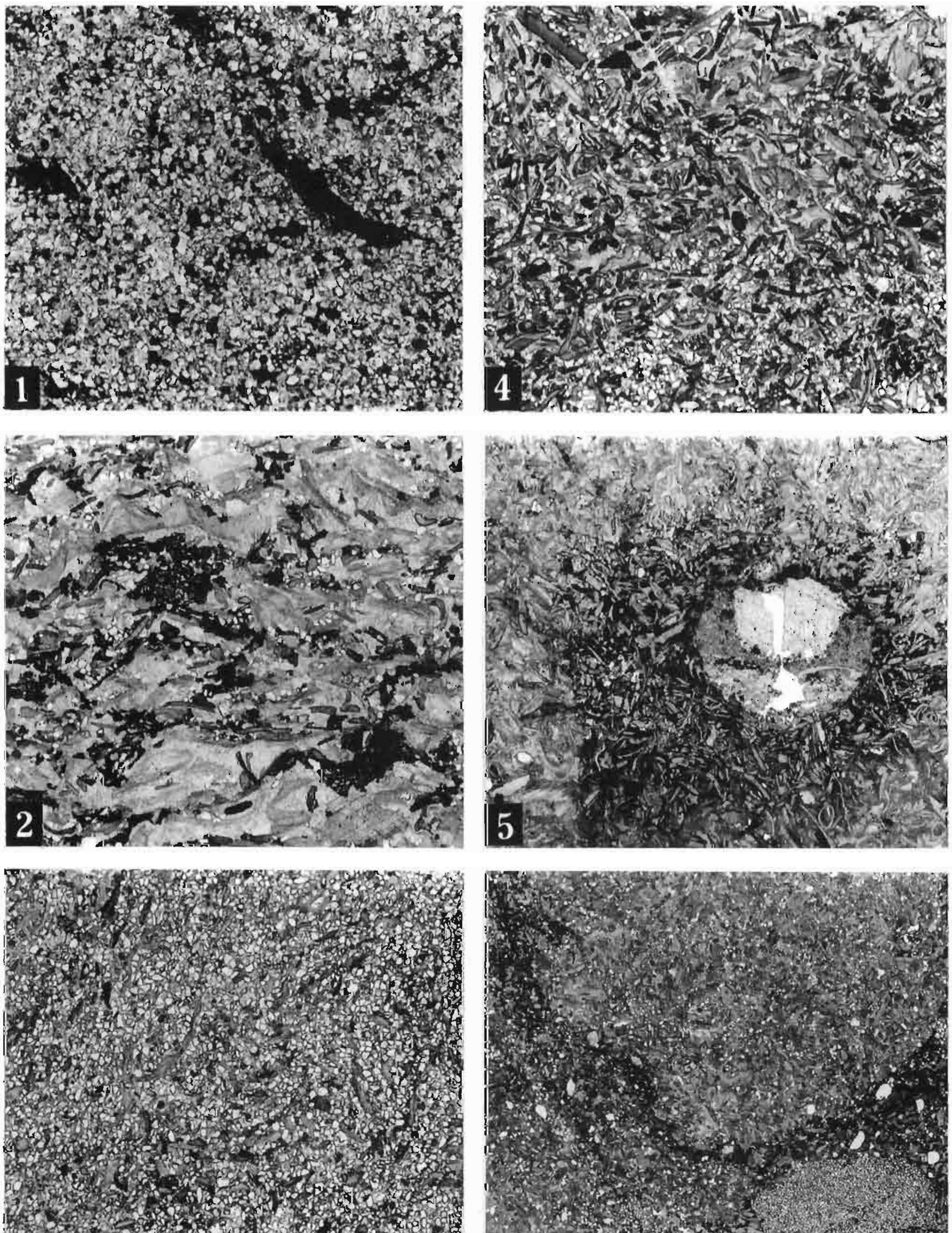
Fig. 2. Sandy brachiopod biosparite, sampe·MA-32; black patches are iron hydroxides; × 10.

Fig. 3. Calcareous sandstone (compare size of the quartz grains in this sample and the Bukówka sandstone) with bioclast (mostly fragments of brachiopd shells), MA-36; × 10.

Fig. 4. Sandy trilobite-brachiopod biosparite; note irregular distribution of quartz (more abundant in lower part), MA-37; × 10.

Fig. 5. Biosparite with preserved burrow (infilled with sparite) surrounded by a helo of iron oxides and hydroxides, MA-41 (just below the discontinuity surface); × 10.

Fig. 6. Sandy biosparite; upper parts shows a fraction of large irregular ?burrow with a helo of iron oxides and hydroxides, in the lower corner extraclasts of phosphorite; MA-42 (discontinuity zone); × 6.



J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 3

Petrography of the rocks from the middle part of the Mójcza Limestone in the type section at Mójcza.

Fig. 1. Biomicrosparite to biosparite (grainstone) with numerous fragments of trilobites, sample MA-45; × 10.

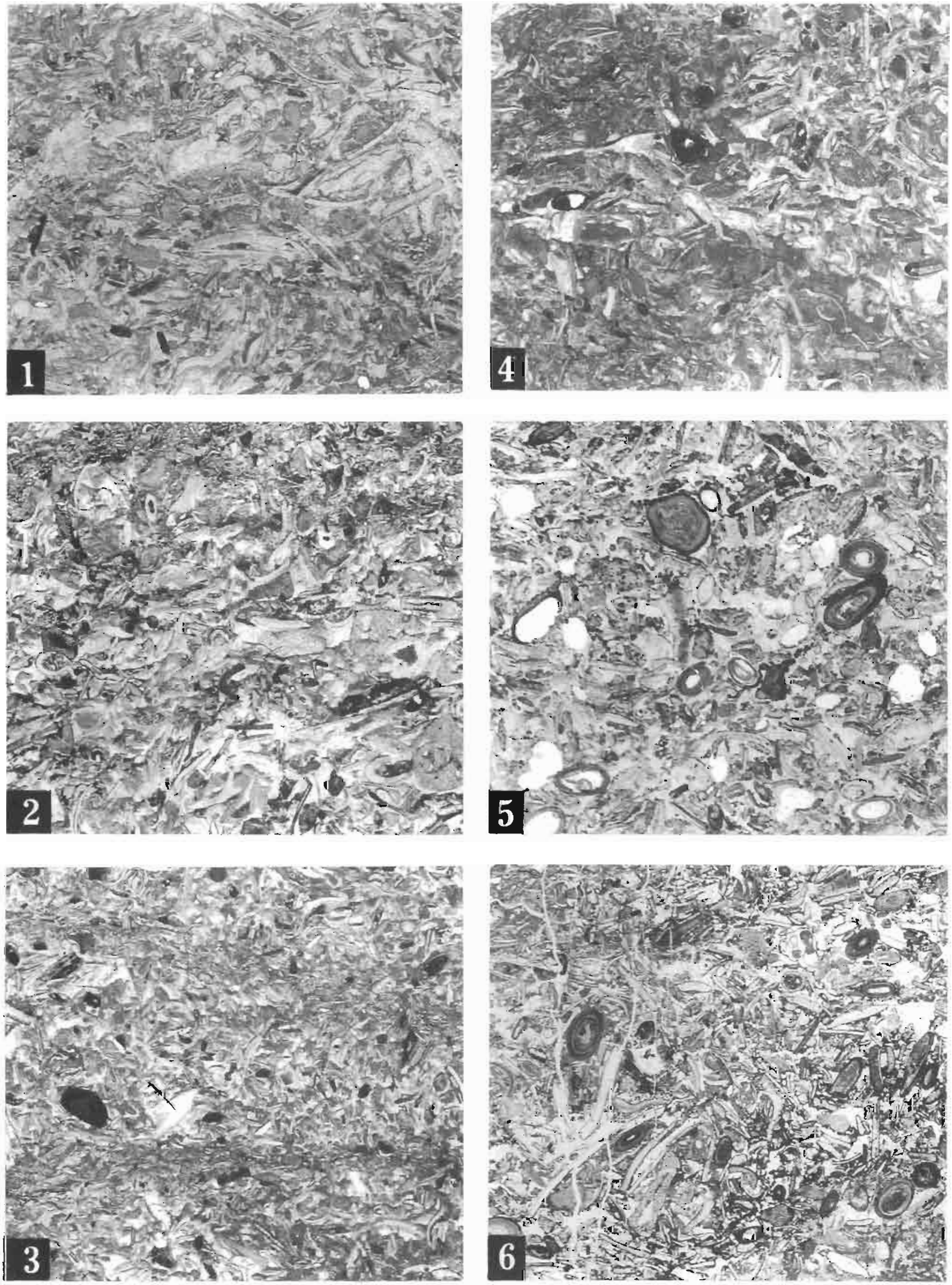
Fig. 2. Echinoderm-trilobite biosparite, MA-66; × 10.

Fig. 3. Biomicrosparite showing some lamination (lower part); ferruginous ooid black, MA-70; × 10.

Fig. 4. Poorly sorted trilobite-echinoderm biomicrosparite, ferruginous ooids black, MA-79; × 10.

Fig. 5. Echinoderm-trilobite biosparite with numerous ferruginous ooids (dark and white) occuring in patches, MA-92; × 10.

Fig. 6. Trilobite-echinoderm biosparite (bioclasts not well sorted) and common patchily distributed ferruginous ooids (dark), MA-99; × 10.



J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 4

Petrography of the rocks from the upper part of the type section at Mójcza (Zalesie Formation).

Fig. 1. Ostracode-trilobite biomicrosparite, some cauliflower structures are also present (upper left corner and middle right), MA-101; × 10.

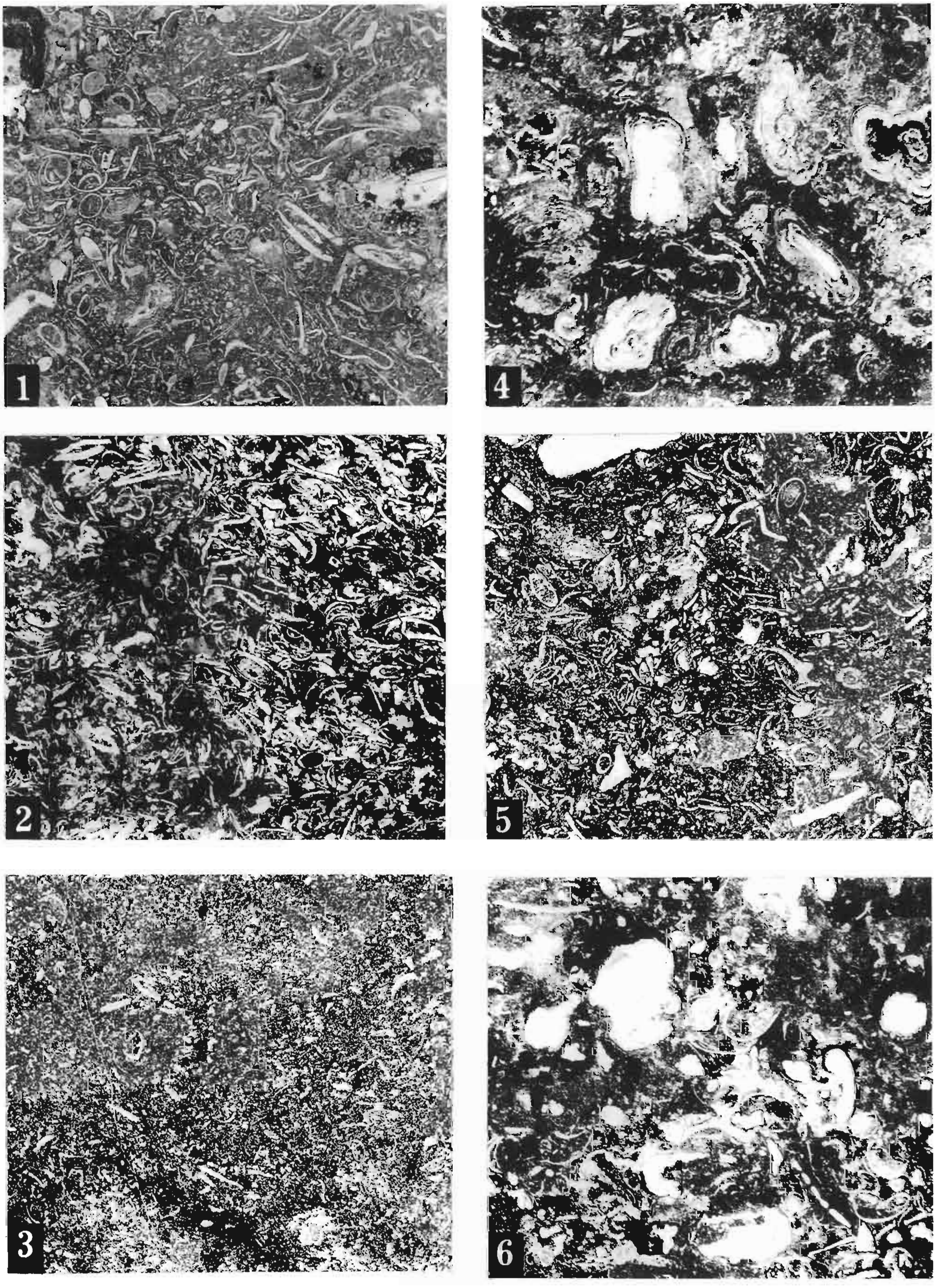
Fig. 2. Dense ostracod biomicrite, MA-106; × 10.

Fig. 3. Sparse biomicrosparite, MA-108; × 10.

Fig. 4. Biomicrite with numerous cauliflower structures, MA-113; × 10.

Fig. 5. Ostracode-trilobite biomicrite, MA-114, × 10.

Fig. 6. Biomicrite with numerous cauliflower structures (white and grey), MA-116 × 10.



J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

J. DZIK and A. PISERA: SEDIMENTATION AND FOSSILS OF THE MÓJCZA LIMESTONE

PLATE 5

Fig. 1. The quarry at Międzygórz near Sandomierz, the north side with the Mójcza Limestone exposed (a) and the main western wall (b).