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GEOLOGY

Remarks on the Callovian and Lower Oxfordian of the Zalas Area (Cracow Upland, Southern Poland)

by

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Summary. The profile of Callovian and Lower Oxfordian deposits from a new quarry at Zalas is discussed. It appears that the Middle Jurassic transgression reached this area in Early Callovian times. The analysis of sedimentary environment has shown a gradual deepening of marine basin during the Callovian and Early Oxfordian. Stromatolites and iron-manganese nodules were found above the discontinuity connected with break in sedimentation during the Middle Callovian.

Introduction. Middle Jurassic deposits from Zalas have been known for about a hundred years. On the basis of rich ammonite fauna they were divided into stages by Zeuschner [40] and into zones by Wójcik[38]. The subdivision was somewhat modified by Różycki [32] who was the first to found stromatolites in this area. Several new observations concerning the geological setting of the Zalas area and the environment of sedimentation of deposits from the turn of the Middle and Upper Jurassic were made by Dżułyński [6–9].

Some additional observations were made and new data concerning stratigraphy and sedimentary environment of the Jurassic strata were gathered due to large-scale quarrying works recently carried out between Zalas and Frywałd (Fig. 1). The Jurassic strata eposed in the quarry represent a north-eastern extension of a belt of Jurassic outcrops of the vicinity of Zalas hitherto known from the literature [15, 39]. In the quarry there are exploited Lower Permian porphyres representing a part of laccolith penetrating the Lower Carboniferous rocks [9]. Middle Jurassic deposits forming lower part of sedimentary blanket of the porphyres may be traced nowadays at the distance of some hundred meters. Both porphyres and overlying Jurassic rocks are cut by numerous faults of the Tertiary age [8, 9].

The characteristics of sediments. The transgressive Middle Jurassic rocks discordantly overlay uneven surface of the porphyres with denivelations of the order of several meters (Fig. 2). Porphyre blocks found in basal parts of the transgressive deposits evidence cliff character of the coast (see [6]). Top surface of porphyres

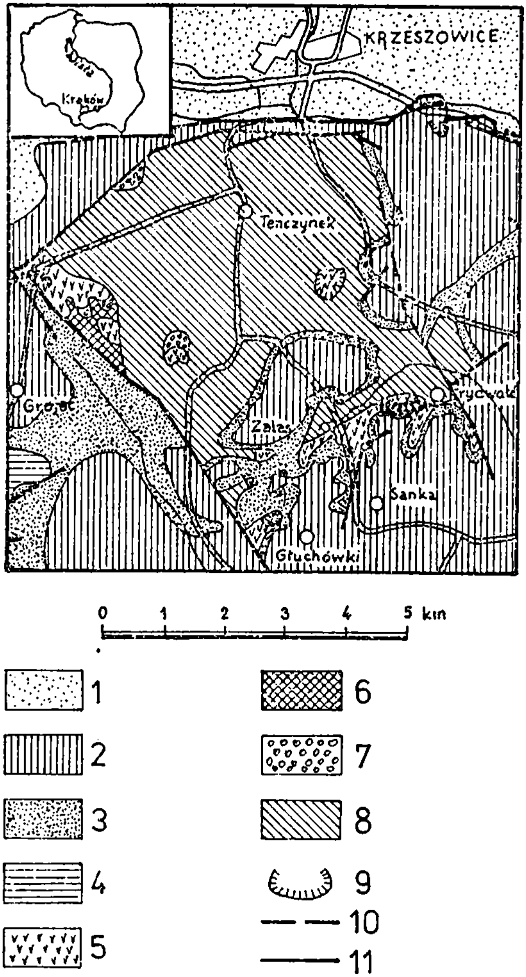


Fig. 1. Geological sketch map of the Zalas area (without the Cenozoic/continental deposits)—after Gradziński [15]

1—Miocene, 2—Upper Jurassic, 3—Lower and Middle Jurassic, 4—Triassic, Permian: 5—porphyres, 6—other igneous rocks, 7—sedimentary rocks, 8—Carboniferous, 9—quarries, 10—inferred faults, 11—faults

is smoothened and sometimes overgrown by serpulids. Porphyres are covered by white, uncemented quartz sands variable in thickness (but not more than 6 m thick) and, sometimes, directly by sandy crinoid limestones (Fig. 2-I). The material for these clearly littoral sands was derived from erosion of Permian and Upper Carboniferous rocks [6]. The sands sometimes yield nodules of calcareous sandstone usually rich in pelecypod shells and sometimes with borings. In upper parts of the

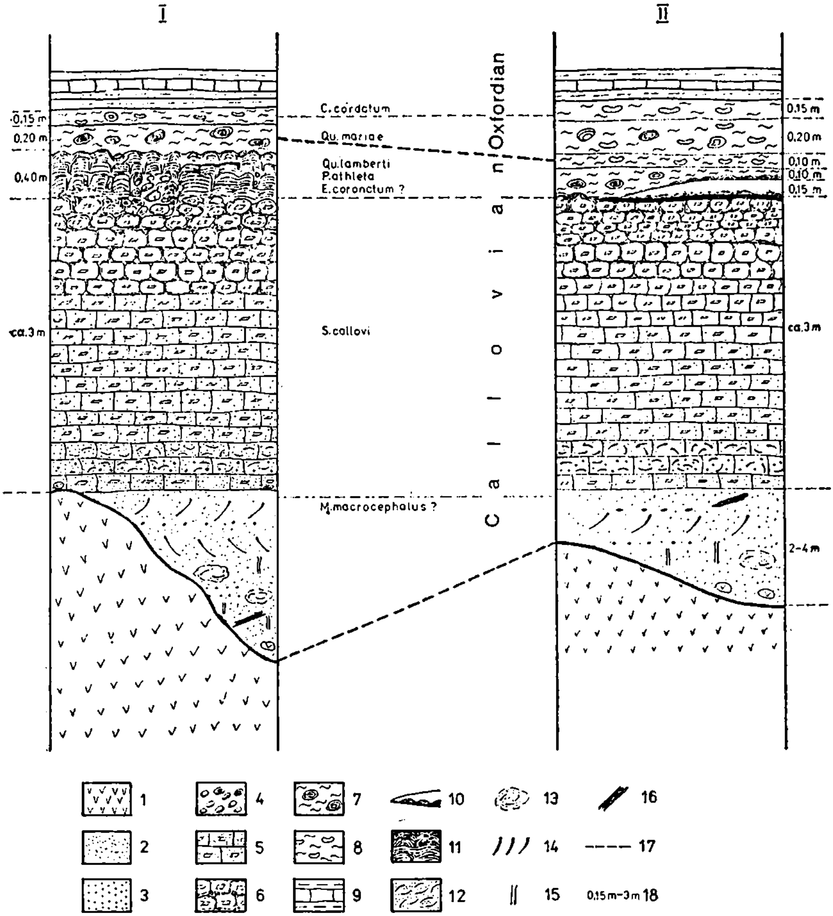


Fig. 2. Schematic profiles of the Jurassic from Zalas

1—Permian porphyres, 2—uncemented sands, 3—gravels, 4—crinoid limestone pebbles, 5—sandy crinoid limestones, 6—nodular crinoid limestones, 7—marls with oncolites, 8—marls with sponges, 9—alternating marls and limestones, 10—pinky limestone lenses with ferruginous crust at the base and stromatolite, 11—stromatolites, 12—shelly layers with gravels, 13—nodules of calcareous sandstones with shell debris, 14—ripple cross-bedding, 15—bioturbations, 16—wood fragments, 17—boundaries of stratigraphic units, 18—thickness of strata.

sands pelecypods (oysters and trigoniids) are accompanied by occasional brachiopods, nautiloids and ammonites.

Lower parts of sandy crinoid limestones display intercalations of conglomerate with quartz pebbles and shelly layers (Fig. 2, Photo 1). The rich faunal assemblage of these layers comprises pelecypods (*Chlamys*, *Entolium*, *Trigonia*, *Liostrea*, *Gryphea*, *Oxytoma*, *Anisocardia*, *Trichites*), brachiopods (terebratulids and rhynchonelids), corals, bryozoans, serpulids, nautiloids, ammonites and calcareous sponges. Coral colonies and shells of *Trichites* are sometimes bored by pelecypods.

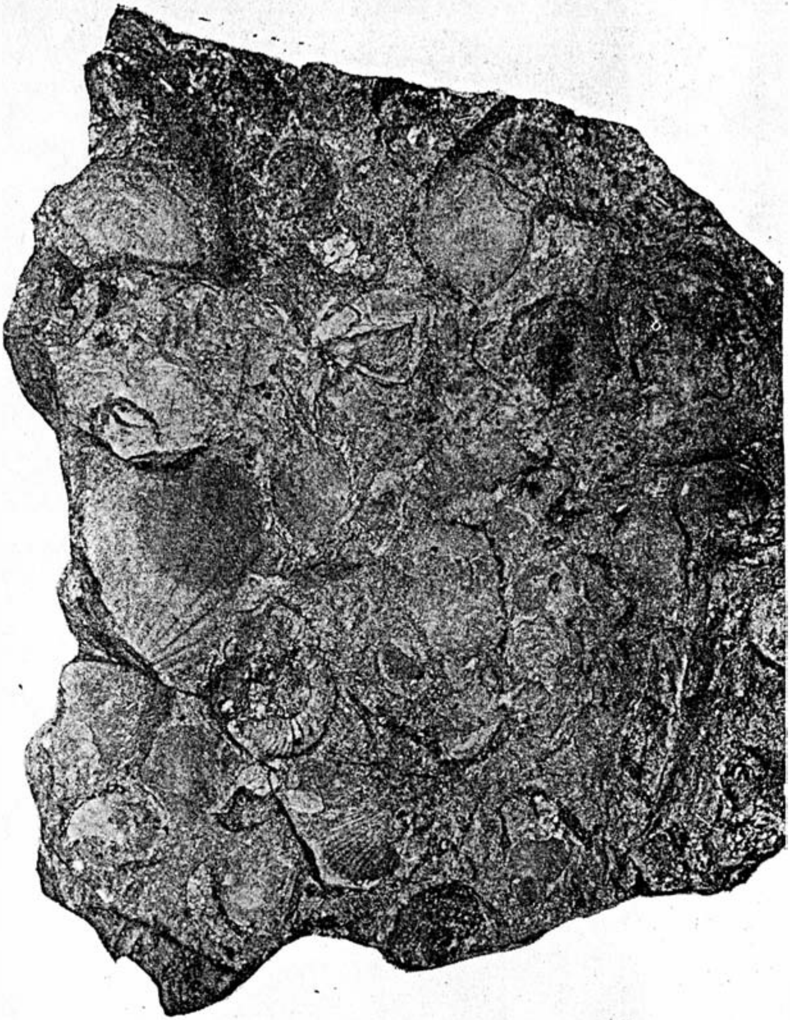
The upper part of crinoid limestones is very poor in fossils. It displays characteristic nodular structure presumably resulting from the action of burrowing organisms (? crabs). In the uppermost layer of crinoid limestone irregular nodules are separated by narrow interstices filled with somewhat marly deposit enriched in iron compounds (Photo 2). Similar crinoid limestones are known from the Mediterranean Jurassic where their nodular structure is explained by early-diagenetic segregation of calcium carbonate [22, 24].

Ammonites, pelecypods and gastropods in uppermost parts of the crinoid limestones occur usually as internal moulds. The fossils (both shells and moulds) display iron compounds coatings and are overgrown by serpulids and bryozoans. Shells display traces of both chemical corrosion and erosional truncation.

The top of crinoid limestones has some features of hard-ground . The upper surface is smoothened in some places only and it is usually uneven with denivellations up to few cm in height. In some places it displays ferruginous encrustations (Fig. 2-II). Iron compounds also impregnate deposits infilling interstices between crinoid limestone nodules to the depth of a dozen cm from the top surface (Photo 2). Pebbles of these limestones with ferromanganese envelopes and sometimes overgrown by serpulids are occasionally found in the upper part of crinoid limestones (Fig. 2-I, Photo 3). These pebbles are cemented with pink marls and their presence evidences a mechanical desintegration of crinoid limestone and redeposition of the resulting fragments.

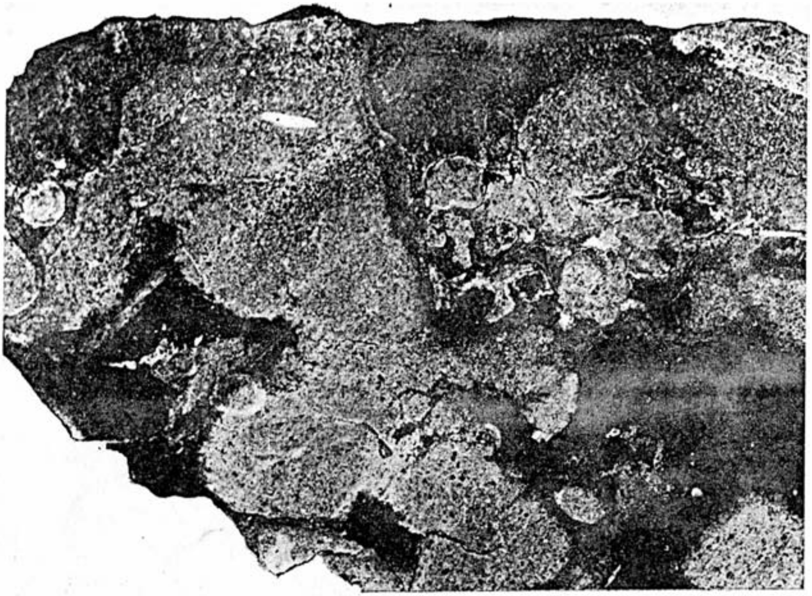
Top surface of crinoid limestones is usually covered by stromatolite layer up to 40 cm thick (Fig. 2-I). The base of stromatolitic layer follows the substratum morphology. In the lower part of the stromatolite there occur "pockets" up to 20 cm in size, infilled with pink marls with crinoid limestone pebbles (Fig. 2-I, Photo 4) with ferromanganese coatings. The pebbles are sometimes bored and the surface of ferromanganese coatings overgrown by serpulids. Some pebbles display stromatolite encrustations. The pebbles were also found in stromatolite interstices (Photos 6, 7) infilled with pinky marls. In stromatolite interstices and "pockets" thre are some times found belemnite rostra and redeposited shells or shell fragments of ammonites of the genera *Macrocephalites* and *Choffatia*, pelecypods and gastropods (*Pleurotomaria*) infilled with crinoid limestone and with ferromanganese envelopes.

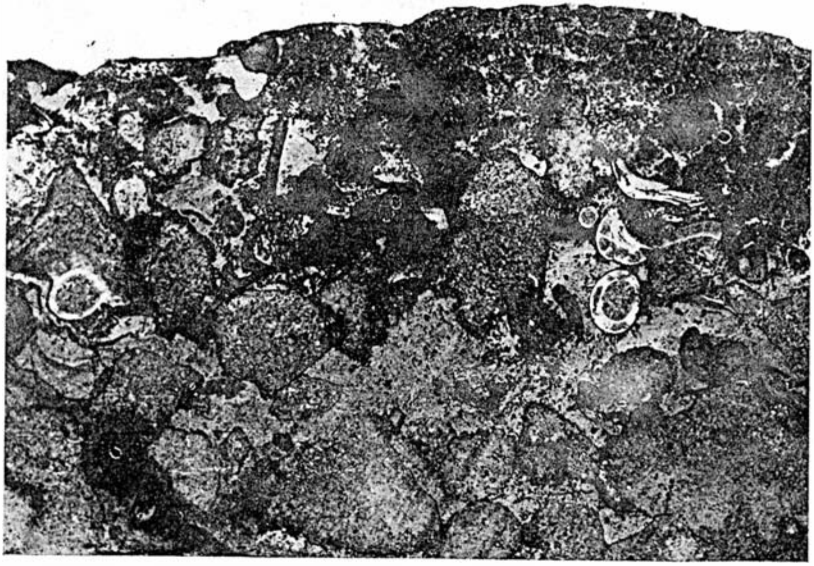
Stromatolites are built of micritic calcium carbonate with a marked admixture of quartz grains. Calcitized siliceous sponge spicules and pelecypod prodissoconchs are common while all the other fossils are rather scarce. Black or red colour of lower part of the stromatolite results from impregnation of stromatolite laminae with manganese and iron compounds (Photos 6,7). Upper parts of the stromatolite are greenish to brownish. In the top of the stromatolite layer occur dome stromatolites and in the overlying layer of pinky marls numerous oncolites with nuclei formed of crinoid limestone pebbles with ferromanganese coatings (Photo 5).



1. Fragment of shelly layer intercalating sandy crinoid limestone. Note *Gowericeras* in the lower part of the specimen. Somewhat reduced

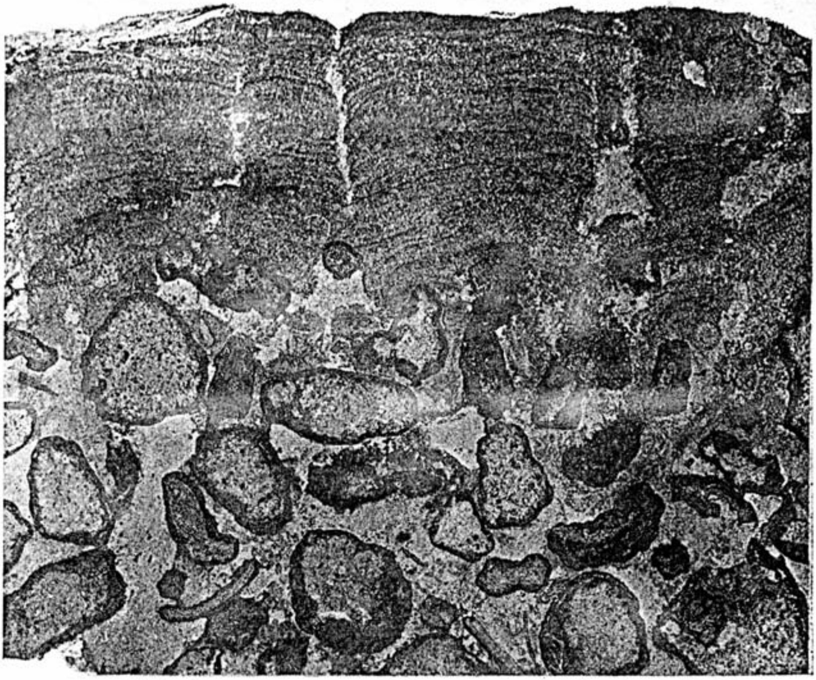
Photo K. Zielińska





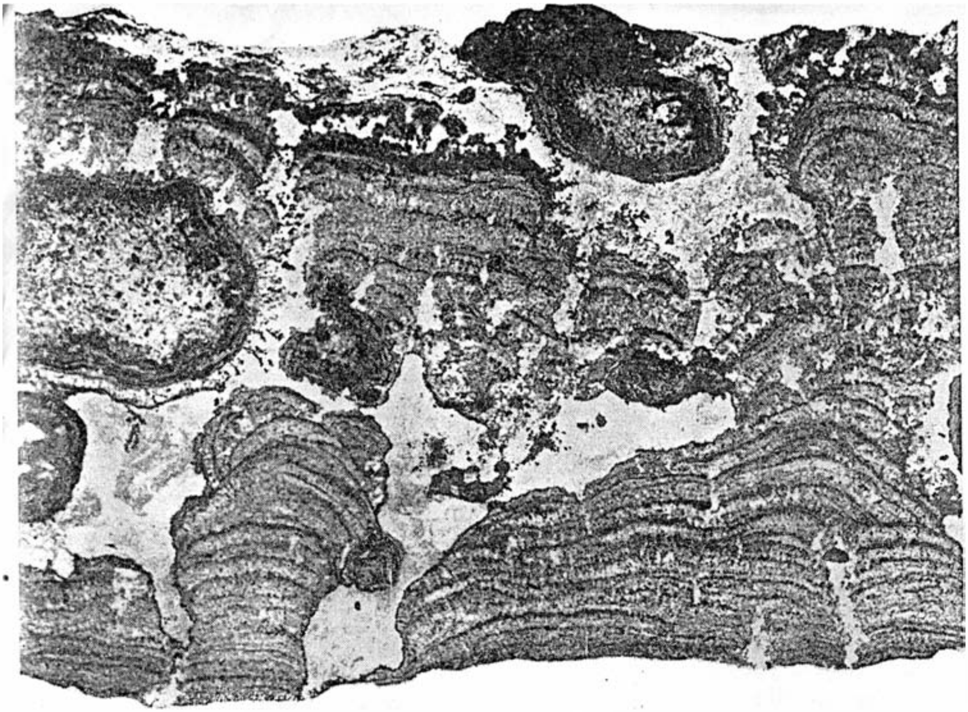
2 (top), 3 (bottom). Top surface of nodular crinoid limestone series. Note stromatolitic encrustations. (Explanations in text, p. 170) ×2/3

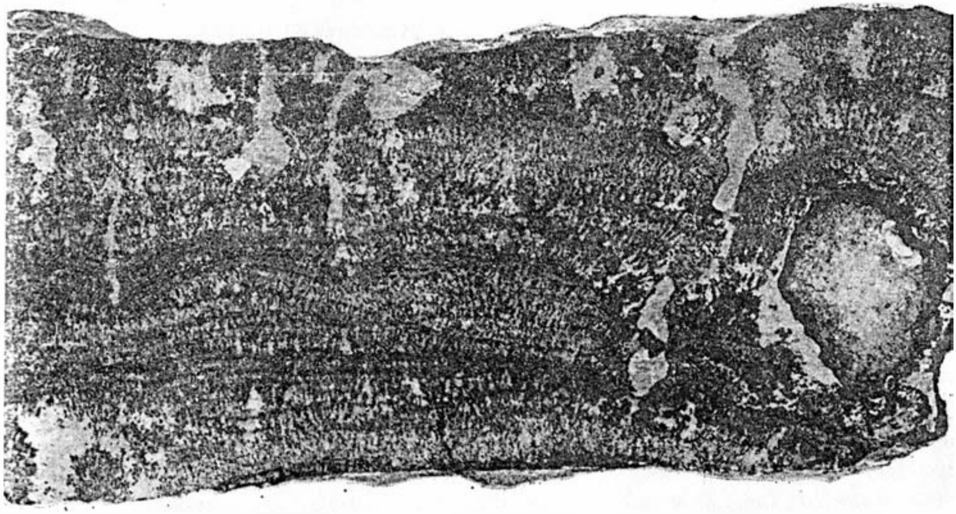
Photos 2, 3, 5 by K. Fedorowicz



4 (top). Stromatolite layer above "pocket" infilled with crinoid limestone pebbles with Fe-Mn envelopes and pinky marls. ×1

5 (bottom). Upper part of stromatolite layer overlain by pinky marls with oncolites. ×2/3

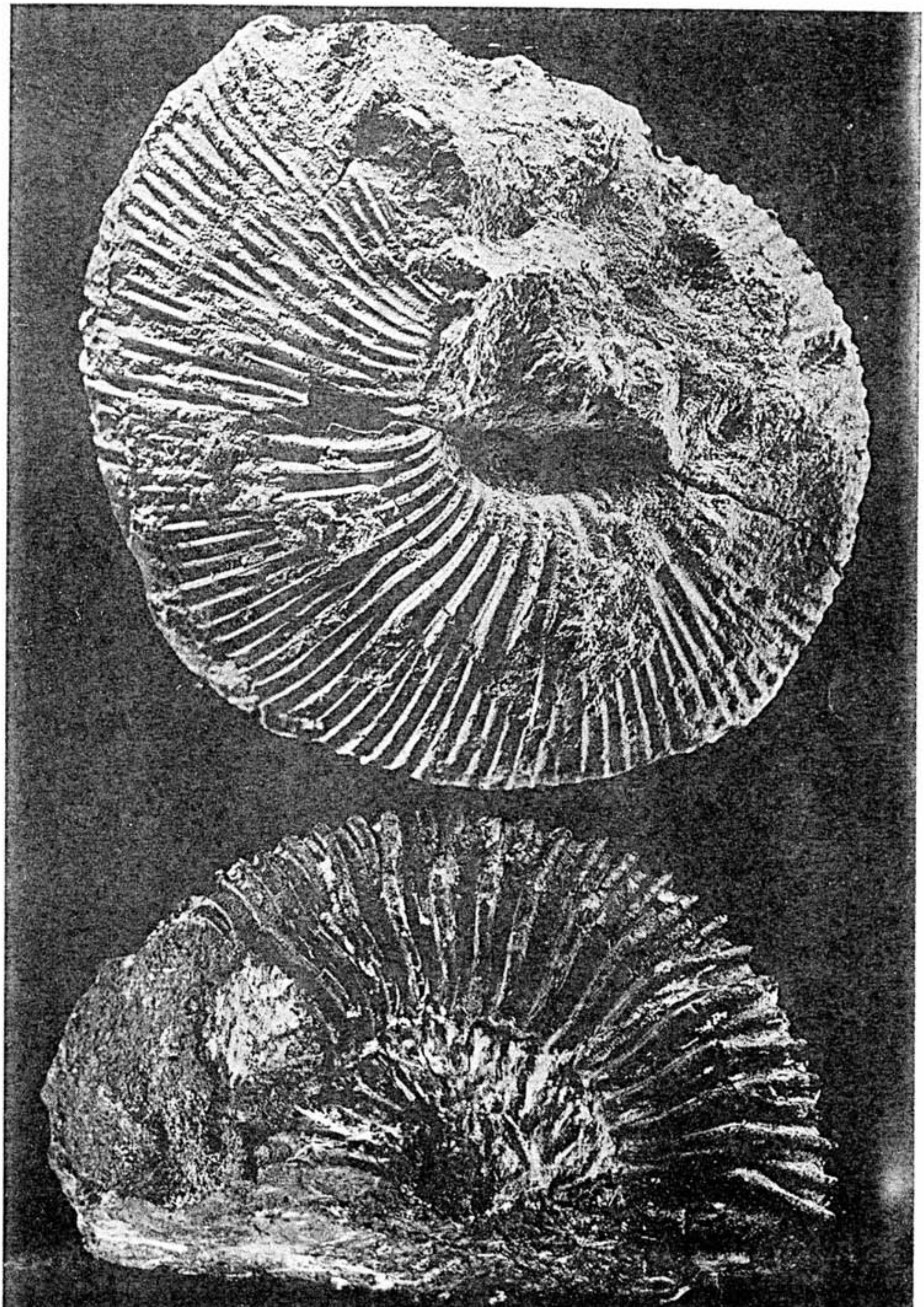




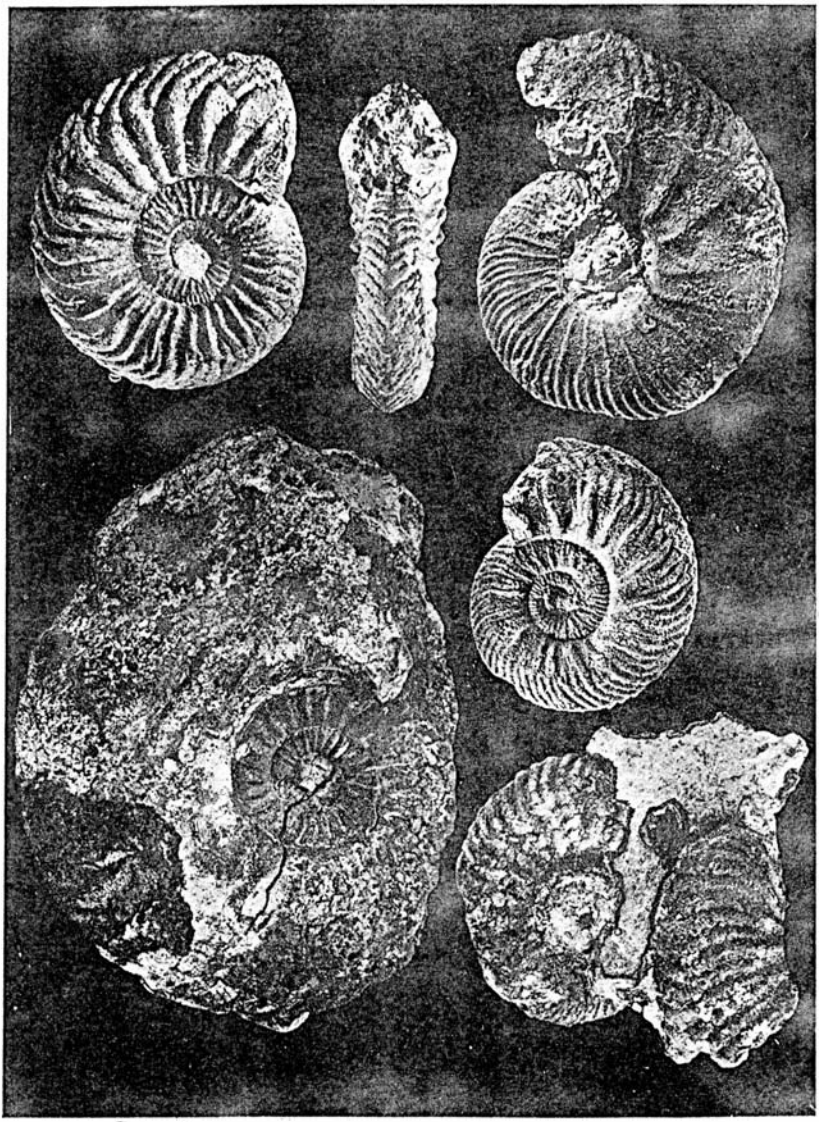
6 (top). Fragment of stromatolite layer with ferruginous laminae. In the interstices there are crinoid limestonepebbles with Fe-Mn envelopes and pinky marls. ×1

Photos 4, 6–14 by K. Zielińska

7 (bottom). Fragment of blake (Mn-rich) stromatolite layer. ×1



8 (top). *Macrocephalites* (*Kamptokephalites*) *lamellosus* (Sow.). ×0.75
9 (bottom). *Kosmoceras spinosum* (Sow.). ×1



10 (bottom right). Two fragments of *Quenstedtoceras henrici* Douv. in the yellow-greenish marls with oncolites
11 (bottom left). *Quenstedtoceras henrici* Douv. (macroconch)
12 (centre right). *Quenstedtoceras praelamberti* Douv.
13 (top right). *Quenstedtoceras lamberti* (sow.)
14a, b (top left, centre). *Quenstedtoceras mariae* (d'Orb.). (all $\times$1)

In other parts of the quarry flat top surface of crinoid limestone usually with ferruginous encrustations is covered by thin stromatolite layer and yellow-greenish marls with oncolites (Photo 5) or by pink limestone lenses. Limestones forming the lenses yield belemnite rostra sometimes bored by polychaetes, as well as ammonite shells. The limestones are built of micrite yielding numerous calcitized siliceous sponge spicules and pelecypod prodissoconchs. Thin layers of stromatolites are sometimes found at the base and top of limestone lenses (Fig. 2-II). The limestones pass upwards and laterally into marls with oncolites and crinoid limestone pebbles. Upper part of the marls is pinky and yielding numerous sponges, ammonites as well as some brachiopods (terebratulids) and belemnites. Numerous narrow branching channels of mud-eaters (?*Chondrites*) are also found here.

The uppermost part of the profile is formed by alternating layers of white marls and sponge limestones with numerous ammonites.

Stratigraphy. Wójcik [38] and Różycki [32] assumed that the oldest Jurassic strata from Zalas may represent the Oppelia aspidoides or even Oppelia fusca zone of the Bathonian. However, the species *Perisphinctes procerus* (v. Seeb.) and *P. moorei* (Opp.) reported by them cannot be treated as good evidence for the Bathonian age of these strata (see [25]), especially as they were derived from the layer also yielding *Macrocephalites macrocephalus* (Schl.). The ammonite *Macrocephalites* sp. reported by Dżułyński from upper part of sands indicates that they are of the Callovian age. Therefore, the Bathonian age of underlying sands deposited under the conditions of fairly rapid and continuous sedimentation from the first phase of marine transgression seems hardly probable.

In the lowermost layer of sandy crinoid limestone the following ammonite species were found by the present authors: *Macrocephalites* (*Kamptokephalites*) *lamellosus* (Sow.) (Photo 8), *M.* (*Pleurocephalites*) *subtumidus* (Waag.), *Kepplerites* (*Gowericeras*) *gowerianus* (Sow.), *K.* (*Toricellites*) sp. The top parts of nodular crinoid limestones yielded: *Macrocephalites* (*Kamptokephalites*) *lamellosus* (Sow.), *M.* (*Pleurocephalites*) *subtumidus* (Waag.), *M.* (*Pleurocephalites*) *pila* (Nik.) and numerous representatives of the subfamily Pseudoperisphinctinae. The faunal assemblage indicates that the whole series of crinoid limestones belongs to the S. calloviense zone of the Lower Callovian. The underlying sands presumably represent lower part of the S. calloviense zone or the M. macrophalus zone.

No ammonites indicative of the K. jason zone nor lower parts of the E. coronatum zone were found here. The presence of the Middle Callovian was assumed by Wój cik[38] and Różycki [32] taking into account the record of the following species: *Reineckeia stuebeli* (Stein). *Spheroceras bombur* (d'Orb.), *Macrocephalites subtumidus* (Waag.). *Perisphinctes subtilis* (Neum.) and *Oppelia subcostaria* (Opp.). According to Bourquin [3], *R. stuebeli* ranges from the S. calloviense to P. athleta zone, inclusively, whilst the remaining species are more charecteristic of the S. calloviense zone [21, 25], which clearly follows from Różycki's monograph [32]. Therefore, there is no faunal evidence for the occurrence of zones of the Middle Callovian at Zalas.

Up to the present there was no unequivocal evidence for the occurrence of the P. athleta zone here [38]. Różycki [32] and Dżułyński [7] suggested the existence of a gap corresponding to that zone. Directly above the discontinuity (Fig. 2) the present authors found fragments of kosmoceratids displaying bundles of secondary ribs — typical *Kosmoceras* from the turn of the Middle and Late Callovian. They were assigned to the species: *Kosmoceras castor fasciculatum* Tintant known from the uppermost parts of the E. coronatum zone [36] and *Kosmoceras* cf. *proniae* Teisseyre, indicative of the P. athleta zone [5]. There were also found *Peltoceras athleta* (Phill.) and others peltoceratids typical of Upper Callovian and especially of the P. athleta zone. These ammonites evidently occurred *in situ* in yellow-greenish marls and in the lenses of pinky limestone and they are infilled with the same deposits. The ammonite indicate that the basal parts of the marls belong to the P. athleta and presumably upper parts of the E. coronatum zone (Fig. 2).

The Qu. lamberti zone is here evidenced by newly recorded highly diversified ammonite assemblage comprising representatives of the genus *Quenstedtoceras* including *Qu. lamberti* (Sow.), *Qu. praelamberti* Douv., *Qu. henrici* Douv. as well as *Kosmoceras spinosum* (Sow.) (Photos 9–13). This assemblage was recorded from the higher part of yellow-greenish marls with oncolites and pink limestone lenses (Fig. 2-II).

Despite of the lack of any ammonites occurring *in situ*, the thick stromatolite layer should be also assigned to the Upper Callovian (Fig. 2-I) as it is occupying similar position in the profile (above the discontinuity) and laterally passes in marls with oncolites ang good faunal record. It should be noted that analogous marls also occur in interstices and "pockets" of the stromatolite layer (Photos 6, 7).

The lowermost zone of the Oxfordian, Qu. mariae, is represented by pink marls with oncolites yielding index species *Quenstedtoceras mariae* (d'Orb.) (Photos 14a, b) as well as *Cardioceras praecordatum* (Douv.) and numerous representatives of the genera *Taramelliceras*, *Peltoceratoides*, *Goliathiceras* and *Perisphinctes*.

In the uppermost parts of the pink marls (marls with sponges , see Fig. 2) there were found ammonites of the genera *Cardioceras*, *Taramelliceras*, *Creniceras* and *Perisphinctes*, indicative of the C. cordatum zone. The overlying white marls and limestones with sponges also belong to that zone.

Interpretation. The profile from Zalas displays deposits of the Middle Jurassic transgression which reached this area in Early Callovian time. The uneven surface of the porphyres exposed here became completely covered in the S. calloviense time at Zalas and not before Late Callovian in the Sanka area [6]. The presence of large porphyre blocks in sandy sediments evidences the existence of porphyre cliffs in that region at least at the early stage of the transgression. Single fragments of porphyre found in sandy crinoid limestones were presumably torn off after submergence of the area.

Wójcik [38] suggested the gradual widening of the transgression in the Bathonian, Callovian and Oxfordian, accompanied by deepening of the sea, stating at the same time the sedimentary continuity throughout the profile. In turn, Dżułyński [7], Różycki [32] and Szulczewski [33] assumed discontinuity of sedimentation in the Cracow–Częstochowa Jurassic at the turn of the Callovian and Oxfordian. Szulczewski [33] assumed extremal shallowing of the basin in the latest Callovian time and the existence of a stratigraphic gap above the stromatolite. Szulczewski [33] interpreted this shallowing as a result of complete infilling of the basin and the stromatolite layer as formed directly after the nodular layer. In this interpretation stromatolites represented the end stage of sedimentation in a gradually shallowing basin and a new sedimentary cycle connected with a gradual subsidence started after formation of stromatolite layer.

We regard it as more probable that Callovian and Lower Oxfordian sediments in the vicinity of Zalas were deposited in gradually deepening marine basin. Sandy crinoid limestones with rich and highly diversified benthic fauna presumably represent shallow but sublittoral environment. The content of terrigenic components decreases upwards the profile which may be explained by widening of the transgression and disappearance of alimentary areas. The increasing distance from shoreline and decreasing supply of terrigenic matter resulted in conditions of markedly limited or even stopped sedimentation. The sedimentation was additionally limited by the fact that Zalas area presumably represented a subaqueous elevation in relation to neighbouring areas of continuous sedimentation during the Callovian and Oxfordian (e.g. Rudno and Trzebinia areas).

A markedly lower rate of sedimentation evidenced by increased frequency of faunal remains may be observed from the uppermost parts of the S. calloviense zone. The period of slow sedimentation was favourable for processes of early subaqueous lithification of deposits (compare data concerning the present-day environments [35]) traces of which may be observed in the top of crinoid limestones.

The stratigraphic data show that the period of the non-deposition preceding formation of stromatolite layer in the Zalas area comprised the K. jason and almost the whole E. coronatum zone. It should be noted that the Callovian is the period of a crisis in carbonate sedimentation in epicontinental areas, presumably resulting from climatic reasons. Moreover, in the case of the break in terrigenic sedimentation due to a progress in transgression, a marked condensation of deposits and stratigraphic gaps are found in several profiles of the Callovian [2, 14, 16].

The conditions of impeded sedimentation in the Zalas area were also facilitated by submarine erosion evidenced by mechanically truncated fossils and redeposited pebbles of crinoid limestones. The intensification of erosion may be explained by hydrodynamic changes resulting from disappearance of relief of sea floor along with the widening of the transgression. The area of Zalas was situated in the high-energy zone, that is the zone of intersection of effective basis of the wave action with the sea floor surface [17, 20]. The turbulent hydrodynamic conditions prevailing in that zone did not favour the development of benthic fauna and therefore the biogenic limestones such as those from S. calloviense zone could not originate.

A new sedimentary cycle following the period of impeded deposition began with stromatolite layer. This layer was formed along with pink limestones and yellow-greenish marls and no marked change in sedimentation are observed above the stromatolite.

We think that the development of stromatolitic layer above the discontinuity does not indicate an extremal shallowing of thebas in. Although the recent stromatolites are mainly connected with supra- and intertidal zones [29], subtidal stromatolites are also known [10, 12, 27] and oncolites are known to originate even at depths over 100 m [27]. Fossil subtidal stromatolites seems common too [1, 4, 19, 31]. It follows from the ecology of blue-green algae that they may live at large depths and even in the aphotic zone [28]. The recent manganese structures resembling stromatolites are known from a few hundred meters depths [18].

There are no deposits in the Zalas profile which may be related to the tidal zone (see the characteristics of tidal deposits in [13]). The appearance of stromatolites in such profile is explained by the authors by hydrodynamic changes presumably resulting from a further deepening of the basin and passing of the area into the low energy zone of the open shelf [17, 20]. It should be noted the high-energy environment in which the Zalas was previously situated was not favourable for the development of stromatolites because of the destructive influence of water flow on algal mat [30].

The deepening of the basin and milder hydrodynamic conditions are evidenced by the succession of stromatolites, that is the replacement of continuous stromatolite layer by dome stromatolites and finally oncolites (compare data concerning present--day environments [34]) as well as the appearance of marly deposits rich in pelagic fauna. Despite the difficulties in accurate evaluation of depth of formation of stromatolitic layer the depth interval from about a dozen to some tens of meters seems most probable to us.

The Upper Callovian and Lower Oxfordian deposits overlying the discontinuity display features typical of condensed sequences (compare [11, 23, 37]). Ferruginous crusts and ferromanganese concretions occurring here are known from several others profiles of the Jurassic [16]. The terrestrial weathering products supplied to the basin as well as subaqueous weathering of porphyres could be the source of Fe and Mn.

The presence of pebbles of Lower Callovian crinoid limestones in stromatolite layer and in marls of the P. athleta to C. cordatum zones may be related to erosion in neighbouring parts of the basin. The eroded areas (as, e.g., the Sanka area [33]) were presumably effected by slow synsedimentary uplifting movements.

A detailed analysis of the stratigraphy and sedimentary environment of the Callovian and Lower Oxfordian deposits of the Wieluń-Cracow Jurassic will be the. subject of subsequent works of the authors.

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Н. Гижеевска, Ю. Вечорек, Замечания об келовею и нижнею оксфорду окресности Заляса Юра Краковская — южная Польша

Содержание. Описан разрез осадков келовея и нижнего оксфорда в новом обнажении в Залясе (южная Польша). Доказано, что морская трансгрессия достигла этого района в раннем келовее. Обсуждено условия возникновения осадков келовея и нижнего оксфорда. Секвенция осадков, по мнению авторов, указывает постепенное погружение морского бассейна в ето время. Обнаружено присутсвие строматолитов, а также железисто-манранцевых конкреции выше несогласия вызванного отсутсвием седиментации во время среднего келовея.