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Late Middle Jurassic to earliest Cretaceous stratigraphy and microfacies of the Czorsztyn Succession in the Spisz area, Pieniny Klippen Belt, Poland

ABSTRACT: A stratigraphic and microfacies study of the pelagic carbonate sequence of late Middle Jurassic to earliest Cretaceous age of the Czorsztyn Succession in the Spisz area of the Pieniny Klippen Belt is presented. The sequence begins with the Czorsztyn Limestone Formation which developed on subsiding blocks of shallow-water crinoid limestones during the time interval from the Bathonian to Early/Middle Tithonian. The three succeeding microfacies are recognized and dated: the filament microfacies (Bathonian–Callovian, and ?earliest Oxfordian), the *Globuligerina* microfacies (Oxfordian), the *Saccocoma* microfacies (Kimmeridgian to Early/Middle Tithonian). The still younger microfacies of the Dursztyn Limestone Formation include the *Globochaete* microfacies, and calpionellid microfacies of Middle/Late Tithonian to Middle Berriasian age. The organogenic limestones and breccias of the Łysa Limestone Formation are of Late Berriasian age; their origin was related to tectonic activity which produced a highly diversified sea bottom topography markedly changing the previous sedimentation pattern. The lowermost part of the Spisz Limestone Formation is extremely condensed, and corresponds to a large part of the Valanginian, excluding its uppermost part. The most important new findings of Valanginian ammonites include representatives of genera: *Thurmanniceras*, *Karakaschiceras*, *Olcostephanus*, and *Jeanthieuloyites*.

INTRODUCTION

The Spisz section of the Pieniny Klippen Belt in Poland stretches between the Białka River in the West and the Dunajec River in the East, being one of the best areas to study the stratigraphy of the Czorsztyn Succession. The present paper covers the lithostratigraphic sequence from the Czorsztyn Limestone Formation up to the Spisz Limestone Formation, *i.e.* a wide time span from late Middle Jurassic to earliest Cretaceous. Five localities of the Spisz area have been carefully investigated: the Korowa Klippe, the Lorencowe Klippes, the Pomiedznik Klippes, the Łysa Klippes, and the Niedzica Castle Klippe (Text-fig. 1). The lithology of rock units was determined during field-work, and supported by thin sections study of microfacies. Biostratigraphic correlation was based on collected ammonites, and to lesser degree calpionellids. In addition, the previously recognized succession of ammonites in the Callovian to Kimmeridgian (MYCZYŃSKI & WIERZBOWSKI 1994), and that of ammonites and calpionellids in the Berriasian to lowermost Valanginian (WIERZBOWSKI & REMANE 1992), in the Czorsztyn area, permitted such a correlation on a wider scale. All these data provide the close chronostratigraphic control of the here reported microfacies.

The formal lithostratigraphic scheme accepted here is that of BIRKENMAJER (1977). The Spisz area contains a number of type localities of the Upper Jurassic to lowermost Cretaceous lithostratigraphic units of the formation and member ranks of the Czorsztyn Succession. These units include: the Dursztyn Limestone Formation (with the Korowa Limestone Member), the Łysa Limestone Formation (with the Harbatowa Limestone Member, the Walentowa Breccia Member, the Kosarzyska Limestone Member), and the Spisz Limestone Formation (BIRKENMAJER 1977). The studies of the type localities of these units generally confirm the validity of the lithostratigraphic scheme, but the present author suggests that the boundary between the Czorsztyn Limestone Formation and the Dursztyn Limestone Formation should be drawn somewhat lower than recently accepted.

All ammonites are registered in the Museum of the Faculty of Geology, University of Warsaw, collection number IGPUW/A/30/1-35. Thin sections are housed in the Institute of Geology, University of Warsaw.

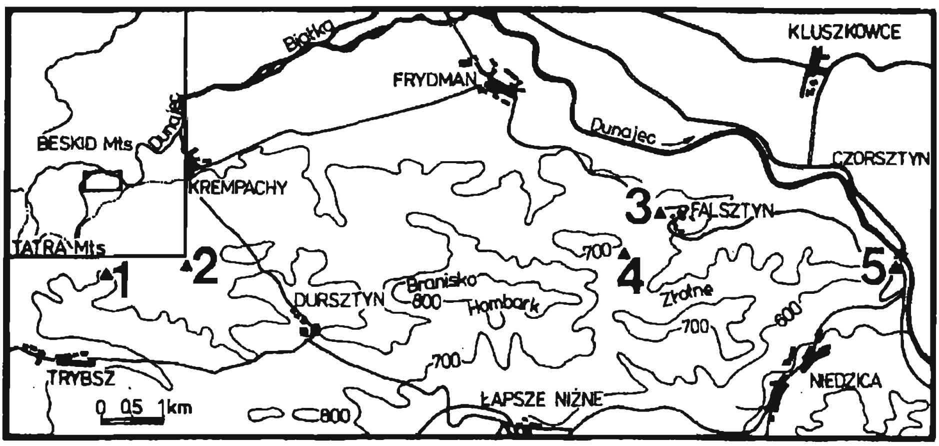


Fig. 1. Location of the sections studied in the Spisz area of the Pieniny Klippen Belt in Poland

1 — Korowa Klippe, 2 — Lorencowe Klippes, 3 — Pomiedznik Klippes, 4 — Łysa Klippes, 5 — Niedzica Castle Klippe

LITHOLOGY AND STRATIGRAPHY OF THE STUDIED DEPOSITS

KOROWA KLIPPE

The Korowa Klippe at Krempachy (*see* Text-fig. 1) shows a sequence of Jurassic and Lower Cretaceous deposits representative of the so-called Korowa Klippe facies type of the Czorsztyn Succession (BIRKENMAJER 1963). It is the type locality of the two formal lithostratigraphic units of the Pieniny Klippen Belt, namely the Korowa Limestone Member of the Dursztyn Limestone Formation, and the Spisz Limestone Formation (BIRKENMAJER 1977; *cf. also* BIRKENMAJER & GĄSIOROWSKI 1961, and the earlier papers cited therein). The

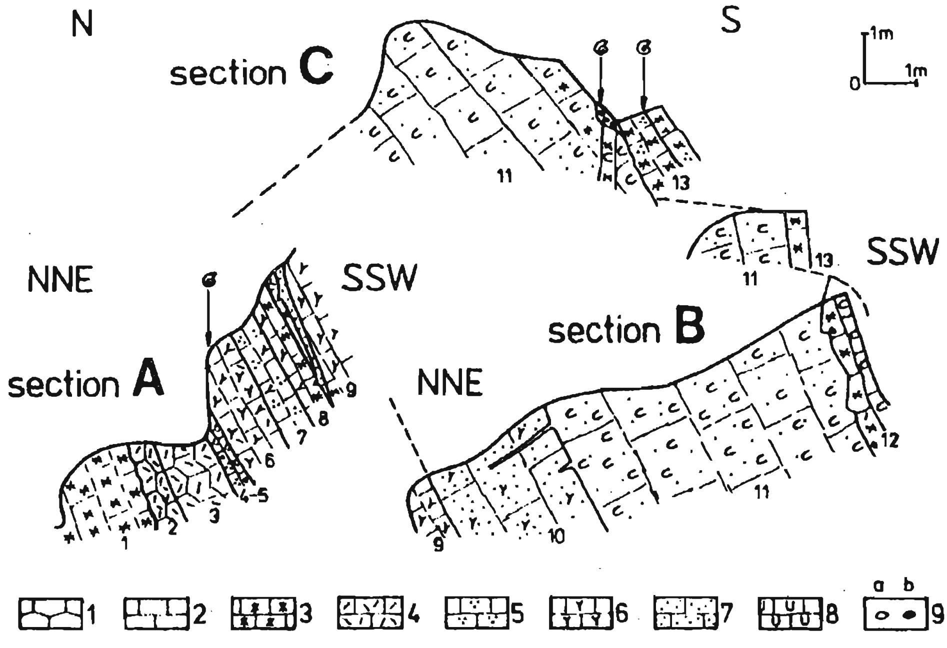


Fig. 2

Geological sections A–C through the Korowa Klippe

LITHOSTRATIGRAPHY: bed *1* — Krupianka Limestone Formation, beds *2-9* — Czorsztyn Limestone Formation emend.; beds *10-11* — Dursztyn Limestone Formation (bed *10* — Korowa Limestone Member, emend.; bed *11* — Sobótka Limestone Member); bed *12* — Łysa Limestone Formation; bed *13* — Spisz Limestone Formation

LITHOLOGY (microfacies included): **1** — nodular limestones, **2** — limestones other than nodular, **3** — crinoid limestones, **4** — filament limestones, **5** — "protoglobigerinid" limestones, **6** — *Saccocoma* limestones, **7** — *Globochaete* limestones, **8** — calpionellid limestones, **9a** — limestone clasts, **9b** — ferromanganese nodules; ammonite findings discussed in text are indicated general sequence of the deposits of the klippe, their lithology, and faunas, were studied in three sections (A-C in Text-fig. 2).

Section A, in the northern part of the Klippe (Pl. 1, Fig. 2), shows the oldest strata which extend for about 50m in an East-West direction and are steeply inclined (90/70 S). The succession begins with red crinoid limestones of the Krupianka Limestone Formation of Middle Jurassic (? Bajocian) age (BIRKENMAJER 1963, Pl. 9, Figs 1-2; BIRKENMAJER 1977, Fig. 27C; Text-fig. 2, bed *1*, herein; *cf.* RAKÚS 1990). The upper boundary of these limestones is an omission surface coated with ferruginous crusts. Still younger (Text-fig. 2, beds *2* and *3*: 0.45m, and 1.1m in thickness, respectively) are dark gray-red, partly nodular limestones attributed to the Czorsztyn Limestone Formation (BIRKENMAJER 1977; *see also* BIRKENMAJER 1963, p. 128, unit 2). The limestones are wackstones to packstones, with abundant filaments of the pelagic bivalve *Bositra*, *Globochaete* and less commonly crinoid fragments, calcified radiolarian tests, small pelagic gastropods and foraminifers. It is the filament microfacies typical of the lower part of the Czorsztyn Limestone Formation (ZYDOROWICZ & WIERZBOWSKI 1986, BROŻEK & WIERZBOWSKI 1991, ZYDOROWICZ 1991, MYCZYŃSKI & WIERZBOWSKI 1994). The two thin beds above (beds *4* and *5*, each 0.2m in thickness) consist of red-brown limestones. Most common here are packstones rich in the planktonic foraminifers *Globuligerina* ("*Protoglobigerina*"), and locally also a very fine *Saccocoma* debris; limited amounts of small pelagic gastropods and small ferromanganese nodules occur. It is the *Globuligerina* ("*Protoglobigerina*") microfacies, which generally follows the filament one in the various sections of the Czorsztyn Limestone Formation in the Pieniny Klippen Belt (ZYDOROWICZ & WIERZBOWSKI 1986, ZYDOROWICZ 1991). No ammonites were discovered in beds *2-5* in the section studied, but the filament microfacies and the *Globuligerina* ("*Protoglobigerina*") microfacies occurring here are typical of the Bathonian/ Callovian and Oxfordian in the Czorsztyn Succession, respectively (MYCZYŃSKI & WIERZBOWSKI 1994; *cf.* RAKÚS 1990).

Bed *6*, younger still, consists of light red-brown limestones, 0.85m in thickness (Text-fig. 2). It is predominantly a packstone rich in shell fragments and *Saccocoma* debris. The bed yields abundant, but poorly preserved ammonites indicative of the Kimmeridgian (Pl. 4, Figs 10-12):

Taramelliceras (*Taramelliceras*) *compsum* (OPPEL)
Aspidoceras cf. *binodum* (OPPEL).

The overlying bed *7*, about 0.45m in thickness, consists of red-brown packstones rich in the planktonic foraminifers *Globuligerina*, and also *Globochaete*, with some admixture of fine *Saccocoma* debris. This indicates the reappearance of the *Globuligerina* ("*Protoglobigerina*") microfacies.

Still younger bed *8*, about 0.45m in thickness, consisting of red-brown limestones, shows a somewhat more complex microfacies pattern. The lowermost part of this bed consists mainly of packstones with abundant *Saccocoma* fragments and *Globochaete* (*Saccocoma* microfacies). In the middle part of the bed, a few thin intercalations of crinoid grainstones are encountered. These contain abundant fragments of sessile crinoids, but also fragments of *Saccocoma*. The upper part of the bed is composed only of packstones with abundant *Saccocoma* fragments and *Globochaete* (*Saccocoma* microfacies).

In bed *9*, about 0.5m in thickness, at the top of section A (Text-fig. 2), are found light red-brown packstones rich in *Saccocoma* debris, with a small amount of other crinoid fragments, and *Globochaete*, similar to bed *8*. Subparallel to the bedding a neptunian sill, a few centimeters thick, cuts through the lower part of bed *9*. The sill has markedly erosional boundaries and the minute insets extend downward from its lower surface, penetrating the underlying limestones of bed *8*. The sill is filled with mudstones, locally also wackstones, with *Globochaete*, ammonite shells, aptychi, small gastropods and *Saccocoma* fragments. No calpionellids were found. A few clasts of red-brown packstones with common *Saccocoma* fragments, sparsely placed within the mudstones were encountered. The original voids in the top of the neptunian sill are infilled by blocky calcite. The lithology of the infilling of the neptunian sill very much resembles that of the overlying deposits of bed *10*, section B.

Section B, in the western part of the Korowa Klippe (*see* Pl. 1, Fig. 1), consists of limestones representing a direct continuation of the sequence from section A. The limestones are possibly thick-bedded, but the bedding planes are difficult to recognize due to a dense, and irregular network of cracks. The total thickness is about 8 meters. The limestones may be subdivided into two parts: the lower one, distinguished as bed/set of beds *10* (Text-fig. 2), and the upper one, bed/set of beds *11*.

Bed *10* consists of red-brown wackstones and locally mudstones with abundant *Globochaete*, and usually some admixture of *Saccocoma* debris (*Globochaete* microfacies). The base is marked by an erosion surface with neptunian sills extending down into bed *9* (*cf.* description of section A). Bed *10* is about 2.5m thick.

The deposits originally distinguished as the Korowa Limestone Member at its type locality, the Korowa Klippe (BIRKENMAJER 1977, Fig. 27C; *cf.* BIRKENMAJER 1963, Pl. 9, Fig. 1, p. 129, beds 3a-3d) correspond to beds *6-10* of the sections studied (Text-fig. 2). These deposits however, show marked differences in their lithology. The dominant lithology of beds *6-9* is packstone developed as the *Saccocoma* microfacies, which differs only in lack of nodular structure from that of the upper part of the Czorsztyn Limestone Formation. Moreover, the beds *6-9* are of Kimmeridgian to (?)Early Tithonian age similar to the corresponding deposits of the Czorsztyn Limestone Fm. On the other hand, bed *10* consisting of *Globochaete* wackstones and mudstones corresponds much more closely to the Korowa Limestone Member according to its original lithological description (BIRKENMAJER 1977, pp. 78-79). The reddish limestones developed as the *Globochaete* microfacies correspond to the informal lithostratigraphic unit "Pink *Globochaete* Limestone" (BIRKENMAJER 1963). This unit as well as "Red *Calpionella* Limestone" have been recognised as the main equivalents of the Korowa Limestone Member (BIRKENMAJER 1977). In addition, the occurrence of a marked erosional boundary between beds *9* and *10* suggests that this boundary should be possibly treated as a more convenient boundary between the Czorsztyn Limestone Formation and the Korowa Limestone Member (and thus, the Dursztyn Limestone Formation).

Bed *11* consists of cream to pink coloured mudstones, commonly with calpionellids, sometimes also *Globochaete* and less abundantly *Saccocoma*, other crinoid ossicles, calcified radiolarian tests, and shell fragments. The bed is about 5.5m thick. The base of this bed is an erosion surface with neptunian dykes at least 2 meters in depth which penetrate bed *10*. The calpionellids occurring in the neptunian dykes belong to the genera *Crassicolaria* and *Tintinnopsella*, thus being idicative of the Upper Tithonian. The calpionellids such as *Calpionella alpina* (LORENZ), *Remaniella cadischiana* (COLOM), and *Tintinnopsella carpathica* (MURGEANU & FILIPESCU) commonly occur in bed *11*, indicating the Early Berriasian age of these deposits (*cf.* REMANE & *al.* 1986). The limestones of bed *11* correspond to the Sobótka Limestone Member of the Dursztyn Limestone Formation (BIRKENMAJER 1977, Fig. 27C).

Brown-violet wackstones rich in crinoid debris and shell fragments form bed *12*, constituting the uppermost part of section B (Text-fig. 2). The boundary of this bed with underlying bed *11* is marked by a well developed erosion surface. Clasts derived from the limestones of Sobótka Limestone Member containing *Calpionella alpina*, are commonly encountered in the lower part of bed *12*. The upper part of bed *12* consists of mudstones with calpionellids of the genera *Calpionellopsis* and *Tintinnopsella*. They are indicative of Late Berriasian age (*cf.* REMANE & *al.* 1986). The incomplete thickness of bed *12* is about 0.8m. These deposits have not previously been recognized in the Korowa Klippe. Their lithology and stratigraphic position support correlation with the Łysa Limestone Formation (*cf.* BIRKENMAJER 1977, WIERZBOWSKI & REMANE 1992).

About 4 meters East from section B, on the western slope of the Korowa Klippe, deposits of the Sobótka Limestone Member directly underlie deposits of the Spisz Limestone Formation (Text-fig. 2), whereas the deposits of the Łysa Limestone Formation comparable to those of bed *12*, section B, do not occur. As a result, bed *12* should be interpreted either as a non-continuous horizon of local occurrence at the top of the Sobótka Limestone Member, or as the infilling of a neptunian sill within the Sobótka Limestone Member.

Section C, in the topmost part of the Korowa Klippe (Text-fig. 2), begins with steeply inclined limestones of the Sobótka Limestone Member (100-110/55 S). They are about 11.5m thick (BIRKENMAJER 1963, Pl. 9, Figs 1-2, p. 129, unit 4; BIRKENMAJER 1977). In thin sections, the uppermost part of the unit consists of mudstones, and less commonly wackstones containing crinoid ossicles, shell fragments, and calpionellids, i.a. *Calpionella alpina* LORENZ and *Calpionella elliptica* CADISCH which indicate Middle Berriasian age (*cf.* REMANE & *al.* 1986).

The upper boundary of the Sobótka Limestone Member is a marked omission surface coated with ferrugineous crusts, and furnished with neptunian dykes penetrating the underlying limestones (BIRKENMAJER 1963, 1977). The dykes are filled with brown-violet wackstones with abundant crinoid ossicles, and less common calpionellids, such as *Calpionellites darderi* (COLOM), and *Tintinnopsella carpathica* (MURGEANU & FILIPESCU); some clasts of limestones from the Sobótka Limestone Member are usually encountered. The dyke, well exposed at the top of the klippe, is about 0.25m in thickness (Text-fig. 2). It is steeply inclined and continues a few meters in a North-East direction (40/90). Another dyke, about 0.75m to 0.05m in thickness, filled with crinoid-detrital limestone was observed by BIRKENMAJER (1963, Pl. 9, Fig. 2, pp. 129-130, unit 5). This limestone was originally attributed to the Łysa Limestone Formation (BIRKENMAJER 1977). The lithological similarity of the limestones in both dykes, and the occurrence therein of *Calpionellites darderi* which is indicative of the lowermost Valanginian, suggest however the correlation of these deposits with a somewhat younger litostratigraphic unit, *i.e.*, the Spisz Limestone Formation (*cf.* WIERZBOWSKI & REMANE 1992).

Closely packed ferromanganese nodules, and the ammonite shells coated with ferrugineous crusts are found at the top of the Sobótka Limestone Member, near the opening of the neptunian dyke. These deposits form a lens a few centimeters thick in the depression of the omission surface (Text-fig. 2). The nodules are concentrically laminated, and formed around clasts of the micritic and microsparitic limestones corroded and impregnated by iron oxides and containing crinoid debris, planktonic foraminifers *Globuligerina* ("*Protoglobigerina*"), and calpionellids (i.a. *Calpionellites darderi*). The following ammonites were collected here (Pl. 5, Figs 3-7): *Thurmanniceras* cf. *petransiensis* (SAYN), *Karakaschiceras* cf. *inostranzewi* (KARAKASCH), *Olcostephanus (Olcostephanus) guebhardi* (KILIAN), *Protetragonites quadrisulcatus* (D'ORBIGNY). They are characteristic of the Petransiensis Zone, and of the Campylotoxus Zone of middle and late Early Valanginian age, but some could also indicate an early Late Valanginian age (*cf.* COMPANY 1987, BULOT 1992, HOEDEMAEKER & *al.* 1993).

Overlying the omission surface are orange to brown-violet crinoid limestones of the Spisz Limestone Formation (BIRKENMAJER 1963, 1977). The lowermost part of these deposits is about 1m thick where it crops out at the top of the Korowa Klippe: it is distinguished here as bed *13* (Text-fig. 2). The younger deposits of this formation are covered by the rubble. The limestones of bed *13* are packstones, and less commonly wackstones, rich in crinoid debris, but also containing shell fragments and foraminifer tests (benthonic ones, as well as planktonic *Globuligerina*). A limestone horizon strongly impregnated with iron oxides occurs about 0.85-0.90m above the base of the bed *13*; it probably represents a hardground surface. The ammonites are generally poorly preserved, but the following forms have been identified (Pl. 4, Figs 1-4; Pl. 5, Figs 1-2): *Jeanthieuloyites* sp., *Olcostephanus* (*Olcostephanus*) sp., and *Neolissoceras* sp. Of these, the most important stratigraphically are representatives of the genus *Jeanthieuloyites* which are known to occur in the Upper Valanginian, mostly in the Trinodosum Zone, *i.e.* in the lower part of the Pachydicranus Zone = the Trinodosum Subzone (*cf.* THIEULOY & *al.* 1990, BULOT & *al.* 1992, HOEDEMAEKER & *al.* 1993).

LORENCOWE KLIPPES

The most complete sequence of Jurassic deposits is exposed in the south-eastern part of the Lorencowe Klippes at Krempachy (*see* Text-fig. 1). This sequence is representative of the Lorencowe Klippes facies type of the Czorsztyn Succession (BIRKENMAJER 1963, Pl. 11, Figs 1-2, sections 64C, 64C', pp. 119-121; BIRKENMAJER 1977, Fig. 29A). The best section is seen in an East-West orientated klippe (Text-fig. 3) with the strata inclined toward the South (110-130/25 S).

Bed *1*, about 1.2m in thickness, consists of red-gray crinoid limestones. The limestones are grainstones (mostly in the lower part of the bed) and packstones, rich in crinoid ossicles and usually containing a marked admixture of detrital quartz grains and clasts of carbonate rocks. This bed represents the uppermost part of the Krupianka Limestone Formation, and is of Middle Jurassic (?Bajocian) age (*cf.* BIRKENMAJER 1977, RAKÚS 1990).

Higher in the sequence are red-gray, medium- to very thick-bedded, massive to nodular limestones constituting a rock-unit 9.6m thick (beds *2-9*; Text-fig. 3 and Pl. 3, Fig. 2). Recorded nodular to massive intervals in the unit are as follows: massive limestone (bed *2*; about 0.9m); indistincly nodular limestone (bed *3*; about 1m); markedly nodular limestone (bed *4*; about 0.5m); indistinctly nodular limestone (bed *5*; about 0.8 m); massive limestone (bed *6*; about 1.1m); markedly nodular limestone (bed *7*; about 0.5m); massive limestone (beds *8* and *9*; about 1.3m and 3.5m, respectively). All these limestones are developed as wackstones, and packstones dominated by filaments of the pelagic bivalve *Bositra* (filament microfacies). They also contain, in variable amounts: crinoid ossicles (more common in beds *2-4*), *Globochaete* (more common in beds *3-9*), pelagic gastropods (more common in beds *4-5*), calcified radiolarian tests, planktonic and benthonic foraminifers, and shell debris. Ferromanganese nodules (up to 1 cm in diameter) are fairly common only in bed *2*; they developed around corroded fragments of crinoids and filament limestones. Detrital quartz grains and clasts of carbonate rocks are abundant in bed *2*. The limestones of the discussed unit were attributed to the Czorsztyn Limestone Formation by BIRKENMAJER (1963, Pl. 11, Fig. 1, unit 1; *cf. also* BIRKENMAJER 1977, Fig. 29A).

The higher unit including bed *10*, is about 3 meters thick (Text-fig. 3) and consists of medium- to thin-bedded red-gray limestones. The limestones are generally nodular in character. They are packstones containing an aggregate of filaments (filament microfacies), less commonly crinoid ossicles (some of them a few mm in diameter), planktonic foraminifers (*Globuligerina*), *Globochaete*, and calcified radiolarian tests. These limestones have been attributed to the Korowa Limestone Member of the Dursztyn Limestone Formation (BIRKENMAJER 1977, Fig. 29A; *cf.* BIRKENMAJER 1963, Pl. 11, Figs 1-2, unit 2) which seems debatable. In fact, the limestones are almost identical both in thin section and facies relation, to those of beds *2-9* of the section studied, as well as of other sections (*comp.* Text-fig. 2 *and* 4), which are correlated with the lower part of the Czorsztyn Limestone Formation.

The next lithological unit, attaining about 5m in thickness, includes beds *11-16* (Text-fig. 3). The upper and lower parts of the unit consist of limestone beds between 0.9m to 1.2m thick (beds *11-12*, and *15-16*), whereas the middle part of the unit is composed of thin-bedded limestones (from a few to about 20 cm in thickness) alternating with marly shales. The middle part of the unit corresponding to beds *13-14* (Text-fig. 3 and Pl. 2, Fig. 1) is about 1.1m thick. The limestones are pink to pinkish-light brown coloured showing white crinoid ossicles (a few mm in diameter), and dark fragments of ammonite and brachiopod shells loosely distributed in matrix. When studied in thin sections, the limestones appear to be wackstones, and locally packstones, with frequent tests of planktonic foraminifer *Globuligerina* ("*Protoglobigerina*"), and a marked admixture of crinoid ossicles, *Globochaete*, and shell fragments. Small ferromanganese nodules are sometimes encountered. It is the *Globuligerina* ("*Protoglobigerina*") microfacies. Part of the studied limestones has been

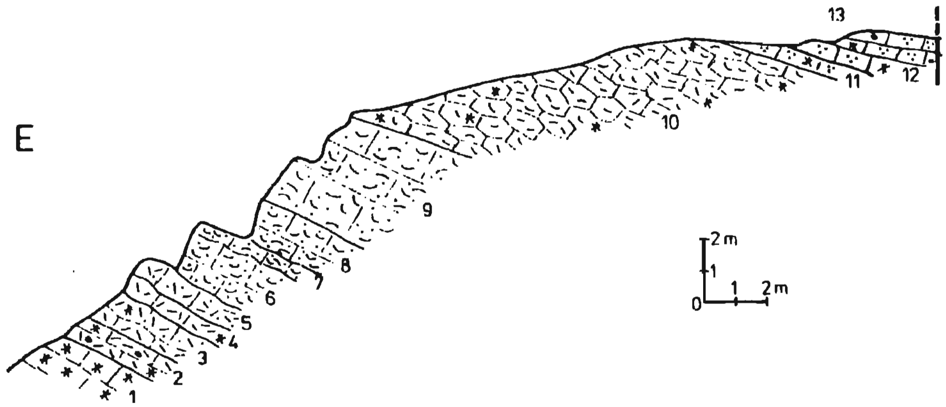


Fig. 3
(continued and explained on the opposite page)

attributed to the Sobótka Limestone Member of the Dursztyn Limestone Formation by BIRKENMAJER (1977, Fig. 29A; *cf.* BIRKENMAJER 1963, Pl. 11, Figs 1-2, unit 3). The new observations suggest however, that these deposits correlate better with the Czorsztyn Limestone Formation.

The overlying unit includes beds *17-30*. It attains a thickness of at least 5.5m, and its upper boundary is not visible in the section. The repeated occurrence of two rock-types, forming many cycles varying in scale from a few centimeters to 1m thick, is the characteristic feature of this unit. The rock-types are as follows:

— pink to light-gray-red limestones with loosely and randomly distributed fragments of ammonite and brachiopod shells, aptychi, and larger crinoid ossicles, sometimes with thin bands showing more densely packed (oriented parallel to bedding) skeletal material; thin-sections study reveals these limestones to be packstones and sometimes also wackstones, rich in *Saccocoma* fragments and locally also in *Globochaete* (*Saccocoma* microfacies, and *Saccocoma-Globochaete* microfacies common in beds *19, 20, 23, 24, 26, 28, 29*, and *30*), or in sessile crinoid ossicles (*Saccocoma*/sessile-crinoid microfacies common in beds *17, 25*),

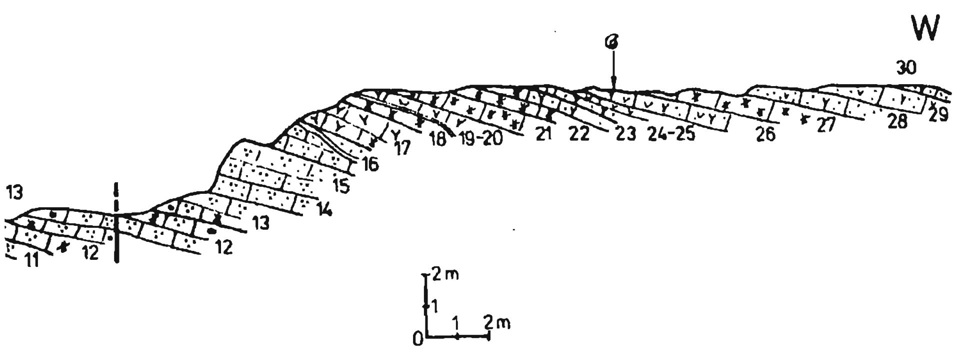
— orange to pink crinoid grainstones consisting of fine- to medium-sized crinoid debris, infrequently with shell fragments and aptychi (common in bed *18, 21, 22, 23*, and *27*).

Of the two discussed rock-types, the former is predominant constituting about 2/3 of the unit sequence.

Identifiable ammonites were obtained only from bed *26*, about 3.7m above the base of the unit (Pl. 4, Figs 6-9):

Hybonoticeras hybonotum (OPPEL)
Schaireria avellana (ZITTEL).

They are indicative of the Hybonotum Zone of the lowermost Tithonian (*cf.* CHECA 1985, KUTEK & WIERZBOWSKI 1986).



Geological section through the Lorencowe Klippes

LITHOSTRATIGRAPHY: bed *1* — Krupianka Limestone Formation; beds *2-30* — Czorsztyn Limestone Formation emend.; infillings of neptunian sills in beds *16* and *18-19* — Dursztyn Limestone Formation (Sobótka Limestone Member)

For lithological symbols *see* Text-fig. 2

The discussed deposits of beds *17-30* have been attributed to the Rogoźnik Coquina Member of the Dursztyn Limestone Formation by BIRKENMAJER (1977, Fig. 29A; *cf.* BIRKENMAJER 1963, Pl. 11, Figs 1-2, unit 4), however, this interpretation is debatable. The deposits discussed differ from those of the Rogoźnik Coquina Member in its type locality at Rogoża Klippes. The former contain less frequent ammonite shells, a complete lack of sparry coquinas, and a greater abundance of crinoid limestones. The deposits from beds *17-30* of the Lorencowe Klippes section should be distinguished as a new lithostratigraphic unit, possibly of a member rank within the Czorsztyn Limestone Formation.

The youngest deposits of the section studied occur in subhorizontal neptunian sills, a few centimeters in thickness, penetrating bed *16* and *18-19* (Text-fig. 3 and Pl. 2). They are reddish to cream coloured, thinly-laminated limestones. The laminae consist of: (*i*) poorly fossiliferous mudstones, (*ii*) mudstones with common calpionellids, and (*iii)* grainstones rich in crinoid debris, shell fragments, and small clasts of mudstone, some of them containing calpionellids. The calpionellids occurring in the mudstone laminae, as well as in the mudstone clasts, include *Calpionella alpina* LORENZ (commonly), and *Crassicolaria parvula* REMANE. They therefore indicate an Early Berriasian age of the neptunian sill (*cf.* REMANE & *al.* 1986). These deposits represent the Dursztyn Limestone Formation (Sobótka Limestone Member).

POMIEDZNIK KLIPPES

The Pomiedznik Klippes at Falsztyn have well exposed deposits of the Czorsztyn Limestone Formation (Text-figs 1 and 4), and of the Spisz Limestone Formation (Text-fig. 5; *cf.* BIRKENMAJER 1963, pp. 169-171, Pl. 16, Fig. 3; BIRKENMAJER 1977, Fig. 31A).

The Czorsztyn Limestone Formation occurs in two klippes, the northern and the southern one, which are tectonically separated by marls and shales of the Krempachy Marl Formation/ Skrzypny Shale Formation of early Middle Jurassic age. The section in the northern klippe (Text-fig. 4) shows the lower part of the Czorsztyn Limestone Formation directly above the Krupianka Limestone Formation, but at no location is the boundary between these two units exposed. The lowermost exposed bed of the Czorsztyn Limestone Formation (bed *1* in Text-fig. 4) is about 1m in thickness and consist of markedly nodular gray-red limestones. The limestones are packstones with abundant filaments of the pelagic bivalve *Bositra* (filament microfacies). Still higher, bed *2* and *3*, about 0.4m and 1.2m in thickness, respectively, consist of massive and indistinctly nodular light gray-red limestones. Packstones are the most common, containing abundant tests of the planktonic foraminifer *Globuligerina*. It is the *Globuligerina* ("*Protoglobigerina*") microfacies. Some fragments of ammonite shells, and belemnites are present, and small ferromanganese nodules are encountered.

The overlying bed *4*, only 0.2m thick, is crowded with ammonites; although poorly preserved this fauna consists of specimens of Ataxioceratidae, possibly including representatives of the genera *Crussoliceras* and *Progeronia*, which suggests late Early Kimmeridgian age. The limestones are packstones rich in *Saccocoma* fragments (*Saccocoma* microfacies).

Higher in the sequence, beds *5-9* in the northern klippe section consist of gray-red nodular limestones about 3.7m in thickness. They are packstones rich in *Saccocoma* fragments, and locally also in tests of the planktonic foraminifer *Globuligerina* (bed *5*), and *Globochaete* (beds *8-9*). The uppermost part of bed *9* contains a rich, but poorly preserved, ammonite fauna including *Schaireria* cf. *avellana* (ZITTEL), which suggests earliest Tithonian age (*cf.* CHECA 1985).

The beds *10-12* of the southern klippe at Pomiedznik (Text-fig. 4), represent the upper part of the Czorsztyn Limestone Formation, but the exact relationship between these deposits and those of the northern klippe is not known. Beds *10-12* are thickly bedded, gray-red coloured nodular limestones with a total thickness of 4.8m. They are mostly packstones rich in *Saccocoma* fragments, and locally also in *Globochaete* (*Saccocoma* microfacies, and

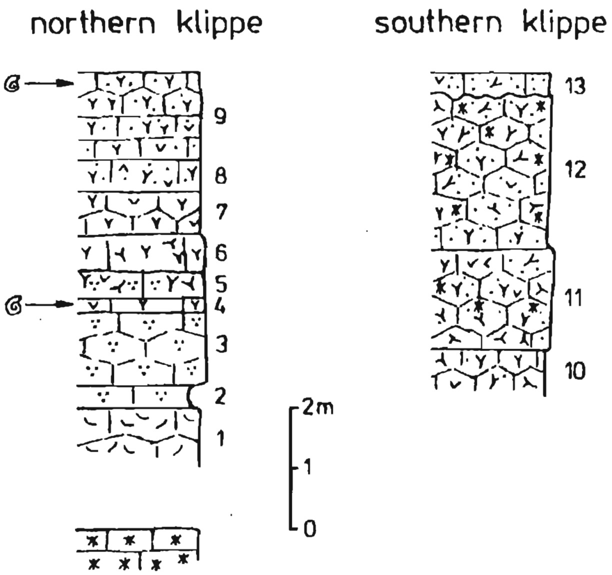


Fig. 4. Lithological log of the Czorsztyn Limestone Formation (beds *1-12*), and lowermost Korowa Limestone Member of the Dursztyn Limestone Formation (bed *13*) at Pomiedznik Klippes; the occurrence of the Krupianka Limestone Formation is indicated in the lower part of the log

For lithological symbols see Text-fig. 2

Saccocoma-Globochaete microfacies). In places within beds *11-12* sessile crinoid debris is the dominant element (*Saccocoma*/sessile-crinoid microfacies).

The upper boundary of bed *12* is an erosion surface covered by pink-creamy to light-gray coloured limestones. Thin sections show wackstones mostly containing *Globochaete*, with some admixture of *Saccocoma* debris (*Globochaete* microfacies). These deposits correspond to the lowermost part of the Dursztyn Limestone Formation (Korowa Limestone Member).

About 50m South-West from the southern klippe of the Czorsztyn Limestone Formation, in the road-cutting at the "Cisówka" pension, limestones of the Spisz Limestone Formation are exposed (BIRKENMAJER 1963, Pl. 16, Fig. 3, section 15, pp. 169-170; BIRKENMAJER 1977, Fig. 31B; *see also* Text-fig. 5, herein). The limestone beds are oriented East-West and are moderately inclined (95/35 S). These limestones are about 8.5m thick, but as their base is not exposed, the full thickness of the Spisz Limestone Formation must be greater.

The oldest, bed *1* is brown-violet limestone (Text-fig. 5) about 3.5m in thickness. The limestone consists of interstratified packstones rich in crinoid ossicles (crinoid microfacies), and wackstones with abundant tests of the planktonic foraminifer *Globuligerina*, and usually with some admixture of

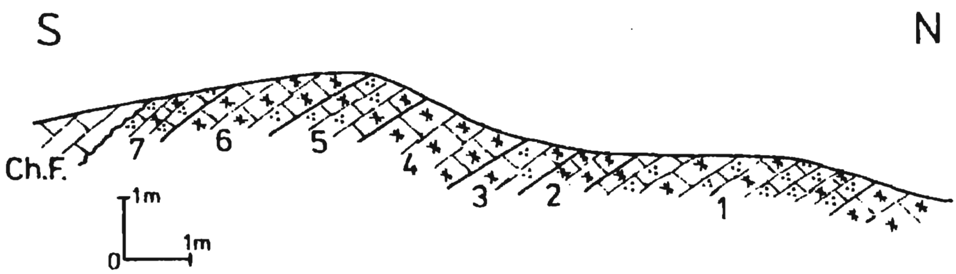


Fig. 5. Geological section through the south-western klippe of the Pomiedznik Klippes
LITHOSTRATIGRAPHY: beds *1-7* — Spisz Limestone Formation, ChF — Chmielowa Formation
For lithological symbols *see* Text-fig. 2

crinoid debris (*Globuligerina* microfacies, and *Globuligerina*-crinoid microfacies). The wackstones from the lower part of the bed contain some poorly preserved calpionellids of the genera *Lorenziella*, *Tintinnopsella*, and *?Calpionellites*. They indicate, if not reworked, Early Valanginian age of the bed. It should be remembered that small limestone clasts with a similar assemblage of calpionellids are encountered in the crinoid packstones.

Beds *2-4* consist of brown-violet, coarse-grained crinoid packstones, and less commonly wackstones. The bedding planes are sharp and clearly erosional in character. Small limestone clasts some of them containing calpionellids, similar to bed *1*, are encountered.

Bed *5* consists of fine-grained, indistinctly nodular, red-violet, and locally also yellow-olive coloured limestones, about 0.8m in thickness. The limestones are interstratified crinoid packstones (crinoid microfacies) and wackstones which contain abundant tests of the planktonic foraminifer *Globuligerina*, crinoid debris (*Globuligerina*-crinoid microfacies), and a few fragments of ammonite shells (Pl. 3, Fig. 3).

Bed *6* has a thickness of about 1m. The lowermost part (about 5 cm thick) consists of yellow-olive mudstone with scarce shell fragments (mostly ammonites) and tests of planktonic foraminifers. The upper boundary of the mudstone layer is a distinct erosion surface with mudstone clasts visible in the overlying rock. Above the erosion surface the bed consists of red-violet, fine-grained to coarse-grained packstones rich in crinoid debris (crinoid microfacies).

Bed *7*, about 0.5m thick, consists of a few interstratified thin layers of crinoid packstones (crinoid microfacies), and of wackstones to mudstones with frequent tests of the planktonic foraminifer *Globuligerina* (*Globuligerina* microfacies). The bases of the crinoid packstone layers are always sharp erosion surfaces. The top of bed *7* marks a distinct non-sequence surface (*see* Text-fig. 5). It is strongly corroded and overlain by dark-red limestones with very abundant planktonic foraminifers *Hedbergella*, and some prisms of *Inoceramus* shells (*Hedbergella* microfacies). These limestones represent the lowermost part of the Chmielowa Formation of Early to Middle Albian age (BIRKENMAJER 1963, 1977; ALEXANDROWICZ 1979).

ŁYSA KLIPPES

The Łysa Klippes at Falsztyn (*see* Text-fig. 1) show a sequence of Jurassic and Lower Cretaceous deposits representative of the so-called Łysa Klippe facies type of the Czorsztyn Succession (BIRKENMAJER 1963). It is the type locality of the Łysa Limestone Formation (BIRKENMAJER 1977). The studied northern part of the klippes is a section through the upper part of the Czorsztyn Limestone Formation, almost the whole of the Dursztyn Limestone Formation, and the lower part of the Łysa Limestone Formation (Text-figs 1 and 6, Pl. 3, Fig. 1; *see also* BIRKENMAJER 1963, section 30/I-I, pp. 187-189, Pl. 8, Fig. 1, and Pl. 18, Fig. 4; BIRKENMAJER 1977, Fig. 28). The beds dip gently southwards at about 20°.

The lowermost bed of the section (bed *1*) consists of pink-coloured fine-grained packstones and grainstones rich in sessile crinoid debris and *Saccocoma* fragments. The base of the bed is not exposed and thus its total thickness must be greater than the measured value of 1m. It is highly probable that this bed corresponds to bed 4b of section no. 30, about 1.2m in thickness as described by BIRKENMAJER (1963, p. 188).

Younger bed *2*, about 0.55m in thickness, is a red-brown nodular limestone rich in *Saccocoma* fragments and *Globochaete*, representing the *Saccocoma-Globochaete* microfacies. This is followed by a sharp lithological change to yellow-pink and orange crinoid grainstones (bed *3*, about 0.2m in thickness). The overlying beds *4* and *5* are red-brown coloured, markedly

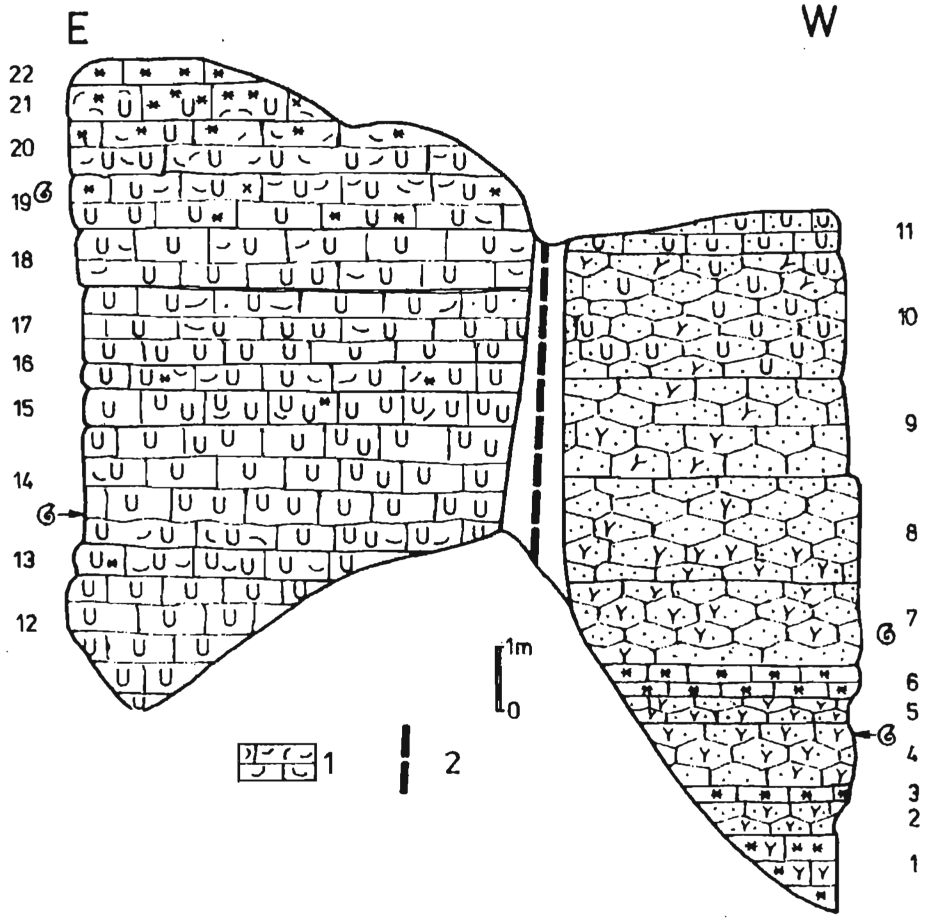


Fig. 6

Geological section through the northern part of the Łysa Klippes

LITHOSTRATIGRAPHY: beds *1-6* — Czorsztyn Limestone Formation, emend.; beds *7-19* — Dursztyn Limestone Formation (beds *7-11* — Korowa Limestone Member, emend.; beds *12-19* — Sobótka Limestone Member); beds *20-22* — Łysa Limestone Formation (Harbatowa Limestone Member)

LITHOLOGY and other explanations: **1** — shell fragments (mostly ammonite debris), for other lithological symbols *see* Text-fig. 2; **2** — fault responsible for a tectonic break in the succession; ammonite findings discussed in text are indicated nodular limestones. They are about 1.1m and 0.4m thick, respectively. The limestones are wackstones with abundant *Globochaete*, and *Saccocoma* fragments (*Globochaete-Saccocoma* microfacies). The upper part of bed *4* yields some poorly preserved ammonites, including representatives of genera *Lytoceras* and *Aspidoceras*. The latter are characteristic of the Kimmeridgian and Tithonian (mostly the Lower Tithonian).

Bed *6* consists of light red-brown to pink coloured crinoid grainstones. Some clasts of *Globochaete-Saccocoma* wackstones, up 0.5 cm in diameter, can be observed.

The overlying beds *7* and *8*, about 1.3m, and 1.7m thick, respectively, consist of red-brown, distinctly nodular limestones. They are wackstones with abundant *Globochaete* and *Saccocoma* fragments (*Globochaete-Saccocoma* microfacies, mostly in bed *7*, and the lower part of bed *8*), and *Globochaete* (*Globochaete* microfacies, mostly in the upper part of bed *8*). Bed *7* yields ammonites including some fragments which almost certainly belong to the genera *Semiformiceras* and *Richterella*. These are indicative of the Semiforme and Fallauxi Zones of the Lower/Middle Tithonian (*cf.* KUTEK & WIERZBOWSKI 1986).

Bed *9*, about 1.5m in thickness, is developed as red-brown nodular limestones. The dominant microfacies is one of mudstones to wackstones with abundant *Globochaete* (*Globochaete* microfacies). Fragments of *Saccocoma*, shell debris, and calcified radiolarian tests occur less commonly.

Bed *10*, about 2m thick, consists of red-brown nodular limestones. Microscope analysis reveals wackstone to be the most common, rich in *Globochaete* and calpionellids, but packstones also occur with a marked admixture of *Saccocoma* debris. The calpionellids belong mostly to the genus *Crassicolaria*, indicating Late Tithonian age.

Bed *11* is partially preserved in the western part of the section (*see* Text-fig. 6) where the incomplete thickness is about 0.7m. It consists of red-brown nodular limestones. These are mudstones containing *Globochaete*, calpionellids and calcified radiolarian tests and less commonly crinoid ossicles, and fragments of ammonite shells. The common occurrence of *Calpionella alpina* LORENZ, with some admixture of *Crassicolaria* is indicative of lowermost Berriasian (*cf.* REMANE 1986).

The discussed part of the section from bed *1* to *11* is comparable with the Czorsztyn Limestone Formation, and with Korowa Limestone Member of the Dursztyn Limestone Formation (*cf.* BIRKENMAJER 1963, 1977). The boundary of the two units is taken (Text-fig. 6) where the limestones become more micritic in character (*Globochaete* mudstones/wackstones), replacing the more grained limestones of the lowermost part of the succession (*Saccocoma* wackstones/packstones with intercalations of crinoid grainstones). Thus defined, the boundary corresponds to the base of bed *7*, and should be placed about 4.5m lower than originally marked by BIRKENMAJER (1963, Pl. 18, Fig. 4; *and* 1977, Fig. 28A).

Still younger beds occur in the eastern part of the klippes. There is, however, an unknown stratigraphic gap between bed *11* and bed *12*, related to tectonic disturbances between the eastern and western part of the klippes (Text-fig. 6).

The stratigraphic interval including beds *12* to *19* is comparable with the Sobótka Limestone Member of the Dursztyn Limestone Formation (BIRKENMAJER 1963, 1977). It is 8.75m in thickness. This interval is characterized by well-bedded, yellow-brown-gray coloured limestones. Bed thickness is generally greater in the lower part of the interval (bed *12* and bed *14*, each about 2m thick), and lesser in its upper part (from 0.4m to 1.2m for beds *15-19*). The limestones are developed as mudstones and wackstones. Calpionellids predominate, sometimes with significant numbers of calcified radiolarian tests (calpionellid and calpionellid-radiolarian microfacies). In addition, ammonite shell and crinoid debris occurs. Bioclasts are either sparsely placed within the matrix, or grouped in thin bands at small scale omission surfaces, mostly in bed *13*, the lower part of bed *14*, beds *15-16*, and in the upper part of bed *19*.

The calpionellids occurring in beds *12* to *19* belong to the genera *Calpionella*, including *C. alpina* LORENZ and *C. elliptica* CADISCH, *Remaniella*, such as *R. cadischiana* (COLOM), and *Tintinnopsella*, such as *T. carpathica* (MURGEANU & FILIPESCU). These are indicative of the Calpionella Zone of Early to Middle Berriasian age (*cf.* REMANE & *al.* 1986, WIERZBOWSKI & REMANE 1992). The ammonite *Berriasella (Berriasella) jacobi* MAZENOT, discovered in the lower part of bed *14* (Pl. 4, Fig. 5) is indicative of the Jacobi = Euxinus Zone of the Lower Berriasian (*cf.* HOEDEMAEKER & *al.* 1993, *see also* WIERZBOWSKI & REMANE 1992). The ammonites *Neolissoceras* cf. *grasianum* (D'ORBIGNY) commonly occurring in the upper part of bed *19* are of minor stratigraphic importance.

The base of bed *20* is a marked omission surface with numerous burrows filled with gray-red crinoid limestone. Bed *20* consists of gray-red to violet coloured limestones. They are developed as wackstones with abundant shell fragments, crinoid ossicles, calpionellids and calcified radiolarian tests; crinoid debris occurs most commonly in the lowermost and uppermost parts of the bed. The total thickness of bed *20* is 0.85m.

Bed *21*, younger still, consists of violet-brown wackstones and packstones rich in shell and crinoid debris, as well as calpionellids. The brachiopod shells are rather common. The bed is 0.6m in thickness.

The calpionellids occurring in beds *20-21* are dominated by genera *Calpionellopsis*, *Tintinnopsella*, and *Remaniella*. They are indicative of the Late Berriasian (REMANE & *al.* 1986; *cf. also* WIERZBOWSKI & REMANE 1992).

Bed *22* is developed as gray-red to violet coloured crinoid packstones; its incomplete thickness is 0.4m.

Beds *20-22* contain infrequent small clasts of limestone, which are superfically covered by iron oxides. The microfossils recognized therein include *Calpionella alpina* LORENZ and calcified radiolarian tests.

All the discussed deposits from beds *20-22*, 1.85m in thickness, correspond to the Harbatowa Limestone Member of the Łysa Limestone Formation (BIRKENMAJER 1977; *cf.* BIRKENMAJER & GĄSIOROWSKI 1961, BIRKENMAJER 1963).

NIEDZICA CASTLE KLIPPE

The section is located in the northern part of the klippe (Text-fig. 1, and 7). It is no longer accessible for observation due to the construction of a dam on the Dunajec River. The section represents the so-called Niedzica Castle Klippe facies type of the Czorsztyn Succession (BIRKENMAJER 1963, section 42, pp. 201-204, Pl. 19; *cf. also* BIRKENMAJER 1977, Fig. 28B).

The oldest studied deposits are violet-brown coloured, markedly nodular limestones. They are very fractured, and cut by calcite veins. The exposure is only about 2.5m thick (bed *1* in Text-fig. 7), but the lower boundary is a tectonic one. Microscopic analysis reveals packstones with abundant *Saccocoma* fragments (*Saccocoma* microfacies), and a few crinoid ossicles.

Beds *2* and *3* are also tectonically disturbed and cut by calcite veins. Thus, their total thickness of about 1m is only approximate. Bed *2* consists of fine-grained, orange-coloured crinoid grainstones, and bed *3* of pink-coloured wackstones with abundant *Globochaete* (*Globochaete* microfacies).

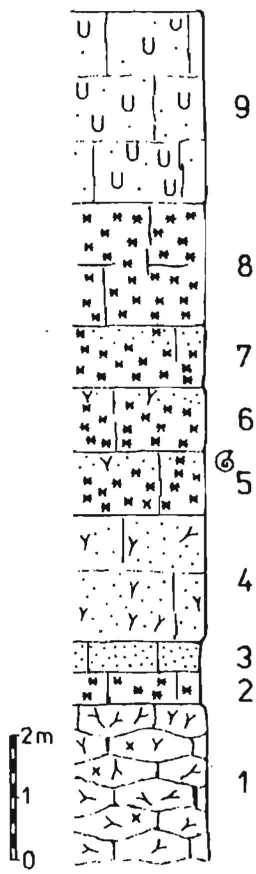


Fig. 7

Lithological log of the Czorsztyn Limestone Formation (beds *1-2*) and Dursztyn Limestone Formation (beds *3-9*) at Niedzica Castle Klippe

For lithological symbols *see* Text-fig. 2

Beds *1* and *2* are correlated with the upper part of the Czorsztyn Limestone Formation. Bed *3* originally corresponding to the "Pink *Globochaete* Limestone" (BIRKENMAJER 1963) should be correlated with the Korowa Limestone Member of the Dursztyn Limestone Formation (BIRKENMAJER 1977). However, due to tectonic disturbances the boundary between these two formations has not been precisely located in the section.

Bed *4*, about 2m thick, consists of gray and brown-gray wackstones with frequent *Globochaete* (*Globochaete* microfacies), and local abundances of *Saccocoma* fragments, also with some admixture of calcified radiolarian tests (*Globochaete-Saccocoma* microfacies). In the lowermost part of this bed crinoid ossicles are fairly common.

Beds *5-8*, with a total thickness about 5m, are represented mostly by yellow-gray to brown-gray coloured crinoid grainstones. The bed thickness is about 1m for beds *5-7*, and about 2m for bed *8*. The uppermost parts of beds *5* to *7* consist of wackstones and mudstones with *Globochaete*, *Saccocoma* fragments, and calcified radiolarian tests. The macrofossils discovered in bed *5* include brachiopods (*Pygope*), aptychi, and poorly preserved ammonites (mostly Haploceratacea, and a single specimen of ?*Simoceras*). The overlying bed (set of beds) *9* represents the youngest deposits of the section. These are white-gray mudstones containing calpionellids, calcified radiolarian tests, and *Globochaete*. Identified calpionellids include representatives of *Crassicolaria*, and *Calpionella alpina* LORENZ, indicative of the lower part of the Calpionella Zone (Zone B) of earliest Berriasian age (REMANE 1986, REMANE & *al.* 1986). Thus, the underlying beds *4-8* without calpionellids are probably of Tithonian age. The occurrence of ?*Simoceras* sp. suggests Early/Middle Tithonian age for bed *5*.

Beds *4-9* can be compared with some informal lithostratigraphic units of BIRKENMAJER (1963): bed *4* corresponds possibly to the "White *Globochaete* Limestone", beds *5-8* to the "Falsztyn Crinoidal Limestone", and bed *9* to the "White *Calpionella* Limestone". All these informal units have been more recently attributed to the Sobótka Limestone Member of the Dursztyn Limestone Formation (BIRKENMAJER 1977). However, the biostratigraphic interpretation of beds *5-9* in the section studied indicates that they are, with the exception of bed *9*, mostly older than the deposits usually attributed to the Sobótka Limestone Member in other sections. It should also be remembered that the deposits of beds *4-8* differ from typical deposits of the Sobótka Limestone Member, having a greater abundance of crinoid limestones and a lesser quantity of micritic limestones (*cf.* BIRKENMAJER 1977). Moreover, the micritic limestones from beds *4-8* are in thin sections similar to these of the Korowa Limestone Member.

The beds *4-8* of the section studied are thus referred to the Sobótka Limestone Member with reservation. Only bed *9* should be unequivocally attributed to the Sobótka Limestone Member.

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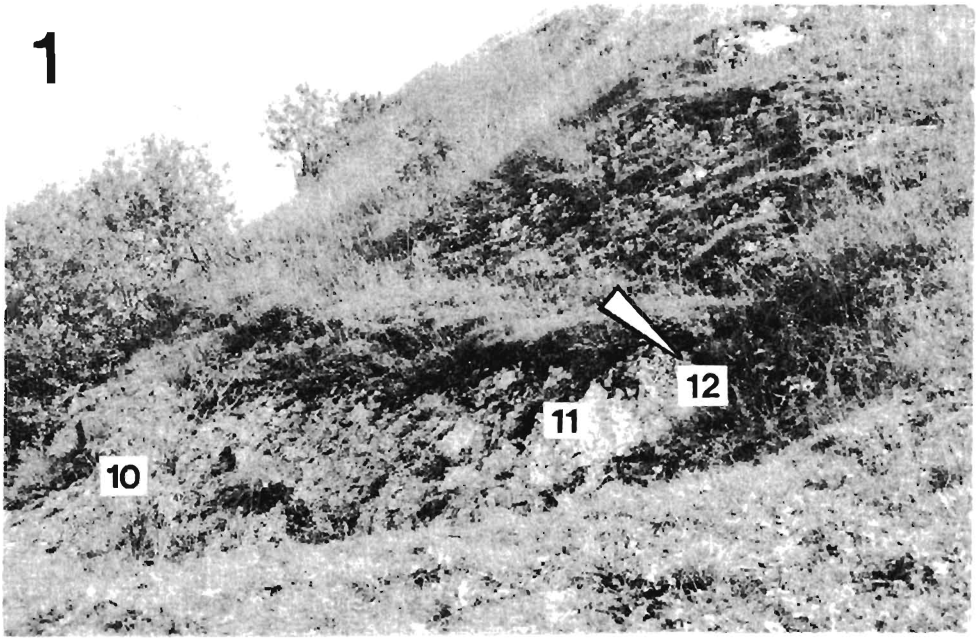

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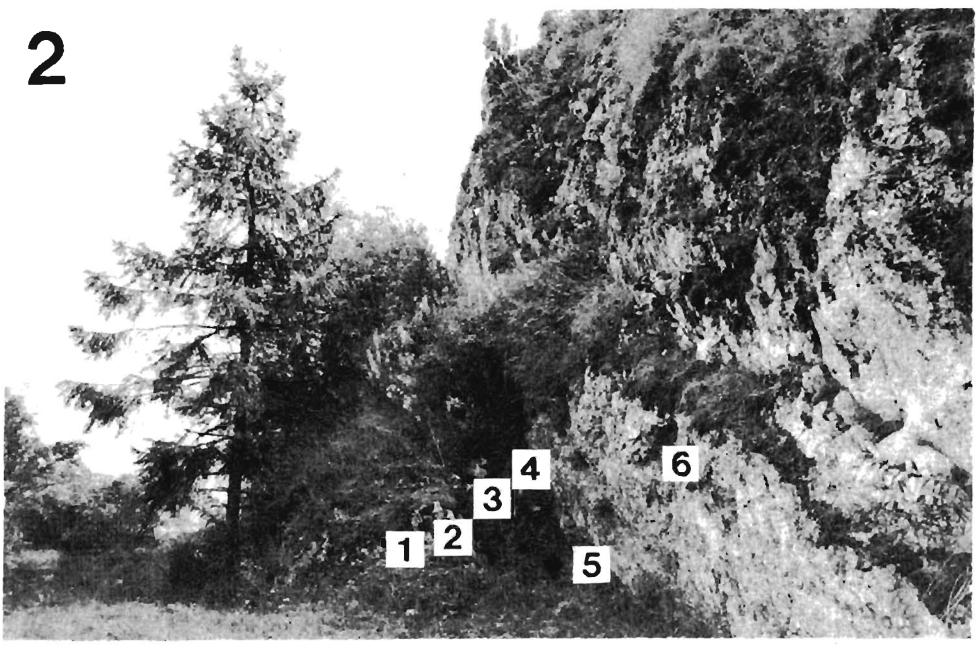
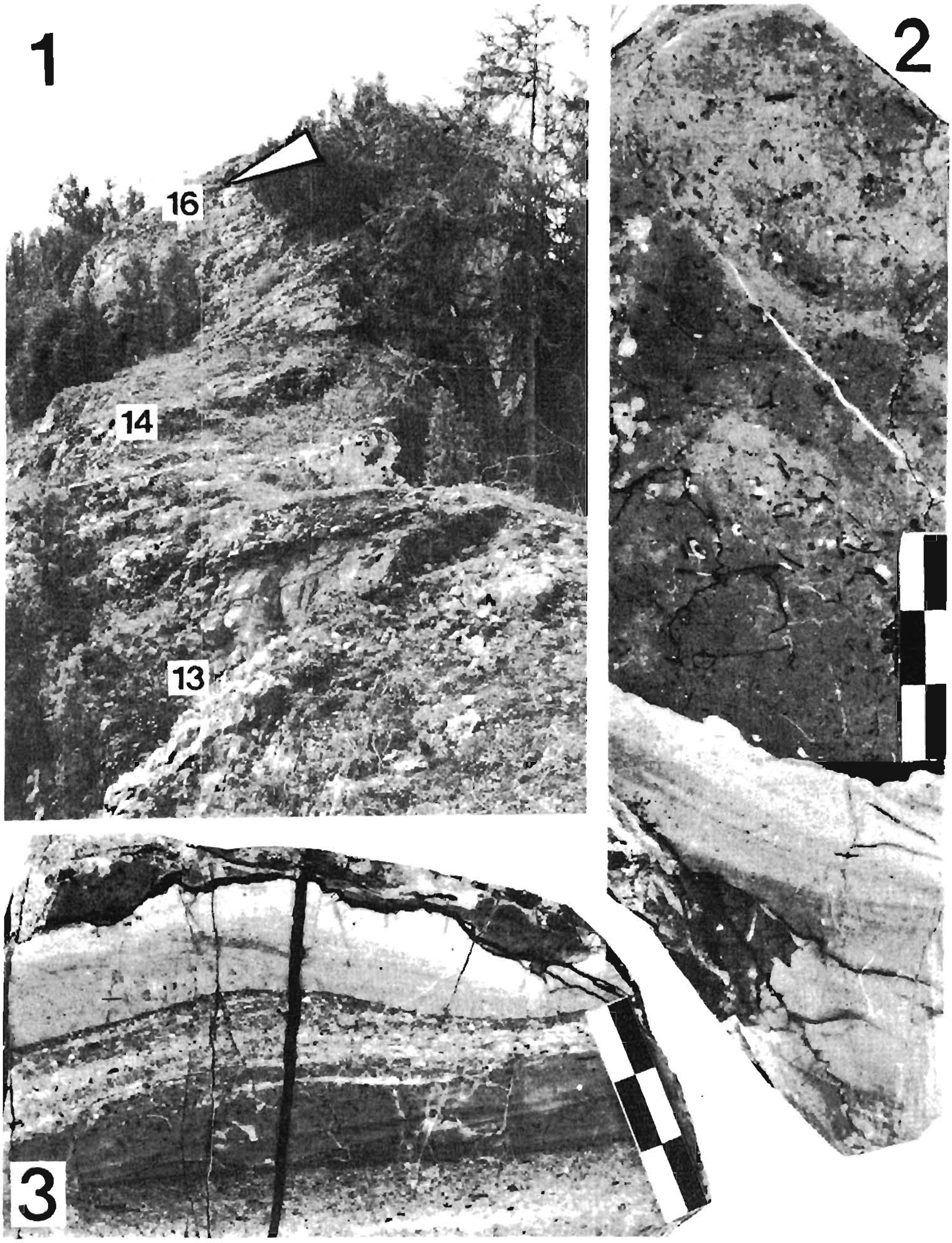


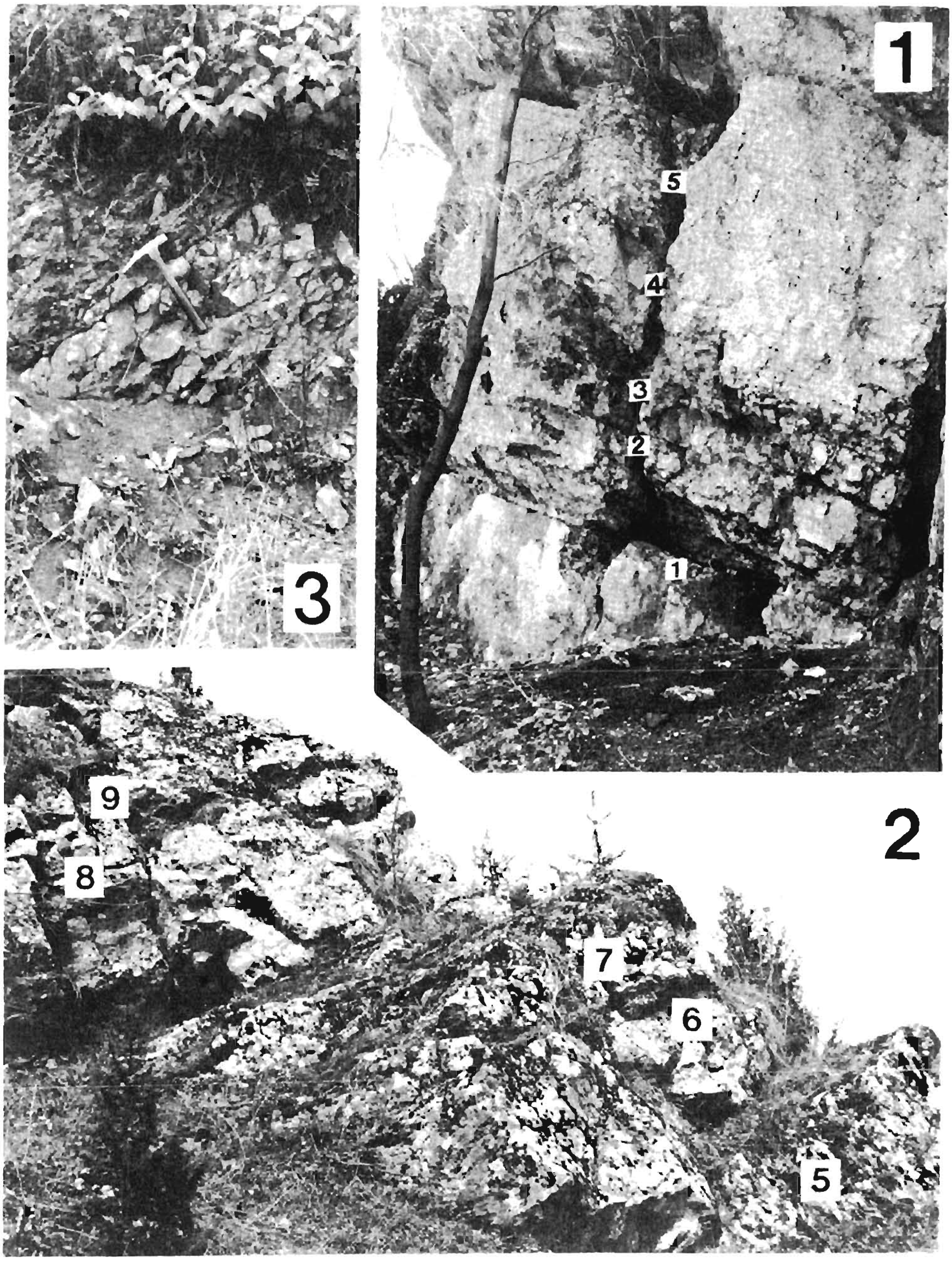
1 — Korowa Klippe, section B (*see* Text-fig. 2): Dursztyn Limestone Fm. (beds *10-11*), and Łysa Limestone Fm. (bed *12*, arrowed)

2 — Korowa Klippe, section A (*see* Text-fig. 2): indicated are bed *1* of the Krupianka Limestone Fm., and beds *2-6* of the Czorsztyn Limestone Fm.; to the right are still younger limestones of the Czorsztyn Limestone Fm. and Dursztyn Limestone Fm.



1 — Lorencowe Klippes (*see* Text-fig. 3); indicated are beds *13* and *14* of the Czorsztyn Limestone Fm.; still younger beds *15-18* of the same formation occur upslope; the neptunian sill of the Sobótka Limestone Mb. penetrating bed *16* is arrowed

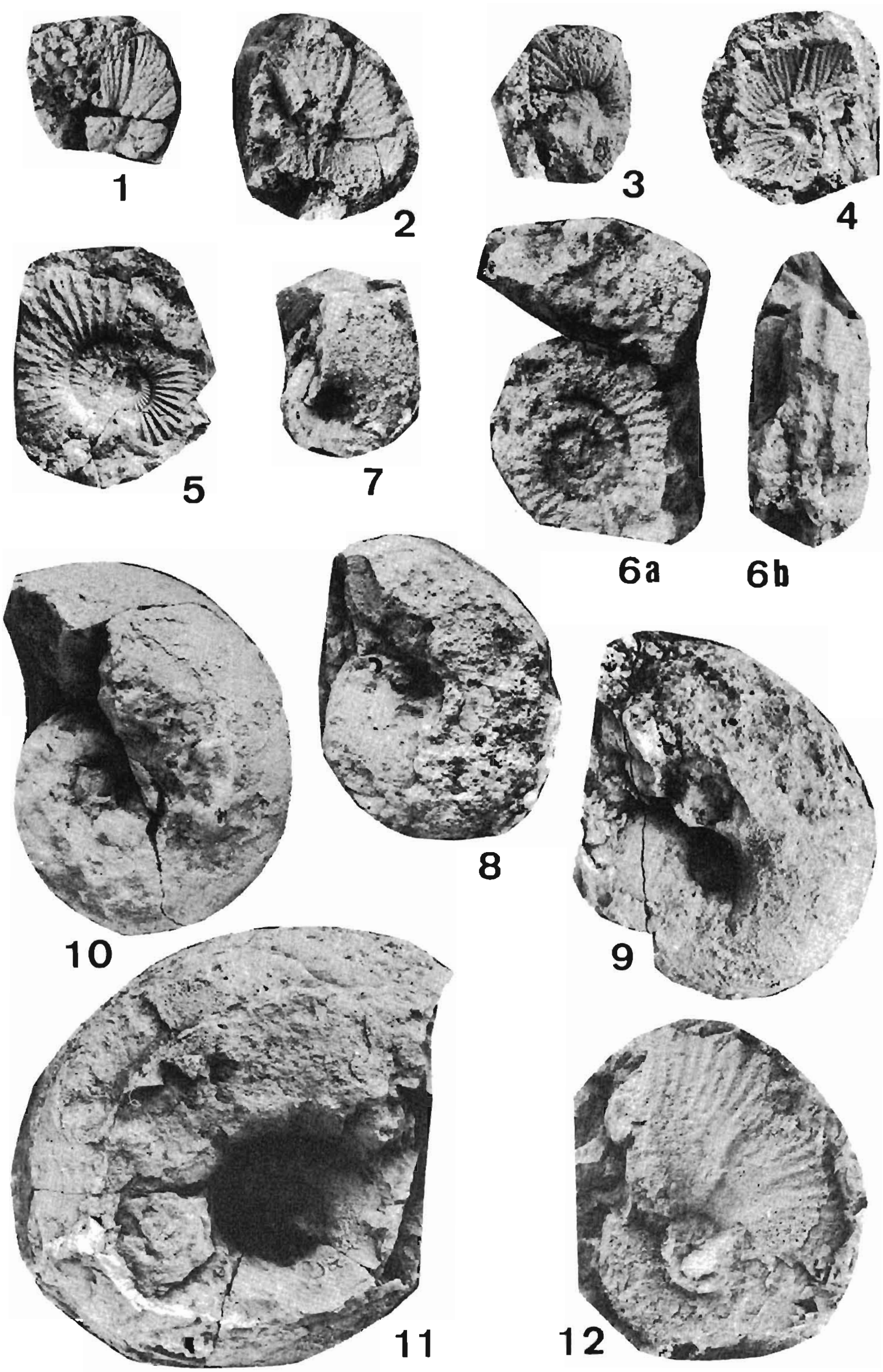
2-3 — Sections of the sill indicated in Fig. 1, to show poorly fossiliferous laminated mudstones and grainstones consisting of skeletal material; scale in centimeters



1 — Łysa Klippes (*see* Text-fig. 6); indicated beds (*1-5*) of the Czorsztyn Limestone Fm. are nodular wackstones to packstones (beds *2*, and *4-5*), and more massive crinoid grainstones (beds *1* and *3*)

2 — Lorencowe Klippes (*see* Text-fig. 3); indicated beds (*5-9*) of the Czorsztyn Limestone Fm. are massive to markedly nodular limestones

3 — Pomiedznik Klippes (*see* Text-fig. 5); nodular wackstones and crinoid packstones (beds *4-5*) of the Spisz Limestone Fm.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NOTES ON AMMONITES

Only some, the most important and newest Early Cretaceous findings are paleontologically reported hereafter and illustrated (*see* Pls 4-5). The enclosed photos contain also some Upper Jurassic forms representing the species previously reported from the Pieniny Klippen Belt, and hence not discussed below.

Family **Neocomitidae** SALFELD, 1921
Genus *Thurmanniceras* COSSMANN, 1901

A fragment of large specimen (Pl. 5, Fig. 4), about 110 mm in maximum diameter, from the highly condensed deposits at the base of the Spisz Limestone Formation in the Korowa Klippe section (*see* Text-fig. 2).

It is moderately evolute: at 100 mm diameter (D), Ud (umbilicus diameter in D%) is 35%, whereas Wh (whorl height in D%) is 41%; the whorl section is high (whorl height to whorl thickness ratio equals 1.23 at D = 100 mm) with flattened sides, and tabulate, thereafter rounded venter. The ribs visible on the last whorl are prorsiradiate, and flexuous; they branch often at the umbilicus, and commonly at 2/3 of the whorl height; the tubercles are commonly developed at the umbilicus. The ribbing tends to fade at the middle of the whorl. Shallow constrictions are often encountered. The specimen can possibly be interpreted as a macroconch, very close to that of *Thurmanniceras petransiensis* (SAYN) described by COMPANY (1987, Pl. 7, Fig. 8). It is also similar to the lectotype of the species (SAYN 1907, Pl. 5, Fig. 10) which is a wholly septate specimen up to 55 mm diameter.

PLATE 4

1-4 — *Jeanthieuloyites* sp.; Upper Valanginian, lower Spisz Limestone Fm., Korowa Klippe, bed *13*; specimens Nos IGPUW/A/30/10, IGPUW/A/30/11, IGPUW/A/30/12 and IGPUW-/A/30/13

5 — *Berriasella (Berriasella) jacobi* MAZENOT; Lower Berriasian, Sobótka Limestone Member, Łysa Klippes, bed *14*; IGPUW/A/30/24

6a-6b — *Hybonoticeras hybonotum* (OPPEL), 6a — lateral and 6b — ventral view; lowermost Tithonian, Hybonotum Zone, Czorsztyn Limestone Formation, Lorencowe Klippes, bed *26*; IGPUW/A/30/17

7-9 — *Schaireria avellana* (ZITTEL); lowermost Tithonian, Hybonotum Zone, Czorsztyn Limestone Formation, Lorencowe Klippes, bed *26*; IGPUW/A/30/18, IGPUW/A/30/19 and IGPUW/A/30/20

10-11 — *Aspidoceras* cf. *binodum* (OPPEL); Kimmeridgian, Czorsztyn Limestone Formation, Korowa Klippe, bed *6*; IGPUW/A/30/2 and IGPUW/A/30/3

12 — *Taramelliceras (Taramelliceras) compsum* (OPPEL); Kimmeridgian, Czorsztyn Limestone Formation, Korowa Klippe, bed *6*; IGPUW/A/30/1

All specimens in natural size

Genus *Karakaschiceras* THIEULOY, 1971

A single specimen (Pl. 5, Fig. 5) from the highly condensed deposits at the base of the Spisz Limestone Formation in the Korowa Klippe section (*see* Text-fig. 2).

It is represented by inner whorls of the phragmocone and a part of the body chamber. The preserved part of the phragmocone, about 50 mm in diameter, is involute (Ud is 27%, whereas Wh is 50%, at D=46 mm), trapezoidal in cross-section with steep umbilical wall and flattened venter. The whorl height to whorl thickness ratio equals 1.21. The ribbing is strong, composed of short, rectiradiate, swollen primary ribs (about 20 per whorl), and prorsiconcave, fairly dense secondary ribs which terminate with small tubercles at the ventrolateral margin. A few shallow constrictions can be observed. At about 45 mm diameter the ribbing seems to disappear in the ventrolateral part of whorl. The preserved part of the body chamber corresponds approximately to a specimen diameter of 120 mm; its surface is corroded, but seems to have originally been smooth; the ventral side is rounded. As far as preservation permits the specimen appears closely related to *Karakaschiceras inostranzewi* (KARAKASCH), *e.g.* to the type of the species illustrated *i.a.* by KARAKASCH (1907, Pl. 26, Fig. 1), as well as other specimens indicated in the synonymy by COMPANY (1987, p. 150).

Family **Olcostephanidae** HAUG, 1910
Genus *Olcostephanus* NEUMAYR, 1875

Two specimens (Pl. 5, Figs 6-7), 35 mm and 80 mm in maximum diameter, from highly condensed deposits at the base of the Spisz Limestone Formation, in the Korowa Klippe section (*see* Text-fig. 2). They are referred to *Olcostephanus (Olcostephanus) guebhardi* (KILIAN). They are involute (Wh is 43% and 39%, Ud is 31.5% and 32.5%, in the smaller and larger specimen, respectively). The ribbing is fairly dense: the short bullate primary ribs are slightly rursiradiate to

PLATE 5

1 — *Jeanthieuloyites* sp.; 1a — lateral and 1b — ventral view; Upper Valanginian, lower Spisz Limestone Fm., Korowa Klippe, bed *13*; specimen No. IGPUW/A/30/14

2 — *Olcostephanus (Olcostephanus)* sp.; Upper Valanginian, lower Spisz Limestone Fm., Korowa Klippe, bed *13*; IGPUW/A/30/15

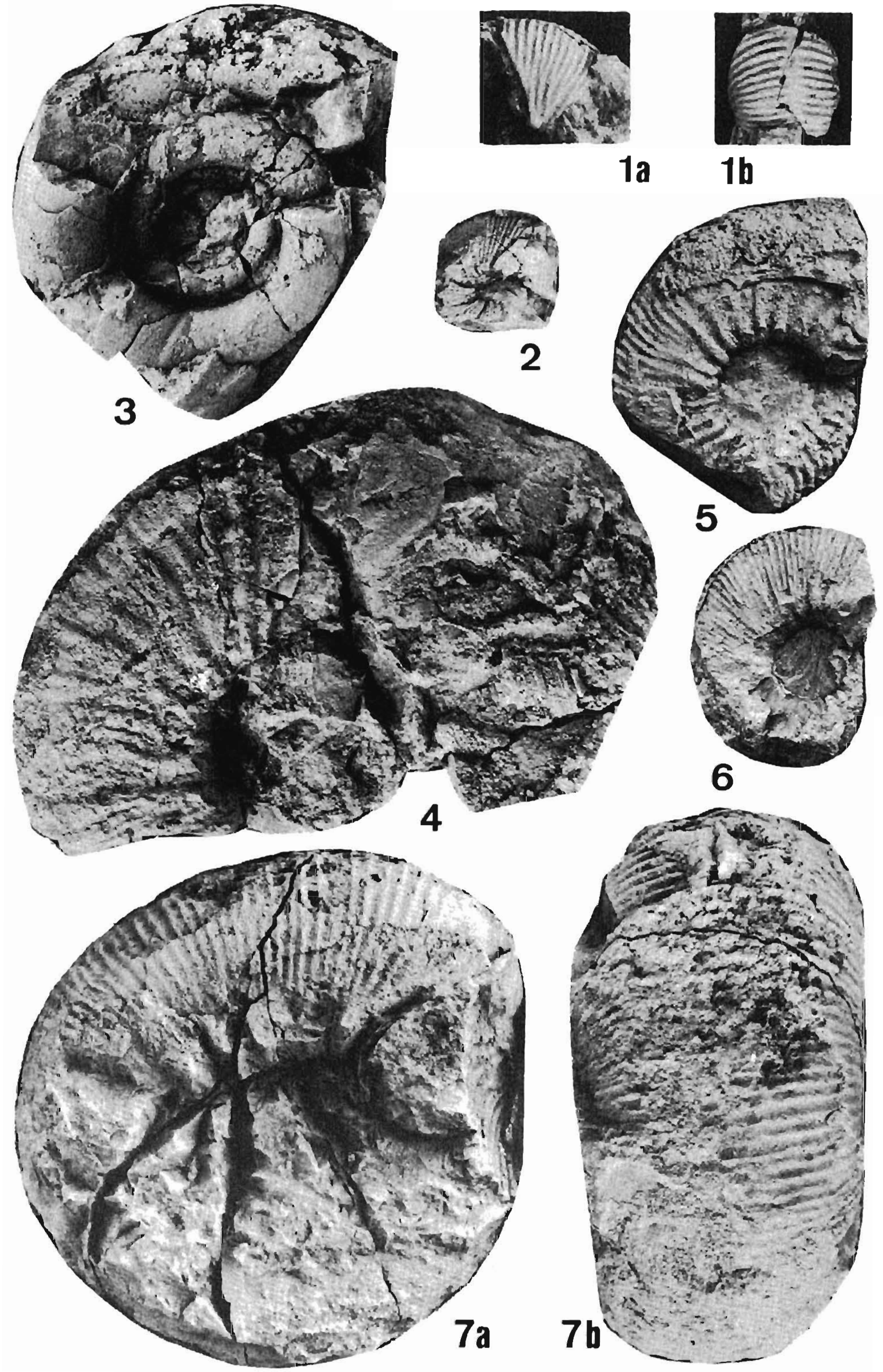
3 — *Protetragonites quadrisulcatus* (D'ORBIGNY); Valanginian, condensed deposits at the base of the Spisz Limestone Fm., Korowa Klippe; IGPUW/A/30/8

4 — *Thurmanniceras* cf. *petransiensis* (SAYN); Valanginian, condensed deposits at the base of the Spisz Limestone Fm., Korowa Klippe; IGPUW/A/30/4

5 — *Karakaschiceras* cf. *inostranzewi* (KARAKASCH); Valanginian, condensed deposits at the base of the Spisz Limestone Fm., Korowa Klippe; IGPUW/A/30/5

6-7 — *Olcostephanus (Olcostephanus) guebhardi* (KILIAN); 7a — lateral and 7b — ventral view of the same specimen; Valanginian, condensed deposits at the base of the Spisz Limestone Fm., Korowa Klippe; IGPUW/A/30/6 and IGPUW/A/30/7

All specimens in natural size


1a
1b
2
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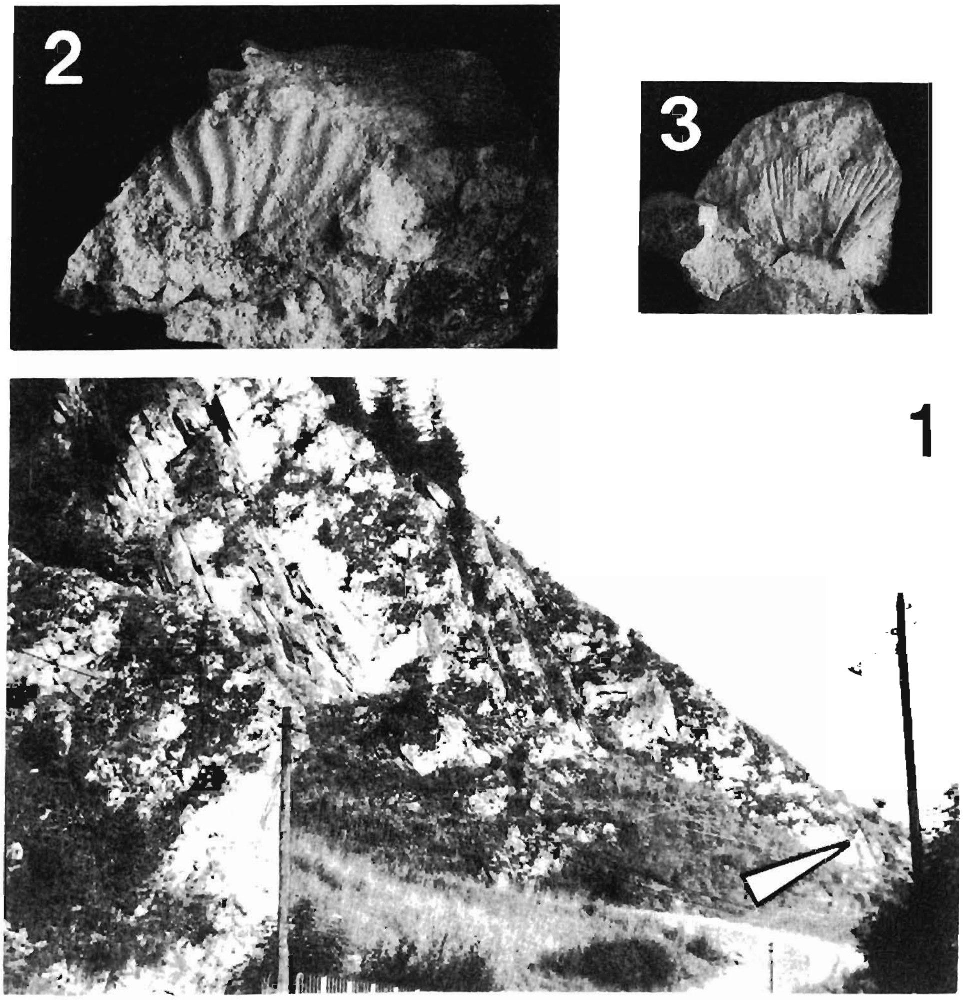
6
7a
7b



1 — Southern slope of the Sobótka Klippe at Czorsztyn showing the lowermost part of the Spisz Limestone Fm. (*arrowed*) yielding the ammonites shown in Figs 2-3

2 — *Busnardoites* sp.; specimen No. IGPUW/A/30/35, nat. size

3 — *Olcostephanus* sp.; specimen No. IGPUW/A/30/34, nat. size rectiradiate, whereas the numerous secondary ribs are rectiradiate to slightly prorsiradiate; the secondaries do not show any bifurcations. The whorl section is low oval (whorl thickness/whorl height ratio equals 1.48). The specimens studied are very close to the holotype of the species described and illustrated by KILIAN (1902, p. 866, Pl. 57, Figs 2a-b).

Family **Holcodiscidae** SPATH, 1924
Genus *Jeanthieuloyites* COOPER, 1981

A number of specimens (5 partially complete, and a few fragments) come from the lowermost part of the Spisz Limestone Formation in the Korowa Klippe section (*see* Text-fig. 2). The specimens (Pl. 4, Figs 1-4 *and* Pl. 5, Fig. 1) are 20-35 mm in diameter, nearly rectangular in whorl section, strongly involute (Ud: umbilicus diameter in D% ranges between 17.3% and 18.6%), and rather densely ribbed. The primary ribs usually spring from the umbilical swellings, and commonly branch into two secondaries at 2/3 of the whorl height, but some ribs remain single. The ribbing fades somewhat on the ventral side (Pl. 5, Fig. 1b). Marked constrictions obliquely truncating the ribs are common (4 or more per whorl). The overall affinities of these specimens are certainly with the genus *Jeanthieuloyites*. The systematic position of this genus, and its variability are however still poorly known (*see* COOPER 1981, THIEULOY & *al.* 1990) which precludes closer comparisons.

GENERAL REMARKS

A distinct change in sedimentation occurred during late Middle Jurassic in the Czorsztyn Succession. It is recorded in the transition from the crinoid limestones of the Smolegowa Limestone Formation and the Krupianka Limestone Formation, to the red limestones of the *Ammonitico Rosso* type of the Czorsztyn Limestone Formation. This change corresponded to the cessation of shallow-water limestone deposition, and the onset of pelagic sedimentation. The phenomenon was related with the Meso-Cimmerian faulting which split the Czorsztyn Ridge into a series of blocks showing a differential subsidence (BIRKENMAJER 1977, 1986; *cf. also* BERNOULLI & JENKYNS 1974).

The studied deposits of the Czorsztyn Limestone Formation are of varied thickness and to some degree also of different lithological character, dependant possibly on their development in local topographic highs and basins. The thickness of these deposits oscillates markedly in the sections studied, from 4.2m at the Korowa Klippe, the most condensed section of the area, to more than 22m at Lorencowe Klippes (*see* Text-figs 2-3). Nevertheless, independent of some differences in lithology and thickness, the same succession of microfacies is observed everywhere in the Czorsztyn Limestone Formation (Text-figs 2-7; *see also* ZYDOROWICZ & WIERZBOWSKI 1986, ZYDOROWICZ 1991, MYCZYŃSKI & WIERZBOWSKI 1994). The succession grades upwards from the filament microfacies which consists of abundant fragments of pelagic bivalve of the genus *Bositra*, through the *Globuligerina* ("*Protoglobigerina*") microfacies, to the *Saccocoma* microfacies, and *Saccocoma*/sessile-crinoid microfacies. The ammonite datings (Text-figs 2-7, Pl. 4, Figs 6-12; *see also* MYCZYŃSKI & WIERZBOWSKI 1994, *cf.* RAKÚS 1990) strongly suggest the approximate isochronism of particular microfacies in the area of study. The filament microfacies is known from the Bathonian to the Callovian and possibly to the lowermost Oxfordian, the *Globuligerina* microfacies in the Oxfordian, and the *Saccocoma* and *Saccocoma*/sessile-crinoid microfacies in the Kimmeridgian and the Lower/Middle Tithonian.

The filament microfacies, and the *Saccocoma* microfacies are widely recognized within the pelagic deposits of Jurassic age in the Tethys. These are often directly following microfacies, with their transition at the Oxfordian-Kimmeridgian boundary. The vertical range of two main components of microfacies "does not necessarily point to a change in sea depth or environmental energy" (KUHRY & *al.* 1976). On the other hand, the origin of the *Globuligerina* microfacies occurring in places between the former ones needs a discussion. In the area of study, the limestones with the *Globuligerina* microfacies are generally, from 0.4m in Korowa Klippe section, through 1.6m in the Pomiedznik Klippes section, to 5m in the Lorencowe Klippes section (*see* Text-figs 2-4), which corresponds from about 10% to about 20-25% of the total thickness of the Czorsztyn Limestone Formation. These deposits commonly contain ferromanganese nodules which suggests a low sedimentation rate. The *Globuligerina* microfacies developed in the Oxfordian in the Czorsztyn Succession, approximately contemporaneously with the deposition of the radiolarites of the Czajakowa Radiolarite Formation in the Czertezik and Niedzica Successions which were formed on the flanks of the Czorsztyn Ridge in the Pieniny Klippen Belt Basin (BIRKENMAJER 1977; *cf. also* WIDZ 1991, 1992). This contemporaneity suggests that the origin of the *Globuligerina* microfacies could be related to a general increase in plankton productivity, and a decrease in bottom currents activity during Oxfordian, which enabled radiolarites to accumulate on the submarine swells. The latter was possibly related also to some change in water depth, although the deposition place of radiolarites was not necessarily very deep (BAUMGARTNER 1987, DE WEVER 1994; *cf. also* GARRISON & FISCHER 1969).

Upwards, the *Saccocoma* microfacies grades into the *Globochaete* and *Globochaete*-calpionellid microfacies, developed as pink to red-brown, sometimes gray and gray-brown, coloured wackstones and mudstones of the Korowa Limestone Member of the Dursztyn Limestone Formation. Still higher, the calpionellid microfacies occurs, which is represented by white, cream to pink coloured mudstones distinguished as the Sobótka Limestone Member of the Dursztyn Limestone Formation (BIRKENMAJER 1963, 1977; *see also* Text-figs 2-7 herein). Sometimes, intercalations of crinoid grainstones are observed within these deposits: they are more often encountered in the Niedzica Castle Klippe section (*see* Text-fig. 7). The thickness of the Dursztyn Limestone Formation is relatively uniform and range from 8-14m in the Korowa Klippe to over 16m in the Łysa Klippes. The deposits span a time interval from Middle/Late Tithonian to Middle Berriasian as evidenced by paleontological findings (Text-figs 2 and 6-7; Pl. 4, Fig. 5; *see also* WIERZBOWSKI & REMANE 1992).

The sedimentation rate of the deposits of the Dursztyn Limestone Formation had to be higher than that of older pelagic deposits. This evidently resulted from an increase in the production of calcareous nannoplankton which began at the end of Tithonian and continued during earliest Cretaceous (*see* REHAKOVA & MICHALIK 1994). As a consequence, the topographic influence on sedimentation was lessening at that time in the area of study. Some tectonism took place at the beginning of sedimentation of the deposits of the Dursztyn Limestone Formation, during the Tithonian and earliest Berriasian, producing fissures filled with *Globochaete* and calpionellid mudstones at the Korowa Klippe and Lorencowe Klippes (*see* Text-figs 2-3 and Pl. 2).

The Łysa Limestone Formation, mostly of Late Berriasian age, consists of organogenic limestones with crinoid fragments and brachiopods constituting the main faunal elements, but with a variable admixture of limestone clasts; the formation also contains separate breccia beds (BIRKENMAJER 1963, 1977). The limestone clasts derive mostly from the Lower Berriasian, but also from Middle Berriasian and Upper Tithonian deposits, being markedly older than the direct substrate of the Łysa Limestone Formation in the sections studied. The lower boundary of the formation is an erosional surface corresponding to a hiatus which includes a time interval at the Middle/Upper Berriasian boundary (WIERZBOWSKI & REMANE 1992; Text-fig. 6, herein). In some areas the deposits of the Łysa Limestone Formation are either completely missing, or they are strongly reduced in thickness, occurring in fissures and local cavities at the top of the Dursztyn Limestone Formation (*e.g.* in the Korowa Klippe, *see* Text-fig. 2).

The mode of occurrence of the deposits of the Łysa Limestone Formation, and their lithology, indicate a period of tectonic activity which can be dated as corresponding to the Boissieri Zone/Calpionellopsis Zone of the Late Berriasian. The irregular topography of the sea bottom existing at that time consisted of elevated blocks provided detrital material from the erosion of older rocks, *e.g.* the Korowa Klippe area, and local basins *e.g.* the Łysa Klippes area (*see* BIRKENMAJER 1975). The tectonic activity had a wide geographic range in the Western Carpathian basins: a very similar breccia consisting of the Tithonian to Early Berriasian limestone clasts has been recognized in a similar stratigraphic position within the succession of the Križna nappe, in the Stražov Mts, Slovakia (BORZA & *al.* 1980). The tectonism possibly resulted in a change of the paleotopography in the Carpathian area, which enabled free migration of Mediterranean ammonites into the epicratonic sea of Central Poland during the Boissieri Chron in the Late Berriasian (*cf.* MAREK & *al.* 1989).

The youngest studied deposits of Early Cretaceous age are those of the Spisz Limestone Formation (BIRKENMAJER 1963, 1977; Text-figs 2 and 5 herein). Two microfacies are recognized: the *Globuligerina* microfacies, and the crinoid microfacies. The pure crinoid microfacies is represented by packstones and grainstones which constitute separate layers, sometimes with markedly erosional lower boundaries, such as in the Pomiedznik Klippes section (*see* Text-fig. 5); the character of crinoid remains indicates a deep zone of accumulation (GŁUCHOWSKI 1987).

Features indicative of very slow sedimentary rate, such as ferrugineous crusts, ferromanganese nodules, and concentration of ammonites commonly occur at the lower boundary of the Spisz Limestone Formation. In the Korowa Klippe, the deposits of the Spisz Limestone Formation usually rest directly on those of the Sobótka Limestone Member of the Dursztyn Limestone Formation (Text-fig. 2). The oldest are infillings of neptunian dykes with *Calpionellites darderi* representing the Calpionellites Zone of the lowermost Valanginian (but not below the upper part of the Otopeta Zone); still younger are highly condensed deposits of local occurrence containing ammonites of Early Valanginian age (Petransiensis and Campylotoxus Zones), and also possibly of early Late Valanginian age; these are followed by crinoid-*Globuligerina* wackstones and packstones, about 1m thick, with ammonites of the Trinodosum Zone = lower part of Pachydicranus Zone of Late Valanginian age (*see* Pl. 4, Figs 1-4 and Pl. 5, Figs 1-7). These data show that a large part of the Valanginian is represented in the lowermost part of the Spisz Limestone Formation in the Korowa Klippe.

In the Sobótka Klippe near Czorsztyn, the condensed deposits of the lower part of the Otopeta Zone of earliest Valanginian have been attributed to the topmost part of the Łysa Limestone Formation (WIERZBOWSKI & REMANE 1992, Text-fig. 5, uppermost part of bed 6b; *see also* Pl. 6, Fig. 1 herein), but it now seems more justifiable to transfer them into the lowermost part of the Spisz Limestone Formation (into lowermost part of bed 7a). Still higher, at the top of bed 7a, ammonites of the genera *Busnardoites* and *Olcostephanus* have been recently discovered (Pl. 6, Figs 2-3), indicative of the Lower Valanginian.

The condensed deposits of the lowermost part of the Spisz Limestone Formation should be interpreted in terms of a deepening tendency which developed during Valanginian. The sea bottom relief was formed by the older elevated blocks in which new fissures opened at the beginning of Valanginian (Korowa Klippe), and by basins (Sobótka Klippe, possibly Pomiedznik Klippes).

The still younger deposits of the Spisz Limestone Formation are poorly known. Their age is debatable, it may be youngest Valanginian to Hauterivian (BIRKENMAJER 1977).

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A. WIERZBOWSKI

STRATYGRAFIA I MIKROFACJE WYŻSZEJ JURY ŚRODKOWEJ, JURY GÓRNEJ ORAZ NAJNIŻSZEJ DOLNEJ KREDY SUKCESJI CZORSZTYŃSKIEJ PIENIŃSKIEGO PASA SKAŁKOWEGO NA POLSKIM SPISZU

(Streszczenie)

Przedmiotem pracy jest biostratygrafia i charakterystyka mikrofacjalna pelagicznych utworów węglanowych wyższej jury środkowej, jury górnej oraz najniższej dolnej kredy sukcesji czorsztyńskiej pienińskiego pasa skałkowego na polskim Spiszu (*patrz* fig. 1–7 oraz pl. 1–6). Omawiane następstwo rozpoczynają utwory formacji wapienia czorsztyńskiego, wykształcone w trzech następujących po sobie mikrofacjach: mikrofacji filamentowej (baton-kelowej, ?oraz najniższy oksford), mikrofacji globuligerinowej (oksford), oraz mikrofacji sakkokomowej (kimeryd oraz dolny/środkowy tyton). Sedymentacja tych osadów, o zmiennej miąższości w różnych profilach, zachodziła na zróżnicowanych topograficznie blokach podłoża, zbudowanych ze środkowojurajskich wapieni krynoidowych, a powstałych w ruchach mezokimeryjskich.

Utwory młodsze, należące do formacji wapieni dursztyńskich wskazują na bardziej ujednolicony charakter sedymentacji. Wykształcone w mikrofacji globochetowej (w części niższej), oraz mikrofacji kalpionellowej (w części wyższej) należą one do górnego tytonu oraz dolnego i środkowego beriasu.

Utwory formacji wapieni łysańskich należą do górnego beriasu, a ich powstanie związane było z aktywnością tektoniczną, która doprowadziła do powstania zróżnicowanej topografii dna morskiego. Najniższa część formacji wapienia spiskiego wykazuje objawy znacznej kondensacji stratygraficznej, odpowiadając wiekowo prawie całemu walanżynowi, poza jego częścią najwyższą. Nowe znaleziska amonitów walanżynu obejmują przedstawicieli rodzajów *Thurmanniceras*, *Busnardoites*, *Karakaschiceras*, *Olcostephanus*, oraz *Jeanthieuloyites*, nieznanych dotąd z pienińskiego pasa skałkowego w Polsce.