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SHALLOW-WATER AND SUBAERIAL CARBONATES OF THE CZĘSTOCHOWA-CRACOW UPLAND. CASE HISTORIES FROM THE LOWER CARBONIFEROUS TO HOLOCENE

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PART I. INTRODUCTION TO THE TRIP

1. Karniowice Travertine (*E. Piekarska*)

The name „Karniowice Travertine" denotes light, hard, porous and cavernous fresh-water limestones, containing abundant, auto- and allochthonous, Permo-Carboniferous plant remains (numerous calamites, pteridosperms, cordaites and lilpopiae, rare lepidodendrons, sigillarians and conifers – Lipiarski 1971). The Karniowice Travertine was preserved over an area of ca. 7 km², N of the road Kraków-Katowice between the Karniowice and Kamienice valleys (Fig. 1). It is intercalated in the post-Hercynian molasse. The thickness visible in outcrops is 2 to 4 m, locally up to 8 m, and in the bore holes in the E part of the area (Kowalska Góra, Alexandrowicz *et al.* 1971) it attains 17 m. The age of the Karniowice Travertine is most probably lower part of the Autunian (Lipiarski *op. cit.*). The Karniowice Travertine overlies the Karniowice and the Filipowice Sandstones of Westphalian age (Alexsandrowicz *et al. op. cit.*) and is covered by the Lower Permian Myślachowice Conglomerate and Filipowice Tuffs (Siedlecki 1954). In the E (area of Kowalska Góra), the Karniowice Travertine is intercalated in the Myślachowice Conglomerate. Among the numerous papers concerning the Travertine (for bibliography *vide* Lipiarski *op. cit.*), most deal with the plant remains and rare gastropod shells, and with the stratigraphic position. It was believed that the calcium carbonate in the Karniowice Travertine either was due to Late Hercynian volcanic activity or originated from $CaCO_3$-rich solutions flowing westward from the karstified Dębniki Anticline (Siedlecki 1954).

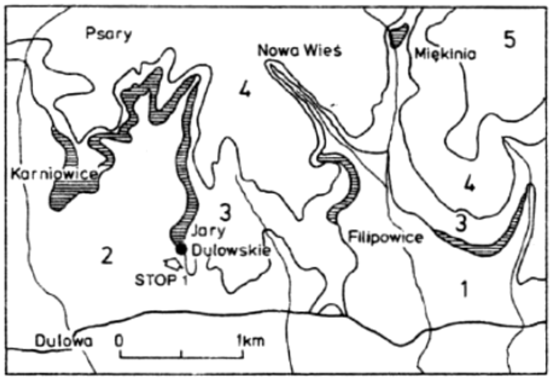

Fig. 1. Occurrence of Karniowice Travertine. *1* – Flora Beds (Namurian A) and Filipowice Sandstones (Westphalian A); *2* – Karniowice Sandstones (Westphalian B/C); *3* – Autunian; *4* – Filipowice Tuffs (Autunian); shaded – Karniowice Travertine; thick line at bottom – N boundary of Krzeszowice Trough

The microscopic examination of the Travertine reveals a micritic-sparitic limestone differentiated mainly by the contents of calcified plant remains allowing to distinguish several microfacies. The most important of them, classified in three groups, are described below:

Group 1. Algal material prevails. Subdivided on the size of algal remains from small pellets to green algae fibers several millimetres long, and on the size of pores.

Microfacies *1.1.* Micritic, with small pellets (Fig. 2). In a micritic or microsparitic matrix, numerous pellets clustered in grapes or nodules, or single, loosely scaterred. Disposition of pellets and of small pores suggests algal mat. This is the most common microfacies of the Karniowice Travertine, it forms frequently the matrix of other components in different microfacies.

Microfacies *1.2.* Characterized by medium size algae (Fig. 2). There occur algal fibres, usually vertical (in life position), more rarely with no prevailing direction. Commonly, laminae a few millimetres thick consisting of vertical algal fibres alternate with thinner (ca. 1 mm) laminae of hard crystalline calcite. Different rates of growth of algae often resulted in changes of thickness of particular laminae.

Microfacies *1.3.* Characterized by large algae and great pores (Fig. 2). There occur numerous pores up to 20 mm in diameter situated between fibres of algae, partly or entirely filled with sparite. The network of the rock consists of long (up to 20 mm) and thin (up to 0.3 mm) algal fibers. Usually, the fibers are overgrown by smaller algae. The algal remains preserved in life position indicate rapid calcitization.

Group 2. Abundant vascular plant remains, commonly overgrown by algae.

Microfacies *2.1.* Abundant vascular plant remains, and abundant matrix (Fig. 2). In the micritic-microsparitic matrix of the microfacies *1.1* type with ghosts of algal structures, there are chaotically dispersed remains of vascular plants (shoots, roots and leaves). Interiors of shoots (growth framework pores) are either void or partly or completely filled with sparite. The partial filling

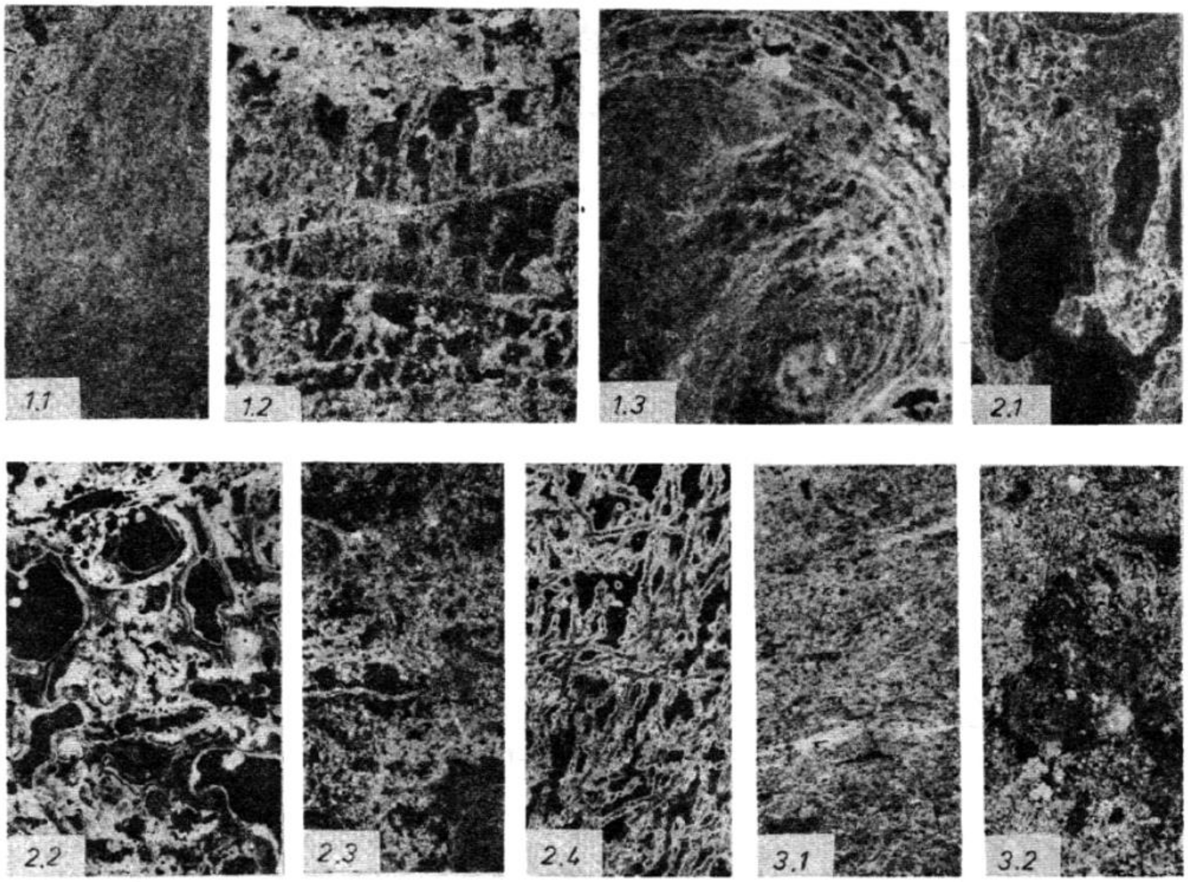

Fig. 2. Microfacies. *3.2.* – specimen from Karniowice Hill; other specimens from Jary Dulowskie; all photos are negatives, magn. ×7

is usually geopetal. The calcitized plant tissue is strongly recrystallized together with the encrusting algae, and it is sometimes difficult to distinguish it from the matrix.

Microfacies *2.2.* Abundant vascular plant remains, numerous large pores, scarce matrix (Fig. 2). The numerous and large fragments of plants occur chaotically. The pores, of the shelter and growth framework type, are present both in the plant structures and between them, and are commonly lined by a few laminae of a micrite probably of an algal origin, in turn overgrown by sparite. The pores are either void, or completely, or partly and geopetally filled with sparite.

Microfacies *2.3.* Characterized by vascular plant remains disposed horizontally. Large parts of shoots and various fragments of plant tissue form horizontal layers in a matrix of algal detritus.

Microfacies *2.4.* Characterized by bryophyta remains (Fig. 2). In outcrops there are visible discontinous intercalations up to 6 cm thick of fine vertical cylindrical bodies divided by large vertical pores. Microscopic study reveals very numerous densely packed sometimes ramificating bryophytan shoots, 0.3-0.5 mm thick, preserved in life position. Matrix is scarce. At the bottom of shoots there occur frequently small horizontal fissures.

Group 3. Microfacies with prevailing detritical material composed mainly of microfacies *1* and *2.* Microfacies of this group differ by grain grade. Sometimes they become breccias.

Microfacies *3.1.* (Fig. 2). The rock is clotted containing calcareous grains of various dimensions, rare animal remains, and an argillaceous admixture.

Microfacies *3.2.* Fine detritical, lamined (Fig. 2). The rock consists of small limestone clasts with an admixture of fine plant detritus. Small pores inside plant shoots. Fine syndepositional lamination, locally undulating.

There are gradual transitions, both lateral and vertical between all the above microfacies. However, group *2* is more clearly delimited than the remaining microfacies. Besides the microfacies where lamination is almost a rule (*1.2* and *3.2*), it occurs locally in other microfacies resulting from interrupted plant growth. In all algal microfacies there occur sporadically stromatolites, and sporadic indeterminable mollusc tests. Different microfacies contain small irregular accumulations and lenses of black or red silica, usually in the upper part of profile. The silica was probably infiltrated from the overlying Filipowice Tuffs.

In spite of great variability of distribution of microfacies, it seems that in the E (Filipowice) and central (Jary Dulowskie) parts of the area the succession of appearance of microfacies was similar. Algal matrial predominates thoughout the profile, but there appeared succesively the following microfacies: with fine algal material (*1.1*), medium algal material (*1.2*), great vascular plant remains (*2.1* and *2.2*), bryophyta and great algal material (*2.4* and *1.3*) and fine algal and detritical material (*1.1* and *3.2*). In the W part of the area (Karniowice hill) the succession is different: besides microfacies of groups *1* and *2*, detrital microfacies are common throughout the profile, and in its upper part, medium algal material (*1.2*) and bryophyta (*2.4*) microfacies are frequent, and the coarser vascular plant detritus becomes less common. This difference may be explained in the following way.

The central and E parts of the area were situated near the $CaCo_3$-rich sources, and thus significant amounts of plants were calcified *in situ*, some of them during life. The westward flowing water carried plant detritus and deposited it in morphological depressions forming small pools in the W part of the area (Karniowice Hills). C and O isotope measurements (Solem and Yochelson 1979) indicated that the temperature of water where the Karniowice Travertine was formed was not high.

2. Origin of the Woźniki Limestone (*S. M. Gąsiorowski, E. Piekarska*)

The name „Woźniki Limestones" has been used since the XIXth century (Oyenhausen 1822; Pusch 1833-1836; Carnall 1846) to mean calcareous and dolomitic deposits believed to form intercalations in the Upper Triassic Variegated Clays. The „Woźniki Limestones" thus defined have been found over the large area between Olkusz, Częstochowa and Opole (Fig. 3A). Gąsiorowski and Piekarska (1977) distinguished between thin calcareous and dolomitic bodies, usually with significant non-carbonate admixtures, forming intercalations in the Variegated Clays, and massive fairly thick pure limestone overlying the Clays in the much smaller area between the environs of Zawiercie and the environs of Lubliniec. They restricted the name „Woźniki Limestone" (singular) to the former.

The most probable age of the Woźniki Limestone (for bibliography *vide* Gąsiorowski 1984) is near the Triassic/Jurassic boundary. A more exact dating might become possible if the climatic succession in the E Central European Upper Triassic-Lower Jurassic were established. The Limestone should correspond to a very arid phase abruptly followed by a clearly humid phase.

Different opinions on the origin of the Woźniki Limestone were expressed: intercalations in the Variegated Clays, considered lagoonal or shallow marine (XIXth century authors), "due to a marine ingression" (Kotański 1977), "travertines" (Różycki 1930), deposited from sources opening in the floor of the basin (Dżułyński, oral information, 1984).

The reasons why we disagree with all these opinions are implicit in the following review of the history:

1. About the Triassic/Jurassic boundary in the E part of Central Europe there extended a dry plain formed in the Upper Triassic Variegated Clays. The plain sloped gently NW-wards to the area of marine ingressions. At the S, the Vindelician Swell divided the plain from the Tethys and her marginal seas.

2. In the Variegated Clays plain, somewhere between 15 and 20° Lat N, in the area which was to become the Woźniki Limestone basin, a closed depression was formed. The reconstruction of its shape shown in Figure 3B was obtained by (a) an analysis of the distribution of the facies of the Lower Woźniki Limestone, (b) an analysis of the changes of height of the post-substratum compaction, pre-tectonic, planation surfaces above the bottom of the Limestone (*cf.* Fig. 3C). There appeared to us a narrow Median Trough gently sloping down to the WNW, bordered, at least in its E part, by wide flat "Shelves". We believe that this depression was either a river valley dammed at the WNW by a slump in the Variegated Clays, or that it was deflational and due to prevailing trade winds, or that it was of a mixed, fluvial-eolian, origin. We exclude internal causes — tectonic movements, variable compaction of the Variegated Clays underlying the Limestone, decrease, by dolomitisation or by karstification, of the Muschelkalk underlying the Variegated Clays —

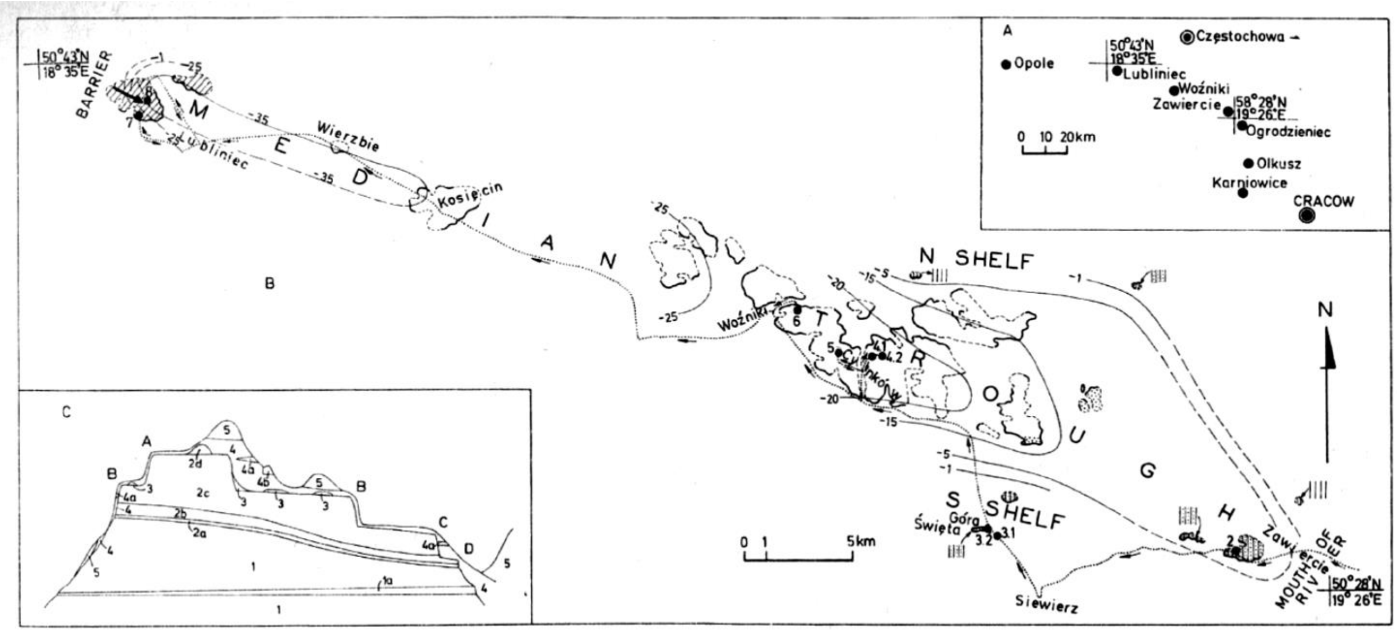

Fig. 3. A. Area of trip. B. Occurrence of Woźniki Limestone (thick lines), presumable isobaths in metres, of bottom of basin referred to plane of bottom of Limestone at Święta Góra (thin lines); itinerary – dotted line, numbers indicate stops; facies of Lower Woźniki Limestone: vertically ruled – mainly shallow lacustrine, obliquely ruled – mud flows, arrow indicate direction; not ruled – mainly deeper lacustrine; dots – allochthonous material. C. Ideal "island" of Woźniki Limestone, not shown: karst, tectonic inclination, Quaternary deposits; *1* – Upper Triassic Variegated Clays; *1a* – an intercalation of Lisów Breccia; *2* – Woźniki Limestone, deposits of *2a* – basal playa, *2b* – first lake, *2c* – main playa, *2d* – second lake; *3* – Upper Triassic Variegated Clays redeposited on Woźniki Limestone, not sandy; *4* – Ferruginous-Argillaceous Sands, *4a* – intercalations of redeposited Variegated Clays reworked with sand, *4b* – block of Lisów Breccia; *5* – Połomia Gràvels *sensu stricto* (*3* and *4* probably lacustrine, *5* – fluvial, *3-5* – Lower Jurassic). *A-D* – planation surfaces, *A* – altiplanational? *B-D* – by river flowing to WNW, asumed gradient 0.5 km/km. Horizontal to vertical scale 1 : < 10

as the shape and position of the depression do not correspond to any characters of the substratum fairly well known due to numerous bore holes (for bibliography *vide* Pomykała *et alii* 1984).

3. In this depression there was deposited the Woźniki Limestone (for petrographical description *vide* Piekarska 1984). Its post-diagenetic and pre-erosional volume was 20-30 km^3, with < 1/8 of non-calcareous admixtures. The primary calcareous material was mainly micrite precipitated by photosynthesis of cyanophytans and algae, subordinatelly precipitated inorganically or brought as clastic mud. The non-calcareous admixtures are mainly argillaceous substances, derived from the bottom of the basin, or carried, from outside the basin, by flowing water and by wind. The unexpectedly low admixture of the argillaceous substances in the Limestone may be explained by a hardening of the surface of the Variegated Clays due to occlusion of the clay by calcium carbonate contained in rain, river and lake water. The gypsum is preserved in insignificant amounts, but pseudomorphoses of calcite after gypsum are rather common. Possibly, the gypsum was repeatedly recycled, and therefore the overall amount of S in the basin was low. The amount of Mg carbonate locally reaches up to 3%. Primary silica occurs dispersed in the rock, and locally forms small chert. Fe, Mn, P, and ? Na compounds occur in small amounts.

The primary, essentialy micritic, deposit was subjected to sparitisations, calichefications, and brecciations.

Life in the Woźniki Limestone basin was primitive, which may be explained by extreme environmental conditions. It was practically limited to *Prokaryota* and lower *Eukaryota* (nodules of denser micrite presumably bacterial, various cyanophytan-algal stromatolites, *Infusoria* remains). It looks almost like an Upper Precambrian relict. The only animal remains are conchostracan and/or ostracod tests occurring locally; and perhaps some of the sporadic bivalve and gastropod shells are autochthonous. The locally occurring *Equisetum* stems, always rootless, were problably carried from a swamp at the mouth of the river alimenting the basin. The remains of conifers are clearly allochthonous.

We believe that the Woźniki Limestone basin was fed by an intermittent river flowing from the SE. The presumable swamp at its mouth should have acted as a filter. Sedimentological data suggest deposition of the Limestone in a very short time – 20 to 100 thousand years – but this would require an improbably high mean annual inflow of water bringing $CaCo_3$. The Ca carbonate may have been derived from the possibly karstified Carboniferous Limestone covering the Vindelician Swell some 10 km to the S, and from the Muschelkalk being dolomitised under the cover of the Variegated Clays as believed by Bogacz, Dżułyński and Harańczyk (1970). We believe that the $CaCo_3$-rich solutions, if any, should have ascended along the klippes of the Devonian-Muschelkalk rocks scattered over the Variegated Clays plain SE of the Woźniki Limestone basin, and then should have flown, by local streams, down to the river feeding the basin.

3.1. Lower Woźniki Limestone begins over the whole area, excepted the WNW extremity of the Median Trough, by playa deposits (3.1.1), 0.5 to 1.0 m thick (micritic-microsparitic limestones with aboundant presudomorphoses of calcite after gypsum, very strongly calichefied and brecciated by desiccation). There follow (3.1.2) in the Median Trough, excepted its WNW and ESE extremities, calcareous deposits of the deeper lake (rather featureless micritic limestones with rare bacterial nodules, rarity of intraclasts of denser micrite), sometimes shallowing to swamp (striotubulae, rhizoids, siderite), seldom completely desiccated (caliche, breccias), 3 to 4 m thick. At the WNW extremity of the Through the entire Lower Woźniki Limestone is represented by argillaceous-calcareous mudflows (re-worked Variegated Clays of the substratum + deeper lacustrine limestones with high argillaceous admixtures), 12 m thick. We believe that the mudflows occurred on the steep SE slope of the previously formed barrier (slump in the Variegated Clays or an argillaceous dune – *vide* supra 2) closing the basin from WNW. At the ESE extremity of the Trough and over both "Shelves" the Lower Woźniki Limestone, 5 to 6 m thick, is represented mainly by lacustrine deposits shallower than those mentioned above (micritic limestone with common bacterial nodules, various stromatolites), and by paludal deposits (striotubulae, rhizoids etc.), sometimes desiccated (caliche, cracks). The allochthonous material in the Lower Woźniki Limestone (clastic carbonate mud clearly different from intraclasts common almost throughout the Limestone, small pebles of Devonian and Muschelkalk rocks, conifer remains), is concentrated in the ESE part of the basin indicating the proximity of the mouth of the feeding river.

3.2. Middle Woźniki Limestone, greatest visible thickness 29 m, was preserved only in the area of the Median Trough. It is represented mainly by playa deposits (similar to those of the Basal

Playa, 3.1.1) at the bottom of the Lower Woźniki Limestone, subordinately by paludal and lacustrine deposits identical with those previously mentioned.

3.3. Upper Woźniki Limestone was preserved only in a small part of the area of the Median Trough. Its greatest preserved thickness is 6 m. It is represented by deposits of a deeper lake intermittently becoming swamp or even playa. It differs from the analogous deposits of the Lower Woźniki Limestone mainly by high admixtures of the material of the Variegated Clays dispersed in the rock, and even, in the highest part, forming clasts up to 5 cm long. Besides, there occur redeposited fragments of diagenised Woźniki Limestone (cannibalism).

4. The character of the Upper Woźniki Limestone indicates that the basin was then fed not only by a river flowing in from the SE, but also by increasingly violent local streams and sheetflows eroding the area just around. We believe that the lake, hitherto closed, overflowed. The barrier closing the basin at the WNW was cut and the lake drained. Most of the Woźniki Limestone was eroded away. There were spared, from the continous sheet of presumably some 1000 km^2, residues forming "islands" – isolated hills surmounting valleys excavated in the Variegated Clays of the substratum – scattered over an area of 700 km^2. The post-Woźniki Limestone history of the area is shown in Figure 3C.

Let us now resume the most probable sequence of events: closed depression (deflational and/or dammed river valley) formed in an argillaceous plain (2) – basal playa (3.1.1) – first lake (3.1.2) – main playa (3.2) – second lake (3.3) (3.1-3.3 all calcareous = Woźniki Limestone) – lake drained, fluvial erosion – lake with redeposited clays (4) – lake drained, fluvial erosion – lake with ferruginous-argillaceous sands – lake drained, fluvial erosion and deposition of gravels – marine transgression.

Roemer (1870) remarked that the Woźniki Limestone was a unique deposit in the whole Middle European Upper Triassic-Lower Jurassic platform basin. It appears that also no deposits similar to the Woźniki Limestone were formed in this part of the basin which lies now in the E North America. Even more, the Woźniki Limestone is probably the greatest massive pure continuous limnic calcareous body hitherto known.

The uniqueness of the Woźniki Limestone may be explained by the improbability of the concurrence of events necessary for its formation. There should have concurred: availability of abundant Ca carbonate-rich solutions; excavation, in an argillaceous plain, of a closed depression inherently ephemeral; and a climatic stage of humidity exactly suited to the size of the depression so as to result in a closed lake or playa, but insufficient for its overflowing. The Woźniki Limestone was a freak.

3. Holocene travertine deposits of the Cracow Upland (*J. Szulc*)

The calcium carbonate precipitation from natural, fresh water follows on the CO_2-content decrease. There are two kinds of these processes: the first depends on the physical removal of CO_2 from solution (by warming up and increasing water turbulence), the second results from organic consumption of carbon dioxide and bicarbonate. Which one of these processes dominates? And consequently: what kind of sediment is it – inorganic or organic? In laboratory experiments, both early (compiled by Pia 1934) and more recently (among others: Ruttner 1947) a close relationship between $CaCO_3$-precipitation and hygrophytes photosynthesis has been obtained. Later, field investigations did not confirm these results (Grüninger 1965; Usdowski *et al.*, 1979). The author's investigations of travertines from southern Poland have proved that both these processes often occur together and it is very hard to separate one from the other. I can assume only that very often physical removal of CO_2 precedes the biogenic loss. Bringing a solution to a point of carbonate precipitation follows assimilation.

In the light of above given facts, the author suggests to consider as biogenical sediments these ones, which depositional structures result mainly from hygrophytes presence. The role of plants may be both active (e.g. secretions, encrustations) and passive (trapping) (see also Schneider 1977). On the other hand, the abiogenic sediments are deposits developed without hygrophytes presence and deposits which structures do not result from randomly attendant plants.

3.1. Biogenic travertines

This term includes all kinds of freshwater limestones (mainly spring and fluviatile deposits) which are formed with plant (mosses, algae, bacteria, lichen) participation. Varied interdependences exist between them. The most common is the epiphyticism, sometimes multistage e.g. system: moss-algae-bacteria (Fig. 4a). The different kinds of travertine deposits, described below, are distinguished according to the predominant types of plants they contain.

3.1.1. Moss travertine

Mosses occur mainly in a spring zone and on waterfalls, therefore moss travertines are characteristic of headwater. Mosses have organized the basis for subsequent algal and bacterial colonization and have formed a structural skeleton for deposited calcareous substance. Microscopic view shows a polygenical character of this sediment. Part of the substrat originates from trapping and binding on mosses thallus and in the mucus of epiphytes, a considerable part consists of epiphytic algal encrustations (Fig. 4b, c). Finally, some part is constructed of $CaCO_3$, physiologically deposited by bacteria (Figs. 4d, e). Moss travertine primary is very soft and fragile but its degree of lithification increases, in intensive and quick diagenesis.

3.1.2. Algal travertines

This kind of travertine partly includes deposits described by Monty (1976) as "cryptalgal" fabrics e.g. stromatolites, trombolites, micro-reefs, oncoids, forms called "mumien" and part of peloidal sediments. Like a moss travertine, these deposits are also related to activity of multiple phytosystems including algae, bacteria (Fig. 4f) and sometimes fungi. Wide form differentiation of biota have an affect in structure diversity. Remarkably stratified, laminar stromatolites are mainly developed in blue-green algal mats. Fluctuations of moisture balance, thermal conditions, mechanical factors (erosion, turbulence etc.) and seasonal biota succesion have effects on the manner of deposition. Other kinds of algae e.g. *Cladophora* (green alga) or *Vaucheria* (*Xantophyceace*) build up irregular fabrics with chaotic internal structure.

Very common form of travertine deposits are oncoids. They are created mainly by *Cyanophyta* and *Gongrosira* (green alga). Their shape can supply some data about energetic conditions of depositional environments, for instance: regular and concentrical oncoids were observed in whirpools, while elipsoidal forms in a shallow, silent water. Changes

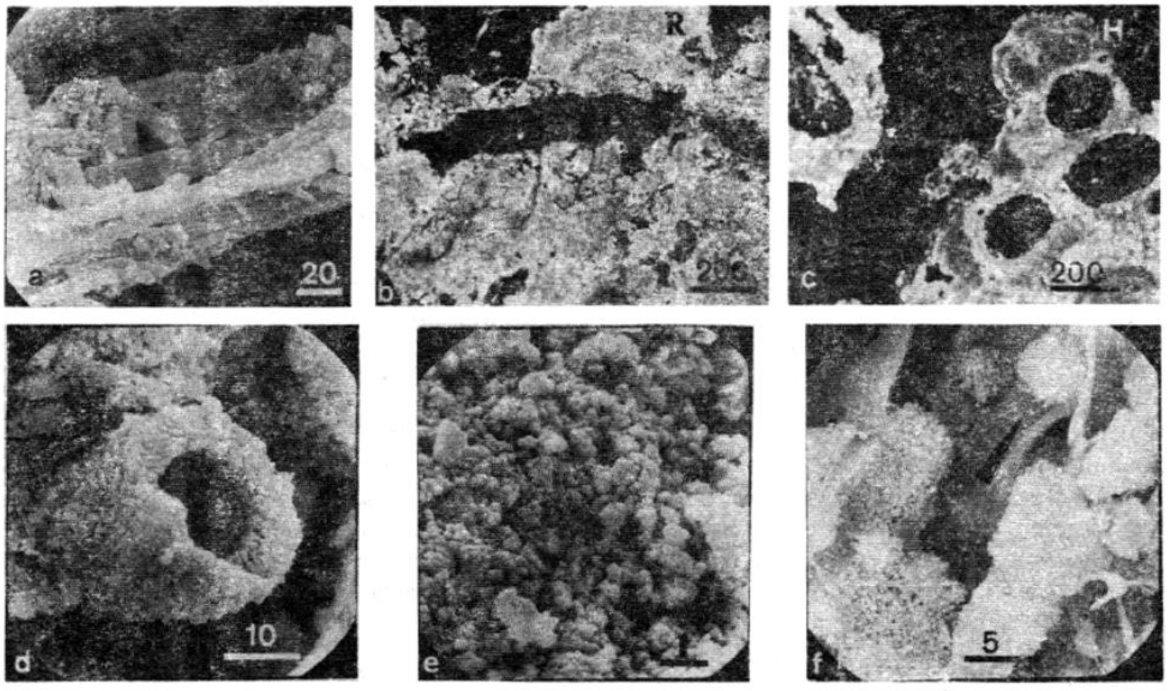

Fig. 4. Origin of the travertine sediment. *a* – see explanation in text: *b-c* – micrographs of moss stalk encrusted by epiphytic algal colonies: *R* – *Rivlaria*: H – *Hydrococcus*; thin sections, crossed niclos; *d* – SEM view of moss stalk encrustation; *e* – detail of *d* – bacterial colonies (*Eubacteria*) replaced by calcite: *f* – SEM view of calcified bacterial colonies (*Myxobacteriales*) within *Schizotrix* mat. After bacteria death primary carbonate substrat is shaped by crystallisation powers and achieves rhombic forms (arrow). All scale bars in microns

of outer conditions lead sometimes to deformational growth and transition to eccentric forms Figure 5d, e.

3.1.3. Lichen carbonate crusts

Special forms of freshwater limestones are crusts developed on the periodically wetted rock surfaces (hygropetric environment). This sediment is connected with lichen and rock-dwelling algae activity. These plants produce a mass of mucilage which protects their organisms before dessication. Mineral particles (partly of eolic derivation) are very strong binded in this mucus. Generally there are two morphological forms of these sediments: laminar stromatolites (Fig. 5a) and botryoidal forms which resembled speleothems called "spaterrmites" (Fig. 5b). Seasonal growth cyclicity is less evident than in "normal" fluviatile stromatolites. In "lichen stromatolites" (Klappa 1979) well preserved plant organs such as gonidia, fruiting bodies or fungal hyphae (Fig. 5c) are very common.

3.1.4. Diagenesis of biogenic travertines

Petrological investigations of travertines with supplemental ^{14}C-dating of these sediments show a distinctive diversity of diagenesis rate in different type of travertine. Very intensive changes take place in moss travertines, where large and irregular porosity favoured a rapid and fast cementation. Diagenesis of *Vaucheria* and *Cladophora* travertine is also quick. Weak traces of diagenesis reveal a *Cyanophyta* stromatolite (Fig. 6a). Irion and Müller (1968) supposed that a small diameter of pores in this sediment impedes diagenetic processes. Radiocarbon dating found that blue-green algal stromatolite older than 8000 years B. P. have not more distinctive postdepositional changes, whereas a moss travertines are lithified in tens- and hundreds-year scale. The first stage of sediment changes depends on organical substance decay. Microenvironments are then more acidic what causes a second dissolution and re-precipitation of $CaCO_3$ in more open places. Fresh sediment can be indirectly changed by microendoliths or even "eated up" by microbionts (Fig. 6c). This process called by Kahle (1977) "sparmicritisation" is caused by bacteria and diatoms. Diatoms produce a very acidic buffer zone around their frustrules which attacks the nearest calcareous substrat (Fig. 6b). Bacteria can cause also a specific recrystallization of carbonate matter. It follows probably on

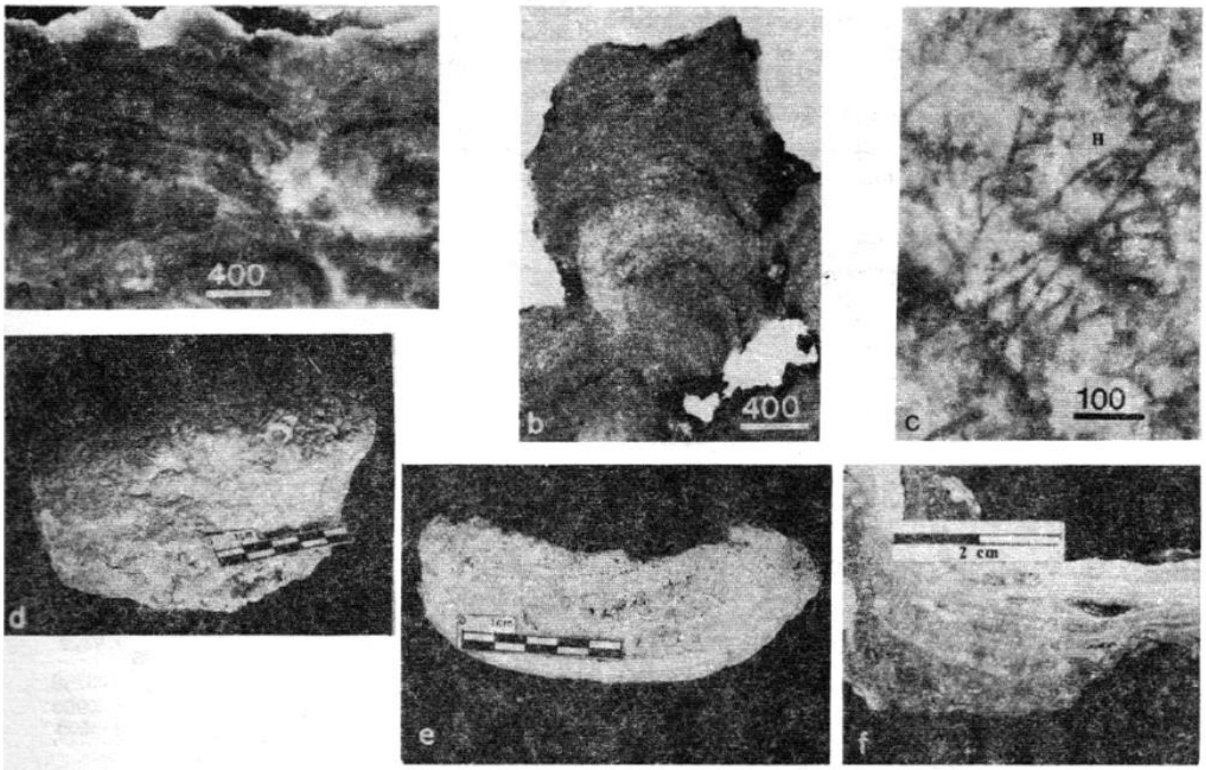

Fig. 5. *a-c* – lichen stromatolites in micrographs, see explanation in the text, *H* – fungal hyphae, thin section, crossed nicols, scale bars in microns; *d-e* – deformational growth forms of oncoids; *d* – microreef; *e* – section of "bowl" form; *f* – polished slab of sinter crust

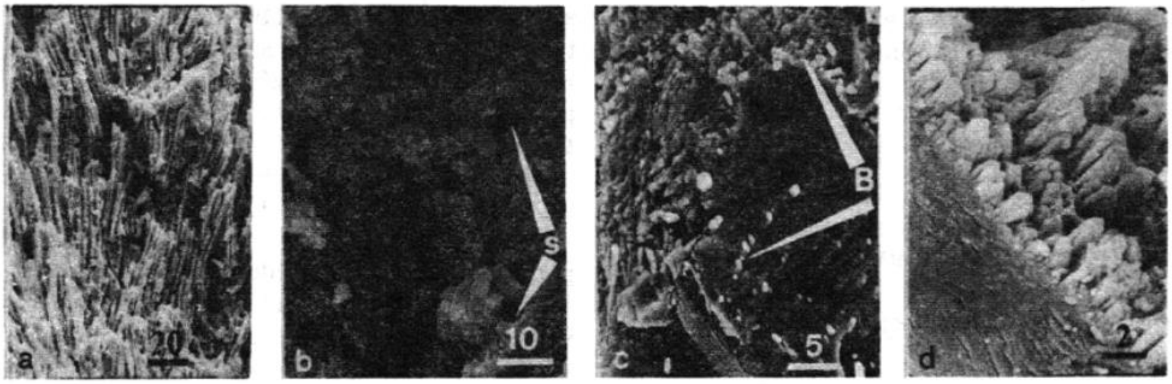

Fig. 6. SEM view of digenetical changes in travertines. *a* – SEM view of *Phormidium* filaments moulds (8000 years old) shows none postdepositional changes; *b* – SEM view of diatoms colony in fresh lime sediment; *S* – traces of diatomical solution of $CaCO_3$-substrate; *c* – bacterial sparmicritization (B) along crystal, lattice plains; *d* – bacterially controlled carbonates recrystalization. Bacteria are grouped along the base line of recrystalization, all scale bars in microns

bacterial "feeding exploitation" an organic matter enclosed in calcite grains. It results in decomposition of primary substrat and its recrystallisation (Fig. 6d).

3.2. Abiogenic travertines

Abiogenic kind of travertine was first defined by Pia (1933) as "kalksinter" and this term in its meaning is commonly used. Sinter developes in varying conditions e.g. can be precipitated instantly in mineral spring water or from water under high CO_2-pressure, but also is able to grow very slowly from thin water film like a speleothem. Commonly sinter is evidently laminated, nonporous very firm and it is built of calcite crystals in size from micrite up to 5 mm sparite. Because of little porosity diagenetic changes are unconsiderable.

3.3. Fluviatile processes in karst regions

Peculiar character of fluviatile processes in karst areas was partly described by Golubič (1969). The author's researches revealed that biochemical character of deposition in karstic streams diminishes stream downcutting or even results in river-bed aggradation. It involves the opposite course of fluviatile processes in karstic and nonkarstic regions (under similar climate regime). In karstic valleys in the Cracow Upland, a humid

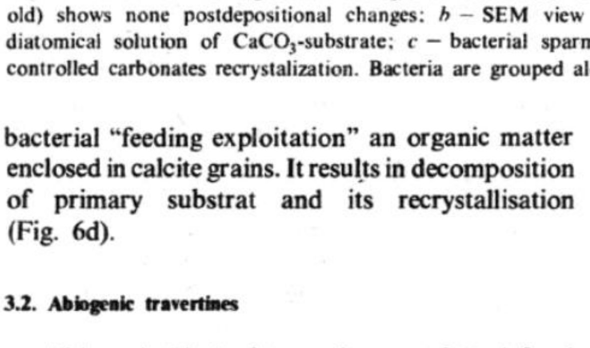

Fig. 7. Environmental agents and fluviatile deposits in karstic terrains. A simplified relationship. *1* – bioclastic carbonates (with mainly peloidal components); *2* – stromatolites; *3* – oncoids; *4* – moss travertines; *5* – muds; *6* – sands; *7* – gravels; *1-4* – autochtonous and subautochtonous (1) carbonate sediments; *5-7* – allochtonous, detrital sediments (also carbonate include)

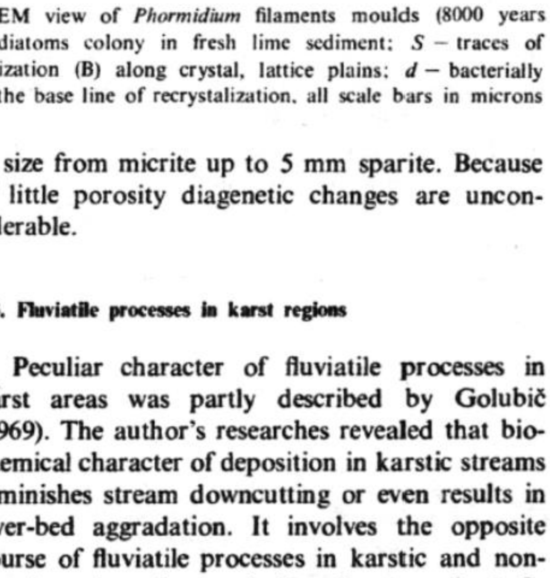

Fig. 8. Travertines deposition and erosion in the Cracow Upland during the Holocene

climate of Atlantic Optimum (8300-5100 years B. P.) caused extensive carbonate deposition and valley bottoms aggradation, while valleys of the nonkarstic flysch Carpathian Mts were being eroded and deepened.

A more detailed analysis of relation between lithofacial diversity of fluviatile deposits in karst terrains and environmental agents is presented in Figure 7. A brief summary of postglacial travertines deposition and erosion based on a wide spectrum of investigations: sedimentological, petrological, geochemical (Sr-contents, $^{16}O/^{18}O$, $^{12}C/^{13}C$, ^{14}C-dating) palynological and archaeological included is shown in Figure 8.

4. Facies Variation of Subaerial Carbonates and Their Role in the Evolution of the Dinantian Carbonate Platform in the Krzeszowice Area, Cracow Upland

4.1. Introduction

The small area of Dinantian carbonates near Krzeszowice has interested research workers since the end of 18th century. The history of research and references are presented by Siedlecki (1954) and Bogacz (1980). Gently folded Dinantian rocks occur as underliers of the Triassic-Jurassic cover in some valleys, which cut the northern edge of the Krzeszowice Graben (Figs. 20, 22).

4.2. Paleogeographical setting

The eastern shelf of the Moravo-Silesian geosyncline contains various lithofacies (Fig. 9). The Krzeszowice area is located in the northern part of a stable, Dinantian, carbonate platform (Figs. 9, 10).

The evolution of this platform occurred in three main stages:

– Its initiation on a fragment of a wider, older Devonian carbonate shelf. The greater part of this shelf was emergent during Fammenian times (Bełka 1984) with the exception of the Krzeszowice area.

– Desintegration of the NW, unstable part of the platform. Development of Waulsortian mud mounds on some blocks in *anchoralis* time Tn3.

– Gradual decline and retrenchment of the stable S part of the platform during Visean times and its onlap by Culm sediments (Bełka 1984). Carbonate sedimentation in the Krzeszowice area therefore ended in the Upper Visean.

4.3. Subaerial carbonates

Changes of bathymetry of a basin are usually the result of interference of subsidence rate,

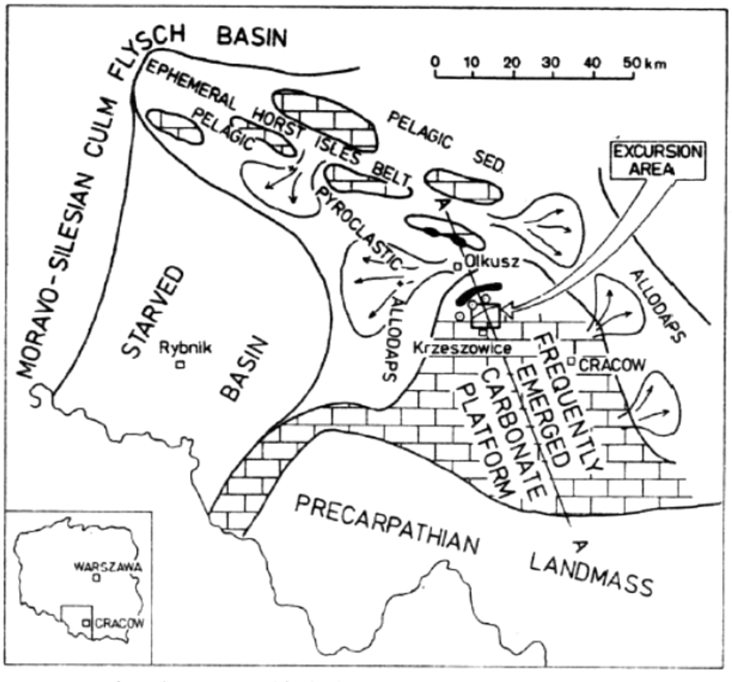

Fig. 9. Simplified, partly conceptual, palaeogeographical sketch map of the eastern shelf of Moravo-Silesian geosyncline during V1 time

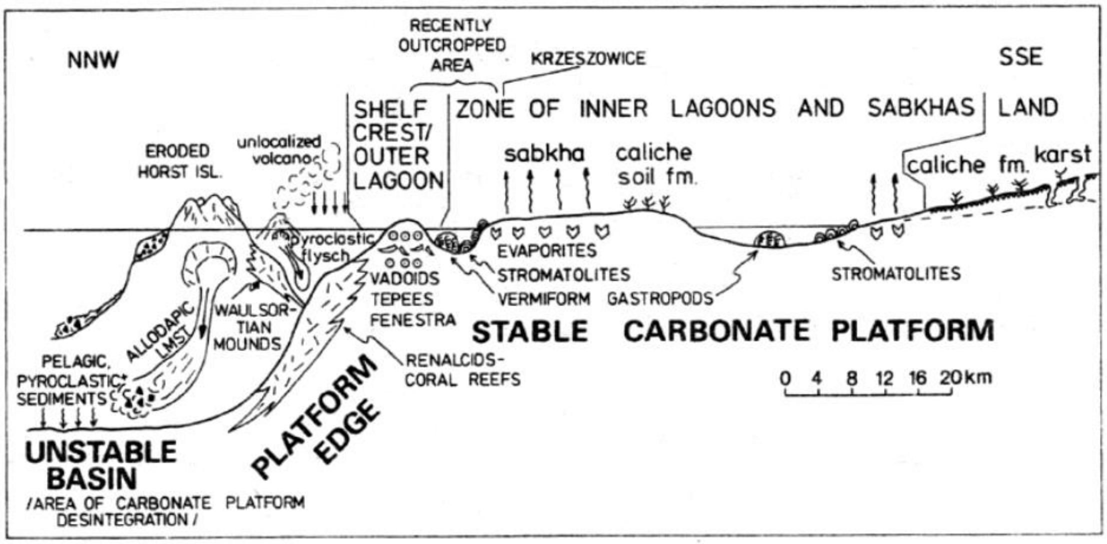

Fig. 10. Idealized and simplified section across the Dinantian carbonate platform and adjacent areas during V1 time. Data from bore-holes

erosion/sedimentation ratio, eustatic and local sea level fluctuations. This platform is dominated by shallow marine backbarrier facies. In such case any disturbance of equilibrium of these factors may have caused emersion. Several dozens of horizons of subaerial carbonate sediments have been identified by the author in the Dinantian section of the Krzeszowice area. Similar subaerial sediments from many Dinantian carbonate shelves have been described, e.g. in Czechoslovakia, West Germany, Belgium, and especially Great Britain, the US and the Russian Platform. Correlation of the eustatically controlled emersion horizons between these areas and the Krzeszowice region is difficult, because of a lack of biostratigraphic control. The great variety of petrographic features and strong lateral variation of subaerial exposure horizons are typical in this section. The proposed classification of the subaerial sediments from the Krzeszowice area is presented below:

A. Peritidal facies: beach rocks, tepees, loferites and fenestral limestones, coniatolites (pelagosites), carbonate marsh and swamp deposits, sabkha evaporites, solution breccias.

B. Terrestrial facies: B1. karst facies: regoliths, and residual deposits on a solution surface, terra rossa, rendzina geosols; B2. caliche facies; paleosols or geosols: caliche (calcrete) covers and crusts, silcretes calcified rendzinas, subaerial stromatolites.

C. Allochtonous admixtures and intercalations: pyroclastics, marine ingression deposits, loesses, eolianites.

Actually, clearly defined lithofacies are rare. They are often changed by several sedimentary, erosional and early diagenetic processes. Deposits of a compound nature usually result from these processes. Such complexity of a given horizon suggests short-term, relatively quick changes of environmental factors during its development e.g. climate, hydrology, activity of plants and soil fauna etc. Differences between the successive horizons show long-term trends of palaeoenvironmental changes, especially the climatic ones (Wright 1980). The position of these deposits in the section indicates some regularities, i.e. in facially montonous units they occur only sporadically. Their concentration, however, is connected with vertical bottom movements of increasing amplitude, which precede radical changes in sedimentation. This indicates tectonic reconstrucions of the basin, e.g. E/F units boundary. Subaerial deposits usually cover the upward shallowing sequences (units B and E), but they can also occur inside an open marine sediment sequence (unit J). The model presented here is an "ideal" profile divided into genetic units related to the simple succession of shallowing-emersion-subaerial exposure-transgression (Fig. 11). In reality the complex *pro naturae* profiles are complicated by the influx of the short marine ingressions. Occassionally, redeposited clasts from subaerial carbonates occur in the permanent basin deposits (unit I). On the other hand, some typical hardground surfaces are abrruptly submerged subaerial exposure surfaces (boundary of units E and F).

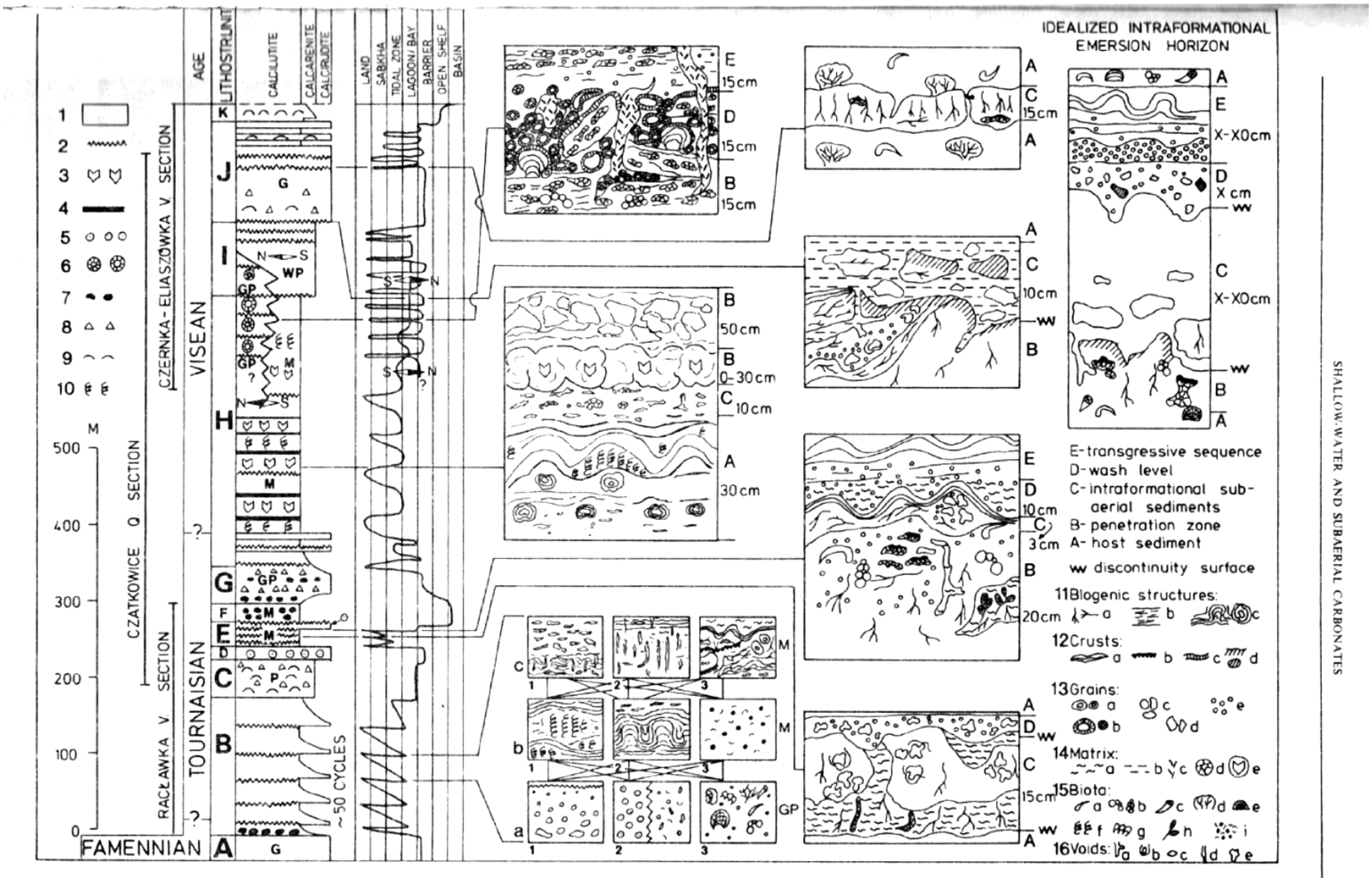

Fig. 11. Vertical changes of lithology and depositional environment during Dinantian time is shown on the left. The right part of the figure shows some examples of subaerial carbonate cover profiles. *1* – various carbonate rocks; *2* – main emersion horizons; *3* – evaporites; *4* – shale intercalation; *5* – ooids; *6* – coniatoids, vaoids etc.; *7* – cherts; *8* – crinoids; *9* – brachiopods; *10* – vermiform gastropods; *11* – rhizolits; *11b* – root mat; *11c* – algal structures; *12a* – laminar; *12b* – microstalactic; *12c* – coniatolitic; *12d* – blackened, redened; *13a* – vadoids, calcans; *13b* – coniatoids, pisoids; *13c* – glaebules, peds etc.; *13d* – intraclasts; *13e* – peloids, pellets; *14a* – marl; *14b* – clay; *14c* – vadose crystal silt; *14d* – spar cement; *14e* – evaporites; *15a* – brachiopods; *15b* – Rugosa; *15c* – *Tabulata*; *15d* – *Stromatoporoidea*; *15f* – vermiform gastropods; *15g* – red algae; *15h* – calcitized plant; *15i* – ostracods-calcispheres consortium; *16a* – various cracks; *16b* – cricumgranular cracks; *16c* – tabular fenestra; *16d* – tubular fenestra, root moulds, burrows etc; *16e* – irregular fenestra, solution voids, keystone vugs etc. M, W, P, G – mudstone, wackestone, packstone, grainstone. The rest of explanation can be found in the text.

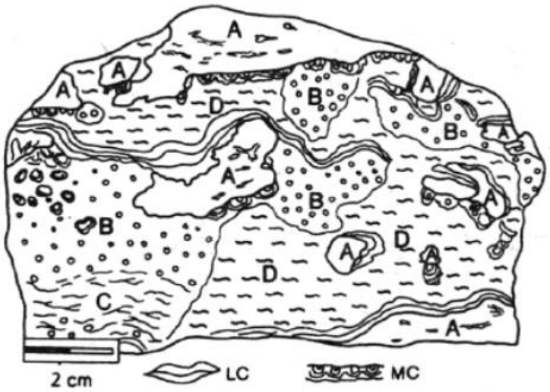

Fig. 12. Tracing of a slab from the caliche cover showing multistaged genesis. Sequence of the respective elements is closely related to the alphabetical order of the symbols: A, MC, B, C, LC, D. The succesion: brecciation of fenestral host lms (A) – precipitation of microstalactic crust under A clast (MC) – formation of chalky caliche rich in clacans (B) – formation of root mats (C) – precipitation of laminar crust on B and A elements (LC) – solution, brecciation and filling with marly matrix (D). Unit B – Racławka valley

5. Tertiary pedogenic carbonates in the Cracow Upland

Tertiary pedogenic carbonate rocks occur in the Cracow region covering Cretaceous marls and Jurassic limestones and underlying Badenian clays. The precise age of this sediment has not been determined yet. Their occurrences are not extensive. Sedimentological research made by the authors revealed a lithological diversity of caliche profiles, dependent on the kind of basement.

Type 1. Caliche profile developed on Oxfordian limestones (Fig. 13A). Usually, this type of caliche profile shows a clear vertical differentiation. Caliche veins penetrate host rocks to a depth of several meters, fill cracks and fissures (Fig. 14), karst hollows etc. (*a* horizon). Somewhat higher, the volume of vadose carbonate increases (*b* horizon) and in the upper part of the profile, host blocks are only floated in a vadose matrix (*c* horizon – massive caliche, Fig. 15). The uppermost part is often subhorizontally laminated (c_1 horizon – hardpan). The massive caliche is covered by a pisolithic layer (*d* horizon). This layer is sometimes loose but often vadoids are firmly cemented. In this case, polygonal fittings of grains can be observed. The above described sequence resembles the "ideal caliche profile" of Esteban and Klappa (1983).

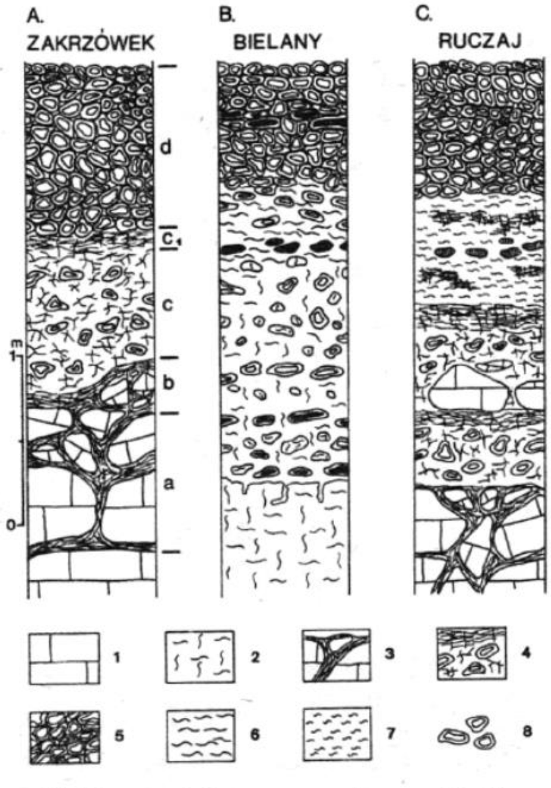

Fig. 13. Three typical profiles of caliche covers on different bedrocks. *1* – Oxfordian bedrocks; *2* – Senonian bedrocks; *3* – caliche veins penetrate in host rocks; *4* – massive caliche with hardpan crusts; *5* – vadoid conglomerats (vadolith); *6* – redeposited Senonian marls; *7* – playa deposits; *8* – vadoids; *9* – vadoids with silicified cores; *10* – black pebbles; *11* – clasts derived from bedrocks; *12* – fragments of montmorillonitic clays

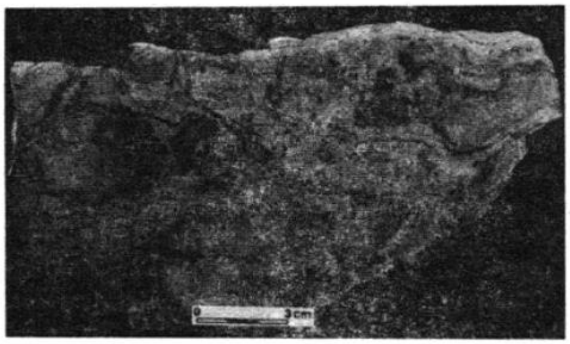

Fig. 14. The sample shows host Oxfordian limestones disrupted by "jigsaw" rhizobrecciation. Craks in this basement are filled with chalky caliche. In the upper part of the sample laminar crust (hardpan) is visible. Ruczaj

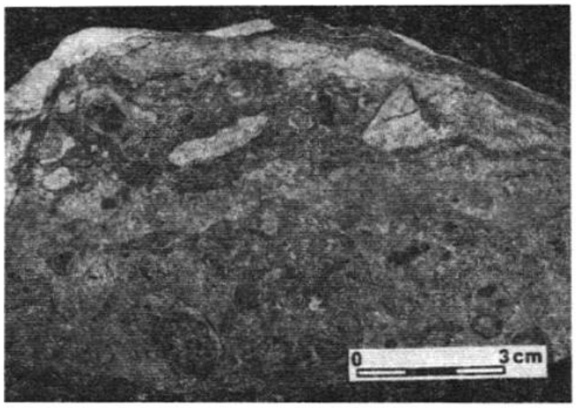

Fig. 15. Fragment of caliche cover. Angular fragments of older reworked caliche and compound vadoids floating in chalky peloidal matrix can be seen. In the upper part of the sample laminar crust overlies the basement (hardpan). Ruczaj

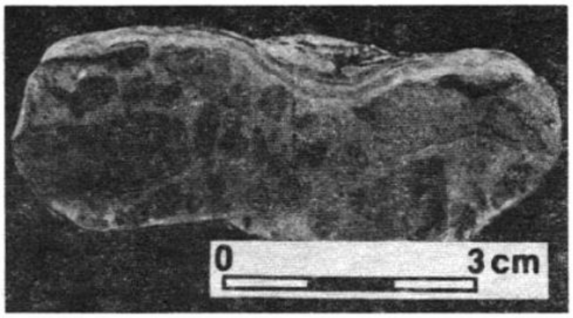

Fig. 16. Asymmetrical vadoid; its cortex is developed only in the upper part of the sample. The core is formed by chalky caliche with numerous angular fragments of reworked caliche and vadoids in micritic-peloidal matrix. Bielany

Type 2. Caliche profile developed on Senonian marls (Fig. 13B). This type of caliche profile does not have such distinctive zonation as type 1. The lack of massive layer is distinctly visible (*c*). The bulk of sediment is built up from vadoids. Vadoids show traces of multiple brecciation and recovering (Fig. 16). All coated grains float in marly matrix. A strong silification of core vadoids (Fig. 17) and the occurrence of black pebbles (Fig. 18) are very characteristic for this profile. The pisolithic layer forms the uppermost part of the profile.

Type 3. Caliche profile of the mixed type (Fig. 13C). In the case of a co-ocurrence of Oxfordian and Senonian rocks a mixed caliche profile with a massive horizon was developed on the Jurassic bedrocks, during the first stage. The cover of redeposited Senonian marls plugged this profile later and involved processes like in the first type profile.

Type 4. Caliche-forming processes in the Cra-

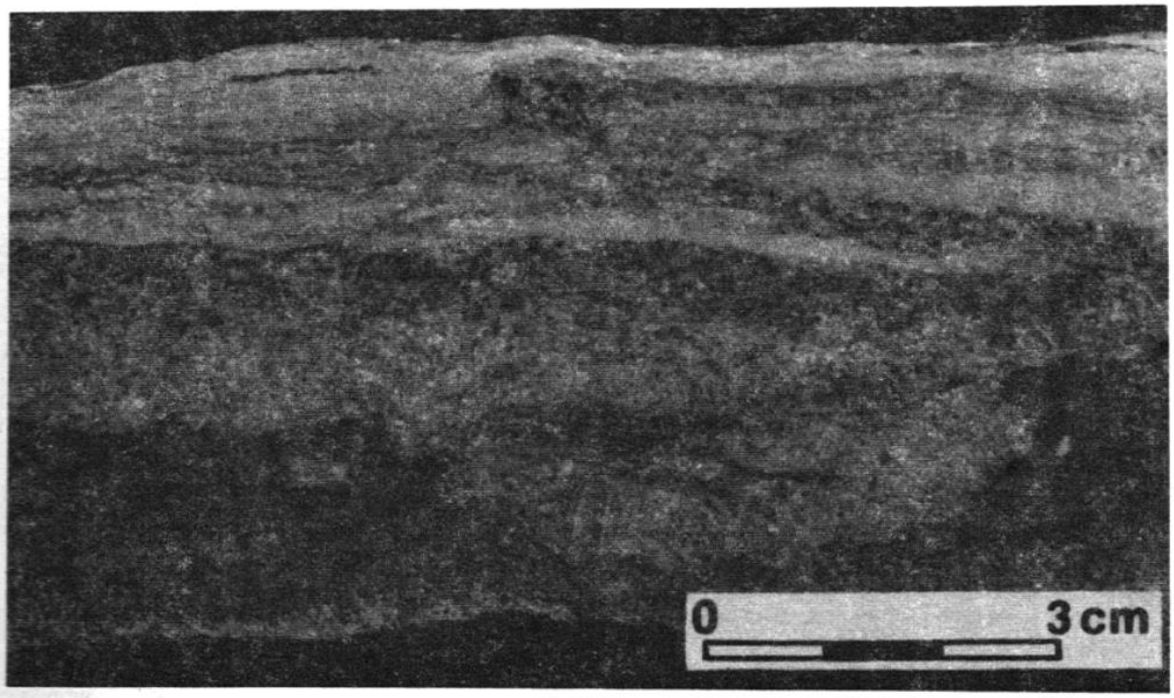

Fig. 17. Fragment of a big, flat vadoid. The lower part of its core shows abundant rhizoliths (root mat), the dark parts form silification zones. The upper part of the core is built by chalky caliche with cracks resulting from rhizobrecciation (rhizoliths in them are visible). The core of the vadoid is covered by laminar cortex (the upper part of the sample). Bielany

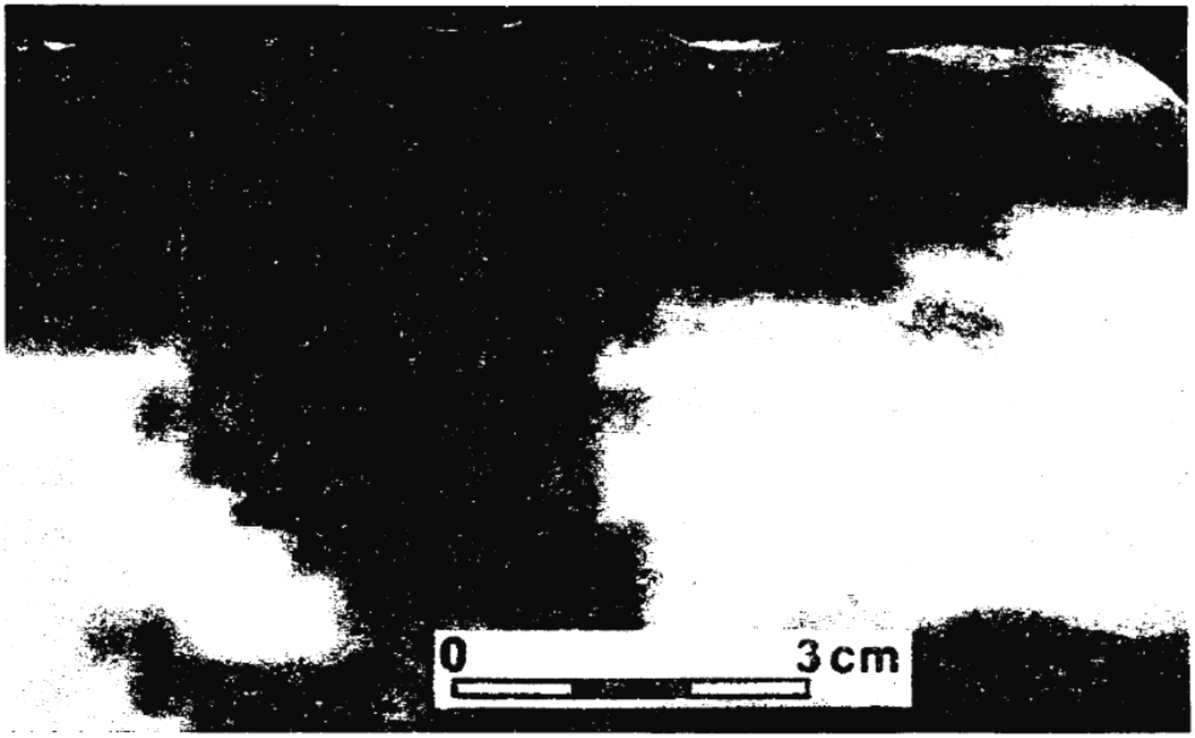

Fig. 18. Globular-chalky caliche. System of cemented cracks resulting from rhizobrecciation in visible here. In the upper left part of the sample blackened area can be seen. Bielany

cow area (Fig. 19). The above mentioned diversity of caliche profiles depends on the surface morphology and lithological features of basement rocks. Clayey Senonian rocks were worse permeable to meteoric water than karstified Jurassic limestones. This caused a different outflow distribution. Immediate run-off often with sheet flood and debris flow to local depressions, dominated on Cretaceous bedrocks. Periodically water stagnation in these depressions formed a small playa with poor algal vegetation (*Charophyta*). During the dry period playa sediments were changed by vadose diagenesis. On Jurassic limestones a meteoric water infiltrated easily into cracked rocks where they could circulate. During the dry season carbonate was precipitated in the upper part of host rocks and on their surface. Thus, in the same climate conditions (semiarid) hydrogeological factors caused a different course of caliche-forming processes. The last, similar parts of the both profiles (*d* horizon) consist of coated clasts of older rocks also derived from the caliche crust. These parts were developed in more humid conditions connected with the approaching Badenian transgression.

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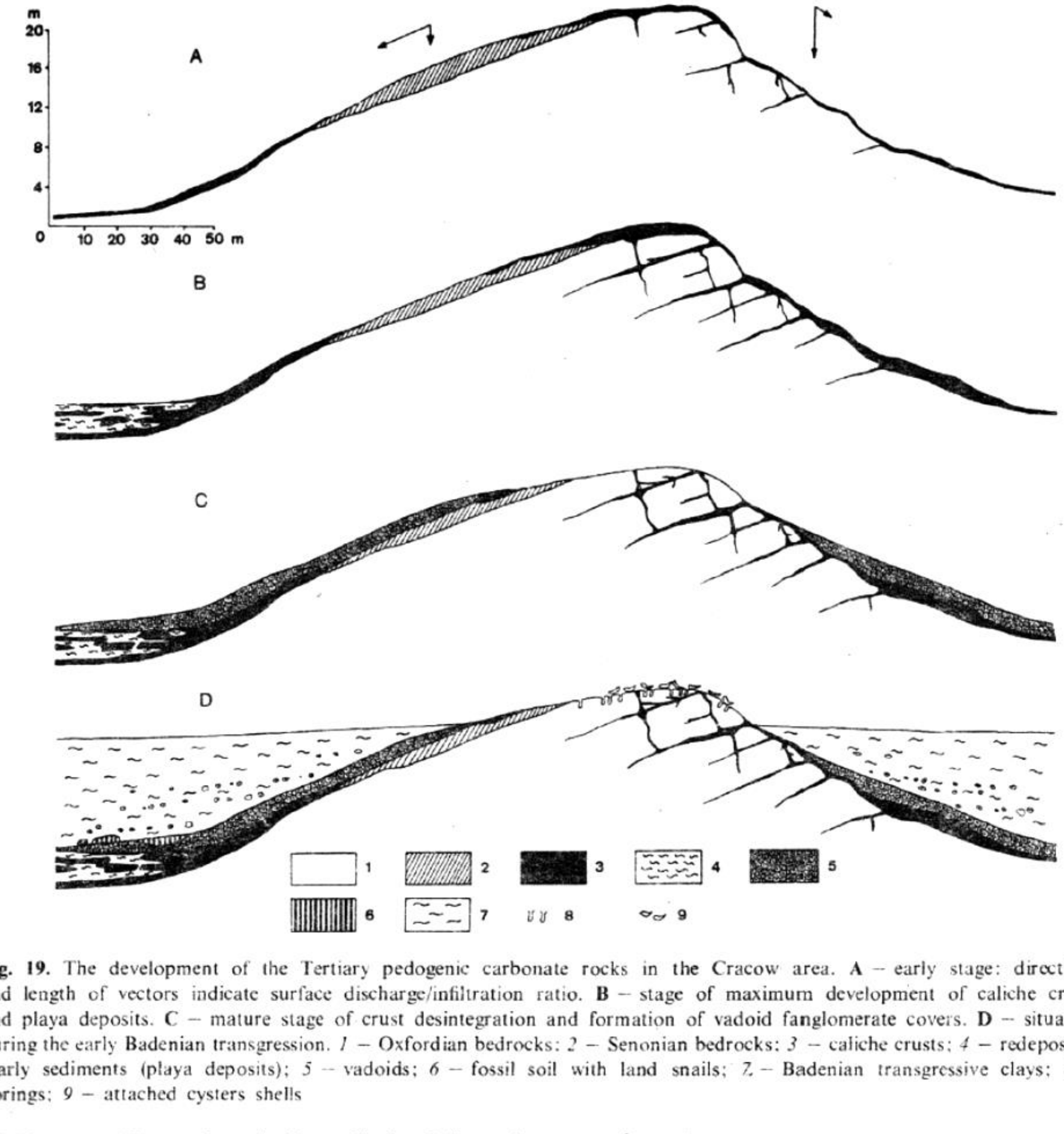

Fig. 19. The development of the Tertiary pedogenic carbonate rocks in the Cracow area. **A** – early stage: directions and length of vectors indicate surface discharge/infiltration ratio. **B** – stage of maximum development of caliche crusts and playa deposits. **C** – mature stage of crust desintegration and formation of vadoid fanglomerate covers. **D** – situation during the early Badenian transgression. *1* – Oxfordian bedrocks; *2* – Senonian bedrocks; *3* – caliche crusts; *4* – redeposited marly sediments (playa deposits); *5* – vadoids; *6* – fossil soil with land snails; *7* – Badenian transgressive clays; *8* – borings; *9* – attached oysters shells

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PART II. DESCRIPTION OF STOPS

First day

KARNIOWICE TRAVERTINE, WOŹNIKI LIMESTONE.

Stop 1

Jary Dulowskie. Lower part of Autunian.

Thickness of outcropped rock ca. 4 m; top and bottom not visible. Five zones may be distinguished upwards, respectively 0.3; 0.8; 1.0; 0.5 and 1:0 m thick (Fig. 21):

1) Compact, fine crystalline, irregularly and finely layered limestone, somewhat porous. Fine algal microfacaies with intercalations of moss microfacies predominates.

2) Compact, indistinctly layered limestone, with porous intercalations. Large algae microfacies predominates, containing intercalations of other algal microfacies and of moss microfacies.

3) Clustered limestone with large lenses of large

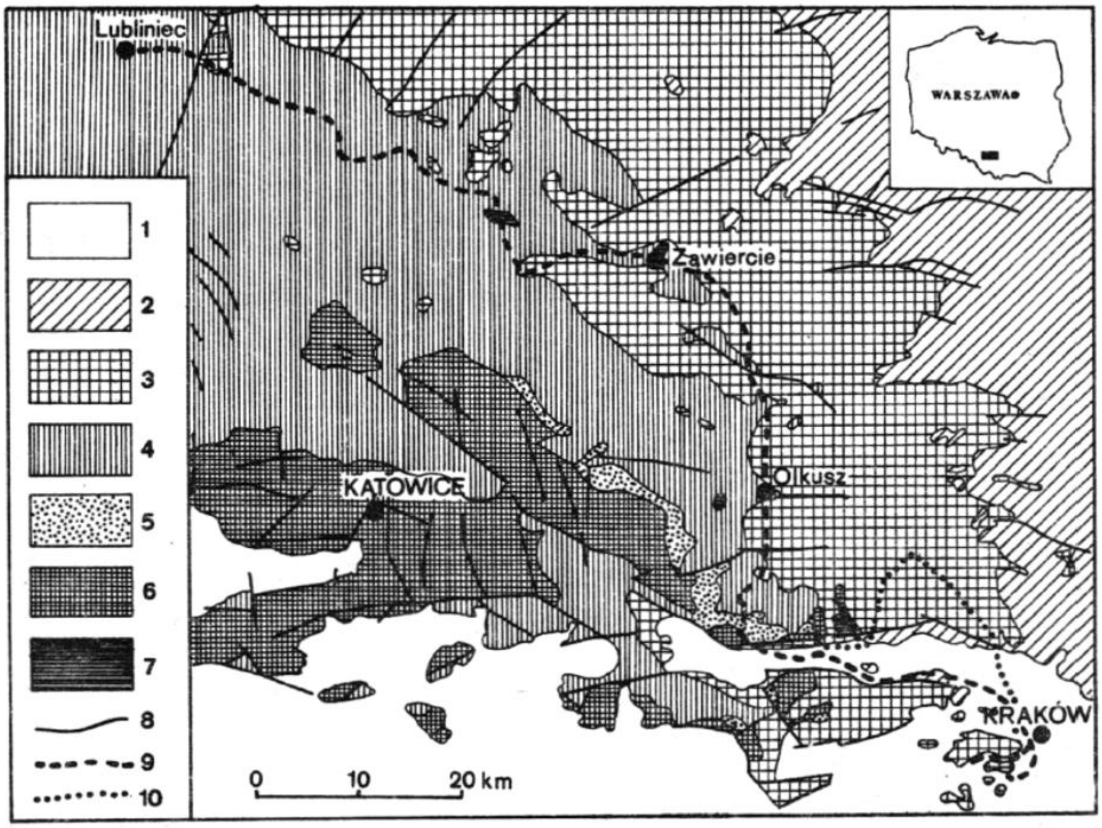


Fig. 20. Geological sketch-map of the excursion area. *1* – Miocene; *2* – Cretaceous; *3* – Jurassic; *4* – Triassic; *5* – Permian; *6* – Carboniferous; *7* – Devonian; *8* – faults; *9* – first day route; *10* – second day route

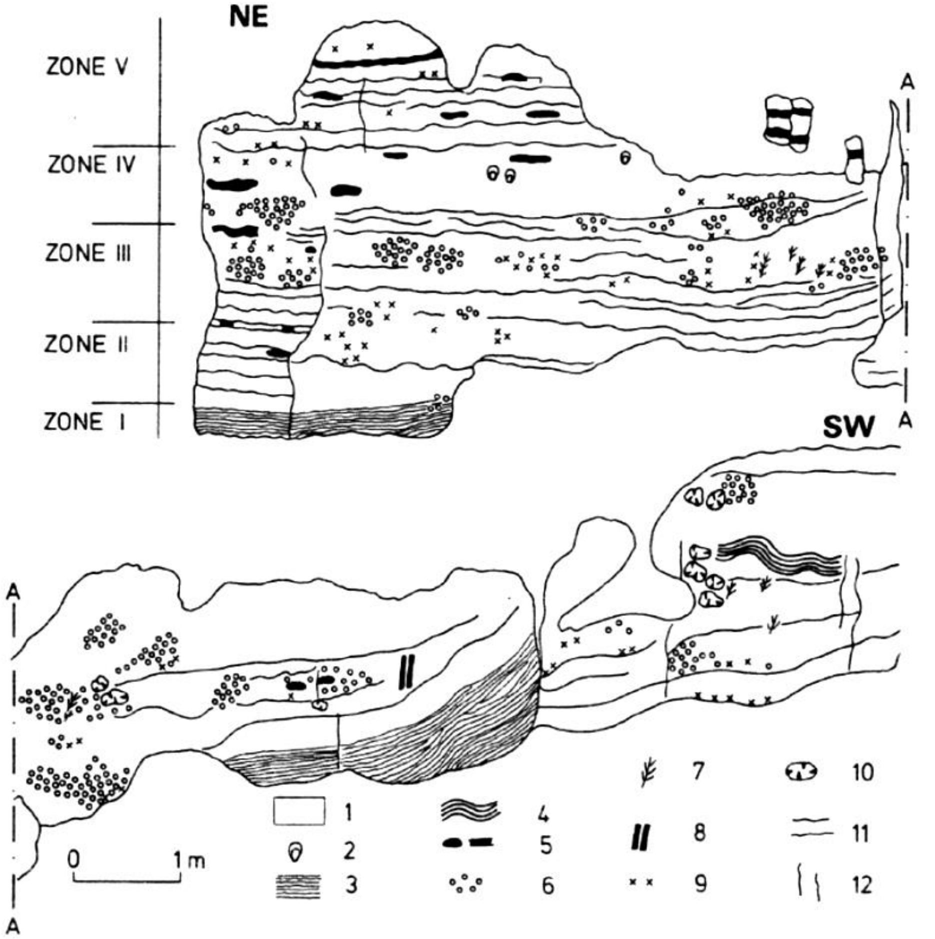


Fig. 21. Outcrop of Karniowice Travertine in Jary Dulowskie (Stop 1). *1* – fine crystalline algal structures; *2* – large algal structures; *3* – fine algal lamination; *4* – stromatolites; *5* – layers with bryophytan structures; *6* – coarse moldic porosity; *7* – large shoot remains; *8* – vertical fragments of trunks; *9* – pores; *10* – voids; *11* – bedding surfaces; *12* – vertical fissures

vascular plants remains, and with large caverns. There occur inclined stems (up to 30 cm long) and fragments of trunks (up to 60 cm long and 10 cm in diameter). Locally stromatolites. The microfacies of large vascular plant remains predominates, containing intercalations of moss microfacies.

4) Very porous limestone with intercalations of a pelitic limestone. Moss microfacies with intercalations of algal microfacies predominates.

5) Compact, slightly porous limestone. There occur algal and moss microfacies, and detritical microfacies at the top.

Stop 2

Czarna Poręba-Kierszula, N of the road Zawiercie-Siewierz. Lower Woźniki Limestone of the ESE extremity of the Median Trough, close to the mouth of the river feeding the basin.

Shallow lake deposits. Clear sedimentary cycles. A complete cycle consists of ooids becoming increasingly larger upwards (reverse graded bedding), covered by a layered stromatolite. All stromatolites are cyanophytan-algal. The cycle closes with desiccation as implied by cracks. Erosional channels visible. Proximity of mouth of river indicated by allochthonous material: small pebbles of Devonian and? Muschelkalk rocks. Conifer shoots and stems. The lowermost (not visible) part of the Woźniki Limestone developed as Basal Playa deposits. Upper surface erosional, this is planation surface C, here 6 m above bottom, covered by Ferruginous-Argillaceous Sands. Karst-connected mineralisation of the Limestone mainly with Fe compounds.

W of stop 2 the road abandons the Median Trough and crosses the area of the S „Shelf".

Stop 3

Point 1

View of Góra Święta from S. Flat top surface of the hill, bounded by a low white escarpment, below it wide gentle slope, reddish and brown. The gentle slope is formed in the Upper Triassic Variegated Clays and residues of the Lower Jurassic Ferruginous-Argillaceous Sands; the top part is an "island" of the Woźniki Limestone cut by planation Surface B, here 4,5 m above bottom. Thus we see an excavated fragment of the Lower Jurassic relief. Inclination of surface B due to Tertiary faulting.

Point 2

Góra Święta, Lower Woźniki Limestone of the S "Shelf".

Besides the lowermost part, poorly outcropped, developed as Basal Playa deposits, some limestones such as at stop 2, but mainly white limestones with numerous spots being bacterial nodules of denser micrite, formed in a shallow lake; they contain intercalations of deeper lake deposits (spots gradually rarer) on the one hand, and of paludal deposits (dense spots, rhizoids, siderite admixture) on the other. Allochthonous material much rarer than in stop 2 – we are farther from the mouth of the river.

Stop 4

Point 1

Near church at Cynków, E of road Cynków-Wojsławice. Middle part of Middle Woźniki Limestone of the Median Trough.

Mainly playa, subordinately lacustrine, deposits. Breccias, caliche, pseudomorphs of calcite after gypsum outlined by thin argillaceous coatings. Thin argillaceous intercalations, presumably eolian. The Woźniki Limestone is cut by planation surface B, here 22 m above bottom. The surface is covered, and karst cavities filled, successively by redeposited Upper Triassic Variegated Clays and Lower Jurassic Ferruginous-Argillaceous Sands, with residues of the Połomia Gravels at the top.

We take on foot the road to the E and pass over the Ferruginous-Argillaceous Sands with olistostromes of the Variegated Clays.

Point 2

S slope of hill 363, E of church in Cynków. Uppermost part of Middle Woźniki Limestone, Median Trough.

Limestones such as at point 1., but more lacustrine intercalations. Woźniki Limestone cut by planation surface A, here 33 m above bottom, covered successively by Ferruginous-Argillaceous Sands and residues of Połomia Gravels.

We return to the bus, and proceed first S over the Połomia Gravels filling a narrow valley between two "islands" of the Woźniki Limestone, and them W over Połomia Gravels underlain by residues of Ferruginous-Argillaceous Sands and of redeposited Variegated Clays overlying surface B clearly appearing from below this cover to the S (on our left).

Stop 5

Hill Nieradowa above Cynków-Graniczna. Upper Woźniki Limestone, uppermost preserved part, Median Trough.

Pink marls and marly limestones with clasts of Variegated Clays and of diagenised Woźniki Limestone. These are deposits of a lake intermittently becoming swamp and even playa. The Upper Woźniki Limestone was preserved exclusively as residual hills surmounting planation surface A. We are standing on the highest of them, 6 m above surface A, which is here 33 m above bottom of Woźniki Limestone. Both the hill and surface A are covered by the Ferruginous-Argillaceous Sands.

We return to the bus, proceed down to the foot of the "island", and there we turn NW in the direction of the small town of Woźniki, along the steep slope of surface B on our right. The bottom of the Woźniki Limestone is at the foot of this slope. The town of Woźniki lies in an excavated Lower Jurassic valley. We turn E.

Stop 6

W part of the N slope of the hill Sobolowa Góra above Woźniki. Middle part of Middle Woźniki Limestone, Median Trough.

Mainly playa deposits, brecciated in various ways, on the whole very similar to those at stop 4 point 1. This is the type locality, and possibly the type outcrop, of the Woźniki Limestone as described by the XIXth century authors.

From there we proceed by bus for a long time to the W over the Variegated Clays with residues of the Lower Jurassic Ferruginous–Argillaceous Sands and Połomia Gravels cover. On our way we cross two "islands" of the Woźniki Limestone: at Kosięcin and at Wierzbie.

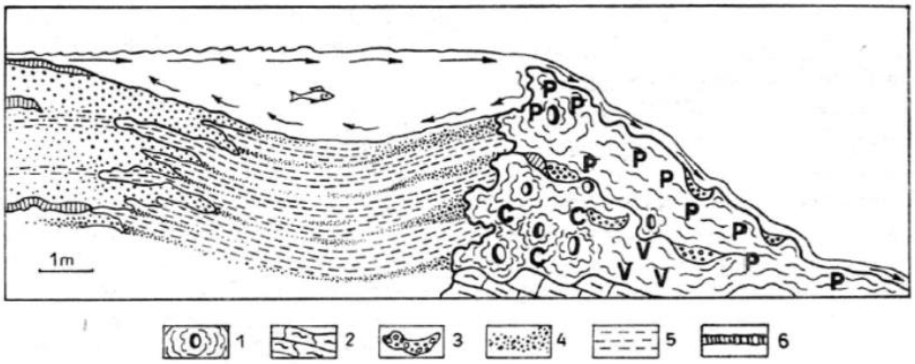


Fig. 23. Model of sedimentation by biohermal bar (based on the Racławka stream dam).
1 – *Cladophora* (C) and *Vaucheria* (V) travertines; *2* – moss travertine; *3* – oncoids. Detrital carbonates: *4* – sands and gravels; *5* – muds; *6* – *Schizothrix* stromatolites

It is one of the key-outcrops for the reconstruction of Holocene environmental changes in the Cracow Upland.

Almost all kinds of travertine deposits are visible. A biohermal bar appears in the central part of exposure. In the past (8000-2700 y.B.P) this bar dammed up the stream. In its lower part, *Cladophora*- and *Vaucheria*-travertines occur and in the upper the *Cyanophyta*-encrustations are very abundant. "Oncoidal pockets" – the former whirpools are visible inside the bioherm. A vertical growth of bioherm was intensive (up to 2 cm/year) and caused a small pond located upstream from the dam. Development of biohermal bar stopped about 2700 y.B.P. It depended on climatic changes (cooling and drying) and was replaced by soil-forming processes. Since 1600 years B.P. an intensive erosion of early deposited sediments has been carried on.

Stop 12

Racławka Valley. Unit B *costatus-sulcata* Zone?

70 m thick section of the middle part of B unit contains several horizons of subaerial exposure capping several shallowing upward cycles. They usually consist of 3 parts (Fig. 11 a, b, c):

a 1, 2, 3. Detritic limestones often rich in biota, e.g. mixed consortium of "Strunian" stromatoporoids including forms typical both for the Western Europe and the Russian Platform;

b 1, 2, 3. Mudstones with strongly restricted biota; calcispheres-ostracods consortium and various algal structures associated with attached vermiform gastropods (*Serpula advena, S. vipera*). These biota indicate a restricted basin with abnormal salinity and are typical for the similar conterminous facies found from the Ural Mts to Wales;

c 1, 2, 3. Subaerial stage is represented by loferites, carbonate swamp and marsh deposits and various geosols, e.g. Fig. 12.

Stop 13

Żarska Valley. Unit B.

Several horizons of loferites and caliche covers are visible in a road section.

Stop 14

Czatkowice Quarry. Units C-J.

Some horizons of geosols (rendzina and caliche type) will be examined in the largest quarry. Typical sabkha sequences with evaporites and solution breccias will be seen in unit H (Fig. 11). Various algal structures (stromatolites, thrombolites and compound masses) can be examined. These, together with attached vermiform gastropods form bioherms and biostromes. Palaeokarstic surfaces in units H and J will be examined.

Stop 15

Eliaszówka Valley. Unit H or I?

White limestones of "fenestral-pisolitic" facies are closely related to the shelf crest facies from Permian of the Guadalupe Mts. (Esteban, Pray 1983). They are also similar to the Calcare Massicio from Jurassic of the Central Italy and recent carbonates from the Persian Gulf. Fenestral algal mats form tepees. Various types of pisoids, vadoids and coniatoids and related crusts are visible here. Fenestra, cracks and keystone vugs

Stop 7

S slope of Góra Lubecka above Lipie Śląskie. Lower Woźniki Limestone, WNW extremity of Median Trough.

Argillaceous-calcareous mudflows directed ESE (mean of measurements), i.e. from the presumable steep inner slope of the barrier (situated to the W of us, not preserved) closing the Woźniki Limestone basin, towards the axis of the Median Trough. The mud flows consist of marly limestones and marls, deeper lacustrine, and of re-worked Variegated Clays. Thickness of mud flow deposits – 12 m.

We go back to Lubliniec, and there we turn NW in a Lower Jurassic valley between two "islands" of the Woźniki Limestone. On our left, NE slope of the "island" of Góra Lubecka below surface B, whose height above bottom of Woźniki Limestone diminishes NW-wards from 23 to 16 m over a distance of 0,7 km, indicating steep inclination of the bottom of the basin.

Stop 8

Top of Góra Lubecka. Lower part of Middle Woźniki Limestone, WNW extremity of Median Trough.

Playa limestones as in stop 4 point 1 alternating with paludal and lacustrine micritic limestones (as in stop 3). Thin intercalations of clay may be eolian or due to slight mud flows from the barrier. The Woźniki Limestone is cut by surface B, covered successively by Variegated Clays, Ferruginous-Argillaceous Sands, and Połomia Gravels. We believe that fragments of Woźniki Limestone scattered over the fields were silicified non *in situ* in the Tertiary.

Return to Cracow.

Second day

DINANTIAN PEDOGENIC CARBONATES, TERTIARY CALICHE, HOLOCENE TRAVERTINES

Stop 9

Holocene moss travertines of the Szklarka Valley.

This outcrop presents moss travertines described in part 1 (see also Figs. 4 a-d). On these rocks a small (2,5 m high) water-fall is developed. Travertine form layer from 20 to 40 cm thick dipping downstream. The sediment is porous but firm. Larger caverns are filled with "pseudo-speleothems". Prints of leaves (*Tilia, Ulmus, Cornus*) and grass are common. ^{14}C-age of travertine ca 7100 y.B.P.

Stop 10

Recent lichen calcareous crust in the Racławka Valley.

A lichen stromatolites up to 20 cm thick, covering the surface of crag rised sheer above the stream. Accretional layers parallel to the rock surface are remarkable. Stromatolites are partly developed on the base of case-worm (*Trichoptera*) anchoraged in a fissure (see also Figs. 5 a-c).

Stop 11

Holocene biohermal bar of the Racławka Valley (Fig. 23).

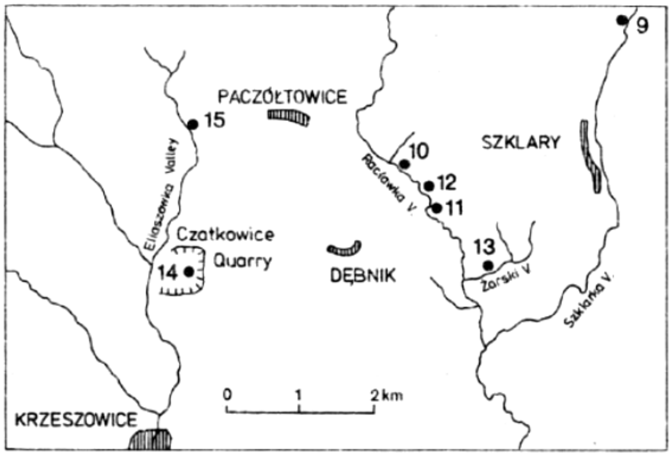
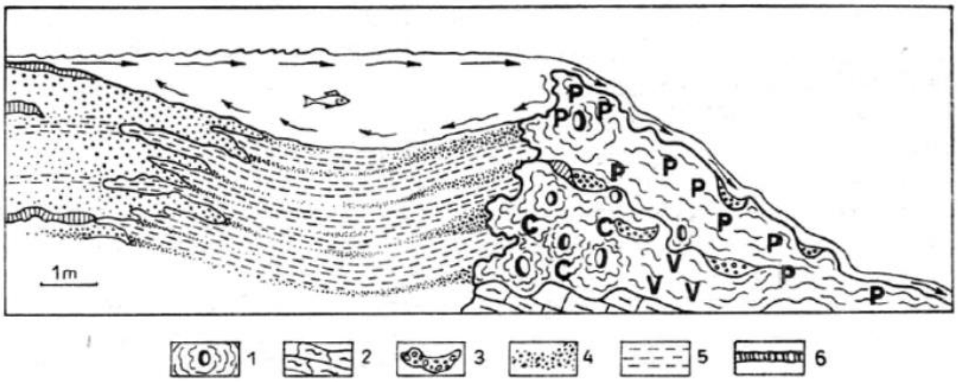


Fig. 22. Location map of second day excursion.



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Stop 16

Kraków-Bielany. Tertiary caliche profile (Figs. 13B, 24).

The caliche profile developed on the Senonian marls is presented in the old, disused quarry. Vadoids, black pebbles, rhizoliths and silicified caliche are visible.

Stop 17

Kraków-Zakrzówek (Fig. 13A).

The first type of caliche profile with massive and platy horizon, vadoid conglomerates, montmorillonitic residual clays and Miocene marine clays are visible in the big quarry of Oxfordian limestones.

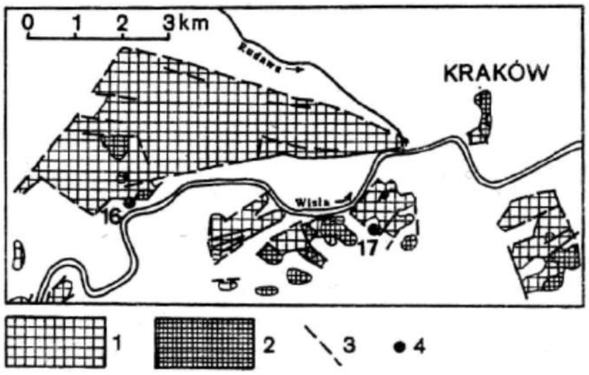

Fig. 24. Geologic sketch-map of the Cracow area and location of stops. *1* – Oxfordian rocks; *2* – Senonian rocks; *3* – faults; *4* – stops