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Interglacial Mindel *I*/Mindel *II* in fossil-bearing karst at Kozi Grzbiet in the Holy Cross Mts

ABSTRACT: Deposits filling the ancient cave in the Devonian limestones at the Kozi Grzbiet Hill in the Holy Cross Mts, Central Poland, consist of red sands and clays being redeposited waste of the Buntsandstein. The top part of the red deposits has been reworked by periglacial processes, eroded and ultimately covered with brown cave loams containing fossils, as well as ice-transported material derived from deposits of the Mindel *I* Glaciation. The overlying glacifluvial sands are attributed to the Mindel *II* Glaciation. Rich vertebrate and snail fauna, containing i.a. *Mimomys savini*, *Pliomys lenki*, *Dicrostonyx simplicior*, *Lemmus* sp., *Ursus deningeri* and *Helicigona banatica* indicates several climatic phases during deposition of cave loams, and proper interglacial conditions. These conditions are indicative of the existence of the two separate glaciations, Mindel *I* and Mindel *II*, in the territory of Poland.

INTRODUCTION

A karst locality of Old Pleistocene age, very rich in fossil remains, was discovered in 1970 at Kozi Grzbiet Hill by Wódkowski (1971). Excavations have been in progress here since 1970 till 1974 under the management of Professor K. Kowalski (paleontology) and Dr. J. Głazek (geology). About 10 tons of bone-bearing cave loams were excavated, washed and sieved. The whole, very rich paleontological material is deposited in the Institute of Systematic and Experimental Zoology of the Polish Academy of Sciences, in Cracow. The first results of paleontological investigations (Black & K. Kowalski 1974, K. Kowalski 1975, K. Kowalski *in:* Bartolomei & al. 1975), as well as a preliminary report on geological investigations (Głazek, Lindner & Wysoczański-Minkowicz 1976) have been published recently. The aim of this paper is to discuss the geological setting of this locality, the age and development of the fossil karst.

The locality Kozi Grzbiet is situated in the south-western part of the Holy Cross Mts, in the northern limb of the Chęciny anticline (Fig. 1), where Devonian carbonates are exploited in a series of quarries. The investigated karst form appears in the northern wall of the abandoned quarry at Kozi Grzbiet (Pl. 1, Fig. 1).

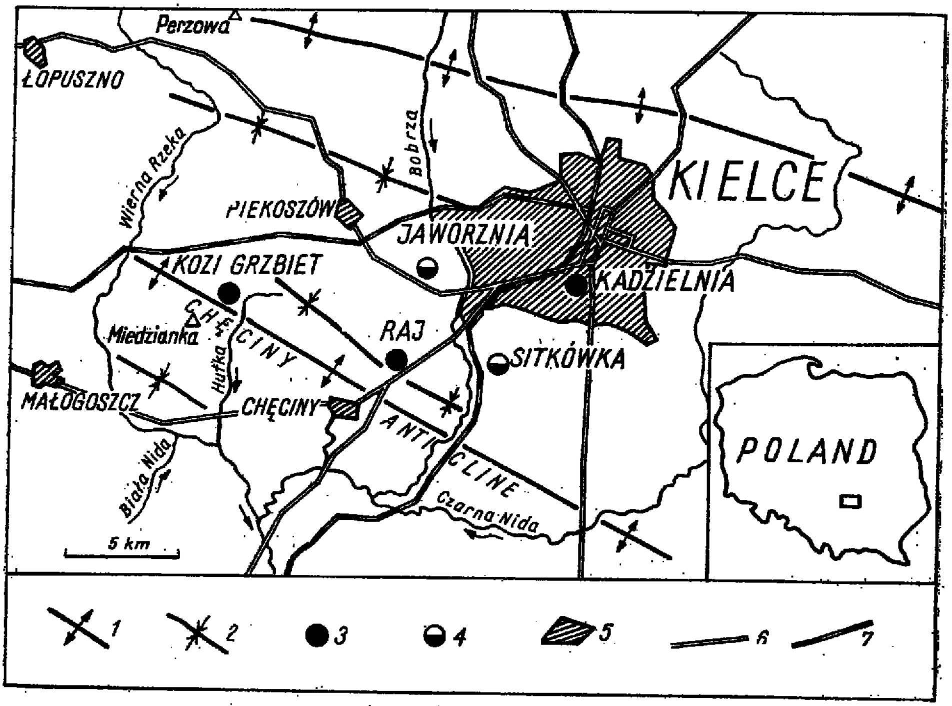

Fig. 1. Location sketch of karst bone-bearing localities in the Holy Cross Mts
1 axes of main anticlines, 2 axes of main synclines
Bone-bearing karst localities: 3 paleontologically documented, 4 reported
5 towns, 6 highways, 7 railroads

The only detailed geological map of the discussed area was published by Czarnocki (1938). A general evolution of the region was discussed recently by Kutek & Głazek (1972), and the tectonics of the nearest vicinity by W. R. Kowalski (1975). The Quaternary history of the area is presented by Lindner & W. R. Kowalski (1974) and Lindner (1977). The fossil karst of the region was the subject of Majchert's (1966) paper, and the karst processes were discussed by Głazek & Markowicz-Łohinowicz (1973).

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Institute of Systematic and Experimental Zoology, Polish Academy of Sciences, Cracow) for information on the results of paleontological investigations and collaboration during the field investigations.

GEOLOGICAL SETTING

The oldest rocks cropping-out in the area are shales and siltstones with sandstone intercalation of the Lower Cambrian forming the diapiric core of the Chęciny anticline (Fig. 2). These rocks are generally unresistant to denudation processes. The limbs of the Chęciny anticline are built of dolomites (Eifelian-Givetian) and limestones (Givetian-Famennian). The thick-bedded limestones (biosparites) referred to the Givetian (?), are more resistant to the denudation processes and therefore they form elevations. Further on the anticline limbs there occur clays, siltstones and sandstones of Buntsandstein; they are also unresistant to denudation.

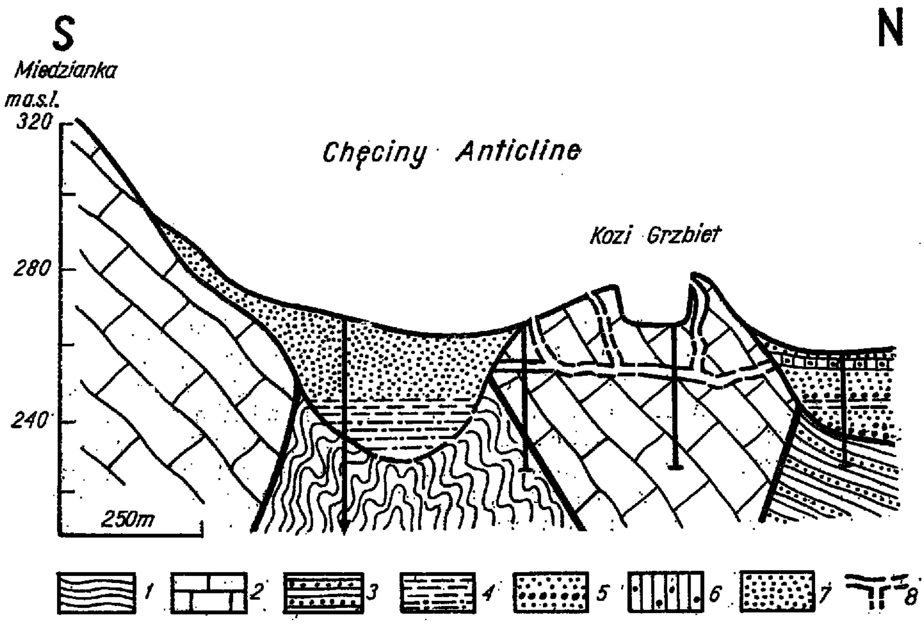


Fig. 2. Geological cross-section through the Kozi Grzbiet Hill (boreholes are indicated)
1 Cambrian shales, 2 Devonian limestones, 3 Buntsandstein sandstones and shales Cracovian (Mindel) Glaciation: 4 glacifluvial sands, silts and limnic clays, 5 fluvial and glacifluvial sands and gravels, 6 tills of maximal stadial (*G II max.*), 7 glacifluvial sands; 8 karst forms

The Kozi Grzbiet Hill is formed by a limestone block with tectonic contacts of the Cambrian shales in the south and Buntsandstein clays in the north; limestones are dipped to NNE c 50°.

Since the Laramian rise of the Holy Cross Anticlinorium (cf. Kutek & Głazek 1972) denudational processes have started, the morphologic inversion developed and the Paleozoic substrate was dissected by numerous valleys. These valleys were buried under 30—40 m thick Old Pleistocene deposits before the maximal stadial of the Cracovian (Mindel) Glaciation. During this glaciation, the marked hills along the limbs of the Chęciny anticline stopped the icesheet and in effect, an oasis surrounded by ice and sheltered by those hills was formed. The oasis was filled up to 320 m a.s.l. with silts and sands (Lindner & W. R. Kowalski 1974, Lindner 1977). Subsequent erosion and sedimentation during the younger Quaternary is out of scope of this paper.

The Devonian limestones at Kozi Grzbiet Hill are strongly karstified. Karst forms are filled with red sandy-clayey deposits and/or brown loams and sands. The investigated site represents a fragment of cave filled with both the red and brown types of deposits.

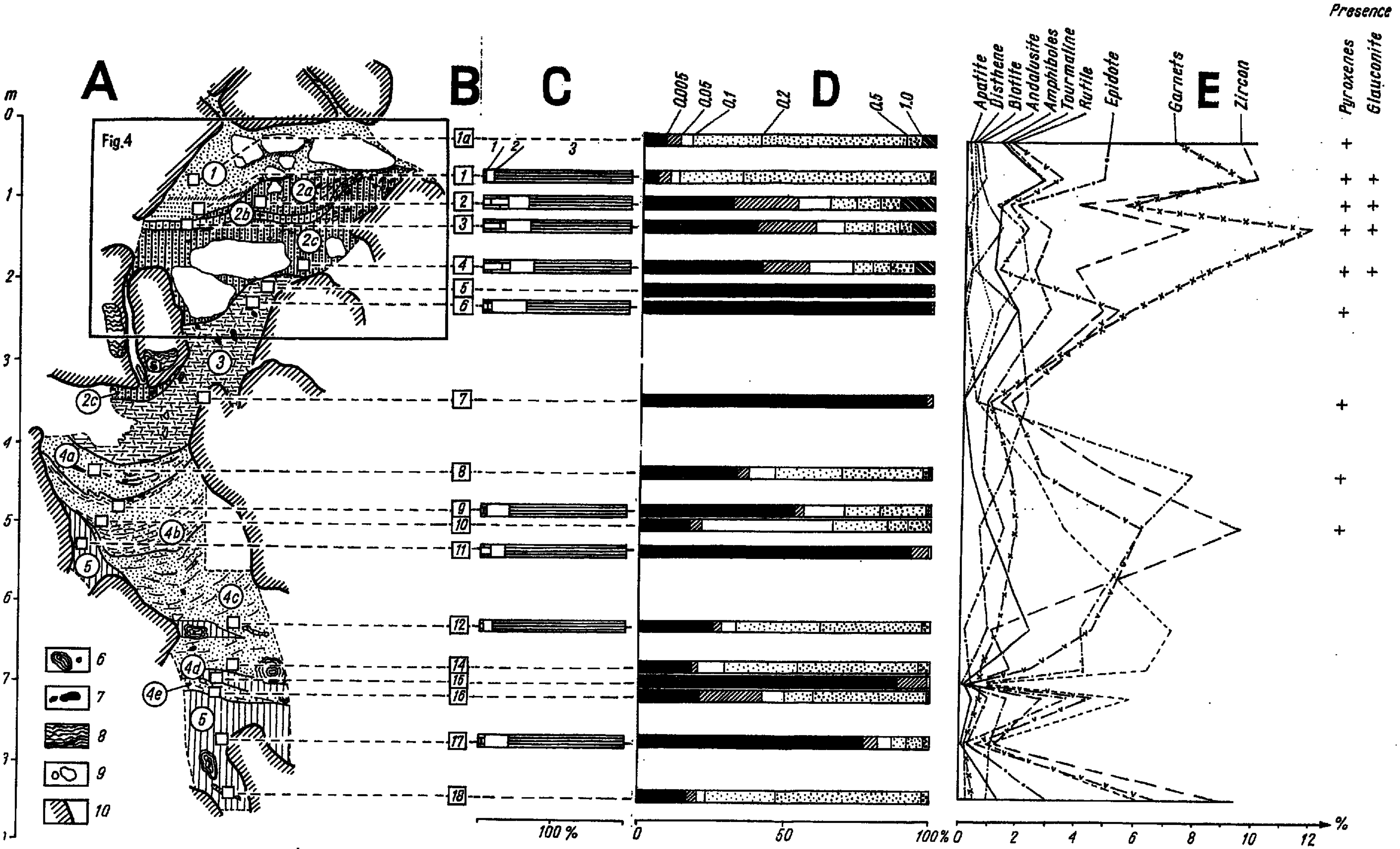
KARST SEQUENCE AND ITS INTERPRETATION

SEQUENCE OF CAVE SEDIMENTS

During the excavation 5 lithological units were recognized in the sequence of unconsolidated sediments filling the discussed karst form. These units, as well as the samples representing them, were numbered in descending order according to the progress of excavation (Fig. 3); some of the units were divided into layers (a, b, c..., where *a* is at the top of a divided unit).

Unit *1* consists of yellow fine sands with limestone blocks and flowstone debris (Fig. 3). The sands reveal tangential bedding in the lower part (Pl. 1, Fig. 2), whereas in the top part stratification is not observed. Along the limestone blocks, the sands are reddish and enriched with clay minerals and iron oxides. The sands contain an admixture of kaolinized feldspars and a very diversified heavy mineral association. These sands are typical glacifluvial deposits, laid down in conditions of relatively tranquil flow (fine grains, tangential bedding). Rock debris that occur in these sands were derived from cave walls and roof. The lower part of sands remains undisturbed, whilst the upper part is deprived of bedding and more easily weathered minerals due to the periglacial and soil forming processes. These processes account for the presence of soil concentration of calcium carbonate and hydrated iron oxide — clayey bands around limestone blocks.

Unit *2* represents sandy loams with bones, snail shells, smoothed debris of limestones and flowstones (Pl. 2, Fig. 1). There are numerous debris of white fine-crystalline flowstones, while reddish coarse-crystalline flowstone debris are scarce. The loams contain over 50% of clay and silt fractions, while the contents of psammitic particles is of the order of 10—15%. Calcium carbonate content is 17—19%. The heavy mineral association is similar as in Unit *1*. Similarly, the kaolinized feldspars occur apart from quartz. The X-ray diffraction studies revealed, besides quartz and calcite, some smectite, kaolinite, illite and feldspars as subordinate components. This Unit represents typical cave loams commonly encountered in Quaternary fillings of caves in the Central Polish Uplands (*cf.* Madeyska-Niklewska 1969, Madeyska 1972); such loams are connected with warmer periods.



Properties of the sediments in the locality Kozi Grzbiet

A — Cross section of the cave sequence: *1–5* units and layers (marked *a, b, c*) described in the text, *6* carbonate concretions, *7* flowstone debris, *8* preserved flowstone on cave walls (*s* stalagmite), *9* limestone blocks in cave sediments; *10* cave walls; squares — location of samples

B — numeration of samples

C — chemical composition of samples (in weight per cent): *1* calcium carbonate, *2* other soluble components, *3* insoluble components

D — granulometric composition

E — heavy minerals (in vol. per cent; opaque and undetermined minerals omitted)

Within this Unit during the field investigations 3 layers were distinguished which slightly differ as to their color, and distribution of rock debris and animal remnants.

Layer *2a* yellowish-brown in color; it contains small bones and snail shells, as well as numerous debris of limestones and flowstones. Layer *2b* is marked for its dark--brown color. In this layer large bones occur, but limestone and flowstone debris are less frequent and more smoothed than in layers *2a* and *2c*. Snail shells, too occur in this layer. Layer *2b* in the eastern part (right in Fig. *3A*) is mixed with the neighbouring layers by sliding. Layer *2c* differs from higher layers by its light brown color, presence of large limestone blocks and slices of fine-crystalline flowstone crusts. This layer contains numerous remnants of large mammals, while snail shells are lacking.

Unit *3* consists of brecciated cherry-red clay which is composed of crumbled and distorted small pieces of laminated clay. It contains scarce smoothed limestone debris and knobby concretions of calcium carbonate together with clay impurities. The sediment consists *c* 99% of clay-grade material which includes kaolinite, hematite and vermiculite. Sand grade detrital grains consist of well rounded quartz. The heavy mineral association is small and undifferentiated.

This Unit resembles the underlying Unit *4*, but differs from it by brecciation of clays, presence of vermiculite and lower content of sand-grade fraction. Probably Unit *3* represents the top, more clayey part of the cherry-red clay-sand sequence (Unit *4*) altered by weathering processes. Vermiculite might have originated from hypergenic alteration of layered silicates. Brecciation may be explained by frost action before sedimentation of overlying Unit *2;* at the same time huge blocks could fall from the cave roof due to frost action and be subsequently covered with sediments of the overlying unit.

Unit *4* consists of a set of thin layers of cherry-red fine-grained clayey sands and sandy clays; these deposits are sagged and slightly slid to the axis of karst form (*cf.* Pl. 2, Fig. 2 and Text-fig. 3*A*). The clayey intercalation of this Unit consists of *c* 55% of clay-grade material, 5% of silt-grade fraction and *c* 40% of fine-sand, while the sandy intercalations consists of *c* 30% of clay-grade fraction, and 60—70% of fine sand. The light fraction beside the dominant quartz contains kaolinized feldspars and siliceous rock fragments. The heavy fraction contains markedly less of easily weathered minerals. Clay-grade material consists predominantly of kaolinite, with small admixtures of illite and smectite. The cherry-red color of sediments is caused by high hematite contents. The sediments contain sparse debris of coarse--crystalline reddish flowstone and smoothed limestone debris. Moreover, there are flakes and slabs of brownish-yellow clays, that had originally filled the cave and constituted the underlying Unit *5*.

Lithological differentiation of Unit *4* enabled to distinguish several layers during field works: *4a* — sands with clay intercalations in their upper part, the clays containing also debris of corroded coarse-crystalline flowstones and surrounding limestones; *4b* — sandy clays with intercalation of clayey sands; *4c* — clayey sands with lenses of cherry-red clay, debris of limestones and coarse-crystalline flowstones, and carbonate concretions. In the middle of this layer flakes and slabs of brownish-yellow clays occur which constitute Unit *5* and are also preserved in a niche on a cave wall (*cf.* Fig. 3A); *4d* — a great tongue of clays identical with the underlying unit, covering the whole investigated section of the cave. In these clays carbonate concretions also occur; *4e* — cherry-red clayey sands with carbonate concretions.

The described set of layers, with the exception of layer 4d, resembles Buntsandstein deposits of the Holy Cross area. This Unit was formed by redeposition of Buntsandstein waste into the karst caverns.

Unit *5* consists of brownish-yellow clays with carbonate concretions, corroded limestone debris and lenses of cherry-red clayey sand resembling the overlying unit. These clays fill the lower part of the investigated cave fragment, and a niche on the western wall of this cave at the boundary between layers 4b and 4c, and they form slices and tongues (*e.g.* layer *4d*). The latter had probably slid from the cave walls during sedimentation of the overlying unit. First appearance of sliding processes caused also the presence of red sand lense in the clays of Unit *5* (cf. 3). These clays consist predominantly of clay-grande material (85—95%) with silt admixture, while the sand fraction is often lacking. The light fraction consists only of quartz grains, whereas heavy fraction consists of small quantities of zircon and tourmaline (besides iron hydrated oxides and carbonates). Generally, this clay consists of kaolinite with admixtures of smectite, illite, quartz, hematite and traces of hydrated oxides of iron and aluminium. This mineral composition of clays is very close to that of the residuum of the Devonian limestones in this area (*cf.* Majchert 1966, Fig. 6); the clays therefore may be treated as a residuum of Devonian limestones.

OTHER OBSERVATIONS

Limestone walls of the investigated cave are corroded and partly covered with reddish coarse-crystalline flowstone; even a stalagmite (*s* in Fig. 3*A* and Pl. 1, Fig. 1) raising from the flowstone cover was preserved. The flowstone rarely occurs in situ, but in Units *1—4*, it supplied many debris. It is evident that coarse--crystalline flowstones had covered the cave before or during the sedimentation of Unit *4*. Later, after the deposition of Unit *3*, fine-crystalline white flowstones were formed, as their fragments were encountered only in Units *1* and *2*.

In the described sequence of cave deposits, there evidently occur hiatuses, connected with erosion of older cave formations, between deposition of Units *1* and *2*, Units *2* and *3*, and probably also between Units *4* and *5*.

Primary sedimentation of Unit *5* was accompanied by deep karstification of the Devonian limestones and it had probably taken place in freatic conditions. Deposition of cherry-red clayey-sandy sediments (Unit *4*) took place later and it was connected with redeposition of older karst sediments (Unit *5*) and supplied with material from Buntsandstein deposits weathered on the surface. The origin of Unit *3* is more complicated: primary sedimentation of clays was the final stage of sandy-clayey sedimentation (Unit *4*), thus both of these units were deposited in one sedimentary cycle, probably in conditions of a periodically flooded cave. Brecciation of the clays of Unit *3* was connected with erosion and may be explained by frost action under periglacial conditions during an older glaciation stage. As an evidence of periglacial conditions at this time may also serve huge blocks of limestones that occur on the boundary between Units *3* and *2*. The latter Unit contains a rich suite of heavy minerals and many feldspar grains, remarkable for glacial deposits of this area. Cave loams were deposited by percolating waters in vadous conditions. These loams contain local coarse material (limestone and flowstone debris) and silt-sand grade material of glacial provenience which was transported from the surface by sinking waters. Presence of animal remnants in Unit *2* enabled precise biostratigraphic and chemical (*cf.* Wysoczański-Minkowicz 1969) dating, as well as a determination of the climatic conditions. During the deposition of the loams the cave must have been partly unroofed, as the forest snail shells occur in the upper part of loams section. Sands of Unit *1* were deposited in the destroyed cave as a result of the inflow of melting waters from the ice-sheet.

Red sandy-clayey deposits were found by boreholes 20 m below the bottom of the quarry at Kozi Grzbiet (*cf.* Fig. 2). Probably the development of these caves was controlled by the valley incised in the Cambrian shales, and buried at present. It is possible that the karst channels had originated before the final overdeeping of this buried valley. The overdeeping seems to have followed immediately before the first continental glaciation (Podlasian, Günz), as on the bottom of the valley periglacial slope deposits of Günz age were found (Lindner & W. R. Kowalski 1974).

The syngenetic carbonate concretions of Units *3–5* consist of calcium carbonate (50–60%), undissolved matter (clay and sand: 30–40%), and nearly 10% of dissolving hydrated oxides.

BIOSTRATIGRAPHY

Cave loams (Unit *2*) contain vertebrate and snail remnants, of which the vertebrates occur in each of the distinguished layers, whereas snails appear in layer *2b* and they are most common in the lower part of layer *2a*.

Very rich snail fauna consists of over 30 continental species. Among them *Helicigona banatica* (Rossm.) and numerous Clausilidae species indicate warm and wet interglacial climate, as well as deciduous forest environment (E. Stworzewicz, letter information, 1976). This fauna belongs to hygrophile association of the culminating interglacial period, denoted as *Banatica* fauna (Ložek 1961). This fauna is considerably more thermophilic and more hygrophilic than the recent fauna of this area.

Vertebrate fauna is rich and includes large mammals, i.a. *Ursus deningeri* v. Reichenau, suids and cervids (K. Kowalski 1975). Numerous micromammals were partly described or determined (Black & Kowalski 1974, K. Kowalski 1975, K. Kowalski *in:* Bartolomei & al. 1975). From these papers the following list of taxa so far determined may be cited: *Citellus polonicus* Gromov, *Petauria* sp., *Dicrostonyx simplicior* Fejfar, *Lemmus* sp., *Pliomys lenki* (Heller), *Castor fiber* L., *Glis* with intermediate character between *G. glis* (L.) and *G. sackdillingensis* (Heller), *Muscardinus* sp., *Sicista* sp., *Mimomys savini* Hinton, *Clethrionomys* cf. *glareolus* (Schreber), *Pliomys episcopalis* Méhely, *Pitymys gregaloides* Hinton, *Pitymys arvaloides* Hinton, *Microtus* ex gr. *arvalis* (Pallas), *Microtus* ex gr. *oeconomus* (Pallas), as well as various amphibians and reptiles [1]. The so far determined vertebrate taxa indicate the Cromerian age of the assemblage, as stated by K. Kowalski (1975), who regarded it as Early Cromerian. However, the presence of *Pliomys lenki* (Heller), the species which appears in Middle Europe during the Günz/Mindel Interglacial, as well as the presence of *Dicrostonyx simplicior* Fejfar, the species which appears in Bohemia since the maximal phase of Mindel *I* (Elsterian *I*, Cracovian *I*, G II-1) Glaciation (Fejfar *in:* Bartolomei & al. 1975) seem to indicate the Late Cromerian.

It is generally understood that the Cromerian Interglacial was distinguished on geological and paleobotanical data, although for the Cromerian type locality in east England paleobotanical data are not complete (cf. West & Wilson 1966, Mitchell & al. 1973); stratigraphical investigations show that the so called "Cromerian complex" covers no less than

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1 This herpetofauna is recently elaborated by Professor M. Młynarski: "New notes on the Pliocene and Pleistocene herpetofauna of Poland" — *Acta Zool. Cracoviensia*, Vol. 22, Kraków 1977 (*in print*).

two cold phases and three warm phases (Hammen, Wijmstra & Zagwijn 1971). More complete sections in the Netherlands enabled to establish, by means of pollen analysis, three interglacials (Zagwijn, Montfrans & Zanstra 1971) between Menapian (Günz) and Elsterian (Mindel). Moreover, in the Cromer area mammal fauna is scarce and mixed [2]. For these reasons the correlation of any "Cromerian vertebrate fauna" with Cromerian type locality is doubtful.

The presence of *Lemmus, Dicrostonyx simplicior, Microtus* and *Pitymys gregaloides* in the investigated fauna is distinctive of cold steppe climate, whereas *Castor fiber, Clethrionomys* cf. *glareolus, Glis,* and snails are indicative of wet deciduous forests. The frequence of arvicolids in the successive layers (Table 1) leads to the conclusion that in layers *2a* and *2c* the forms of cold steppe, whereas in the layer *2b* the forest forms are more frequent. Such a differentiation of micromammal frequence indicates that the whole Unit *2* represents a warm phase antedating the maximal phase of the Mindel Glaciation, and layer *2b* corresponds to the climatic optimum of this phase.

Table 1

Frequency (in per cent of population) of Arvicolidae in layers *2a*, *2b* and *2c* at Kozi Grzbiet (*cf.* Text-fig. 3); based on data presented by K. Kowalski (1975)

Species	Layer 2a	Layer 2b	Layer 2c
Mimomys cf. *savini*	5.0	7.5	8.2
Clethrionomys cf. *glareolus*	41.3	36.1	20.1
Pliomys cf. *lenki*	1.4	1.5	—
Pliomys cf. *episcopalis*	7.8	2.3	3.5
Pitymys gregaloides	8.7	6.8	6.0
Pitymys arvaloides	5.5	1.5	1.9
Microtus ex gr. *oeconomus*	27.6	4.5	10.4
Microtus ex gr. *arvalis*	0.9	38.3	44.0
Lemmus sp.	0.9	0.8	3.1
Dicrostronyx simplicior	0.9	0.8	2.8
Number of specimens	218	133	318

CLIMATO-CHRONOSTRATIGRAPHY

It is widely accepted that the Quaternary may be subdivided by its climatic fluctuations (Różycki 1961, 1972; Mitchell & al. 1973). In general, such fluctuations are reflected by the nature of the deposits described here and, in Unit *2*, by the included animal remnants (*cf.* Table 1).

[2] See SUTCLIFFE A. J. & KOWALSKI K. — Pleistocene rodents of the British Isles: *Bull. Brit. Mus. (Nat. Hist.), Geol.*, Vol. 27, No. 2, 33—147, London 1976.

Against the unsatisfactory results of fluorine-apatite, chlorine-apatite and collagene methods used separately for determination of the absolute age of fossil bones, a complex method was proposed (Wysoczański-Minkowicz 1969) and applied to Pleistocene and Neogene bone materials from different karst localities with very promising results (Wysoczański-Minkowicz 1969; Różycki & Wysoczański 1969; Głazek, Sulimski & Wysoczański-Minkowicz 1976; Głazek, Lindner & Wysoczański-Minkowicz 1976; Głazek, Galewski & Wysoczański-Minkowicz 1976; Głazek, Sulimski, Szynkiewicz & Wysoczański-Minkowicz 1976). The methods were discussed in earlier papers (Wysoczański-Minkowicz 1969, Różycki & Wysoczański 1969); it was found that the fluorine and chlorine contents in fossil bones depend principally on paleohydrochemical environments and are generally reciprocal.

Values of the FCl/P age coefficient obtained for bones from localities with high content of $CaCO_3$ and low alcaline sedimentary environment (karst deposits) are lower than those from localities deprived of $CaCO_3$ and with acid environments (peat, fluviatile deposits, loess). Moreover, the values obtained for bones differ markedly from those obtained for teeth. During prolonged investigations and after improvements in measurements techniques, numerous values of this coefficient were obtained for samples taken from the Miocene up to Recent. These values for the bones from karst localities were plotted by Wysoczański-Minkowicz (1969, 1975) on a half-logarithmic diagram and as a result a curve illustrating the steady increase of the FCl/P coefficient with increasing age of the samples was obtained. This curve was correlated with geological and radiometric data and thus it enabled absolute age determination. The confidence limits of such age determination for Late Pleistocene bones is *c* 10 000 years (Różycki & Wysoczański 1969), while for Early Pleistocene it is c 100 000 years.

The age values as well as the initial chemical results, obtained for samples from the Kozi Grzbiet are given in Table 2. The age coefficient FCl/P ranges between 1.01 and 1.28 and points to the period between 700—550 · 10^3 years B.P. (Table 2).

The relation of the weight of mineral components of bones and the loss of weight during one hour burning in the temperature of *c* 800° C was determined as the collagene loss coefficient (Wysoczański-Minkowicz 1969). This coefficient is closely dependent on climatic conditions during the sedimentation. For bones of colder periods during Holocene and Pleistocene, these values range from 2.0 to 5.0. On the contrary, the bones coming from the warmer periods of these epochs have shown higher values from about 5.0 to 10.0. For older epochs (Pliocene and Miocene) this indicator is always higher than 8 and varies from c 8.5 in colder phases to *c* 16 in the warmest phases (Wysoczański-Minkowicz 1969; Głazek, Sulimski & Wysoczański-Minkowicz 1976; Głazek, Galewski & Wysoczański-Minkowicz 1976). This dependence clearly shows (Table 2) that bones taken from different places in the bone-bearing layers at Kozi Grzbiet (Fig. 4) point to different climatic phases during the deposition of these layers.

The collagene loss coefficient for samples from the Kozi Grzbiet ranges between 5.8—10.5 and it points to the interglacial climatic condition. Moreover, it is clearly visible (Table 2) that the bones taken from different places in the bone-bearing layers at Kozi Grzbiet (Fig. 4) point to several climatic phases during the deposition of the bone-bearing layers.

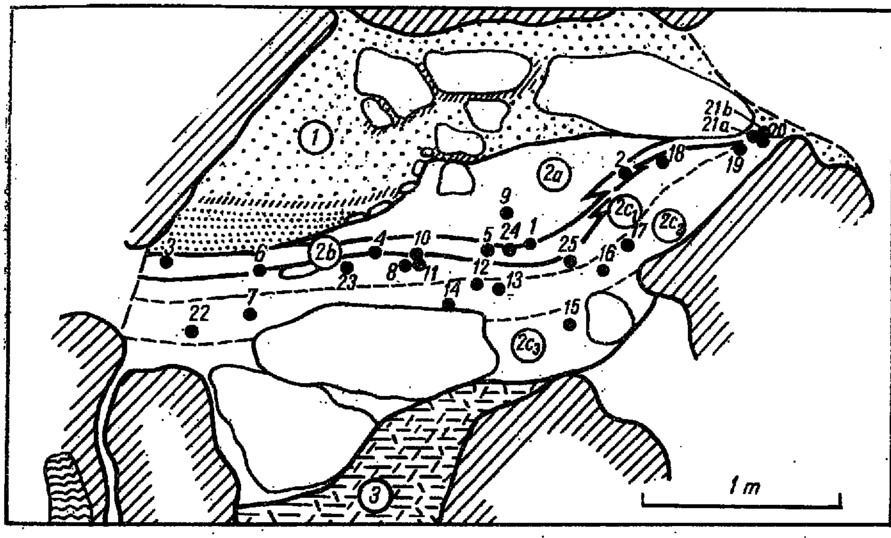


Fig. 4. Location of the analysed bone samples (*1–25*; *cf.* Text-fig. 3 and Table 2 circled are the numbers of distinguished layers

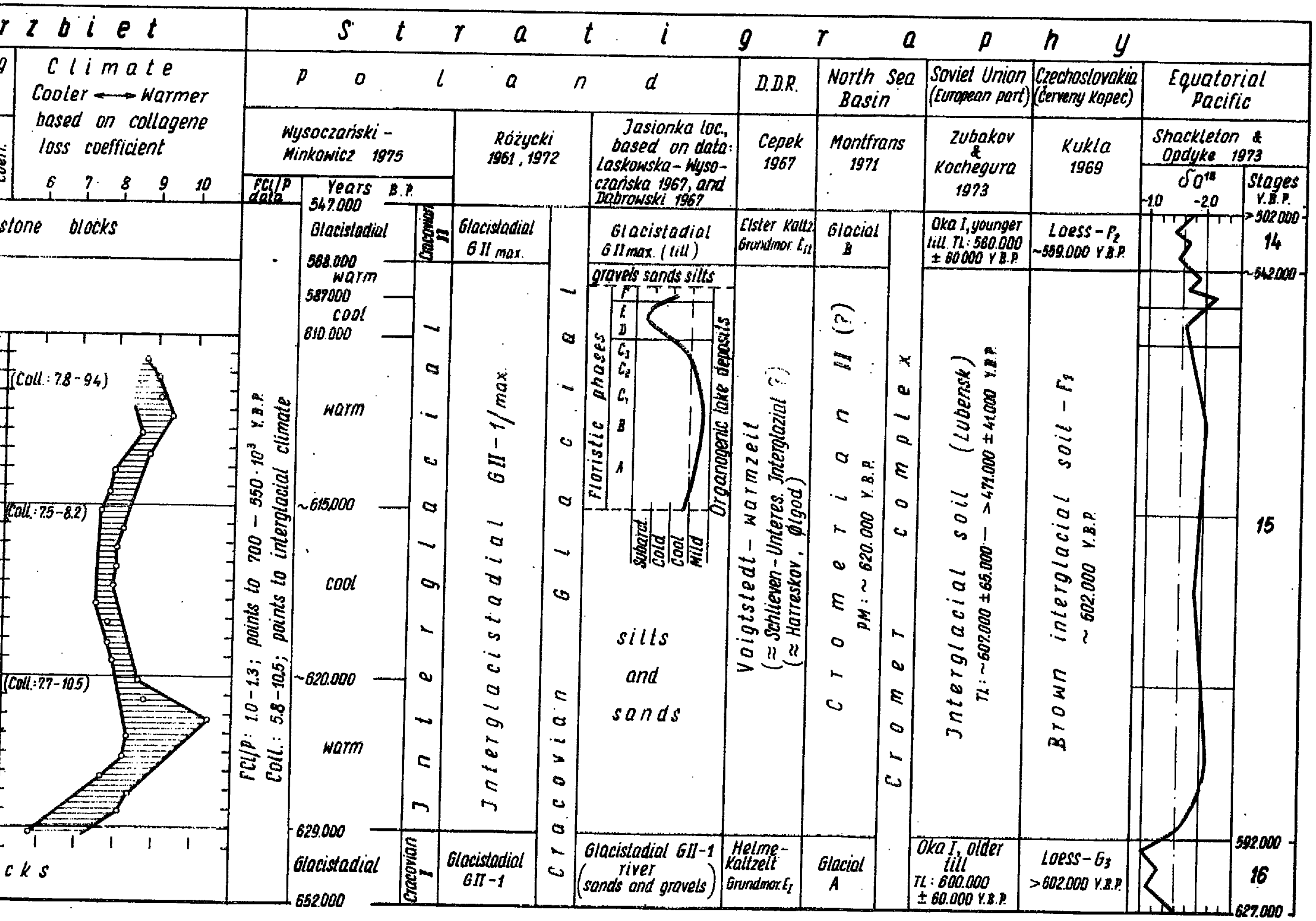
The collagene loss coefficient allows to distinguish 3 climatic phase during the sedimentation of the lower layer *2c* (cf. Table 2; extremel cold in the lower part (*2c₃* — sample *15*) passing upwards in to the war mer phase (*2c₂*) and cool phase (*2c₁*). Such climatic changes explain we the coexistence of forest and tundra inhabitants in this layer (*cf.* Table 1 layer *2b* represents the second warmer phase, and layer *2a* may corres pond to the beginning of a decline of the same warmer phase.

CORRELATION

The whole presented materials prove that the Kozi Grzbiet cave loams (Unit *2*) represent the warm interstadial between Pre-Maximal (G II-1) and Maximal Stadials (G II max.) of the Cracovian Glaciation (Różycki 1961, 1972). This interstadial was discovered in Poland in the Jasionka profile near Rzeszów (Laskowska-Wysoczańska 1967, Dąbrowski 1967). In the Holy Cross area, this interstadial separated the first invasion of the icesheet on the northern slope of this area (Fig. 5*A*) from the maximal phase of the Cracovian Glaciation (Fig. 5*B*). During the maximal phase the icesheet covered almost the whole area, with the exception of the topmost part of the hills forming the nunataks (Lindner & W. R. Kowalski 1974, Lindner 1977). Those nunataks were partly covered by the kame Miedzianka sands (Unit *1*).

According to collagene method two warmer phases (layers *2c₂* and *2b*) and three cooler phases (layers *2c₃*, *2c₁* and *2a*) were determined in Kozi Grzbiet loams. The palynologically studied borehole at Jasionka

The bone dating and climato-stratigraphic correlations of the bone-bearing deposits from Kozi Grzbiet



No. of layer (cf. Figs 3 and 4)	No. of bone sample (cf. Fig. 4)	Laboratory no. of sample	Weight %: F	Weight %: Cl	Weight %: P_2O_5	Age coefficients: $\frac{F}{P_2O_5}\times 100$	Age coefficients: $\frac{Cl}{P_2O_5}\times 1000$	Age coefficients: $\frac{F\times Cl}{(P_2O_5)^2}\times 10^5$	Burning loss 800°C: Weight %	Burning loss 800°C: Collagene coeff.
1	Glacifluvial sands with limestone blocks									
1/2a	Erosion									
2a										
2b	9	420P	0.80	0.021	37.9	2.11	0.55	1.16	10.3	8.7
	5	403P	0.84	0.021	38.0	2.21	0.55	1.27	10.0	9.0
	1	399P	0.76	0.021	38.6	1.97	0.54	1.08	9.9	9.1
	24	421P							9.6	9.4
	3	401P							10.4	8.6
	4	402P							10.2	8.8
	2	400P							11.2	7.9
	6	404P							11.4	7.8
$2c_1$	10	407P	0.66	0.021	37.0	1.78	0.57	1.01	11.6	7.6
	11	408P							11.4	8.2
	8	406P							11.1	8.0
	18	415P							11.1	8.0
	23	423P							11.2	7.9
	20	417P							11.8	7.5
	25	424P							11.3	7.8
	21a	418P							11.3	7.8
	21b	419P							11.2	7.9
$2c_2$	12	409P							10.4	8.6
	14	416P							10.2	8.8
	17	414P							8.7	10.5
	13	410P	0.85	0.021	37.3	2.28	0.56	1.28	10.6	8.3
	16	413P							10.9	8.2
	7	405P							11.8	7.7
	14	411P							10.6	8.4
	22	422P							11.0	8.1
$2c_3$	15	412P	0.49	0.021	31.2	1.57	0.67	1.05	14.3	5.8
	Limestone blocks									
	Erosion									

revealed, under the Cracovian till (G II max.), river deposits with oxbow--lake organogenic intercalation (Laskowska-Wysoczańska 1967). In this organogenic deposits six phases of vegetation development were described (Dąbrowski 1967) which represent one sequence starting from boreal pine forest (phase *A*) through deciduous forest (phases *B* and C_1), mixed-forest (phases C_2 and C_3) to boreal forest (phase *D*) and tundra peat (phase *E*) replaced before sedimentation of glacifluvial sands and gravels by a boreal forest (phase *F*). The whole section of Jasionka may be correlated with a part of the Kozi Grzbiet sequence, viz. with the younger warm phase (Table 2). Such correlation postulates that at Kozi Grzbiet a more complete section of the "Jasionka Interstadial" occurs than in its type locality.

This "interstadial" was correlated by Dąbrowski (1967) with Ølgod *I* Interglacial in Denmark. Moreover, this "Interstadial" may be correlated with Harreeskovian in Denmark, Voigtsted-Warmzeit or „Schlieven unteres Interglazial?", which occurs between Elster *I* Grundmoränen and Elster *II* Grundmoränen (Cepek 1967). In the Netherlands it seems probable that the Jasionka — Kozi Grzbiet "Interstadial" has an equivalent

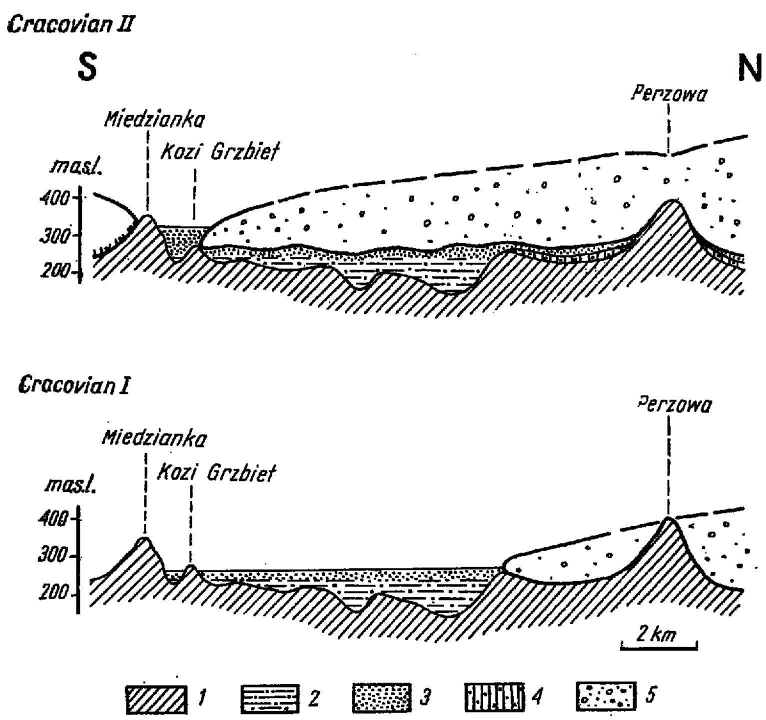


Fig. 5. Interpretation of sedimentary conditions during the Cracovian (Mindel) Glaciations in the area studied (*cf.* Text-fig. 1, and Lindner 1977)

1 pre-Quaternary substrate, *2* older Quaternary deposits, *3* glacifluvial deposits, *4* tills, *5* ice-sheet in Cromerian *II* between Glacial *A* and Glacial *B* (Montfrans 1971), named Westerhoven Interglacial (Hammen & al. 1971). As an equivalent in Czechoslovakia may be treated the "soil F_1" from the Cervený kopec (Kukla *in:* Demek & Kukla 1969). In the USSR, the equivalent of Jasionka — Kozi Grzbiet "Interstadial" may occur in the Lubensk fossil soil which corresponds to the warm phase between the older and younger Oka *I* Till (Zubakov & Kochegura 1973). All these correlations are compiled in Table 2. Moreover, analogous climatic changes were also recognized in deep sea cores (*e.g.* Shackleton & Opdyke 1973; *cf.* Table 2). All these correlations are based on geological and indirect palynological data, whereas direct paleozoological correlation is possible only with separate localities, usually representing a single necrocoenose.

The presence of *Mimomys savini* Hinton with *Microtus* and *Pitymys* indicates the Upper Zone (C) or "Niveau chronologique des Valerots" (Chaline & Michaux 1974). Among numerous karst localities in the Federal Republic of Germany comparable in age are certainly the localities Erpfingen *1* and *3*, Sudmer-Berg *2*, Voigtstedt and Süssenborn (*cf.* Koenigswald & Fejfar *in:* Bartolomei & al. 1975). Interesting analogies may be pointed to the excellently studied profiles in Czechoslovakia of Cave *C 718* near Koneprusy where the layers *E1-H8* may directly correspond to layers *2a-2c*, at Kozi Grzbiet and of Southern Chimeny at Zlaty Kun near Koneprusy (Fejfar 1961, *in:* Bartolomei & al. 1975); it should be stressed that Fejfar classified these fauna as interglacial. In Hungary, a similar locality is that at Tarkö rock-shelter (Janossy *in:* Bartolomei & al. 1975), and in the Younger Biharian localities (*cf.* Kretzoi 1961, Janossy 1972).

The locality Kozi Grzbiet seems in general to be a little younger than the older zones of "Niveau Valerots" (*cf.* Chaline & Michaux 1974), as well as Sackdilling in FRG (*cf.* Koenigswald *in:* Bartolomei & al. 1975), Gombasek and Plesivec in Czechoslovakia (*cf.* Fejfar 1961), Kadzielnia and Kamyk in Poland (*cf.* K. Kowalski 1964, 1975, *in:* Bartolomei & al. 1975).

Absolute age determination of Older Pleistocene deposits is very difficult. Outside the ^{14}C dating range, the most reliably dated material of Middle and Lower Pleistocene age is probably the K/Ar dating of volcanic rocks. But such data are scarce and poorly correlated with a more refined "climatic" chronostratigraphy based on the succession of cool or cold and warmer periods, as reflected by the changing vegetation and faunal associations, lithology of sediments and oxygen isotope temperatures. "Climatic" chronostratigraphy may also be correlated with paleomagnetic reversals and thus with "standard magnetic time scale" (*PM* in Table 2). Another method of "absolute age determination" was proposed on the thermoluminescence of continental sediments (*TL* in Table 2). All these methods have relatively wide confidence limits, and the proposed "absolute age" for these same "climatic" chronostratigraphic unit based on different data differ markedly (*cf.* Table 2). The third of the authors has attempted to correlate the climatic succession with different "absolute age" determinations for the Quaternary (Wysoczański-Minkowicz 1975); a fragment of this attempt is here presented (Table 2).

FEATURES OF CAENOZOIC KARST IN THE HOLY CROSS MTS

In the Holy Cross area, the last subaerial karstification period started after the Laramian uplift of the region (Kutek & Głazek 1972). This period, commenced of the Late Maastrichtian and still lasting has given numerous karst forms with complicated evolution. Precise dating of these karst forms is difficult due to the lack of biostratigraphical data. But generally, most of preserved karst forms were formed and filled during the Late Tertiary and Quaternary (Głazek & Markowicz-Łohinowicz 1973), after a removal of c 3 km thick Zechstein-Mesozoic sediments during the Paleogene (*cf.* Kutek & Głazek 1972). This is confirmed by the arrangement of well dated karst forms in the whole territory of Poland (*cf.* Gradziński & Wójcik 1966; Głazek, Dąbrowski & Gradziński 1972; Głazek 1973), as well as paleontological localities in karst forms of the Holy Cross Mts known up to now (*cf.* Fig. 1) which contain Pleistocene fossils only.

The oldest karst deposits at Kozi Grzbiet (Units *3*—*5*) reveal no fossils, with the exception of those redeposited from older weathered rocks. Such deposits were found at Kozi Grzbiet in boreholes up to the level of 247 m a.s.l. (*cf.* Fig. 2). The level of karst caves was controlled by valleys at the corresponding height. The valleys were deepened c 20 m during the Latest Tertiary and Early Quaternary, before the Cracovian Glaciation (*cf.* Lindner & W. R. Kowalski 1974). The period of valleys deepening may be responsible for the disturbances observed in Units *3*—*5*.

At Kadzielnia Hill in Kielce, K. Kowalski (1958) described a mammal fauna of Early Pleistocene age (probably Günz/Mindel Interglacial). As the Kadzielnia fauna was found in the bone-bearing layer of reddish clay with high content of calcium carbonate (K. Kowalski 1958), it is clear that this clay is evidently different from the bone-bearing loams at Kozi Grzbiet (Unit *2*), as well as from Units *3*—*5* in this locality. The fauna of Kadzielnia is evidently older than that of Kozi Grzbiet (K. Kowalski 1975) and thus it may correspond to the hiatus between Unit *3* and the Kozi Grzbiet cave loams (Unit *2*). Similar in age to the fauna of Kadzielnia may be that one found in red clays at Jaworznia (*cf.* Fig. 1) by Professor K. Kermack (*cf.* Wódkowski 1971), whereas other fauna found in karst of the Holy Cross area (*cf.* Fig. 1: Sitkówka — Czarnocki 1935; Raj Cave —

K. Kowalski 1972, 1974) are evidently younger than that of Kozi Grzbiet. It is also clear that the red loams have been deposited before the Mindel *I* (Elsterian *I*, G II-1) Glacial, while the brown cave loams were deposited since the "Interstadial" between Mindel *I* and Mindel *II* glacials.

FINAL REMARKS

The fossil karst at Kozi Grzbiet in the Holy Cross Mts contains very rich fauna of Cromerian character which was deposited between the Cracovian *I* (Mindel *I*, Elsterian *I*, G II-1) and Cracovian *II* (Mindel *II*, Elsterian *II*, G II max.) Glaciations. It appears to be the first karst locality with rich mammal fauna in Europe correlatable with glacial events of Early Pleistocene, as the Bohemian localities were correlated with loess, while tills were encountered some tens of kilometers northward from the bone-bearing caves near Koneprusy. The Cromerian character of this fauna evidenced that even north of the Carpathians a fundamental turn in the history of the Middle European fauna of mammals was connected with the younger maximal glaciation named Cracovian *II* (G II max., Elsterian *II*, Mindel *II*).

Generally, it seems that the reddish cave loams in Poland are older than the "Interstadial" between Cracovian *I* (Mindel *I*, Elsterian *I*, G II-1) and Cracovian *II* (Mindel *II*, Elsterian *II*, G II max.) and in consequence also older than Mindel *I* Glaciation, because ever since the Kozi Grzbiet — Jasionka "Interstadial" all mammal faunae in karst localities have occurred in brown cave loams.

Moreover, if between Cracovian *I* and Cracovian *II* "stadials" there was a true interglacial period, then these "stadials" must be regarded as separate glaciations; this conclusion agrees with that of Hammen & al. (1971) and Fejfar (*in*: Bartolomei & al. 1975). If the *Jasionka — Kozi Grzbiet Interglacial* had been a long lasting period of erosion, this explains why the traces of Cracovian *I* (G II-1) tills are so poorely preserved and may be confused with also very poorely preserved Günz (G I, Podlasian) tills.

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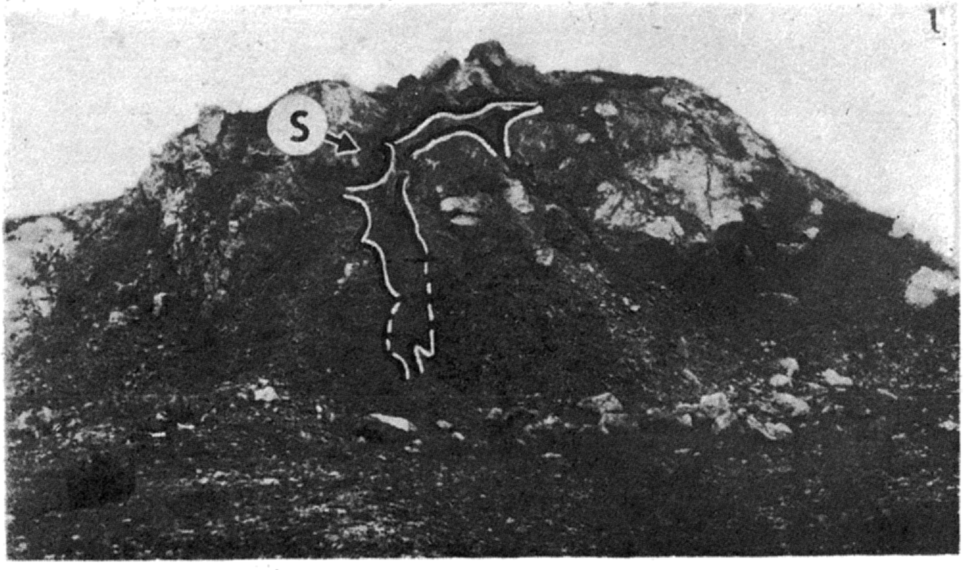
INTERGLACJAŁ MINDEL I/MINDEL II W STANOWISKU KRASOWYM NA KOZIM GRZBIECIE W GÓRACH ŚWIĘTOKRZYSKICH

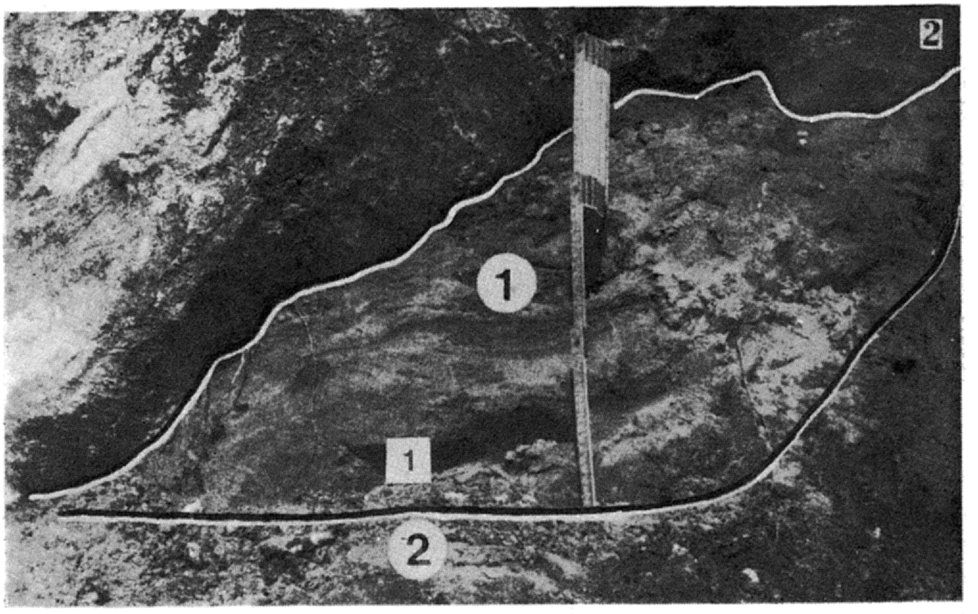
(Streszczenie)

Przedmiotem pracy jest analiza osadów wypełniających fragment zniszczonej jaskini w wapieniach dewońskich na Kozim Grzbiecie koło Chęcin (*por.* fig. 1—3, pl. 1 i 2). Na żółtych iłach rezidualnych leżą tutaj czerwone piaski i iły stanowiące redeponowaną zwietrzelinę pstrego piaskowca, którego osady pierwotnie przykrywały wapienie dewońskie. Górna część tych osadów jest przerobiona przez procesy peryglacjalne i przykryta brązowymi glinami jaskiniowymi zawierającymi materiał pochodzący z najstarszych osadów lodowcowych zlodowacenia krakowskiego *I* (Mindel *I*, Elsterian *I*, G II-1). Na zerodowanej powierzchni tych glin leżą piaski fluwioglacjalne młodszej części zlodowacenia krakowskiego (Mindel *II*, Elsterian *II*, G II max.).

Bogata fauna kręgowców i ślimaków, zawierająca m.in. *Mimomys savini*, *Pliomys lenki*, *Dicrostonyx simplicior*, *Lemnus* sp., *Ursus deningeri* i *Helicigona banatica*, wskazuje na kilka faz klimatycznych w czasie osadzania glin jaskiniowych (*por.* tab. 1—2 i fig. 4) oraz na interglacjalne warunki klimatyczne (*por.* Black & K. Kowalski 1974, K. Kowalski 1975, K. Kowalski *in* Bartolomei & al. 1975). Przedstawiono wyniki datowania kości metodą fluoro-chloro-apatytową i kolagenową (*por.* Wysoczański-Minkowicz 1969) oraz przeprowadzono korelacje stratygraficzne (tab. 2).

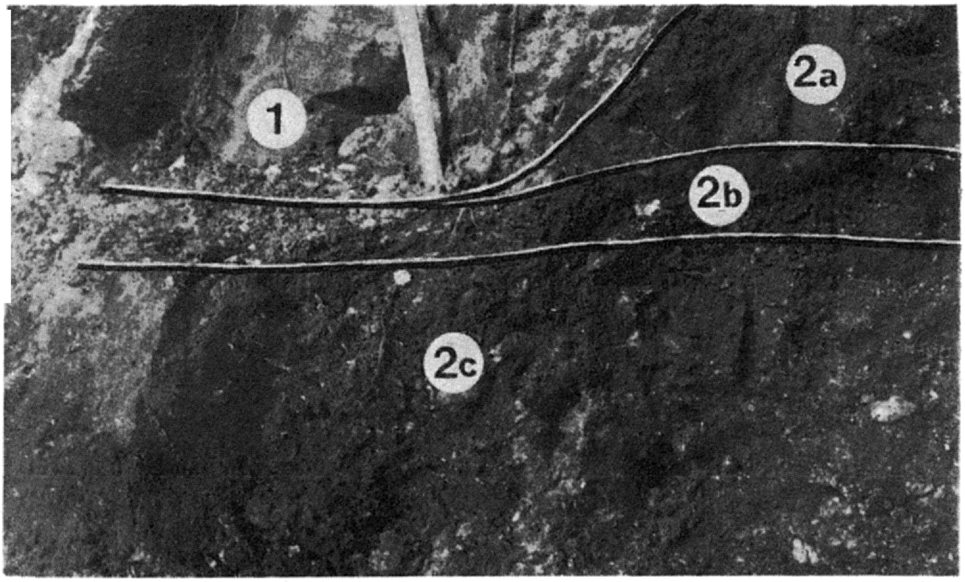
Obecność serii interglacjalnej pomiędzy najstarszym nasunięciem lądolodu zlodowacenia krakowskiego (Cracovian *I*, G II-1) na północny skłon Gór Świętokrzyskich (Lindner & W. R. Kowalski 1974, Lindner 1977) a maksymalnym stadium tego zlodowacenia (Cracovian *II*, G II max.) dowodzi, że są to dwa odrębne zlodowacenia (fig. 5), a nie stadiały. Zlodowacenia te odpowiadają zlodowaceniom Mindel *I* (Elsterian *I*) i Mindel *II* (Elsterian *II*), zaś rozdzielający je interglacjał, poprzednio stwierdzony w Jasionce koło Rzeszowa (Dąbrowski 1967, Laskowska-Wysoczańska 1967) odpowiada interglacjalnym profilom Voigtstedt, Harreskov i Ølgod.

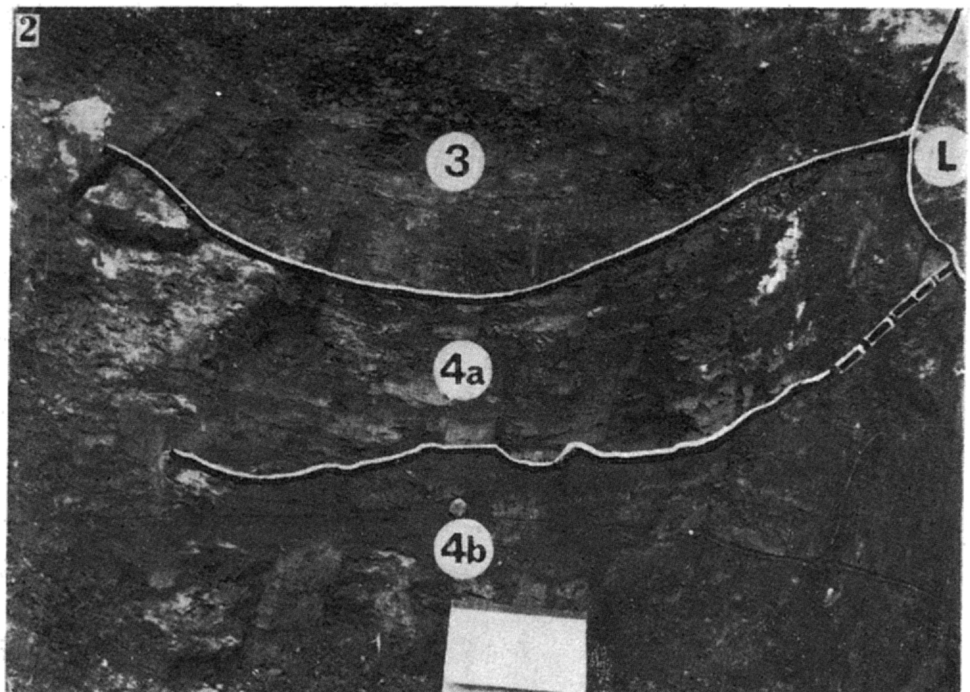




1 — Investigated karst structure in the northern wall of the quarry at Kozi Grzbiet; position of the stalagmite (*s*) is marked.

2 — Glacifluvial sands of Unit *1* (squared is the place where sample *1* was taken, *cf.* Text-fig. 3), and the underlying bone-bearing Unit *2* (*cf.* Pl. 2, Fig. 1).





1 — Bone-bearing cave loams of Unit *2*; successive layers (*2a*, *2b*, *2c* are marked; *cf.* Text-fig. 3).

2 — Cherry-red clays and sands of Units *3* and *4* (*cf.* Text-fig. 3; note brecciation of clays in the upper part of Unit *3*); *L* — limestone wall of the cave.