Acta Geologica Polonica, Vol. 52 (2002), No. 1, pp. 97-110

Geological value of Biśnik Cave sediments (Cracow-Częstochowa Upland).

JOANNA MIROSŁAW-GRABOWSKA

Institute of Geological Sciences Polish Academy of Sciences, ul. Twarda 51/55, PL-00-818 Warsaw, Poland.
E-mail: jmirosla@twarda.pan.pl

ABSTRACT:

MIROSŁAW-GRABOWSKA, J. 2002. Geological value of Biśnik Cave sediments (Cracow-Częstochowa Upland). *Acta Geologica Polonica*, **52** (1), 97-110. Warszawa.

The Biśnik Cave is located near the town of Pilica in the central part of the Smoleń-Niegowonice Range (Cracow-Częstochowa Upland). During archaeological excavations a section of clastic sediments above 7 m thick was exposed. Based on sedimentological, mineralogical and archaeological data, the lithology and stratigraphy of the deposits were documented. Series I (layers 18-8) accumulated in a dry cave environment in the Tertiary (layer 18), during the Middle Polish Glaciation (layers 17-14), the Eemian Interglacial (layers 13-12) and in the older part of the Vistulian (layers 11-8). Series II (layers 7-5) reflects accumulation under fluvial conditions during the Middle Vistulian. Series III (layers 4-2) consists of aeolian deposits accumulated during the Upper Vistulian. The humus layers (layers 1b-1a) were formed during the Holocene. The composition of the rich palaeontological material was used for reconstruction of the natural environment and the climatic conditions during the accumulation of the sediments. The existence of forest is documented during the time of the accumulation of layers 15, 13, 12. The presence of aquatic species of fauna testifies to the existence of a small river in the neighbourhood of the cave (e.g. layers 11, 6-7). The high proportion of remains of steppe-tundra fauna indicates a periglacial environment (e.g. layers 14, 8, 2). The results of the investigations of the Biśnik Cave sediments helped in reconstructing the evolution of the relief of the surrounding area.

Key words: Cave sediments, Cracow-Częstochowa Upland, Quaternary.

INTRODUCTION

The Smoleń-Niegowonice Range (Cracow-Częstochowa Upland) is built up of Upper Jurassic limestone covered by Quaternary, mainly Pleistocene sediments. The peaks reaching 494 m above sea level (m.a.s.l.), are formed by massive Oxfordian limestone. The relief forms and the Quaternary deposits covering the Smoleń-Niegowonice Range were investigated. Several genetic types of Quaternary sediments, preserved as remnants only, were distinguished: weathering loams, glacifluvial sands, lacustrine sands and silts, loess, aeolian sands, fluvial sands and silts (MIROSŁAW-GRABOWSKA 1998).

Several caves filled with sediments were found in the hills of the Smoleń-Niegowonice Range, for example the Biśnik Cave, located near the town of Pilica in the central part of this area (Text-fig. 1). The cave sediments reflect climatic changes, as well as geological and geomorphological processes outside and inside the cave.

The sediments of the Biśnik Cave contain both archaeological and palaeontological material. The investigations of these sediments enabled their stratigraphy to be established and helped in the interpretation of the Quaternary deposits accumulated outside the cave. Analyses of the fossil faunas (mainly bones of vertebrates) in the various layers of the cave sediments allowed reconstruction of the changes in environment and the climatic conditions in surrounding area.

LOCATION AND DESCRIPTION OF THE CAVE

The Biśnik Cave is situated in the western slope of the Biśnik Klippe (405 m a.s.l.) on the left side of a dry valley (Wodąca) – Text-fig. 1. Weathering loams are preserved at the bottom of this valley. The slopes of the surrounding hills are covered by loess. A fragment of lacustrine terrace was documented in the central part of the valley in front of the Biśnik Klippe.

The Biśnik Cave has two NW-facing entrances, situated at 395 m a.s.l. and about 5 m above the valley bottom. The cave is above 73 m long and consists of a rock-shelter and a cave proper connected with it (Text-fig. 2). The rock-shelter has an approximately rectangular shape, about 5 m x 8 m in dimensions, and is shielded on three sides by rocky walls. The cave proper consists of three chambers, each about a dozen or so square metres in plan. Before the excava-

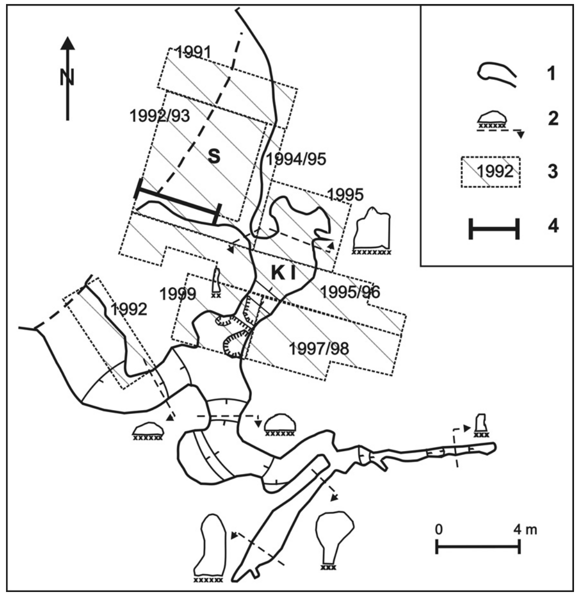

Fig. 2. Plan of the Biśnik Cave *after* A. POLONIUS 1991. 1 – cave walls at the surface of the sediments prior to excavations; 2 – cross-sections of the cave; 3 – exploration trenches in particular years; 4 – section described in text; S – rock-shelter; KI – the first chamber of the cave

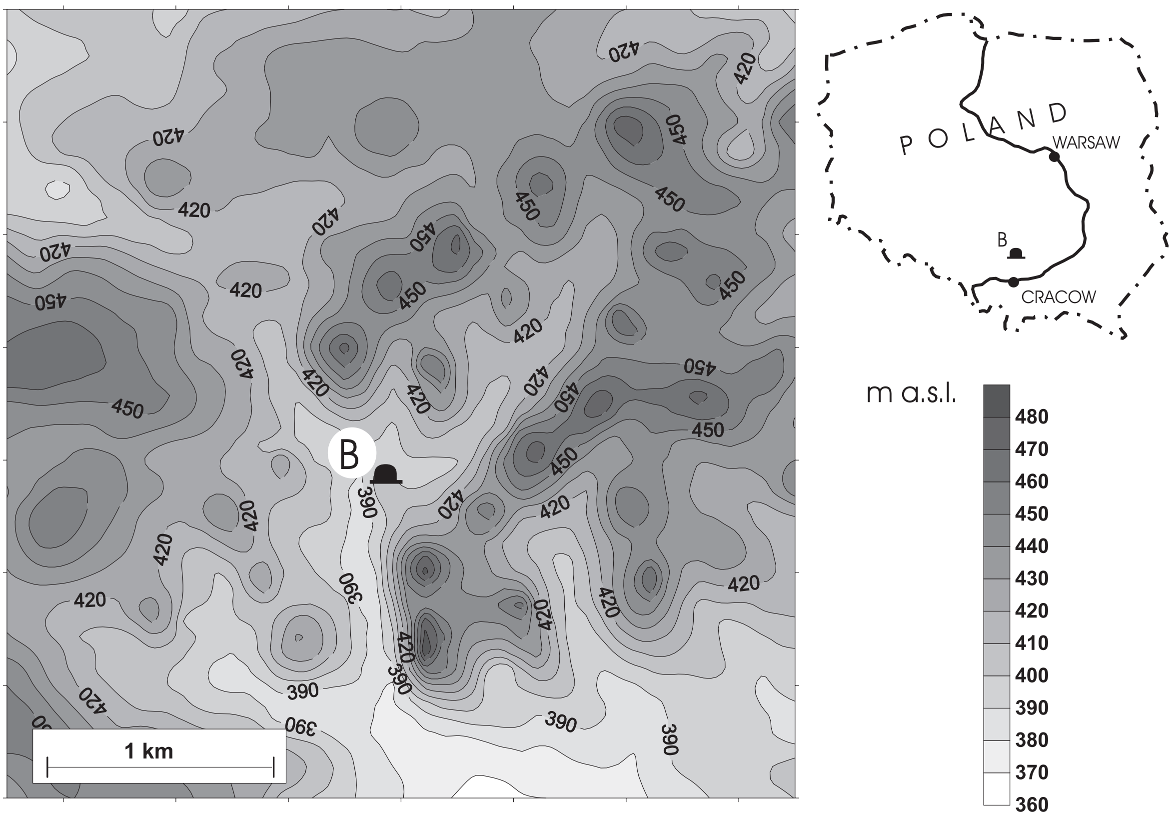

Fig. 1. Location of the Biśnik Cave. B – Biśnik Cave

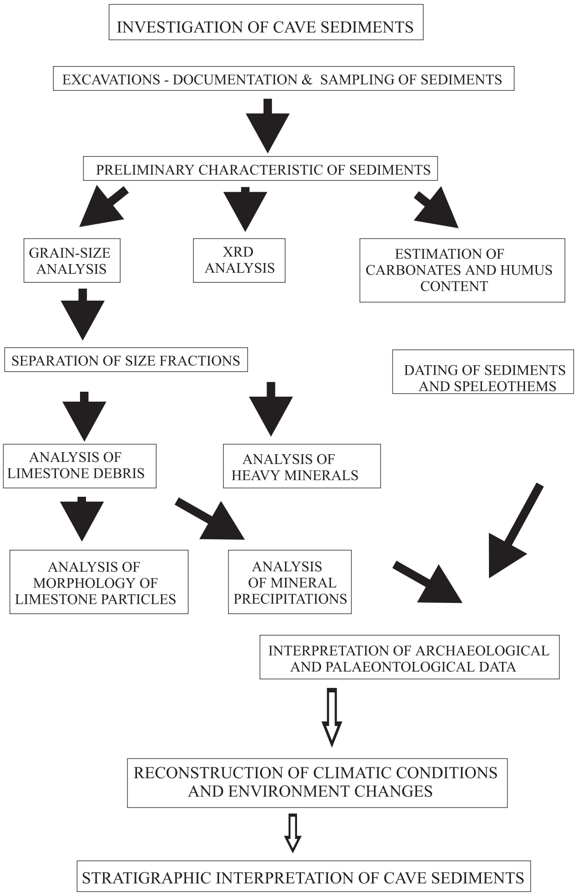

Fig. 3. Scheme of cave sediment investigations

tions, the entry to the first chamber was a narrow, spindle-shaped opening. During the excavations a main bigger opening was exposed. Text-fig. 2 shows a sketch map of the cave made in 1991, before the excavations. The outlines of the walls were drawn on the surface of the sediments. During the excavations, a lot of deposits were removed from an area of about 154 m^2. The cave turned out to be bigger and deeper than was previously imagined.

In 1991 interesting Neolithic and Palaeolithic flint tools were found in the shelter. Krzysztof CYREK started systematic archaeological excavations in 1992. The excavations were conducted with the support of the Silesian Jurassic Landscape Parks Complex in 1992-96 and with the support of the State Committee for Scientific Research project (KBN 1HO 1G 01613) in 1997-2000. The author of this paper has participated in these investigations analysing the cave sediments since 1994 (researches financed also by the Institute of Geological Sciences of the Polish Academy of Sciences).

METHODS OF INVESTIGATION OF CAVE SEDIMENTS

Particular stages of investigations of cave sediments are shown on Text-fig. 3. During the excavations, the exposed sections of sediments were described, drawn and photographed. Several samples of sediments from each layer and series were collected. The grain-size composition of the sediments was analysed by the author using the combined sieve (1.0-0.063 mm fraction) and areometric (below 0.063 mm fraction) methods. The contents of carbonates and humus in the fine (<1 mm) fraction were estimated using volumetric analysis by A. MULCZYK. The humus content was determined by means of the Tiurin method. The heavy mineral composition was identified under the polarizing microscope by R. MICHNIAK. More than 300 grains in the 0.25-0.1 mm fraction of each sample were analysed. Identification of the mineral composition of clay was carried out using the X-ray diffraction (XRD) method by M. KUŹNIARSKI.

The investigation of the limestone debris comprised determination of the morphology of the particles and analyses of the mineral precipitations on their surfaces. The limestone debris resulted from the disintegration of the cave walls and roof. Previously angular limestone particles accumulated on the surface of the sediments at the bottom of the cave. Chemical processes rounded them during warmer periods. The particles were subsequently covered by loam, clays, silts or sands to form the layer of cave sediments. Consequently the particles are older than the fine material. The morphology of the limestone particles in the >10 mm fraction was analysed by the author. The following types of particles were distinguished: particles with even surfaces (angular particles, slightly rounded particles and rounded particles) and particles with pit-like hollows on the surfaces. Predominance of angular particles in a layer testifies to cold climate conditions during the accumulation of the sediments (MADEYSKA-NIKLEWSKA 1969, 1971). The roundness of the particles and the presence of secondary mineral precipitations reflect the chemical weathering connected with warmer and wet climates. The identification of the secondary mineral precipitations was undertaken by the author under the scanning electron microscope (SEM).

The archaeological assemblages were studied by K. CYREK. The faunal remains were collected during the excavations (larger fragments) and by washing the sediments through a sieve (smaller fragments). The identification of the palaeontological material was carried out by the team of zoologists from the Zoological Institute of the University of Wrocław: T.

WISZNIOWSKA, P. SOCHA, K. STEFANIAK. The author of this paper compared the data, distinguishing the following ecological groups of vertebrates: steppe-tundra fauna, eurytopic fauna, forest fauna and domesticated fauna. The comparison includes only the quantity of bones of particular ecological groups of each layer. The bones of the Biśnik Cave sediments were used for testing the model of U-series dating (HERCMAN & GÓRKA 2000). The preliminary results enable the distinction of the Vistulian bones from older bones.

CHARACTERISTICS OF THE BIŚNIK CAVE SEDIMENTS

A section of sediments more than 7 m thick was exposed. The succession consists of three main series of deposits comprising 18 layers (Text-fig. 4). The layers differ in colour, grain-size composition, amount and weathering degree of limestone rubble, heavy mineral composition, content of carbonates and humus. Some of them contained very interesting archaeological and palaeontological assemblages. Three main series of sediments, differing in their genesis and processes of accumulation were distinguished (MIROSŁAW-GRABOWSKA 1995, MIROSŁAW-GRABOWSKA & *al*. 1995, CYREK & *al*. 1999).

The lowest series (Series I) consists of layers 8-18 and represents accumulation in a typical dry cave environment, with limited fluctuation of temperature and humidity. The sediments comprise autochthonous limestone rubble with loam and allochthonous sands with silts.

Layer 18 consists of red or red-brown residual clays of terra rossa-type. The fine fraction (<1 mm) consists of about 36% clay (< 0.002 mm), 55% silt (0.063 – 0.002 mm) and 9% sand (1.0 - 0.063 mm). The clay fraction can reach 77%. The content of carbonates is 24% and the humus content is only just 0.2% (Text-fig. 4). The amount of limestone rubble reaches 35%. Slightly rounded particles predominate over angular ones (Text-fig. 4). Orange ferriferous precipitations are

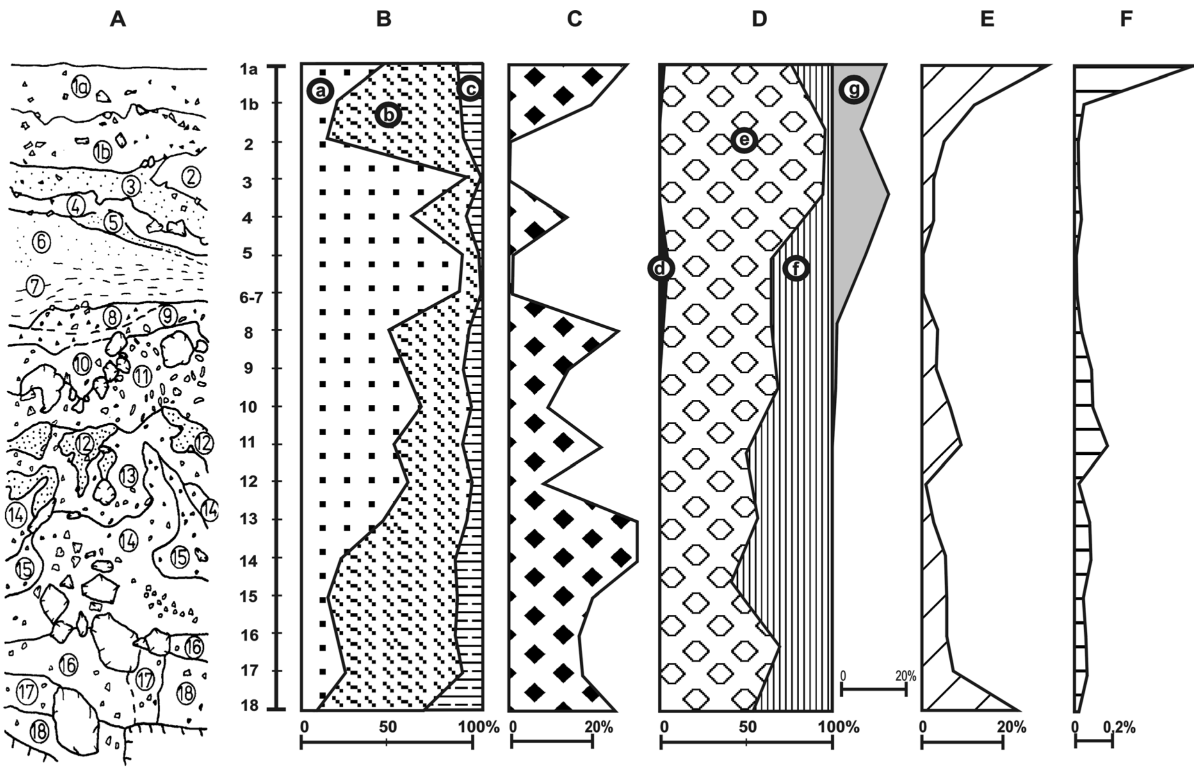

Fig. 4. The results of analyses of Biśnik Cave. A – fragment of profile of Biśnik Cave sediments (location on Fig. 2): 1a-18 – numbers of the layers of sediments; B – grain-size composition of fine fraction (< 1mm): a – sand (1.0-0.063 mm), b – silt (0.063-0.002 mm), c – clay (<0.002 mm); C – content of limestone rubble in whole sample; D – morphology of limestone debris in fraction > 10 mm: limestone particles with even surfaces: d – rounded, e – slightly rounded, f – angular; g – limestone particles with pit-like hollows; E – content of carbonates in fine fraction (< 1 mm); F - humus content in fine fraction (< 1 mm)

visible on the surfaces of all of the particles. The heavy mineral composition is very homogeneous (Text-fig. 5). Except for vestigial amounts of tourmaline (0.16%) and zircon (0.08%) only authigenic minerals - angular fragments of ferriferous crustifications are present (91%). The remaining components of the heavy mineral fraction are siderite (about 4%) and phosphate-apatite (5%). The phosphate-apatite mineral are osseous fragments (osseous pelite) characterized by visible organic structure. XRD analysis of the clay fraction proved the presence of kaolinite, illite and goethite, which are typical of weathering clays accumulated during the Pliocene (BEDNAREK & LISZKOWSKI 1982)

Layers 17-16 form continuous about 2 m thick, consisting of green-brown and green-grey silty loams. The fine fraction (< 1mm) consists of 13-17% clay, 61-63% silt and 20-26% sand. The content of carbonates is 6.5-8.0% and the humus content is 0.6-0.8% (Text-fig. 4). The amount of limestone rubble reaches 37%. At first slightly rounded particles predominate over the angular ones and then angular particles predominate (Text-fig. 4). Green-yellow precipitations of phosphates and black manganese oxides are visible on the surfaces of all of the particles. The heavy mineral composition differs from that of layer 18 (Text-fig. 5). In layers 17-16 the authigenic phosphate minerals prevail (> 90%). In layer 17 the content of ferriferous minerals is insignificant (3%). In addition to the authigenic minerals, the following resistant minerals are present: rutile (0.5-0.6%), tourmaline (1-2%), zircon (0.3-1%), kyanite (0.4-0.5%), medium resistant minerals: garnets (about 1%) and epidotes (0.7-0.9%) also appear. Such a heavy mineral composition, except for the authigenic minerals, is noted in the residue of Cretaceous rocks (KRYSOWSKA-IWASZKIEWICZ 1974). XRD analysis proved the presence of kaolinite and illite in the clay fraction of layer 17. In layer 16 smectite additionally occurs. Such a composition of the clay minerals suggests that they formed under colder climate conditions than those of the sediments of layer 18.

Palaeontological material, including bones of vertebrates, was found in these layers. Identification of the bones, partly even to species, helped the author to reconstruct the environment in which the animals lived, and thereby the conditions under which the sediments were formed (Text-fig. 6). The remains of steppe-tundra species comprise 9-15% of the fauna (*Rangifer tarandus, Coelodonta antiquitatis, Bison priscus, Equus caballus, Megaloceros giganteus*). The eurytopic faunal element amounts to 78-85% (*Ursus spelaeus* 53-60%, *Crocuta crocuta spelaea, Vulpes vulpes* and other Carnivora) and the forest fauna 6-7% (*Capreolus capreolus, Cervus elaphus, Alces alces*). The faunal composition suggests an environment of open spaces, as well as taiga and deciduous forests in places.

The oldest archaeological assemblages appear in the upper part of layer 17. The flint artifacts, constituting culture horizon A6 (Text-fig. 7) have features of the Middle Palaeolithic Acheulian-type culture (CYREK 1997). They represent the oldest trace of human settlement in Polish caves (CYREK 2000 – personal communication, MADEYSKA & CYREK 2002). Analogous assemblages were found in layer 16, constituting culture horizon A5 (Text-fig. 7).

Layer 15 consists of yellow-brown silty loams, in places orange-brown. The sediments form a continuous layer about 1 m thick. In the fine fraction (< 1mm) the silt (68%) dominates over clay (16%) and sand (16%). The content of carbonates is about 6% and the humus content is about 0.4% (Text-fig. 4). The amount of limestone rubble increases to 43%. Slightly rounded particles predominate over angular ones (Text-fig. 4). The surfaces of the particles are covered by secondary green-yellow precipitations of phosphates, black manganese oxides and ferriferous compounds. The heavy mineral composition differs diametrically from those of layers 16-17 (Text-fig. 5). Layer 15 consists of only 30% of authigenic phosphate minerals. About 17 % of the heavy fraction consists of the resistant minerals: rutile (2%), tourmaline (3%), zircon (4%), kyanite (1%), staurolite; and 50% consists of medium resistant minerals: garnets (32%) and epidotes (18%). The garnet grains differ in appearance from those from older layers. They are colourless and slightly rounded. Such a heavy mineral composition, dominated by garnets and epidotes together with small quantities of rutile, tourmaline, zircon and kyanite, is typical of glacial-derived sediments (KRYSOWSKA-IWASZKIEWICZ 1974, RACINOWSKI 1995). XRD analysis of the clay fraction proved the presence of kaolinite, illite and smectite.

The flint and bone tools, culture horizon A4 (Text-fig. 7), were identified as assemblages of Middle Palaeolithic, Acheulian-type culture (CYREK 1994, 1997). The fauna of layer 15 consists of 15% remains of steppe-tundra species mainly *Rangifer tarandus, Bison priscus* and *Equus caballus* (Text-fig. 6). The eurytopic elements of the fauna comprise 74% (*Ursus spelaeus* 65%, *Canis lupus, Vulpes vulpes* and other Carnivora and *Arvicola terrestris, Microtus oeconomus*) and the forest element about 7% (*Capreolus capreolus, Cervus elaphus, Sus scrofa, Apodemus sylvaticus, Clethrionomys glareolus*). The fauna composition suggests that these deposits accumulated in warmer and more humid conditions than the sediments of layers 17-16.

Layer 14 consists of grey-brown silty loams. The sediments form a continuous layer about 0.8 m thick.

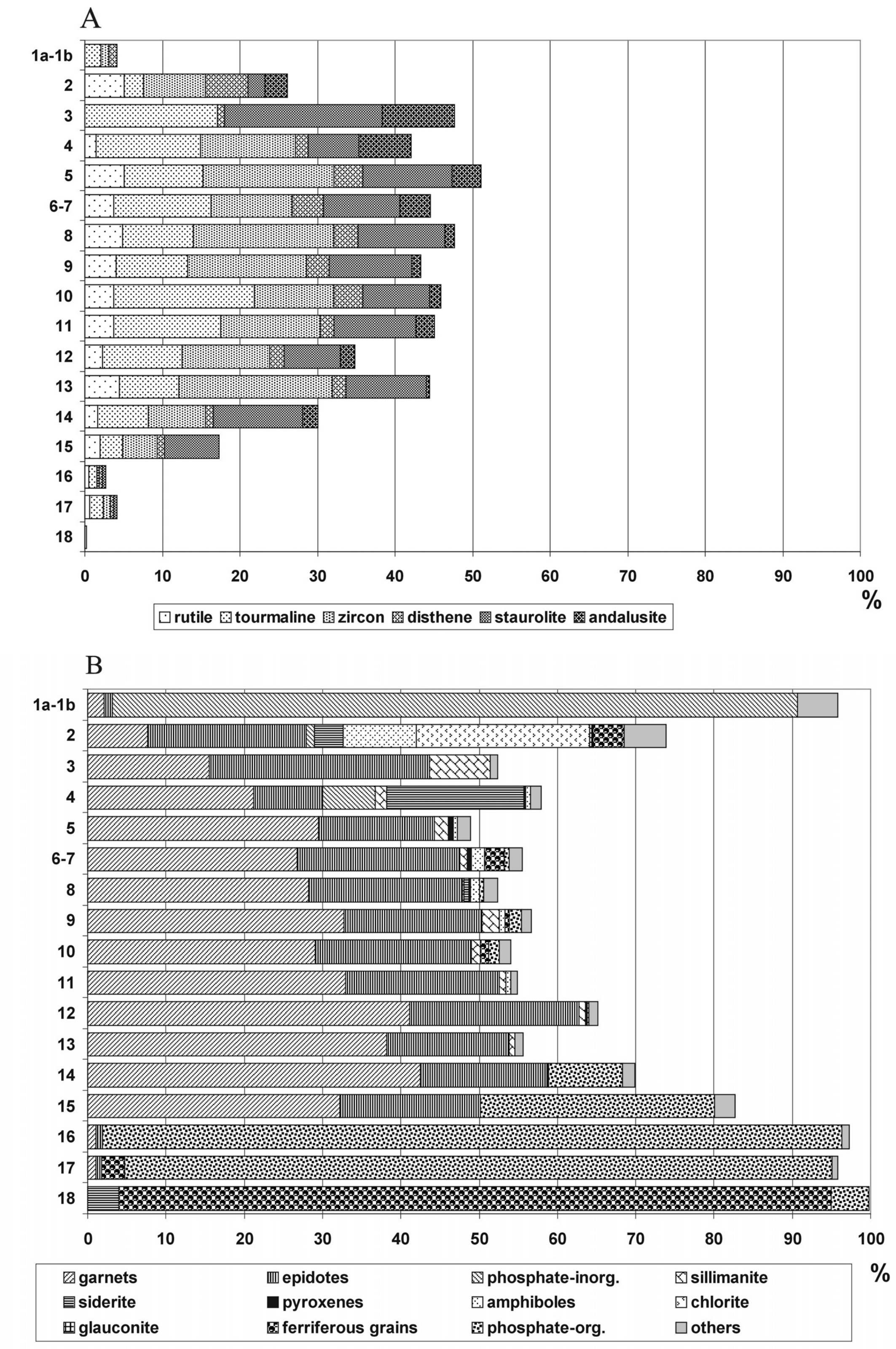

Fig. 5. Composition of the heavy mineral of the Biśnik Cave sediments. A- resistant minerals; B – medium and low resistant minerals; 1a-18 – numbers of the layers of the sediments

The fine fraction (< 1mm) consists of about 17% clay, 60% silt and 23% sand. The content of carbonates is about 5.8% and the humus content is about 0.9% (Text-fig. 4). The amount of limestone rubble increases to 65%. Both angular as well as slightly rounded particles occur (Text-fig. 4). They are characterized by pale surfaces without precipitations of phosphates. Precipitations of black manganese oxides are sporadically observed. The heavy mineral composition differs from that of layer 15 (Text-fig. 5). The authigenic minerals, represented by phosphate minerals only, reaches 9%. About 30% of the heavy fraction comprises the resistant minerals: rutile (about 2%), tourmaline (7%), zircon (7%), kyanite (1%), staurolite (11%) and andalusite (2%). The content of medium resistant minerals reaches about 58%: garnets (42%) and epidotes (16%). Grains of andalusite and of low resistant minerals: pyroxenes (0.02%) appear for the first time. Such a heavy mineral composition is observed in glacial-derived sediments (KRYSOWSKA-IWASZKIEWICZ 1974, RACINOWSKI 1995). It testifies to the greater aeolian or nival delivery of glacial material to the cave from outside. XRD analysis of the clay fraction proved the presence of illite and smectite.

A lot of fragments of bones and flint tools, constituting the culture horizon A3, were found (Text-fig. 7). The artifacts are very similar to assemblages from layer 15 and form the next horizon of the Middle Palaeolithic, Acheulian-type culture (CYREK 1997). 17 species of vertebrates were identified in this layer (Text-fig. 6). The steppe-tundra faunal element comprises about 17% (*Rangifer tarandus, Bison priscus, Equus caballus, Megaloceros giganteus*). The eurytopic element fauna amounts to 73% (*Ursus spelaeus* 67%, *Canis lupus, Arvicola terrestris, Microtus oeconomus* and other Carnivora) and the forest element about 9% (mainly *Clethrionomys glareolus, Cervus elaphus, Sus scrofa*). The faunal composition indicates an environment of grassy open spaces with single trees and a small river in the vicinity. The climatic conditions were similar to present climatic conditions from the borderlands of taiga and tundra.

Layer 13 consists of yellow-brown and light brown sandy loams. The sediments form a continuous layer about 0.8 m thick. The fine fraction (< 1mm) consists of 48% sand, 42% silt and 10% clay. The content of carbonates is about 3% and the humus content is about 0.9% (Text-fig. 4). The amount of limestone rubble reaches about 65%. Slightly rounded particles predominate over angular ones (Text-fig. 4). Limestone particles with corrosional pit-like hollows on surfaces occur. The surfaces of all of the particles are covered by secondary green-yellow precipitations of phosphates

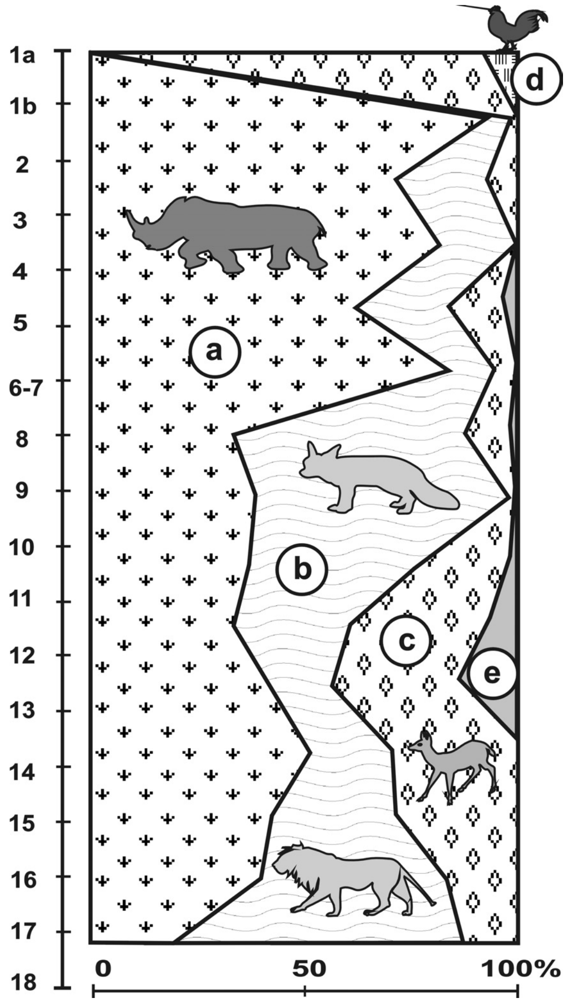

Fig. 6. Composition of the vertebrate fauna. a – steppe-tundra fauna, b – eurytopic fauna, c – forest fauna, d – domesticated fauna, e – unidentified fauna; 1a-18 - numbers of the layers

and black manganese oxides. Some of the particles are very strongly weathered and covered by a calcareous crust. The heavy mineral composition differs from those of the underlying layers (Text-fig. 5). About 44 % of the heavy fraction consists of the resistant minerals: rutile (4%), tourmaline (8%), zircon (20%), kyanite (2%), staurolite (10%); and 54% consists of the medium resistant minerals: garnets (38%) and epidotes (16%). The heavy mineral grains are characterized by mechanically rounded and weathered surfaces.

Flint and bone tools from this layer constitute the culture horizon A2 (Text-fig. 7), identified as assemblages of Middle Palaeolithic, Acheulian-type culture (CYREK 1997). The fauna of layer 13 consists of only 5% steppe-tundra fauna, comprising the single species, *Rangifer tarandus*, which characterises tundra as well as taiga (Text-fig. 6). The eurytopic element comprises 90%,

Layer	climate	fauna	symbols of archaeological horizons[1)]	archaeological cultures[1)]	stratigraphy	approximate age of layers
1a[2)] *1b*	☼	🍁 🐈	I, J H	Middle Ages Bronze Age, Neolithic	Holocene	
2	❄❄	🌿🌲			Vistulian - Main Stadial	15-20 ka B.P.
3 *4*	❄	🌿🌲	G	Upper Palaeolithic (?)	Vistulian – Grudziądz Interstadial	30-35 ka B.P.
5 *6* *7*	❄ 🌧	🌿🌲	F1 F2	Micoquo-Prondnikian Middle Palaeolithic	Vistulian – Gniew Interstadial	70-80 ka B.P.
8 *9* *10* *11*	❄ 🌧	🌿🌲	D B/C	Micoquo-Prondnikian Middle Palaeolithic	Vistulian - Toruń Stadial	80-100 ka B.P. 100-115 ka B.P.
12 *13*	☼ 🌧	🍁	A1 A2	Acheulian Middle Palaeolithic	Eemian Interglacial	115-128 ka B.P.
14	❄	🌿🌲	A3	Acheulian Middle Palaeolithic	Warthanian	128-200 ka B.P.
15	☼ 🌧	🍁	A4	Acheulian Middle Palaeolithic	Lubawa Interglacial	200-250 ka B.P.
16 *17*	❄	🌿🌲	A5 A6	Acheulian Middle Palaeolithic	Odranian	250-270 ka B.P.
18	☼☼				Tertiary - Pliocene –	

Fig. 7. Stratigraphy and archaeological horizons of the Biśnik Cave sediments. 1) after CYREK (1997); [2)] 1a – layers with archaeological assemblages; climate: ☼ - warm, ❄ - cold, 🌧 - wet; fauna: 🌿🌲 - steppe-tundra, 🍁 - forest, 🐈 - domesticated

mainly *Ursus spelaeus* (88%). The remaining, 5% consists of the forest elements (*Cervus elaphus, Bos primigenius*). It is interesting in the analysis of faunal remains, that only a few species of animals occurred. The author considers that this can be attributed to warmer climatic conditions, which caused the migration of a lot of steppe-tundra animals and accelerated the decay of bones. The numerous bones of cave bear are probably due to sporadic human settlement in the cave during the accumulation of these deposits.

Layer 12 consists of yellow-brown sandy loams and loamy sands. The sediments form discontinuous lenticles with irregular borders. In the fine fraction (< 1mm) the sand dominates (62%) over silt (31%) and clay (7%). The content of carbonates is about 1% and the humus content is about 0.2% (Text-fig. 4). The amount of limestone rubble decreases to 18%. Slightly rounded particles predominate over angular ones (Text-fig. 4). In addition, rounded particles and particles with corrosional pit-like hollows occur. Extensive black manganese oxides cover the surfaces of particles. Some of the particles are very strongly weathered and porous. These features testify to the intense chemical weathering during sedimentation of layer 12. The heavy mineral composition is similar to that of layer 13 (Text-fig. 5). About 35 % of the heavy fraction consists of the resistant minerals: rutile (2%), tourmaline (10%), zircon (11%), kyanite (2%) and staurolite (7%). The content of medium resistant minerals reaches 63%: garnets (41%), epidotes (21%) and sillimanite (about 1%). Amphiboles (0.2%) and pyroxenes (0.2%) represent the low resistant minerals. Such a heavy mineral composition, with an especially high quantity of medium resistant minerals and the presence of low resistant minerals testifies to the supply of new "fresh" materials into the cave.

In layer 12, flint and bone tools were found – culture horizon A1 (Text-fig. 7). The artifacts are identified as assemblages of the Middle Palaeolithic Acheulian-type culture (CYREK 1997). The fauna of layer 12 consists of about 5.5% of steppe-tundra animals, mainly *Rangifer tarandus* and *Equus caballus*

(Text-fig. 7). The eurytopic fauna comprises 88%, mainly *Ursus spelaeus* (83%). The forest element reaches about 5.5% and is represented by *Capreolus capreolus, Cervus elaphus* and *Clethrionomys glareolus*. The faunal composition of layers 13-12 suggests that these deposits accumulated under warmer and humid climate conditions than the sediments of layer 14.

Layers 11-9 consist of dark-brown, grey-brown sandy loams. The sediments form the continuous layers about 0.8-1m thick each. In the fine fraction (< 1mm) sand dominates (54-70%) over silt (22-33%) and clay (8-13%). The content of carbonates is 3-10% and the humus content is 1-2% (Text-fig. 4). The amount of limestone rubble is variable – 20-47%. The limestone particles differ from those of layers 12-13 in that they are characterized by rounded edges (Text-fig. 4). The content of particles with corrosional pit-like hollows is 17-33%. The limestone particles have pale surfaces without secondary precipitations. Some of the particles are weathered and their surfaces are soft and chalky. Such particles testify to slight chemical weathering. The heavy mineral composition is similar to that of layer 12 (Text-fig. 5). In layers 10-9 about 2% of authigenic minerals are identified. These comprise phosphate minerals with visible organic structure and aggregates of ferriferous minerals. About 43-46 % of the heavy fraction consists of the resistant minerals: rutile (4%), tourmaline (9-18%), zircon (10-15%), kyanite (2-4%) and staurolite (9-11%); 50-54% comprise the medium resistant minerals: garnets (29-33%), epidotes (18-20%) and sillimanite (1-2%). The low resistant minerals are represented by amphiboles (0.7%).

Many flint and bone tools occurred in these layers, constituting culture horizons B, C and D (Text-fig. 7). The artifacts are identified as assemblages of the Middle Palaeolithic, Micoquo – Prondnikian-type culture (CYREK 1997). Layers 11-9 contain rich palaeontological material (19 species). About 6% comprise steppe-tundra fauna (*Equus caballus, Rangifer tarandus, Bison priscus, Megaloceros giganteus, Rupricapra rupricapra, Lemmus lemmus*) – Text-fig. 6. The eurytopic element comprises 90-92% (*Ursus spelaeus* 84%, *Canis lupus, Vulpes vulpes, Crocuta crocuta spelaea, Arvicola terrestris*). The bones of forest fauna (*Clethrionomys glareolus, Cervus elaphus*) are scarce. Such a faunal composition shows deterioration of climatic conditions with a reduction of the deciduous forest environment and domination of the open spaces environment.

Layer 8 consists of yellow-brown sandy silts. The sediments form a single lenticles in the part near the entrance of the cave. In the fine fraction (< 1mm) the proportion of silt increases to 40% with concomitant reduction of the sand (51%) and clay (9%). The content of carbonates is about 4% and the humus content is only 0.4% (Text-fig. 4). The amount of limestone rubble increases to 56%. Slightly rounded particles predominate over angular ones (Text-fig. 4). The content of particles with corrosional pit-like hollows increases to 30%. The limestone particles have pale surfaces without secondary precipitations. The heavy mineral composition is similar to that of layers 11-9 (Text-fig. 5). About 1.2 % of authigenic minerals is identified, these comprising only phosphate minerals with visible organic structure. About 48 % of the heavy fraction consists of the resistant minerals: rutile (5%), tourmaline (9%), zircon (18%), kyanite (3%) and staurolite (11%). The content of medium resistant minerals reaches 48%: garnets (28%), epidotes (20%) and sillimanite (about 0.2%). The content of low resistant minerals increases to 1.4%: amphibole (1.2%) and pyroxene (0.2%).

In layer 8, remnants of steppe-tundra fauna comprises about 25% (*Equus caballus, Rangifer tarandus, Rupricapra rupricapra, Dicrostonyx gulielmi*) – Text-fig. 6. The eurytopic element comprises 74% (*Ursus spelaeus* 71%, *Panthera leo spelaea, Arvicola terrestris*). The forest fauna is represented by single bones of *Cervus elaphus* (about 1%). The faunal composition of this layer indicates further cooling and drying of the climate and the domination of open spaces environment.

Series II, overlying series I, consists of three sandy layers (layers 7-5), which reflect considerable influence of the geological processes outside the cave in the Wodąca Valley on the accumulation of sediments in the cave. The sediments were deposited in the Biśnik Cave after an episode of partial cave ceiling collapse, creating a rock-shelter. The deposits result from accumulation under flowing water conditions.

Layers 7-5 consist of dark-yellow and yellow sands. The sediments form continuous layers 0.1-1.4 m thick. The deposits have visible lamination. Orange loamy sands appear in layer 5. In the fine fraction (< 1mm) sand dominates (92-94%) over silt (3-6%) and clay (2-3%). The content of carbonates is about 0.2% and the humus content is about 0.1% (Text-fig. 4). The amount of limestone rubble decreases to only 2%. Rounded particles and particles with corrosional pit-like hollows occur. The limestone particles are characterized by porous surfaces without secondary precipitations. The heavy mineral composition differs from that of layer 8 (Text-fig. 5). The authigenic minerals appear only in layers 7-6 (3%). About 45-51 % of the heavy fraction consists of the resistant minerals: rutile (4-5%), tourmaline (10-13%), zircon (10-17%), kyanite (4%), staurolite (10-11%) and andalusite (4%). The content of medium resistant minerals amounts to 46-48%: garnets (26-29%), epidotes

(15-21%) and sillimanite (about 1-2%). Amphiboles (0.5-1.7%) and pyroxenes (0.6%) represent the low resistant minerals. Such a heavy mineral composition, especially the high quantity of low resistant minerals and the low quantity of garnets, testifies to the supply into the cave of different material from that in layer 8.

Layers 7-5 contain flint and bone tools. They constitute culture horizon F2 (Text-fig. 7) and are identified as assemblages of the Middle Palaeolithic Micoquo-Prondnikian-type culture (CYREK 1997). Besides flint and bone artifacts, fragments of a shelter or wind-screen were found in the top of layer 5.

The fauna of layers 6-7 consists of about 24% steppe-tundra animals: *Equus caballus, Rangifer tarandus, Bison priscus, Megaloceros giganteus, Coelodonta antiquitatis* and *Lemmus lemmus* (Text-fig. 6). The eurytopic element comprises 68%, mainly *Ursus spelaeus* 61% and *Crocuta crocuta spelaea*, *Panthera leo spelaea*, *Vulpes vulpes* and other Carnivora. The forest fauna (5%) is represented by *Capreolus capreolus, Sus scrofa, Martes martes* and *Castor fiber*. Such a faunal composition indicates an environment of grassy, open spaces with single trees and a small river in the vicinity.

The fauna of layer 5 consists of about 64% steppe-tundra animals: *Equus caballus, Rangifer tarandus, Bison priscus, Megaloceros giganteus* and *Lagopus lagopus* (Text-fig. 6). The eurytopic element comprises 36%, mainly *Ursus spelaeus* 22%, *Vulpes vulpes, Mustela putorius* and other Carnivora. No forest faunal elements were found. Such a faunal composition testifies to the deterioration of climatic conditions and the domination of a grassy, open spaces environment.

Series III – sandy, loess and loess-like silty layers 4-2 – consists of deposits accumulated mainly as the result of aeolian processes.

Layer 4 consists of grey-brown sandy loams and loamy sands. The sediments form a continuous layer about 0.3 m thick only in the rock-shelter. The fine fraction (< 1mm) consists of about 63% sand, 26% silt and 11% clay. The content of carbonates is about 3% and the humus content is about 0.4% (Text-fig. 4). The amount of limestone rubble increases to 30%. Small, angular particles predominate. They are characterized by surfaces without secondary precipitations. Precipitations of black manganese oxides are sporadically observed. The heavy mineral composition differs from that of the underlying layers (Text-fig. 5). The authigenic minerals, represented by siderite and inorganic phosphates are present (24%). About 42% of the heavy fraction consists of the resistant minerals: rutile (about 1%), tourmaline (14%), zircon (12%), kyanite (2%), staurolite (6%) and andalusite (7%). The content of medium resistant minerals reaches about 31%: garnets (21%), epidotes (9%) and sillimanite (1%). The low resistant minerals consist of amphiboles (0.6%) and pyroxenes (0.3%). This composition testifies to a larger supply of glacial material from outside to the cave.

In layer 4 single fragments of bones and flint tools were found, constituting culture horizon G (Text-fig. 7). The artifacts form the level of the Upper Palaeolithic indefinite culture (CYREK 1997).

Layer 3 consists of light-brown sands. The sediments form a continuous layer 0.3 m thick in the rock-shelter only. In the fine fraction (< 1mm) the sand dominates (97%) over silt (1%) and clay (2%). The content of carbonates is about 3% and the humus content is about 0.3% (Text-fig. 4). Single angular limestone particles without secondary precipitations are sporadically observed. The heavy mineral composition differs from that of layer 4 (Text-fig. 5). About 48% of the heavy fraction consists of the resistant minerals: tourmaline (17%), kyanite (1%), staurolite (20%) and andalusite (9%). The content of medium resistant minerals reaches 51%: garnets (15%), epidotes (28%) and sillimanite (about 8%). Such a heavy mineral composition indicates the intense weathering of these sediments.

In layers 3-4 remains of steppe-tundra animals comprise about 46%, mainly *Rangifer tarandus* and *Equus caballus* (Text-fig. 6). The eurytopic element comprises 49% (*Ursus spelaeus* 34%, *Canis lupus, Vulpes vulpes, Crocuta crocuta spelaea* and *Mustela erminea*); and the forest element about 5% (mainly *Cervus elaphus, Capreolus capreolus* and *Sus scrofa*). The faunal composition indicates an environment of grassy open spaces with single trees.

Layer 2 consists of yellow-brown silty loams. The sediments form a lenticle in the part near the entrance of the cave. In the fine fraction (< 1mm) silt dominates (73%) over sand (15%) and clay (12%). The content of carbonates is about 6% and the humus content is only 0.2% (Text-fig. 4). The heavy mineral composition differs from that of the other layers (Text-fig. 5). About 9% of authigenic minerals are identified: siderite (4%), inorganic phosphate minerals (1%) and aggregates of ferriferous mineral (4%). Only about 26 % of the heavy fraction consists of grains of the resistant minerals: rutile (5%), tourmaline (3%), zircon (8%), kyanite (5%), staurolite (2%) and andalusite (3%). The content of medium resistant minerals reaches 28%: garnets (8%) and epidotes (20%). The proportion of low resistant minerals increases to 32%. Grains of chlorites (22%) are observed for the first time. The content of amphiboles increases to 10%.

The remains of steppe-tundra animals comprise about 63% (*Dicrostonyx gulielmi* 48%, *Megaloceros giganteus*, *Equus caballus, Rangifer tarandus*) of the fauna in layer 2 (Text-fig. 6). The eurytopic element comprises 36% (*Ursus spelaeus* 32%, *Vulpes vulpes, Mustela erminea*). The forest fauna is represented by single bones of *Cervus elaphus* (about 1%). The faunal composition of this layer indicates further cooling and drying of the climate and the domination of the open spaces environment.

Layer 1b consists of light-brown silty loams. The sediments form a continuous layer 0.4 m thick, in the rock-shelter only. In the fine fraction (< 1 mm) silt dominates (65%) over sand (21%) and clay (14%). The content of carbonates is about 14% and the humus content is about 0.5% (Text-fig. 4). The amount of limestone rubble reaches 43%. Only angular particles are observed. The limestone particles are characterized by surfaces without secondary precipitations. The heavy mineral composition of this layer was identified together that of layer 1a (Text-fig. 5). The content of authigenic minerals reaches 88%, these are comprise only inorganic phosphate minerals. About 4% of the heavy fraction consists of the resistant minerals: tourmaline (2%), zircon (1%) and kyanite (1%). The content of medium resistant minerals amounts to 3%: garnets (2%) and epidotes (1%). Such a heavy mineral composition indicates intense weathering of these sediments.

Flint tools (horizon H) and fragments of ceramics (horizon I) were found in the top of layer 1b (Text-fig. 7). The assemblages are identified as artifacts of Neolithic and Bronze Age cultures (Cyrek 1997).

Layer 1a consists of dark-gray sandy loams. The sediments form a continuous layer 0.5 m thick, in the rock-shelter only. In the fine fraction (< 1 mm) sand prevails (49%) over silt (36%) and clay (15%). The content of carbonates is about 32% and the humus content is about 6% (Text-fig. 4). The amount of limestone rubble reaches 60%. Only angular particles without secondary precipitations are observed.

Fragments of ceramics and iron tools were found, constituting horizon J (Text-fig. 7). The archaeological materials are identified as assemblages of the Middle Ages (Cyrek 1994, 1997).

In layers 1a-1b the remains of steppe-tundra animals amount to about 2% only (*Equus caballus*) – Text-fig. 6. The eurytopic element comprises 3% (Carnivora) and the forest fauna about 92% (*Cervus elaphus, Capreolus capreolus, Alces alces* and *Sus scrofa*). In addition, bones of domesticated fauna were found in layer 1a. The faunal composition shows the occurrence of deciduous forest and testifies to human settlement.

STRATIGRAPHIC INTERPRETATION

The stratigraphy of Biśnik Cave sediments was established mainly on the basis of the archaeological data and three key geological observations: the presence of residual clays of terra rossa-type (layer 18) at the bottom (Pliocene), strongly chemical weathered limestone particles in layers 12-13 (Eemian) and the loess layer 2 near the top of the succession (Main Stadial of the Vistulian).

The terra rossa-type sediments of layer 18 are similar to the deposits found at the bottom of the Nietoperzowa Cave (Madeyska-Niklewska 1969, Madeyska 1981) and Żabia Cave (Bosak & *al*. 1982). The sediments originated as a product of chemical weathering of limestones and accumulated probably in the Tertiary (Pliocene) – Text-fig. 7.

On the basis of geological, archaeological and palaeontological data the author suggests that the sediments of layers 17-16 were deposited during the Odranian – Text-fig. 7. The residue of limestone (clay fraction), limestone rubble, materials originating from the residue of Cretaceous rocks and aeolian silts accumulated in the cave. The aeolian silts were probably blown into the cave from glacial sediments deposited outside the Jurassic cuesta. Beginning with the Odranian, the openings of the cave were enlarged as a result of frost weathering. Layer 17 contains the oldest Acheulian-type artifacts.

The lithological features of the sediments of layer 15, especially the morphology and character of the surfaces of the limestone particles, as well as the ferriferous and phosphate precipitations and the presence of forest fauna suggest that these deposits were accumulated in warmer and humid conditions, probably during the Lubawa Interglacial (Text-fig. 7).

The high proportion of angular particles in layer 14 and the significant representation of steppe-tundra animals indicate that these sediments accumulated during the Warthanian.

The lithological features of the sediments of layers 13-12 (especially the morphology, character of surfaces and the highest degree of chemical weathering of the particles), and the presence of forest fauna, suggest that these deposits accumulated under more humid and warmer conditions than the other layers. These sediments probably formed during the Eemian Interglacial (Text-fig. 7). The presence of *Capreolus capreolus* and *Arvicola terrestris* confirms the existence of deciduous forest and a small river in the vicinity.

The faunal composition of layers 11-9 indicates deterioration of the climatic conditions, reduction of the deciduous forest environment and the predominance of open spaces. These sediments, containing mainly mechanically weathered particles and Middle Palaeolithic artifacts, accumulated during the Early Vistulian (Text-fig. 7). The lithological features of the sediments of layer 8, especially the high content of silt and the high content of low resistant heavy minerals, as well as the high proportion of steppe-tundra fauna, suggest that these deposits correspond to a period of loess accumulation during the Toruń Stadial (Vistulian). Sandy layers 7-5 were deposited in the cave as a result of blocking of the outflow of the Wodąca valley. These sediments accumulated probably during the Gniew Interstadial. The lithological characters of the sediments, the Upper Palaeolithic assemblages and faunal composition of layers 4-3 suggest that these deposits accumulated during the Grudziądz Interstadial (Vistulian). The loess-like features of the sediments of layer 2, especially the high silt content, the high content of the low resistant minerals (mainly chlorite), and the high proportion of steppe-tundra fauna suggest that these deposits consist of loess accumulated during the Vistulian – Main Stadial (Text-fig. 7). The Vistulian loess usually occurs in the entrance parts of caves (SAWICKI 1953, MADEYSKA-NIKLEWSKA 1969, MADEYSKA 1988).

The presence of the Middle Ages and Neolithic archaeological material as well as bones of domesticated animals in layers 1a-1b testify to the accumulation of these sediments during the Holocene (Fig. 7).

RECONSTRUCTION OF THE GEOMORPHOLOGICAL PROCESSES IN BIŚNIK CAVE AND IN SURROUNDING AREA

The Quaternary sediments in the central part of the Smoleń-Niegowonice Range are preserved only as remnants. Neither glacial deposits nor organic sediments, which could be dated were found. The cave sediments containing archaeological artifacts were correlated with the Quaternary deposits. The correlation helped to establish the stratigraphy of the Quaternary deposits and reconstruct the evolution of relief in the surrounding area (MIROSŁAW-GRABOWSKA 1998).

During the Tertiary this area was subjected to intense chemical weathering, followed by denudation and erosion. It was probably during the Miocene that the limestone inselbergs, valleys and gorges were formed (GILEWSKA 1972, RÓŻYCKI 1972, IRMIŃSKI 1995). Weathering loams and residual clays accumulated at this time (GRADZIŃSKI 1962, MIROSŁAW-GRABOWSKA 1998). The residual clays were preserved in the caves (layer 18 in the Biśnik Cave) and in the valley bottoms.

During the Odranian, the fluvioglacial sediments in the surrounding area (BEDNAREK & *al*. 1978, SZCZYPEK 1984) and layers 17-16 in the Biśnik Cave accumulated. Following this, during the Lubawa Interglacial and the Warthanian, the fluvioglacial deposits were eroded and partly redeposited into the Biśnik Cave forming layers 15-14. During the Eemian Interglacial strong erosion of the sediments and chemical weathering of the limestones occurred. In the Biśnik Cave two layers (13-12) with strongly weathered limestone debris are preserved. During the Vistulian Glaciation the area of the central part of the Cracow-Częstochowa Upland was exposed to fluvial and aeolian processes (SZCZYPEK 1984). The lacustrine silts, loess covers and dunes were formed (BEDNAREK & *al*. 1978, MIROSŁAW-GRABOWSKA 1998) at this time. In the Biśnik Cave layers 11-2 accumulated. During the Holocene, the alluvial flood-plains, small dunes (DULIAS 1997) and soil developed outside the cave and layers 1a-1b in the cave formed.

CONCLUSIONS

- The Biśnik Cave is the third cave site, after the Nietoperzowa Cave and the Ciemna Cave in the Cracow-Częstochowa Upland, where deposits and Middle Palaeolithic archaeological artifacts of the Eemian and older are present.
- The Biśnik Cave is the archaeological site in central Poland, containing materials of different ages and an interesting succession of sediments. It is the first cave site in the Cracow-Częstochowa Upland where Acheulian-type flint artifacts have been found.
- Detailed sedimentological, mineralogical and chemical analysis of the Biśnik Cave sediments made possible their description and helped to establish their genesis as well as stratigraphy.
- Detailed analysis of heavy minerals of cave sediments enabled identification of the source of the allochthonous material and the processes of accumulation.
  - The domination of authigenic minerals in the underlying layers testifies to the formation layers 17-16 *in situ*.
  - The presence of resistant minerals, especially rutile, zircon and tourmaline, in layers 16-17 shows their relationship with the residue of Cretaceous rocks.
  - The high content of medium resistant minerals (garnets and epidotes) in layers 15-5 shows their fluvioglacial origin.
  - The occurrence the low resistant minerals,

especially chlorites, in layer 2 testifies to their loess character and aeolian accumulation.

- Using the scanning electron microscope, secondary mineral precipitations on the limestone particles were identified. The presence of secondary compounds testifies to the intense weathering processes, leading to the subsequent precipitation of these minerals, for example, phosphates and manganese oxides.

- The composition of the rich palaeontological material enabled the reconstruction of the natural environment and the climatic conditions during the accumulation of these sediments.
  - The occurrence of a forest environment is documented by the remains of the species *Capreolus capreolus, Bos primigenius, Alces alces, Sus scrofa* and *Clethrionomys glareolus*. Layers 15, 13, 12 originated under such conditions.
  - The presence of bones of *Arvicola terrestris* and *Castor fiber* shows that a small river existed in the neighbourhood of the cave (layers 14, 11, 7-6).
  - A large proportion of remains of *Rangifer tarandus, Coelodonta antiquitatis, Dicrostonyx gulielmi, Lemus lemmus, Bison priscus* and *Equus caballus* indicates a steppe-tundra environment (layers 14, 8).
- The correlation the cave sediments with the Quaternary deposits helped to establish the stratigraphy of the Quaternary deposits and to reconstruct the geomorphological processes in the surrounding area, especially the Vistulian fluvial and lacustrine deposits.

Acknowledgements

The author wishes to express her thanks to Dr K. CYREK for collaboration during excavations; Prof. T. MADEYSKA for discussions; Prof. T. WISZNIOWSKA, P. SOCHA and K. STEFANIAK for making accessible unpublished results of their identification of fauna remnants; Dr R. MICHNIAK and M. KUŹNIARSKI for identification of heavy and clay minerals, and A. MULCZYK for the chemical analysis.

The financial support of KOPIPOL Foundation, Kielce, is acknowledged.

REFERENCES

BEDNAREK, J., KAZIUK, H. & ZAPAŚNIK, T. 1978. Objaśnienia do SMGP w skali 1:50 000, arkusz Ogrodzieniec. *Wydawnictwa Geologiczne*; Warszawa. [*In Polish*]

BEDNAREK, J. & LISZKOWSKI, J. 1982. The section of fossil weathering covers at Dzibice. *Biuletyn Geologiczny UW*, **26**, 89-106. [*In Polish*]

BOSÁK, P., GŁAZEK, J., HORÁČEK, I. & SZYNKIEWICZ, A. 1982. New locality of Early Pleistocene vertebrates - Żabia Cave at Podlesice, Central Poland. *Acta Geologica Polonica*, **32**, 217-226.

CYREK, K. 1994. Omówienie wyników badań interdyscyplinarnych na stanowisku Biśnik w 1992 roku. *IV Sympozjum Jurajskie „Człowiek i środowisko naturalne Wyżyny Krakowsko-Wieluńskiej" materiały z sesji popularno-naukowej*, 17-20.

— 1997. Wyniki interdyscyplinarnych badań wykopaliskowych w schronisku skalnym Biśnik w Strzegowej, woj. katowickie. *In*: *Badania archeologiczne na Górnym Śląsku i ziemiach pogranicznych w 1994 roku*. Centrum Dziedzictwa Kulturowego Górnego Śląska, 21-34, Katowice.

CYREK K., MADEYSKA T., MIROSŁAW-GRABOWSKA J., WISZNIOWSKA T. 1999. Jaskinia na Biśniku. *33 Sympozjum Speleologiczne Sekcji Speleologicznej Pol. Tow. Przyrodników im. Kopernika, Jeziorowice. Materiały*: 13-17.

DULIAS, R. 1997. The Late-glacial and Holocene development of dusty-sandy covers in the southern part of Częstochowa Upland. *Geogr. Stud. Dissert. U. Śl.*, **21**, 7-100. [*In Polish*]

GILEWSKA, S. 1972. Wyżyny Śląsko-Małopolskie. *In*: KLIMASZEWSKI M. (*Ed.*) *Geomorfologia Polski,* Vol. **1**, 232-279, *PWN*; Warszawa.

GRADZIŃSKI, R. 1962. Origin and development of subterranean Karst in the Southern part of the Cracow Upland. *Rocznik Polskiego Towarzystwa Geologicznego*, **32**, 429-492.

HERCMAN, H. & GÓRKA, P. 2000. U-series dating of bones from Biśnik Cave – open system dating models. *Climate Changes – the Karst Record II. Guidebook & Abstracts*, 67. Kraków.

IRMIŃSKI, W. 1995. Górnojurajski kompleks biohermalny w okolicach Niegowonic i Grabowej k. Zawiercia. *Przegląd Geologiczny*, **43**, 853-858. [*In Polish*]

KRYSOWSKA-IWASZKIEWICZ, M. 1974. Mineralogical and petrographical study of Cenozoic continental deposits of the Cracovian Upland. *Prace Mineralogiczne*, **35**, 1-70. [*In Polish with English Summary*]

MADEYSKA-NIKLEWSKA, T. 1969. Upper Pleistocene deposits in caves of the Cracow Upland. *Acta Geologica Polonica*, **19**, 341-392. [*In Polish with English Summary*]

— 1971. Methods used in researches on the Upper Pleistocene sediments of the Cracow Upland caves. *Światowit*, **32**, 5-25. [*In Polish with English Summary*]

MADEYSKA, T. 1981. Le milieu naturel de l'Homme du Paleolithique moyen et superieur en Pologne à la lumiére des recherches geologiques. *Studia Geologica Polonica*, **69**, 1-125. [*In Polish with French Summary*]

— 1988. Deposits of caves in the Sąspowska Valley. *In*: CHMIELEWSKI W. (*Ed.*), *Jaskinie Doliny Sąspowskiej. Tło przyrodnicze osadnictwa pradziejowego*. Archiwum UW, 77-173, Warszawa. [*In Polish*]

MADEYSKA, T. & CYREK, K. 2002. Cave filling – a chronicle of the past. An outline of the Younger pleistocene cave sediments study in Poland. *Acta Geologica Polonica*, 52 (1), 75-95.

MIROSŁAW-GRABOWSKA, J. 1995. Wstępne wyniki badań geologicznych prowadzonych w schronisku Biśnik. *V Sympozjum Jurajskie „Człowiek i środowisko naturalne Wyżyny Krakowsko-Wieluńskiej“ materiały z sesji popularno-naukowej*, 41-49.

— 1998. Quaternary stratigraphy in the eastern part of Smoleń-Niegowonice Range (Kraków-Częstochowa Upland). *Studia Geologica Polonica*, **113**, 105-119. [*In Polish with English Summary*]

MIROSŁAW-GRABOWSKA, J., CYREK, K., MADEYSKA, T. & WISZNIOWSKA , T. 1995. Schronisko Biśnik: osady, fauna, znaleziska archeologiczne. *III Zjazd Geomorfologów Polskich „Procesy geomorfologiczne: zapis w rzeźbie i osadach“ Sosnowiec. Przewodnik wycieczek*, 17-24. Sosnowiec.

RACINOWSKI, R. 1995. Remarks on using the results of heavy mineral analyses for studies on Quaternary deposits of Poland). *In*: MYCIELSKA-DOWGIAŁŁO E. & RUTKOWSKI J. (*Eds*), *Badania osadów czwartorzędowych. Wybrane metody i interpretacja wyników (Researches of Quaternary sediments. Some methods and interpretation of the results).* pp. 151-166. *Wydawnictwa Wydziału Geografii i Studiów Regionalnych Uniwersytetu Warszawskiego*; Warszawa. [*In Polish with English Summary*]

RÓŻYCKI, S. Z. 1972. Plejstocen Polski środkowej na tle przeszłości w górnym Trzeciorzędzie, 315 pp. *Państwowe Wydawnictwo Naukowe*; Warszawa.

SAMSONOWICZ, J. 1935. Zjawiska krasowe i trzeciorzędowa brekcja kostna w Wężach pod Działoszynem. *Zabytki Przyrody Nieożywionej*, **3**, 151-162.

SAWICKI, L. 1953. Geological age of the fossil man in Poland, actual state resarches. *Acta Geologica Polonica*, **3**, 171-186. [*In Polish with English Summary*]

SZCZYPEK, T. 1984. Piaski eoliczne Wyżyny Krakowsko-Wieluńskiej na tle utworów podłoża. *Przew. Konf. Zlodowacenie środkowopolskie na Wyżynach Południowopolskich i terenach przyległych. Sosnowiec 19-23.09.1984*, pp. 39-42. Sosnowiec.

Manuscript submitted: 10th May 2001
Revised version accepted: 15th September 2001