Acta Geologica Polonica, Vol. 52 (2002), No. 1, pp. 75-95

Cave fillings – a chronicle of the past. An outline of the Younger Pleistocene cave sediments study in Poland

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ABSTRACT:

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

The scientific exploration of Polish cave sediments started 130 years ago. Important Palaeolithic sites were discovered and investigated from that time by archaeologists and zoologists. During the second half of the 20th century geological analysis was introduced to the cave filling study. More than 50 caves and rock shelters, differentiated according to their shape and dimensions, have been explored to date, every one of which contained subfossil animal remains. In about 30 sites, culture layers, scattered artefacts or other traces of the activity of Palaeolithic people were found. The sedimentary successions, 2-8 metres thick, consist mainly of clastic components that reflect the past climatic changes. The subfossil fauna includes animals living in tundra, steppe, forest and aquatic environments. The proportions of particular groups vary with the position in the succession. The lithological composition of the sediments and the faunal composition were used for reconstruction of past climatic changes and for the stratigraphical interpretation. Remnants of the oldest Palaeolithic culture in this region - the Acheulian type with Levalloisian technique - were found in deposits dated to the Warthanian and to the penultimate interglacial or even to the Odranian. During the Eemian, this culture coexisted with the Taubachian. For the Early Vistulian, the Levallois-Mousterian, Micoquo-Prondnikian and Charentian are characteristic cultures. Upper Palaeolithic cultures (Jerzmanowician, Aurignacian, Szeletian and then East-Gravettian) developed during younger Vistulian interstadials (Interplenivistulian) correlated with stage 3 of the oxygen isotope curve. Toward the end of the Vistulian, the Magdalenian culture and the Epigravettian appeared.

Key words: Cave sediments, Palaeolithic, Vistulian.

INTRODUCTION

Cave sediments, especially clastic deposits accumulated during the younger part of the Pleistocene, contain important remnants of the past. Besides archaeological material, such as artefacts, wood fragments preserved as charcoal and other traces of human activity, the excavator finds bone remains of animals. Study of all this material, in conjunction with lithological analysis of the sediments, enables us to improve our knowledge of the history of human settlement, the composition and evolution of former faunas, as well as the environmental changes during the younger part of the Pleistocene. These problems and the results of the investigation are demonstrated in the present paper on the basis of Polish caves situated mainly in the Polish

Jura Chain, where about 50 caves and rock shelters have been excavated during the last 130 years.

HISTORY OF INVESTIGATION

The archaeological investigations in Polish caves started as early as about 130 years ago. It was a time of increasing interest in the Palaeolithic in Western Europe, the time of creation of the first chronological scheme of the Palaeolithic by Gabriel de Mortillet.

The first excavator of Polish caves – Jan ZAWISZA, an amateur archaeologist – published, in Polish and in French, the results of his investigations in the important site of the Polish Jura Chain – the Mamutowa Cave – in the 1870s (ZAWISZA 1874, 1878, 1882a,). This cave was the first Polish Palaeolithic site presented to a European international congress. Subsequently, Godfryd OSSOWSKI, a geologist and archaeologist, investigated several caves (OSSOWSKI 1880, 1881, 1883 b, 1885, 1887, 1895). He introduced the first stratigraphical subdivision of the cave sediments into „diluvial" (Pleistocene) and „alluvial" (Holocene) beds. He discovered a very important Magdalenian site in the Maszycka Cave (OSSOWSKI 1884, 1885), but the monographic study of the site was not published until 1993 (KOZŁOWSKI S. K. & *al*. 1993). Unfortunately, G. OSSOWSKI fell victim of unscrupulous people during the excavation in the cave of the Mników valley near Kraków (OSSOWSKI 1882, 1883 a). The people who excavated the cave realising that he was very interested in bone implements, made some very accurate false artefacts from fossil bones dug out from the cave. The falsification was so good that the truth did not come to light until after prolonged discussion by international specialists (Sprawa...1885).

At the same time, F. RÖMER (RÖMER 1883, CZARNOWSKI 1910) collected artefacts and animal bones during the exploitation of cave fillings. A most harmful practice at that time was the exploitation of cave sediments for agricultural purposes – cave loam was used as fertiliser. This activity caused destruction of the sediments in several of the big caves, and was stopped only after a vociferous protest by two famous scientists, Władysław SZAFER and Stefan KRUKOWSKI, as late as the 1920s.

At the beginning of the 20th century, investigations were carried out by S.J. CZARNOWSKI (1889, 1901, 1902, 1904 a, b, 1910, 1911, 1914, 1924, 1926) in caves situated on the slopes of the Prądnik and other valleys in the southern part of the Polish Jura Chain. H. DEMETRYKIEWICZ (DEMETRYKIEWICZ & KUŹNIAR 1914) explored an important Middle Palaeolithic site in the Okiennik Wielki Cave in the central part of the Polish Jura.

L. KOZŁOWSKI (1921, 1922) was the first worker to publish an outline of the Polish Palaeolithic, with the cultures arranged chronologically against the background of the climatic curve. According to the practice, common among archaeologists of that time, of regar ding archaeological cultures as chronological units, material collected from Polish caves was correlated by him with e.g. the Late Acheulian Epoch, Mousterian Epoch or Magdalenian Epoch.

At the same time, beginning in 1914, S. KRUKOWSKI (1921, 1924) carried out excavations, studying the stratigraphy of the sediments in a remarkable advanced way by modern standards. Among other caves, he investigated the Ciemna Cave, which is a very important Middle Palaeolithic site. The results were summarised by him in a synthesis of the Polish Palaeolithic finished just before World War II and published after it (KRUKOWSKI 1939-1948). He was the first Polish archaeologist to define flint assemblages as industry units, giving them local names ("Dupice industry", "Ciemna industry" etc.). For chronological interpretation he used the stratigraphical units of the Quaternary.

A misunderstanding at that time was the recognition of the "bone culture of the cave bear hunters". A. JURA (1949, 1955), following some German investigators, interpreted several bone fragments (e.g. from the Magurska cave in the Tatra Mountains) as artefacts. However, it was found eventually that the bones had been smoothed by water.

Very helpful for the subsequent investigation of caves was the fundamental monographic study of the Polish caves undertaken by K. KOWALSKI (1951, 1952, 1954). Regular explorations in a modern manner star ted at the end of the 1950s by W. CHMIELEWSKI and other archaeologists, in collaboration with geologists and zoologists. Of particular importance was the application of precise methods of excavation, accurate documentation of the different sediments as well as three-dimensional fixing of the position of the artefacts. This provided a framework for the definition of „cultures" as archaeological units and for the analysis of their evolution in time, e.g. the Middle Palaeolithic Micoquo-Prondnikian culture or the Upper Palaeolithic Jerzmanowician culture defined by CHMIELEWSKI (1961, 1969). The results of these, and other investigations, were used in the preparation of two syntheses of the Polish Palaeolithic (CHMIELEWSKI 1975, KOZŁOWSKI J.K. & KOZŁOWSKI S.K. 1977).

T. MADEYSKA introduced detailed lithological analysis into the investigation of Polish cave sediments, based mainly on methods used previously by French and Swiss geologists (MADEYSKA-NIKLEWSKA 1969a, 1971). The grain-size composition of the sediments, the shape and degree of weathering of the limestone particles, and the chemical composition of the fine fractions in particular layers were the main types of analysis. The results were used for the reconstruction of environment and climatic conditions, as these are the main factors determining the composition of the sediment.

Besides collecting bones of larger animals during the excavation, washing of sediment samples on sieves became a very important field method for zoologists. This provides a rich material for analysis, comprising bones and bone fragments of small animals. Several important studies on the history and evolution of the fauna were carried out based on this material (BOCHEŃSKI 1974; KOWALSKI K. 1989; NADACHOWSKI 1982, 1989, 1991 etc.). The environmental changes during the time of development of the Middle and Upper Palaeolithic cultures were additionally documented (MADEYSKA 1979, 1981).

Following this period of synthesis, recent excavations of cave sites have provided new data. The most important new information comprise traces of Palaeolithic cultures older than those known before, found in the Biśnik Cave in the central part of the Polish Jura (CYREK 1997b, 1999b; MIROSŁAW-GRABOWSKA 2000, 2001). It can now be stated that human occupation in the region of the Polish Jura began not at the end of the Warthanian, as was supposed previously, but still earlier, probably during the penultimate interglacial or even the Odranian.

A new possibility of dating clastic cave sediments has become available in the last few years, namely the application of U-series and ESR methods to dating fossil bones (HERCMAN & GÓRKA 2000).

DISTRIBUTION OF CAVES

Sediments of about 50 caves, rock shelters or groups of small cave sites have been investigated to date in Poland (Text-fig. 1). Thirty of them contained cultural layers, scattered artefacts or other traces of occupation by Palaeolithic people. In the others, younger archaeological material or only animal remains were found.

The sites are differentiated according to their dimensions and shape. Besides big caves with passages and chambers, there are small, narrow passage shelters – preserved fragments of destroyed caves, wide rock shelters or small niches.

In addition to the caves of the Polish Jura Chain, the Raj Cave situated in the Holy Cross Mountains and the Obłazowa Cave in the Carpathians are important archaeological sites. The distribution of the sites in the Polish Jura is irregular. The maps (Text-fig. 1) show the main areas where the sites are concentrated.

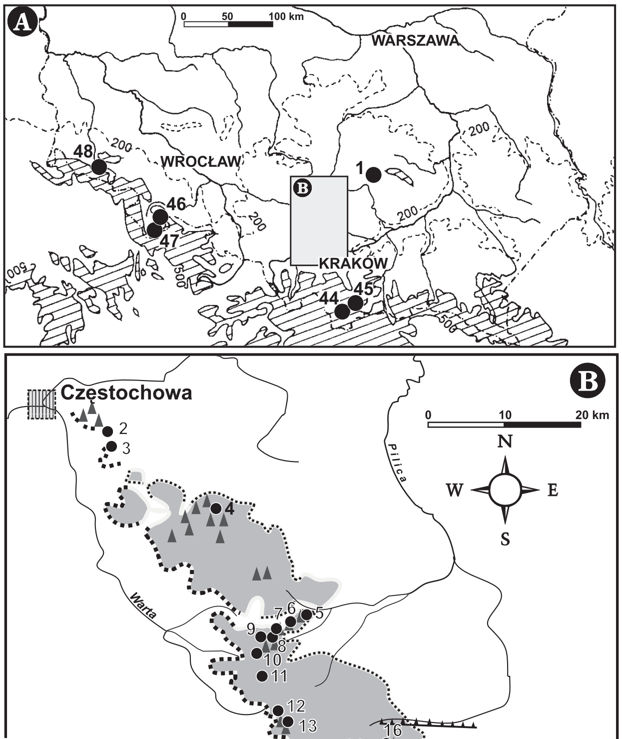
Various limestone rocks of the Upper Jurassic complex, partly covered with Quaternary deposits, form the Polish Jura Chain. The majority of the caves are situated in rocky-massive limestone.

The cave entrances open into the valley sides at different heights. Study of their vertical distribution over a large area shows hardly any regularity (GRADZIŃSKI 1961, 1962). However, in particular valleys, the cave entrances are concentrated in several broad horizons that are subparallel to the present valley bottoms. These horizons locally coincide with erosion terraces formed during the phases of the valley downcutting. Such a complexity in the distribution of the entrances reflects, on the one hand, the complicated tectonic structure of the region (which is in part younger than the caves themselves) and, on the other hand, the erosion history of the valleys.

The Sąspowska Valley, running from WNW to ESE, provides an example of the topographical arrangement of caves (Text-fig. 2) according to their ages based on the stratigraphy of the sediments (MADEYSKA 1977). The sediments of 14 caves and rock shelters were explored in the 1960s and 1970s for archaeological, palaeontological and geological purposes. They are situated in 3 main horizons, apart from the lowest (youngest) one, which is located at the valley bottom and is filled with young alluvial sediments of the Sąspówka stream.

The caves related to the highest – oldest horizon (upper shaded stripe in Text-fig. 2) are distributed almost horizontally, near the surface of the upland (440-450 m a.s.l). They are fragments of a network of karst circulation channels, which developed before or just at the beginning of the valley cutting (terrace „c“ distinguished by DŻUŁYŃSKI & *al*. 1966). The Tunel Wielki Cave with its neighbouring rock shelters, the Ciasna Cave and the Łokietkowa Cave, represent this horizon. The oldest sediments of these caves are preserved as relicts filling up the cavities in the rocky bottom and walls. They are composed of red, yellow or grey clays and clayey sands (Text-fig. 3), partly cemented by carbonates. The sediments contain scarce fossils: old species of *Mimomys* in the Łokietkowa Cave (LIPECKI & *al*. 2000) and *Pliomys lenki* in the Tunel Wielki Cave (NADACHOWSKI 1988). Based on lithological data and comparison with material from the Northern part of the Polish Jura, it can be inferred that these sediments originated during the Pliocene or oldest Pleistocene.

Two important archaeological sites, the Koziarnia



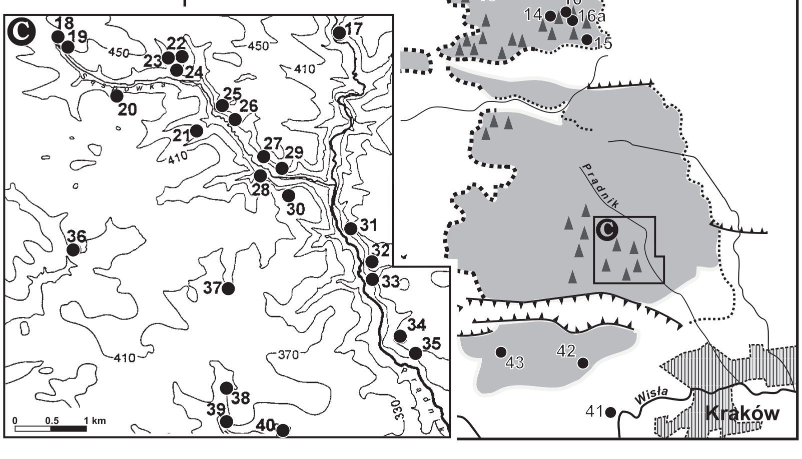


Fig.1. Distribution of excavated cave sites in Poland. A - Southern Poland, B - Polish Jura Chain, C - Sąspówka stream and Prądnik river valleys by Ojców. References and short information concerning the Palaeolithic materials found in particular cave sites:

1. Raj; Studies on Raj...1972, RUBINOWSKI 1974, KACZANOWSKA 1974. After J.K. KOZŁOWSKI (1972, 1974): two Early Vistulian cultural horizons represent East Charentian. 2. Zamkowa Dolna; KOPACZ 1975: Middle Palaeolithic probably in Early Vistulian. 3. Komarowa; GIERLIŃSKI & *al.* 1998: problematic Upper Palaeolithic. 4. Small caves by Złoty Potok; KRUKOWSKI 1921, after CYREK 1993 - traces of Middle Palaeolithic. 5. Słupsko; CYREK 1997c: Middle Palaeolithic. 6. Krucza Skała; CYREK 1994a, b, 1999a: Magdalenian, Epimagdalenian, MADEYSKA 1996. 7. Deszczowa; CYREK 1996, 1997a, 1999a, CYREK & *al.* 2000: Undetermined culture in the Eemian and Older Plenivistulian sediments, Micoquo-Prondnikian of Bockstein type in Early Vistulian, than Epigravettian. 8. Kroczycka; CYREK 1997d. 9. Złodziejska; unpublished. 10. Ruska Skała; CHMIELEWSKA & PIERZCHAŁKO 1956; Early Mesolithic. 11. Dziadowa Skała; DYLIK & al. 1954, CHMIELEWSKI 1958: Micoquo – Prondnikian and East Gravettian, KOWALSKI K. 1958. 12. Okiennik Wielki; DEMETRYKIEWICZ & KUŹNIAR 1914, KOZŁOWSKI L 1922, KRUKOWSKI 1939-1948. One or more assemblages of Micoquo – Prondnikian. 13. Birów; CYREK 1995: traces of Aurignacian, MUZOLF 1995. 14. Biśnik; CYREK 1997b, 1999b: Acheulian-type before and during Eemian, Taubachian and Micoquo – Prondnikian in Early Vistulian. 15. Group of caves by Strzegowa: Jasna Strzegowska, Zaciszna, Pod Oknem, Mroczna; SAWICKI 1953: single artefacts probably Acheulian, Mousterian, Szeletian and Aurignacian, CYREK 1995, RYBICKA & CYREK 1997: Magdalenian. 16. Zegarowa and Jasna Zegarowa; MUZOLF & WISZNIOWSKA 1999, MIROSŁAW-GRABOWSKA 2000. 17. Nad Mosurem Starym Duża; NADACHOWSKI & *al.* 1989. 18. Sąspowska pod Kościołem Zachodnia; CHMIELEWSKI 1988. 19. Sąspowska pod Kościołem Wschodnia; CHMIELEWSKI 1988. 20. Schronisko Kamieniste; CHMIELEWSKI 1988. 21. Jask. Ciasna; CHMIELEWSKI 1988. 22. Tunel Wielki; CHMIELEWSKI 1988, CHMIELEWSKI 1975: Micoquo – Prondnikian , Aurignacian. 23. Pod Tunelem Wielkim and Nad Jaskinią Niedostępną caves; CHMIELEWSKI 1988: Magdalenian. 24. Koziarnia; CHMIELEWSKI & *al.* 1967, MADEYSKA-NIKLEWSKA 1969a; Middle Palaeolithic, probably Micoquo – Prondnikian. 25. Iłowe; CHMIELEWSKI 1988. 26. Bramka; CHMIELEWSKI 1988: single Middle Palaeolithic artefacts, Mesolitic. 27. Wylotne; CHMIELEWSKI 1969, 1970, MADEYSKA-NIKLEWSKA 1969 b, 1970; Micoquo – Prondnikiam, 3 assemblages. 28. Garncarskie; CHMIELEWSKI 1988. 29. Przy Łące; CHMIELEWSKI 1988 30. Łokietkowa; LIPECKI & *al.* 2000: probably Micoquo – Prondnikian and Lavallois – Mousterian, SACHSE-KOZŁOWSKA 1972: Jerzmanowician. 31. Ciemna; CZARNOWSKI 1924, KRUKOWSKI 1939-1948, KOWALSKI S. 1967a. 1971: Micoquo – Prondnikian (Wylotne-type and Ciemna-type assemblages). 32. Okopy; CZARNOWSKI 1901, 1902. 33. Puchacza Skała; KOWALSKI K. & *al.* 1965: Jerzmanowician, Magdalenian. 34. W Ogrojcu; CZARNOWSKI 1914. 35. Maszycka; OSSOWSKI 1884,1885, KOZŁOWSKI J.K. 1963, KOZŁOWSKI S.K. & *al.* 1993. Magdalenian. 36. Nietoperzowa; CHMIELEWSKI 1961, 1975, Mousterian with acheulian tradition (?), Levallois – Mousterian, Micoquo – Prondnikian, Jerzmanowician, East Gravettian (?), KOWALSKI K. 1961, 1964, MADEYSKA-NIKLEWSKA 1969. 37. Żytnia Skała; KOWALSKI K. & *al.* 1967: Aurignacian, Late Palaeolithic. 38. Wierzchowska Górna; OSSOWSKI 1886, 1887. 39. Mamutowa; ZAWISZA 1874, 1878,1882, KOWALSKI S. 1967 b. Jerzmanowician, Aurignacian, East Gravettian. BOCHEŃSKI 1981, MADEYSKA 1992, NADACHOWSKI 1976. 40. Mączna Skała; DAGNAN-GINTER & *al.* 1992. 41. Jaskinie koło Piekar (Nad Galoską, Jama); OSSOWSKI 1880, 1881, KOZŁOWSKI L.1922, KRUKOWSKI 1939-1948, MADEYSKA & *al.* 1994. 42. Caves in Mników valley: Na Łopiankach, Gaik I & II, Zawalona; OSSOWSKI 1881,1882, 1883a, b, ALEXANDROWICZ & *al.* 1992: Middle Palaeolithic, Magdalanian, Epimagdalenian. 43. Zalas; BOCHEŃSKI & *al.* 1985. 44. Obłazowa; VALDE-NOWAK 1987, VALDE-NOWAK & *al.* 1987, 1995: 4 Mousterian layers (with Taubachian and East Charentian elements and Mousterian with denticulate tools), Aurignacian (Olshevian), Szeletian, Jerzmanowician, East Gravettian. MADEYSKA T. 1991. 45. Sobczańska; ALEXANDROWICZ & *al.* 1985. 46. Radochowska; ZOTZ 1939: problematic Palaeolithic. 47. Niedźwiedzia; JAHN 1970, JAHN & *al.* 1989. 48. Caves in Połom; ZOTZ 1939: problematic Palaeolithic.

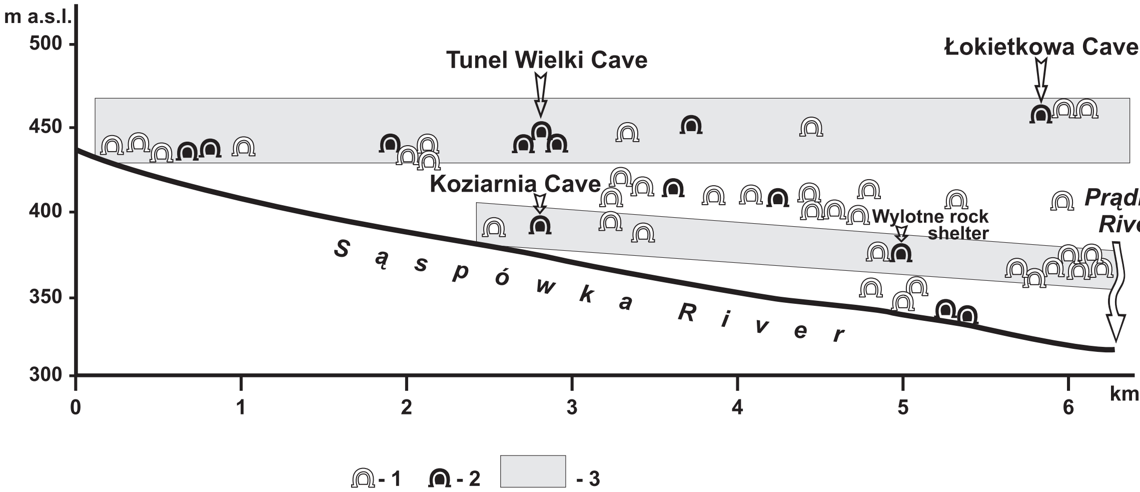
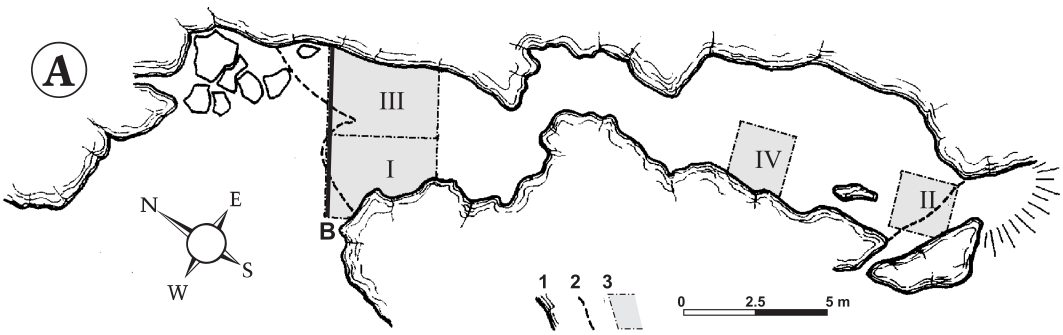


Fig. 2. Vertical disposition of the caves and rock-shelters entrances in the slopes of the Sąspowska valley (after MADEYSKA 1977, supplemented with data from GRADZIŃSKI M. & *al.* 1994, 1995, 1996). At the basis the recent Sąspówka riverbed is marked. 1 – small caves and rock shelters, 2 – caves and rock shelters with excavated sediments, 3 – main horizons of caves and rock shelters



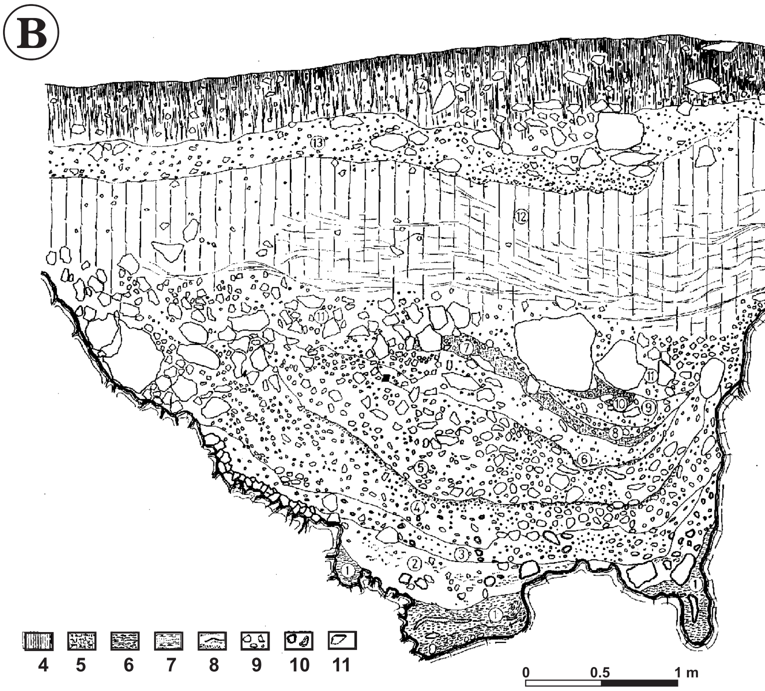


Fig. 3. Tunel Wielki Cave. A – Plan: 1 - rocky walls, 2 – drip-line of the cave, 3 – outlines of trenches. B – Cross-section of sediments (northern wall of the trenches I and III); 4 – humus, 5 – cultural layers, 6 – red and greenish-grey clays, 7 – clays with sands, 8 – black and brown mineral precipitations, 9 – limestone rubble, 10 – rubble with crust of phosphate compounds, 11 – pieces of crystalline dripstones. Numbers in circles correspond to the distinguished layers (after MADEYSKA 1988, simplified)

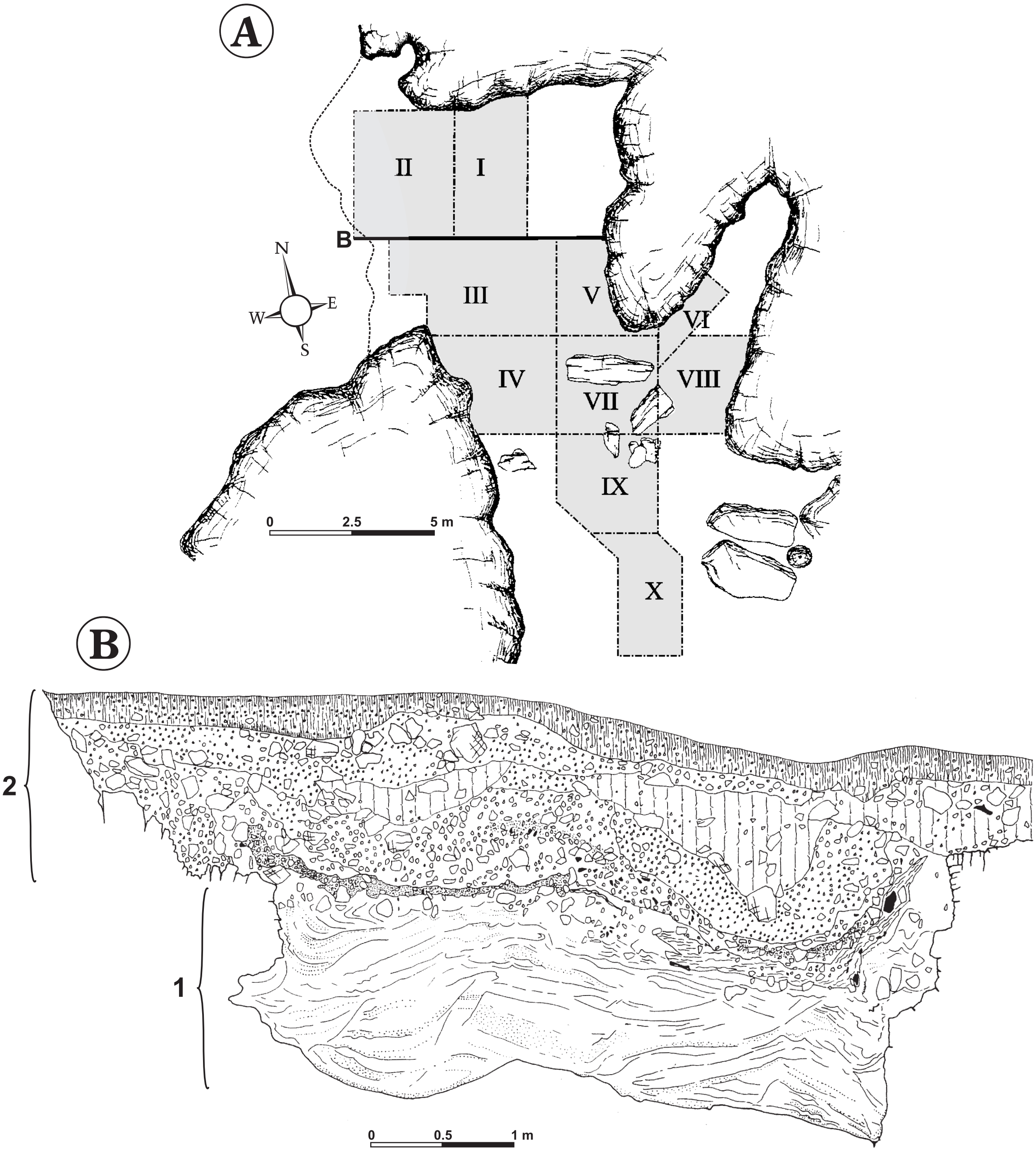


Fig. 4. Wylotne rock-shelter A – Plan (for explanation – see Fig. 3), B – cross section: 1 – sandy series, 2 – loam with limestone rubble series of dry cave sediments (after MADEYSKA 1969 a, simplified)

Cave (CHMIELEWSKI & *al*. 1967) and Wylotne rock-shelter (CHMIELEWSKI 1969, MADEYSKA-NIKLEWSKA 1969 a, 1970), are clearly connected with the distinct valley terrace "e" (DŻUŁYŃSKI & *al*. 1966). This was called by DŻUŁYŃSKI "the gate terrace", as it is often clearly visible at the mouth of small valleys. Well-developed bottom channels, with smoothed and chemically weathered walls, occurs in these caves (Text-fig. 4). The channels were filled with stratified sands and silt transported by flowing water. Fluvioglacial sands deposited close to the Polish Jura Chain during the South-Polish Glaciations are the probable source of the material. Redeposition of the sands through river valleys into the caves took place just after the formation of terrace "e"

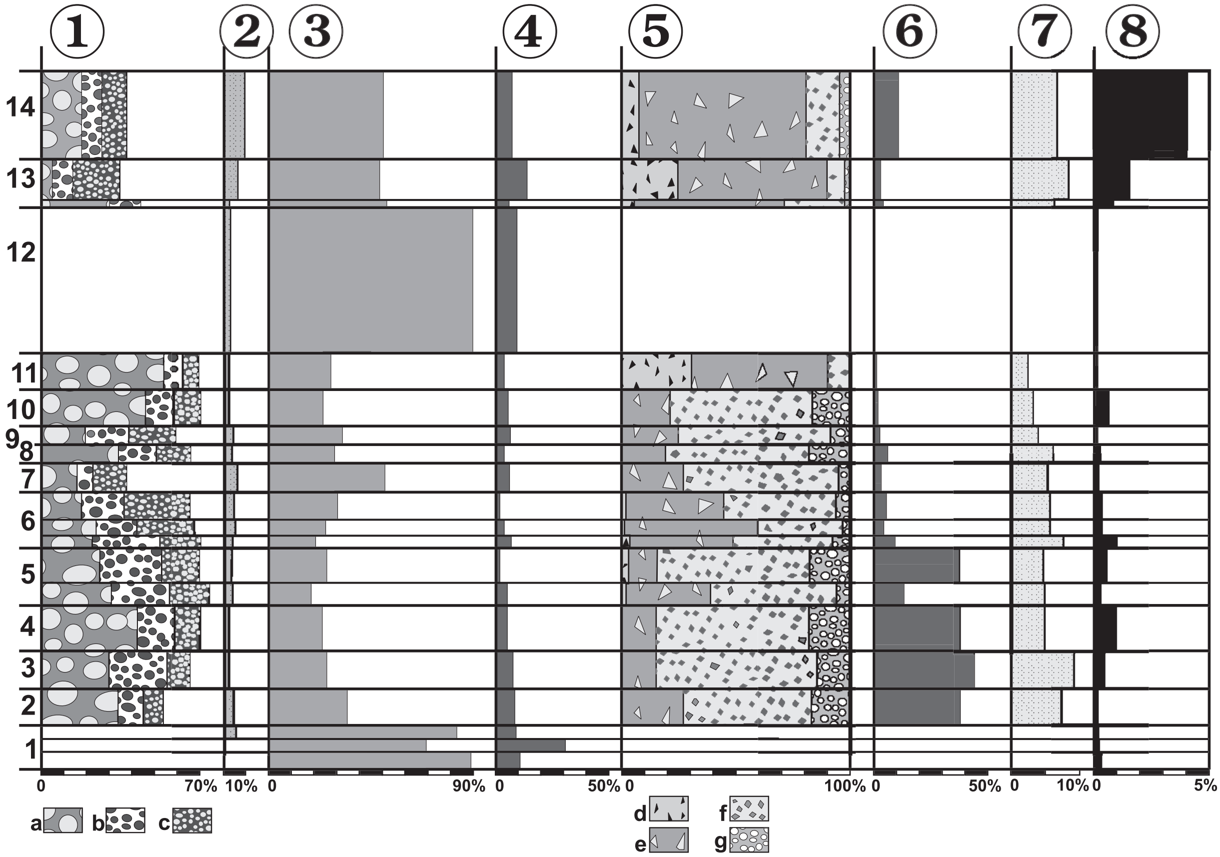


Fig. 5. Tunel Wielki Cave – an example of lithological diagram. Composition of sediments. **1-4** grain-size composition; 1 – limestone rubble: a – > 40 mm, b – 20-40 mm, c – 2-20 mm; 2 – 0.5-2.0 mm; 3 – 0.005-0.5 mm; 4 – < 0.005 mm; **5** – shape of the limestone particles > 10 mm in diameter: d – angular, e – with smooth edges, f – fairly smoothed, g – well smoothed; **6** – corroded rubble; **7** – rubble porosity; **8** – humus content in fraction < 1 mm. Numbers on the left side designate layers as on the Fig. 3 B (after MADEYSKA 1988, simplified)

by erosion, probably before the end of the Middle Polish Glaciations. The inclination of the valley bottom was then smaller than today (lower shaded stripe in Text-fig. 2). Between these two horizons of cave distribution, one more could be observed, represented by many small rock-shelters – the remains of destroyed cave systems – containing young Pleistocene sediments only.

LITHOLOGICAL DIFFERENTIATION OF YOUNG PLEISTOCENE CAVE SEDIMENTS AND METHODS USED IN THEIR INVESTIGATIONS

The most characteristic and common type of cave sediment is a cave loam with limestone rubble that originated in dry caves during the Younger Pleistocene. The grain sizes, the chemical and mineralogical composition of these sediments, the shape and degree of weathering of the limestone debris, as well as the presence of secondary mineral precipitations on the limestone particles, reflect the past environmental changes (Text-fig. 5).

The main factors influencing the origin of the limestone rubble were temperature and humidity fluctuations and, most importantly, the freezing and thawing of water in rock fissures. Consequently, the limestone rubble originated in that part of the cave between the entrance and a point several metres or tens of metres from the entrance, where diurnal or seasonal temperature fluctuations existed. At the cave entrances, mainly south-facing, a talus scree often formed. During periods of cool or cold climates, the rubble sedimentation was rapid, particles were covered quickly by younger ones and by fine material, so that they remained fresh and sharp-edged. During periods of temperate climate, accumulation was slow, and the limestone rubble lying on the surface, or covered only by a thin layer of loam, was exposed to the chemical activity of water entering the cave through precipitating. The degree of chemical weathering depends on the chemical composition of the water, resulting from the vegetation and soil development on the surface above the cave, and on the temperature. The composition of the cave loam, the presence of soluble compounds of iron, manganese or other elements as well as animal remains (source of phosphates) additionally influenced the process of chemical weathering and the development of precipitation crusts on the surfaces of the limestone particles (MIROSŁAW-GRABOWSKA 2000, 2002)

The main components of the cave loam are: autochthonous residual clays and fine material transported into the cave with precipitating water or on the feet of its inhabitants, as well as by the wind, but only close to the entrance. Loess material testifies to dry and cold climatic conditions, residual clays and products of soil processes rich in humus and iron compounds to temperate or warm conditions. Details concerning the methods of investigation of the deposits of dry caves were described earlier (MADEYSKA-NIKLEWSKA 1971).

The thickness of sediments filling the caves and rock shelters differs according to their dimensions and shape, and the topographical position of the entrances (MADEYSKA 1979).

The diversity of sediments described above, documented in the successions of several caves, was used repeatedly as a basis for the reconstruction of climatic changes during the development of cave fillings (CHMIELEWSKI & *al*. 1967; MADEYSKA-NIKLEWSKA 1969a, b; MADEYSKA 1982, 1988, 1991; NADACHOWSKI & *al*. 1989; VALDE-NOWAK & *al*. 1995 etc.)

ANIMAL REMAINS IN CAVE SEDIMENTS AND THEIR SIGNIFICANCE

Animal remains, mainly bones of vertebrates, are rather common in caves and rock shelters, but their amount and state of preservation vary. About 100 species of mammals and 80 of birds have been recognised to date, beside amphibians, reptiles, fishes and molluscs (BOCHEŃSKI 1973, 1974; KOWALSKI K. 1989).

Remains of the cave inhabitants are present, but the majority of animal remains comprise the prey of predators, including man. Man often used animal bones

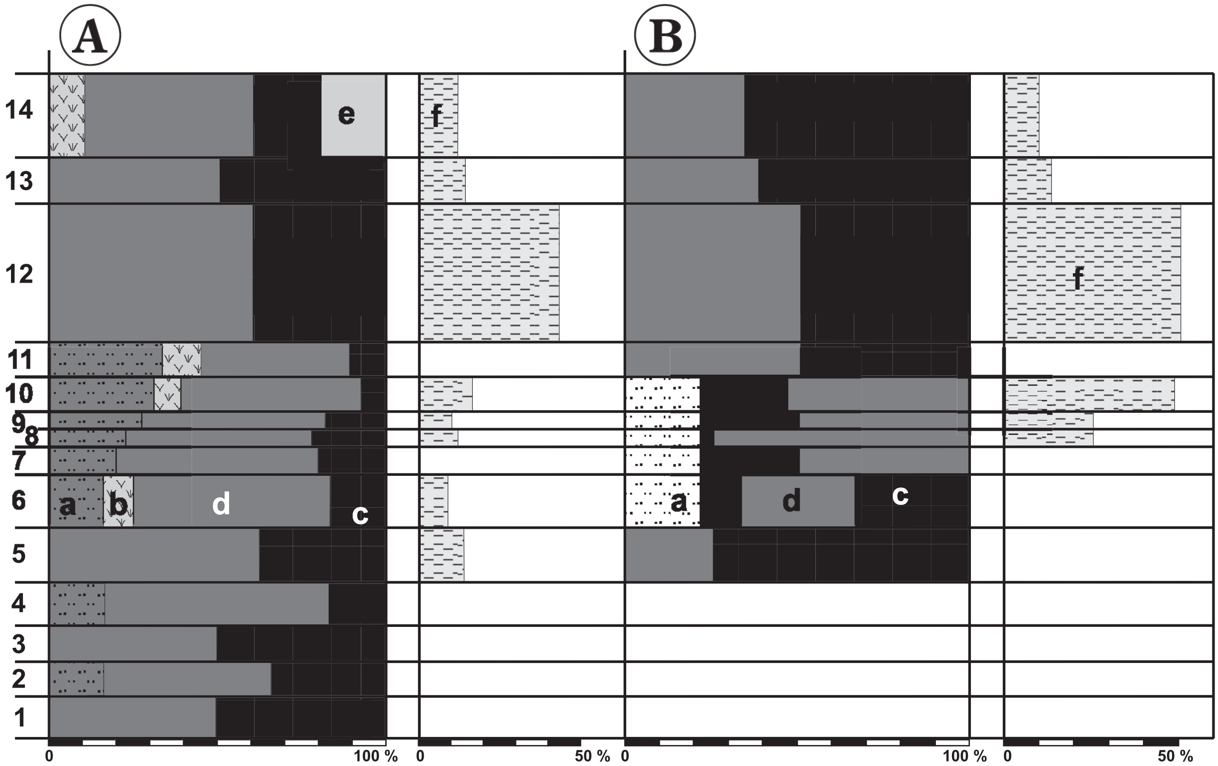


Fig. 6. Tunel Wielki Cave – an example of faunistic diagram. Changes of the fauna composition: A – species spectrum: percentage composition of mammals species characteristic for: a – tundra, b – steppe, c – forest; d – eurytopic animals, e – domesticated animals, f – animals characteristic for water and mire environments. B – individuals spectrum of rodents in similar ecological groups. Numbers on the left side designate layers as on Fig. 3B (after MADEYSKA 1981, simplified)

for the manufacture of tools and weapons; for this reason the bones are studied by archaeologists. Taphonomic analysis of fossil bones can provide very useful information. Bones can give information on seasonality of human activity, evidence of cut marks, carnivore gnaw marks etc. (e.g. CYREK & *al*. 2000). However, bones are also very important for reconstruction of the past environments and the stratigraphy of the sediments. Besides a few distinct species that are of direct biostratigraphical importance as index fossils (KOWALSKI K. 1989), some mammal and bird taxa are characterised by morphological variations that can also be used for biostratigraphy (NADACHOWSKI 1982, 1991). However, the majority of animal remains helps in climatostratigraphical interpretations of the successions of cave deposits.

Zoologists from the Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, in Kraków, investigated the rich bone material from the Polish caves. Occasionally other zoologists also became interested in the caves. Many studies are based on this material. In addition to establishing the faunal composition and migrations of species in the past, the studies deal with the evolution of particular groups of animals, changes of shape, proportions and amount of individuals according to climatic fluctuations (e.g. BOCHEŃSKI 1974; KOWALSKI K. 1961, 1964, 1989; NADACHOWSKI 1982, 1989, 1991).

For climatostratigraphical purposes, animals can be divided into groups of different environmental requirements. The most important are stenotopic species of rodents, because they are closely dependent upon a particular kind of pasture and are of frequent occurrence in cave fillings. In the group of tundra species, the most characteristic are lemmings and other animals such as arctic fox, reindeer, mammoth and woolly rhinoceros. Of the birds, ptarmigan and snow owl are the most characteristic. The steppe or other open landscape environment was characterized by hamsters, spermophiles, picas and horses, as well as bustards and partridges. The forest animals group includes many species still found in Polish woodland, such as bank vole, squirrel, dormouse, beaver, as well as reed deer and elk.

For stratigraphic interpretation, the vertebrate faunal composition can be presented in two ways (Text-fig. 6). The first shows the species spectrum, i.e. the mean percentage composition of mammalian species in the various ecological groups. The second shows the individual spectrum - the percentage of rodent individuals in the same groups. Only rodents can be used for this spectrum because of the large number of individuals required for the statistical analysis.

For ecological interpretation of these data, taphonomical factors should be taken into account. Neither the species spectrum nor the individual spectrum shows the natural composition of living faunal assemblages. These spectra result from the manner in which animal remains accumulated in the cave. Those animals that were the favourite prey of predators will be over-represented, while other species could be very rare. This was clearly seen in places during excavations, for instance a heap of crushed lemming skulls under an owl resting place.

In spite of this, a characteristic feature of the faunal composition is the coexistence of animals characteristic of different environments. This is connected with the highly diversified landscape of the regions where the caves were situated and with the presence of deep, narrow valleys with differently orientated slopes resulting in local microclimates and in a mosaic of various vegetation communities.

ARCHAEOLOGICAL MATERIAL

Besides young material, remnants of Mediaeval, Bronze Age and Neolithic penetration of the caves (ROOK 1980), interesting Palaeolithic material was discovered in several caves. Usually the cultural layers or cultural horizons represented traces of short visits of human groups, hunting in the vicinity, evidence of hunting in the cave or of using the cave as a place for the production of flint artefacts. Exceptionally, however, evidence of longer occupation was found.

The oldest artefacts, found in the last few years in the Biśnik Cave (central part of the Polish Jura Chain), represent the Acheulian tradition. They are characterized by the Levalloisian technique with elements of the blade technique (Text-fig. 7, CYREK 1997b, 1999b; CYREK & *al*. 1999). They were found in sediments dated to the Eemian Interglacial, Warthanian, penultimate interglacial and probably even to the Odranian. The Taubachian culture (Text-fig. 8) was found in the sediments dated to the so-called Early Vistulian. The Levalloisian technique continues in the Mousterian culture. The main cave sites of that culture are the Nietoperzowa and Koziarnia caves (CHMIELEWSKI & *al*. 1967, CHMIELEWSKI 1975). During the Early Vistulian, another culture developed contemporaneously in this region: the Micoquo-Prondnikian with its characteristic hand axes, bifacial knives and scrapers (Text-fig. 9). This culture was defined by W. CHMIELEWSKI mainly on the basis of 3 assemblages found in the Wylotne rock-shelter and on an assemblage from the

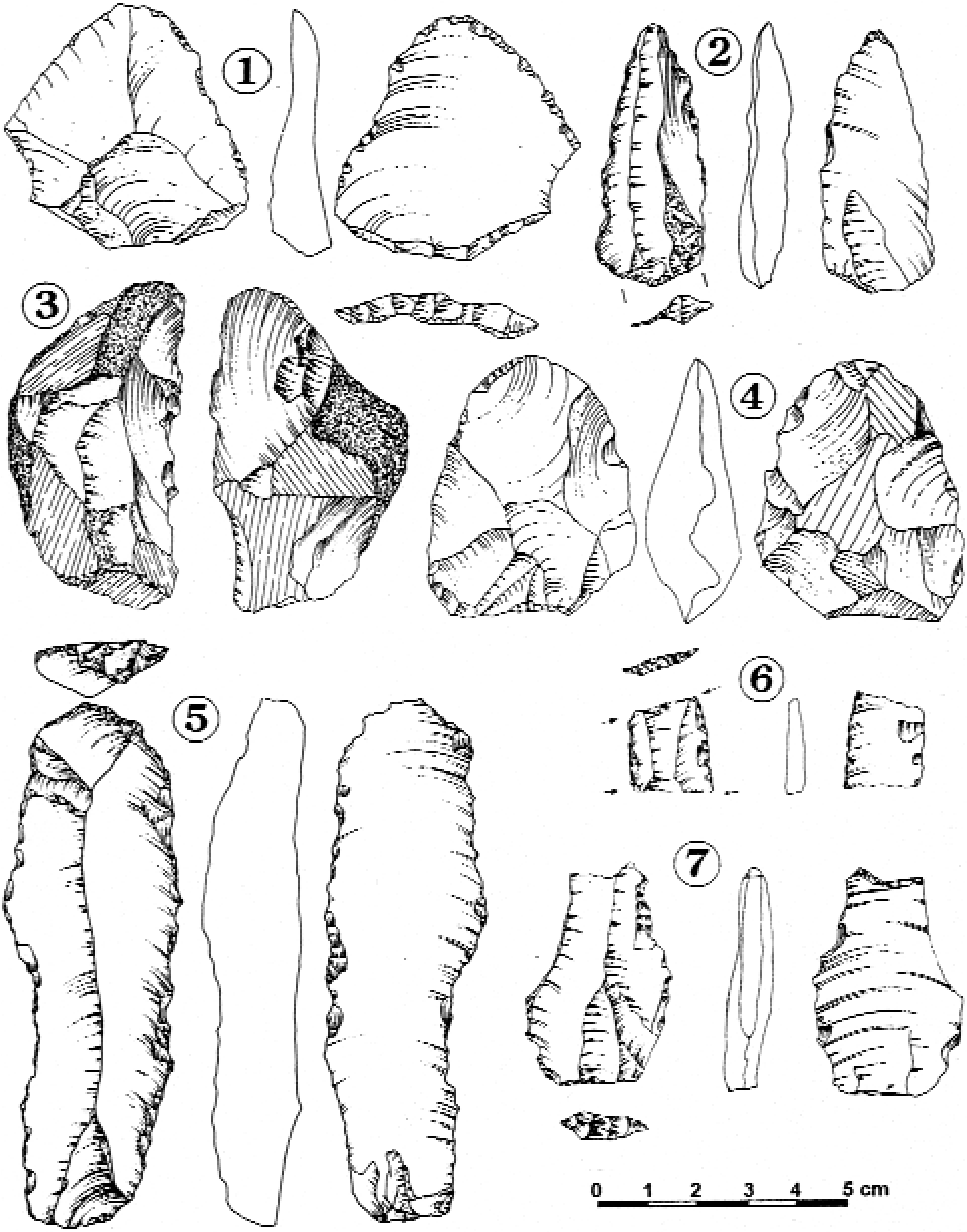


Fig. 7. Flint artefacts representing Acheulian tradition with levalloisian and blade techniques from the Biśnik Cave. 1-2 – levalloisian points, 3 – knife with natural back, 4 – mygdaloid hand-axe, 5 – retouched blade, 6 – retouched blade, 7 – blade with notch

Ciemna Cave (CHMIELEWSKI 1969, 1970, MADEYSKA-NIKLEWSKA 1969b). J.K. KOZŁOWSKI & S.K. KOZŁOWSKI (1977) called them „assemblages of the Bockstein, Ciemna and Wylotne type". A stony construction considered to be a wind-screen, the oldest one in Central Europe, was found at the entrance to the Biśnik Cave. In the same cave, a collection of axes made from red deer antlers was found. Both of these finds are connected with the Micoquo-Prondnikian. (CYREK 1999b). The Charentian culture assemblage (Text-fig. 11), found in the Raj Cave, could also be dated to the Early Vistulian (J.K. KOZŁOWSKI 1972, 1974). An interesting discovery at the entrance to the cave, and connected with this culture, was an accumulation of 293 reindeer antlers, which was probably the remnant of a rampart built by the Charentian people as a defence against predators.

The most characteristic Upper Palaeolithic culture found in Polish caves is the Jerzmanowician, described by W. CHMIELEWSKI (1961). In the Nietoperzowa Cave, almost exclusively leaf-shaped points (spear-heads) were found (Text-fig. 12). They were found in a black layer rich in charcoal. W. CHMIELEWSKI suggested that the Jerzmanowicians hunted cave bear by using big fires

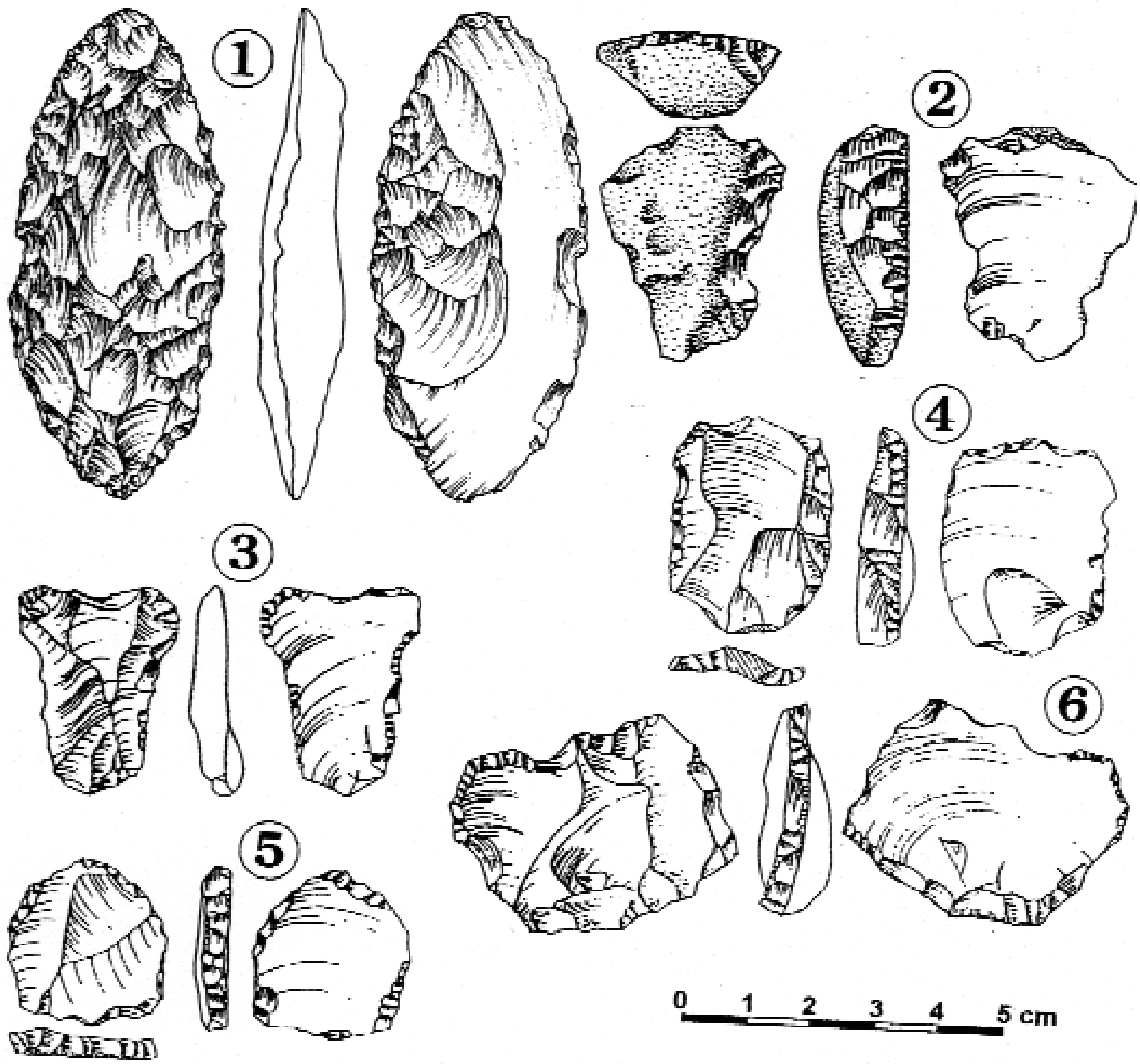


Fig. 8. Flint artefacts representing Taubachian from the Biśnik Cave. 1 – hand-axe (point?), 2, 3, 6 – blades with notches, 4, 5 – scrapers

for smoking them out from inside the cave in order to kill them with spears.

Scarce in the cave sites are small assemblages of the Aurignacian, Szeletian and later East Gravettian cultures (e.g. K. KOWALSKI & *al*. 1967, SAWICKI 1953, VALDE-NOWAK & *al*. 1995). The most interesting discovery from that time was the unique boomerang made from a mammoth tusk (Text-fig. 13), found in the Obłazowa Cave (VALDE-NOWAK & *al*. 1987)

The youngest Palaeolithic culture in the Polish Jura caves is the Magdalenian. Besides poor "satellite" sites of that culture: Puchacza Skała (KOWALSKI & *al*. 1965), or Krucza Skała Cave (CYREK 1994, 1999a), the main site is the Maszycka Cave. The remains of 16 human individuals (3 men, 5 women, and 8 children with damaged skulls) were found there with many remnants of habitation. Besides tools and weapons stored in places, pieces of art such as the curved rib were discovered (Text-fig. 14). A red-painted saiga antelope skull found by the cave entrance was probably used as a totem. Three femoral bones of rhinoceros lying inside the cave probably represented, as S.K. KOZŁOWSKI wrote, a store of rhino hams (S.K. KOZŁOWSKI & *al*. 1993).

Late Palaeolithic and Mesolithic materials are of even rarer occurrence in the caves. Flint and ceramic materials of the Neolithic (ROOK 1980) were found in the upper part of the sediments, commonly mixed with younger artefacts.

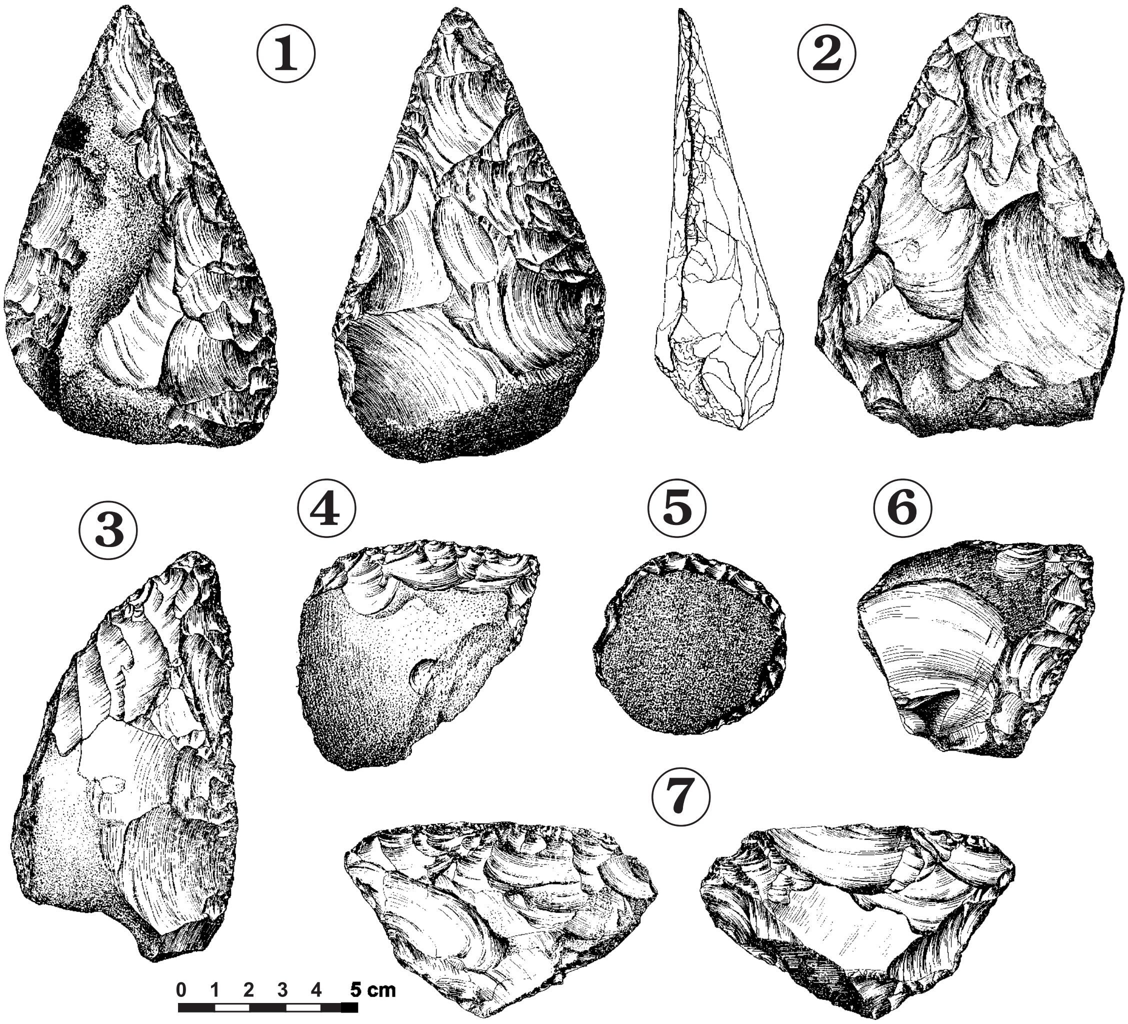


Fig. 9. Flint artefacts representing Micoquo – Prondnikian from the Wylotne rock-shelter (after CHMIELEWSKI 1969, 1975); 1, 2 – hand-axes, 3 – knife, 4, 5, 6, 7 – scrapers

CLIMATOSTRATIGRAPHIC INTERPRETATION OF THE CAVE FILLINGS

A climatostratigraphic scheme constructed on the basis of the investigation of the cave fillings is shown in Text-fig. 15. Fluctuations of the faunal composition are shown by the species spectrum of the animal remains from the Polish cave sediments, mainly caves situated in the Polish Jura Chain. Species are divided into groups of particular ecological requirements: animals living in tundra (T), steppe (S) and forest (F). Eurytopic animals and those not identified to species level are shown as a separate group (E). Changes of the species spectrum composition of the fauna illustrates the sequence of environmental changes and thereby the climatic fluctuations in the past.

The second, even more complete record of climatic fluctuations during the last 250 ka, is the curve of speleothem growth frequencies constructed by HERCMAN (2000) for the Central European Uplands. More intensive dripstone formation took place during periods of warm and wet climate. The phases of such intensity correspond more or less precisely to interglacials and interstadials.

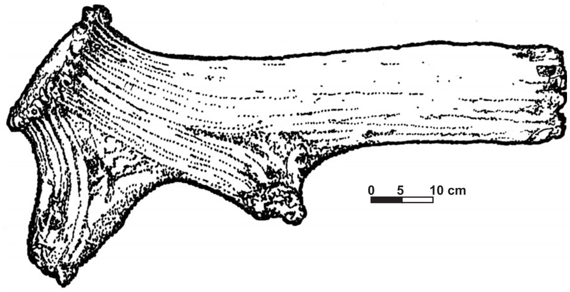


Fig. 10. Axe made of deer antlers from the Biśnik Cave.

In Text-fig. 15 the Palaeolithic cultures identified in the Polish cave sediments are plotted against climatic change determined by the faunal species spectrum and the curve of speleothem growth frequencies. Besides the oldest Acheulian-type culture with Levalloisian

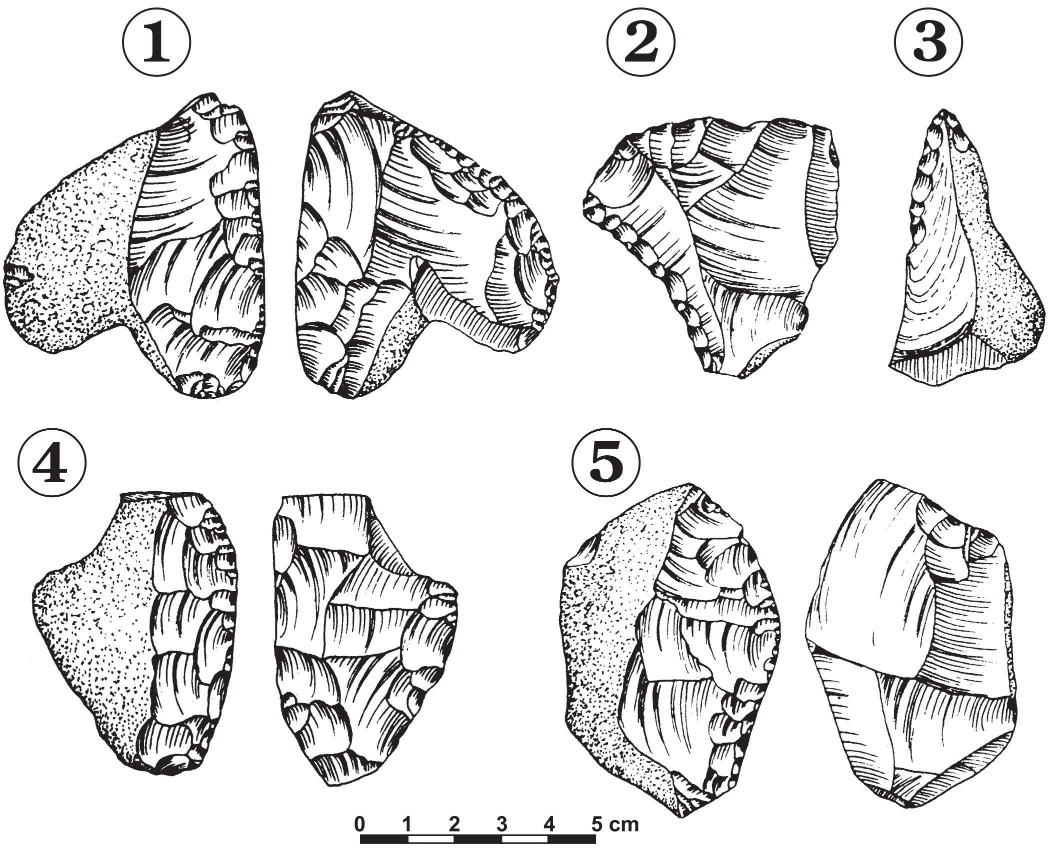


Fig. 11. Flint artefacts representing East Charentian from the Raj Cave: 1, 2, 4, 5 – side scrapers, 3 – perforator (after KOZŁOWSKI J.K. & KOZŁOWSKI S.K. 1977)

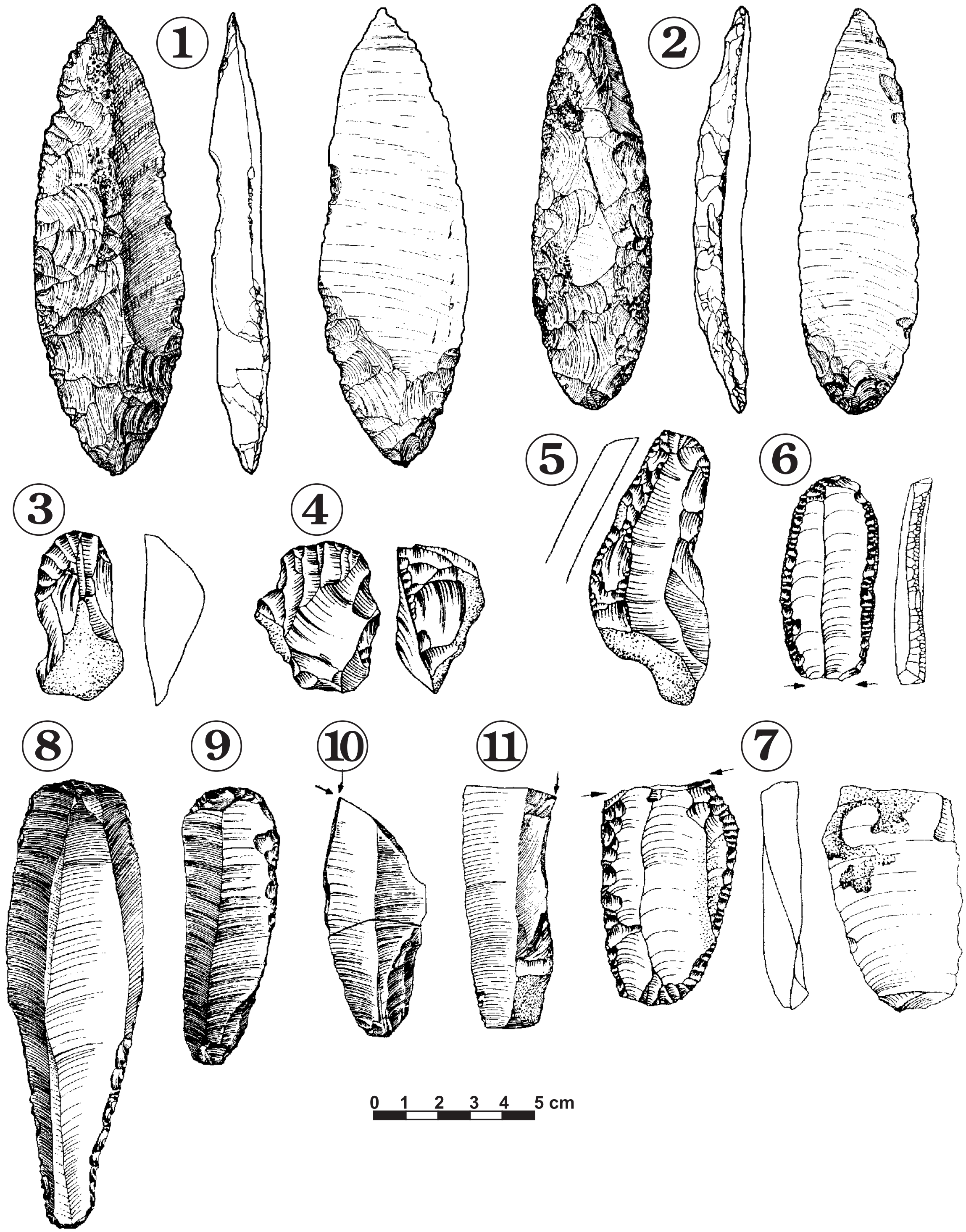


Fig. 12. Examples of Upper Palaeolithic flint artefacts. 1, 2 - Jerzmanowician leaf points from Nietoperzowa cave (after CHMIELEWSKI 1961); 3, 4, 5 - Aurignacian end-scrapers from Mamutowa Cave (after KOZŁOWSKI J.K. & KOZŁOWSKI S.K. 1977); 6, 7 - Epigravetian truncated blades from Deszczowa cave (after CYREK 1999 a); Magdalenian from Maszycka Cave: 8, 9 - end-scrapers, 10, 11 - burins (after KOZŁOWSKI S. K. & al. 1993).

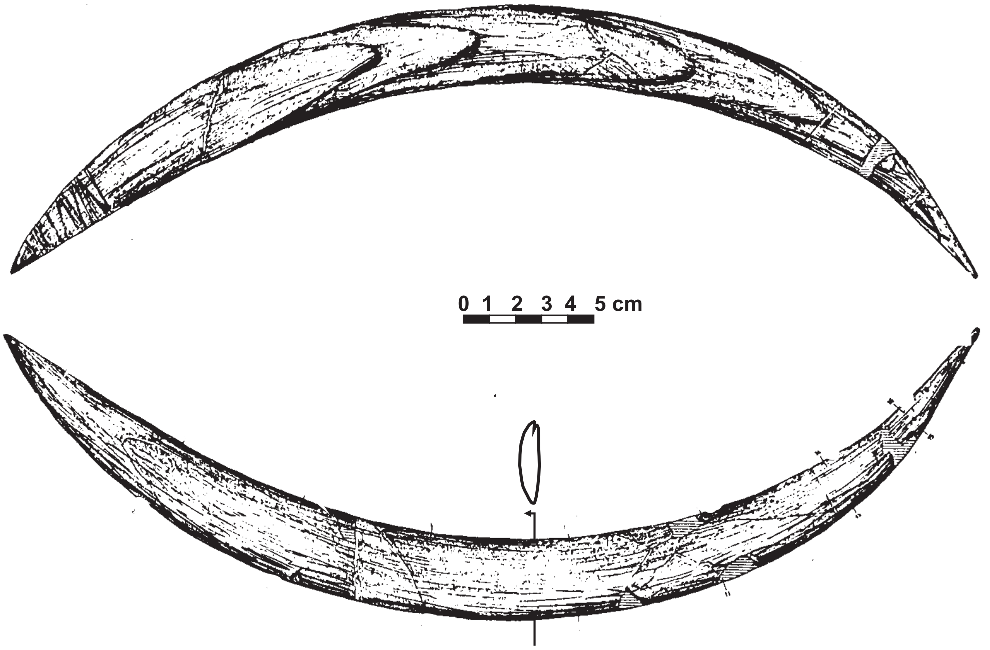


Fig. 13. Boomerang from the Obłazowa Cave (after VALDE-NOWAK & *al.* 1995)

technique (known from the Biśnik Cave), starting probably from the penultimate interglacial (phase I of speleothem formation), the Middle Palaeolithic corresponds to speleothem phases II and III (correlated with the whole of oxygen isotope stage 5). The Taubachian culture from the Biśnik Cave appeared during the warmest period - speleothem phase II, corresponding to the Eemian Interglacial. The Mousterian with Levalloisian technique and the Micoquo – Prondnikian (appearing commonly in the caves of the southern part of the Polish Jura), as well as the South Charentian (in the Raj Cave), developed during the time of speleothem formation phase III, i.e. during the Early Vistulian. The majority of Upper Palaeolithic cultures

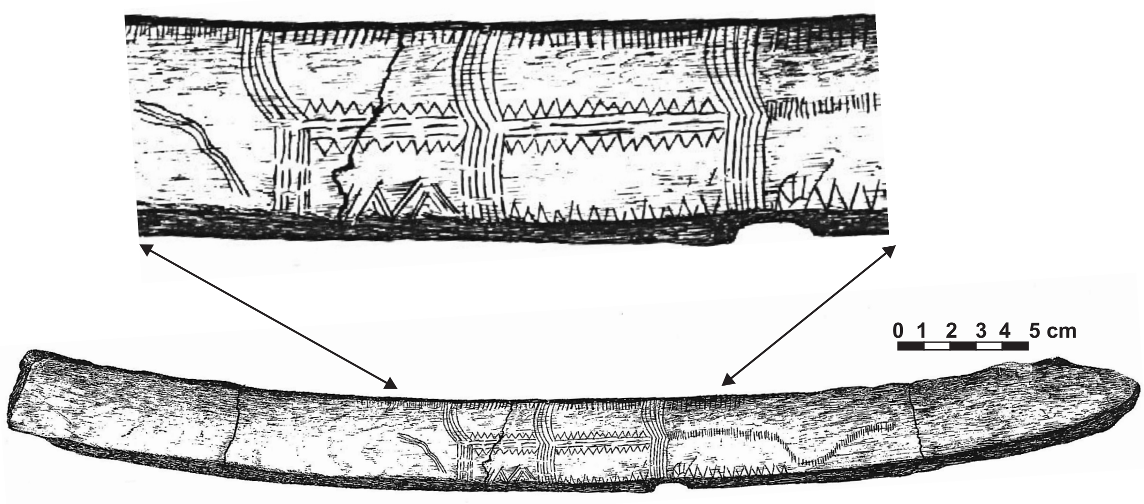


Fig. 14. Decorated rib from Maszycka cave (after KOZŁOWSKI S.K. & *al.* 1993, simplified)

Palaeolithic cultures:
LA - Acheulian - type with Levalloisian technique,
T - Taubachian,
LM - Levallois - Mousterian,
MP - Micoquo-Prondnikian,
CH - East Charentian,
A - Aurignacian,
J - Jerzmanowician,
S - Szeletian, G - Gravettian,
EG - Epigravettian,
MG - Magdalenian;

Schematic species spectrum of fauna:

T - tundra element consists of: rodents: *Dicrostonyx torquatus* (*D. gulielmi*), *Lemmus lemmus, Microtus gregalis, Microtus nivalis*; other mammals: *Mammuthus primigenius, Coelodonta antiquitatis, Rangifer tarandus, Ovibos moschatus, Alopex lagopus, Lepus timidus*

S - steppe element: rodents: *Citellus superciliosus, C. citelloides, Cricetulus migratorius, Cricetus cricetus, Lagurus lagurus*;

other mammals: *Equus caballus, Bison priscus, Ochotona pusilla*

F - forest element: rodents: *Apodemus flavicollis, A. sylvaticus, Castor fiber, Clethrionomys glareolus, Eliomys quercinus, Glis glis, Muscardinus avellanarius, Sciurus vulgaris, Sicista betulina*;

other mammals: *Crocidura* sp., *Talpa europea, Myotis bechsteini, Pipistrellus pipistrellus, Alces alces, Bos primigenius, Capreolus capreolus, Cervus elaphus, Sus scrofa, Felis silvestris, Gulo gulo, Lynx lynx, Martes martes, Meles meles, Ursus arctos*

E - eurytopic element: rodents: *Arvicola terrestris, Micromys minutus, Microtus agrestis, M. arvalis, M. oeconomus, Pitymys subterraneus*;

other mammals: *Neomys fodiens, Sorex araneus, S. minutus, Lepus europeus, Oryctolagus cuniculus, Canis lupus, Crocuta spelaea, Mustela erminea, M. nivalis, M. putorius, Panthera spelaea, Ursus spelaeus, Vulpes vulpes* and many bats: *Barbastella barbastellus, Eptesicus nilssoni, Myotis brandti, M. dasycneme, M. daubentoni, M. emarginatus, M. myotis, M. mystacinus, M. natterei, Plecotus auritus.*

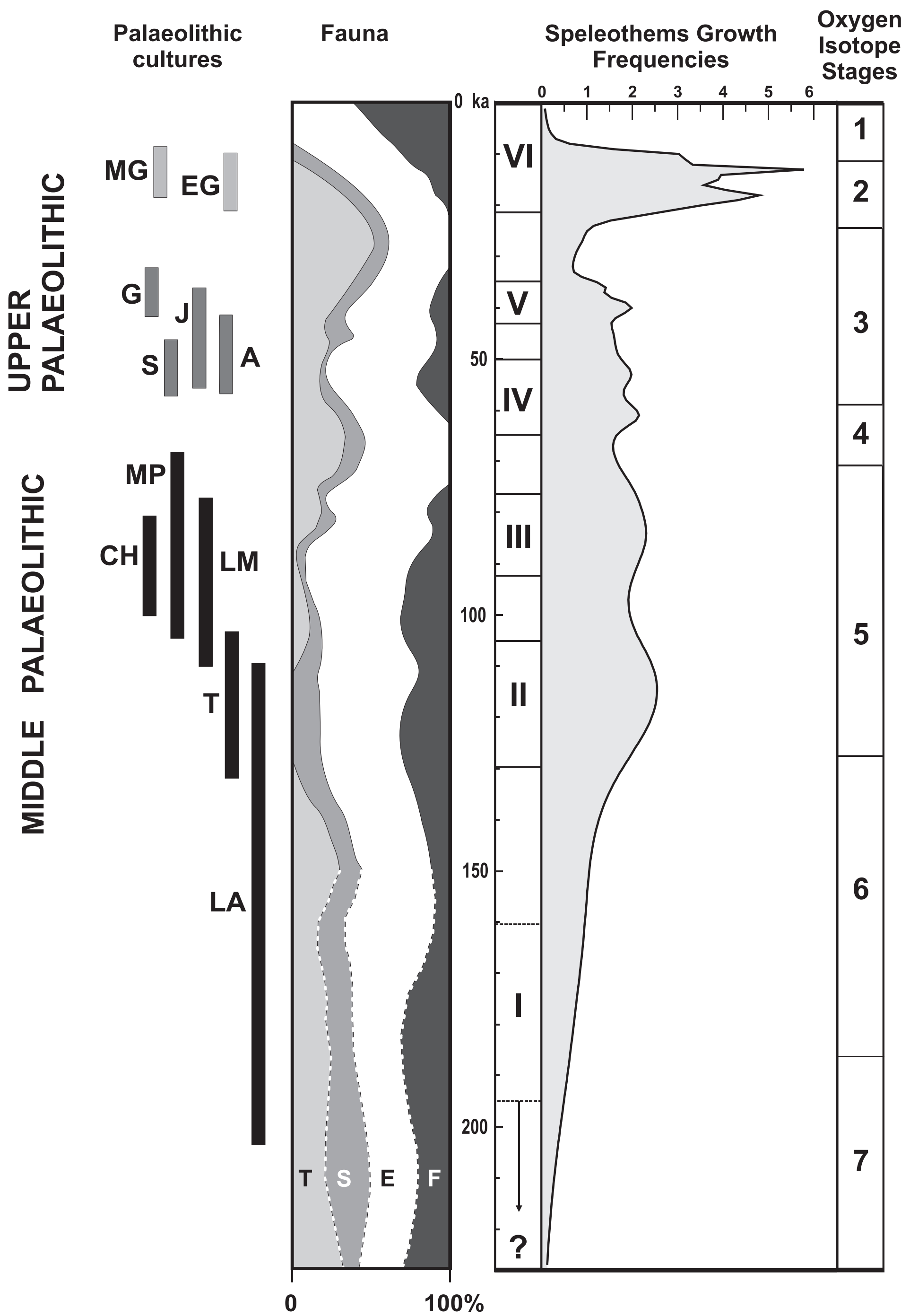


Fig. 15. Correlation of Palaeolithic cultures ranges and fauna composition changes in Polish caves with the speleothems growth frequency curve, constructed for the Middle European Uplands by HERCMAN (2000)

expanded during speleothem phases IV and V, including the short cool break between them (oxygen isotope stage 3 – Interplenivistulian). The Magdalenian and Epigravettian cultures appear at the beginning of phase VI. During the periods of breaks or reduction in speleothem formation, traces of human occupation are absent or very rare.

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