The Quaternary vertebrate fauna of cave deposits of the Podillia-Bukovynian Karst-Speleological Area (Western Ukraine)

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Abstract

The Podillia-Bukovinian Karst-Speleological Area is rich in numerous caves of karst, suffosion, and weathering origin. The gypsum karst is the most widespread in the area. It is famous for the World's largest maze-caves in gypsum. Some of these caves contain Quaternary sediments with vertebrate fauna that can be used for biostratigraphy. The first faunal remains were found as early as 1886. Up to now, at list 30 cave sites with the Quaternary vertebrate fauna are known. Most of the sites are in horizontal caves, which results in specific bone and sediment accumulations. The formation of most of the bone accumulations is related to the inhabitation of caves by the *troglophilic* species, especially carnivores, and only a few inhabited by humans. The oldest among the cave sites is Chortkiv, dated to the late Odesian Fauna (Kryzhanivka Stage, MIS 41–62). The best-studied cave sections with cave fauna are Bukovynka, Kryshtaleva (Kryvchanska), Pryima I, Chortovi Skeli (Lviv VIII). Several caves are promising for further research, such as Martynivka, Tovtry, and others. A very small part of the osteological material was published in detail. Only 15 radiocarbon data are known for the cave sites in the region. Many finds in the caves were made in the 1950s–1960s, sometimes just by accident. Part of the bone collections were lost. The material stored in museums should be revised. They still is a large potential for the future research of the Quaternary cave deposits of the Podillia-Bukovinian Karst-Speleological Area (Western Ukraine).

1. Introduction

The study of cave sediments for paleogeographical reconstructions is one of the essential areas in paleogeography. Conditions of continental sediment accumulation and preservation in caves differ from terrestrial ones. First, due to their intrazonal nature, caves (primarily subhorizontal) attracted the animal population (including hominids), becoming concentrators of their vital activity traces. Vertical cavities, karst pits, and shafts acted as natural traps and accumulated rich faunal material, as well as eolian and fluvial sediments enriched with palynological material.

Due to the significant temperature inertia of the bed rocks, the caves have relatively stable microclimatic (thermo- and hygro-constant) conditions, which contributes to the better preservation of organic residues. In some cases, when the cavities accumulated snow, they formed perennial snowfields and glaciers, which could store even whole tree trunks and other organic remains. Specific for karst massifs are water-chemogenic sediments (flowstones, speleothems), represented mainly by calcium carbonate, which, on the one hand, additionally preserve other sediments, and on the other hand, are themselves a source of radioisotope records.

Geochemically, cave sediments are dominated by an alkaline environment, which contributes to the preservation of calcium in osteological remains. In addition, calcium is part of hydroxyapatite, which, in turn, is a "shield" to protect the fossil DNA from decay. The preservation of DNA is also facilitated by the already mentioned constant and relatively low temperature.

Cave deposits, as a special type of continental deposits, have certain features compared to terrestrial types, which determine the specificity of their study and interpretation.

An important circumstance in the study of the paleogeography of certain regions is that terrestrial Neogene-Quaternary deposits are absent or largely destroyed in many areas of karst formation. In such cases, cave sediments will be almost the only source of information about the paleoenvironmental conditions of the Quaternary period in this particular area.

However, even in the presence of a complete section of terrestrial Quaternary sediments, cave sediments can be a significant source of information, due to the specificity of subterranean sediment genesis, diagenesis, and epigenesis of these deposits.

Sometime ago, we made the preliminary brief reviews of "bear caves" of Ukraine, including the territory to be described (Ridush, 2009, 2014). During the time that passed, new information was obtained, and several previous data were clarified. The purpose of this study is to review the state-of-art in the investigation of cave sediments of the Podillia-Bukovinian Karst-Speleological Area, and to estimate the palaeogeographic potential of these sediments in the karst areas of the continental part of Ukraine.

2. Literature review

The karst and caves in the region were researched by a dozen of scholars in the past. The greatest input in this field was done by B. Ivanov,

V. Dubliansky, A. Klimchouk, V. Rogozhnilov, V. Andreichouk, V. Korzhyk, I. Turchinov and others (Andreychouk and Klimchouk, 2017; Ivanov, 1956, 1961, 1965; Klimchouk, 2012; Klimchouk and Andrejchuk, 2002; Klimchouk and Andreychouk, 2017; Klimchouk and Rogozhnikov, 1982; Klimchuk et al., 2008; Klimchouk et al., 2009; Korzhyk, 2007; Ridush and Kuprich, 2003).

For decades, the studies of cave deposits were provided by paleozoologists: G. Bachynsky, K. Tatarinov, I. Marysova (Bachynskyi, 1965, 1967, 1970; Bachynskyi and Tatarinov, 1966; Bachynskyi et al., 1964; Marysova, 1962; Tatarinov, 1965, 1966b, 2000; Tatarinov and Bachynskyi, 1968). Archeological studiesof the cave Paleolithic were provided by Matskevyi (1998, 2001, 2005). During the time between 1958–1970, the sites of fossil vertebrates were found in 33 out of 600 surveyed caves in Ukraine. Now we know about 30 Quaternary paleontological cave sites only in the Podillia-Bukovynian area.

In recent years the complex studies of cave sediments in the area are carried out by an international team. The palynological studies are provided by N. Gerasimenko and Y. Avdieyenko (Avdieienko, 2018, 2019; Avdieienko et al., 2018; Gerasimenko et al., 2014a, 2014b). Research on the physical properties of cave deposits is conducted by Bondar et al. (2010) and Bondar and Ridush (2015).

Starting from the 1990s, paleozoological research in the caves of Ukraine was carried out by the author in close cooperation with international cooperation (Croitor et al., 2014; Marciszak et al., 2015; Ridush, 1998, 2004b, 2004c, 2012, 2014; Ridush et al., 2012, 2013; Vremir et al., 2000, and others).

The oldest references to caves with bones in the south of Ukraine are found in the notes of Turkish traveler of the 17th century (Çelebi, 1961). Research of the so-called "bear caves" on the territory of modern Ukraine began in the middle of the 19th century (von Nordmann, 1858). A little later, the first cave with Pleistocene fauna in western Ukraine was investigated by Łomnicki (1881). But still the cave sites from this region are unfamiliar to most foreign researchers.

3. Geological and Karstological settings

The described area covers the southwestern part of the East European Platform. The soluble rocks and karst make up most of the area.

The territory of modern Ukraine is rich in karst areas. In the south of Eastern Europe, namely on the territory of Ukraine and Moldova, there are five main karst regions and, accordingly, the same number of areas of cave locations with faunistic fossil remains. Two of them are mountain karst regions: the carbonate karst of the Ukrainian Carpathians and the Mountainous Crimea. The other three represent plain karst: the Podillia-Bukovinian Area with a predominance of gypsum karst, the Eastern Podillia-Bessarabian and Black Sea-Azov Areas with carbonate karst (Ridush, 2013). Up to 2008, the total number of known caves in Ukraine was 1690 (Klimchuk et al., 2008). According to our calculations, there are about 100 caves on the territory of Moldova. Despite the significant distribution of karst caves in these territories, the number of caves with finds of fossil bears is quite limited, compared to Central and Western Europe.

The Podillia-Bukovinian Karst-Speleological Area is one of the karst regions in the south of Eastern Europe. It is famous for the huge maze caves in gypsum (Andreychouk and Klimchouk, 2017; Klimchouk, 2012; Klimchouk and Andreychouk, 2017; and others). According to the karst-speleological regionalization of the south of Eastern Europe (Ridush, 2013) (Fig. 1B), it consists of two regions: the West Podolian, to the north of the Middle Dniester, and Pokuttia-Bukovinian (СЄ-VI-Б-1), to the south of the Middle Dniester reach, with the part of the Prut River valley (СЄ-VI-Б-2).

4. Results (cave sites description)

Back in 1881, the bones of cave bear and cave hyena were found in the cave of unknown genesis, near the village of Melna (now Rohatyn district, Ivano-Frankivsk region) (Łomnicki, 1881). Quaternary vertebrate fauna locations near the villages of Stradch and Vynyava were associated with ancient dens of cave hyenas and cave bears. These dens were found in niches filled with redeposited sand (Bachynskyi, 1970; Goretskiy, 1957; Tatarinov, 1958). One sample of the *Crocuta spelaea* from the Horosno-Vynjava site was radiocarbon dated to 40,770 ± 350 yrs BP (MAMS 31302) (cal 42,480 yrs BP) (Westbury et al., 2020).

Karst-speleological regionalization of a territory means considering not only the karst cavities, but also caves of other origin, like suffosion, weathering etc.

Most of the gypsum caves in the region are of hypogenic origin (Klimchouk and Andreychouk, 2017), but after the area underwent uplift,

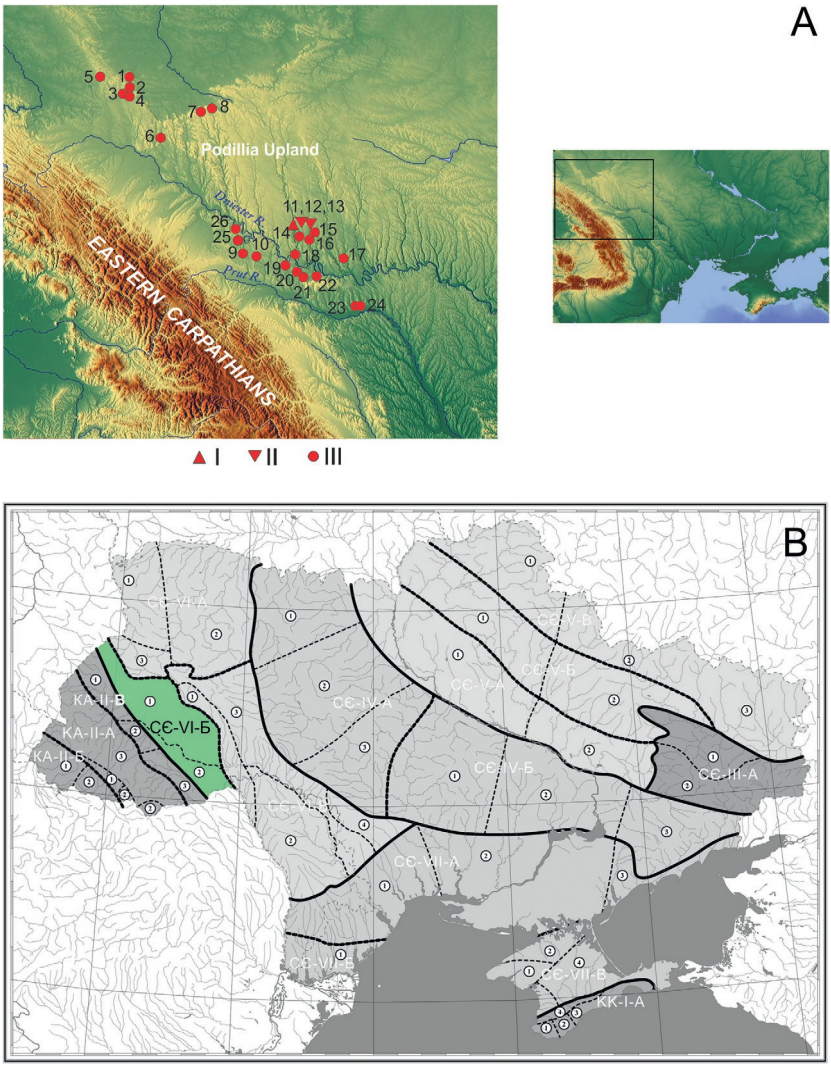

Fig. 1 (A) Location of the main Quaternary paleontological cave sites of the Podillia-Bukovinian Karst-Speleological Area. Legend: The age of site: I—Early Quaternary; II—Middle Quaternary; III—Late Quaternary age. Sites: 1—Chortovi Skeli; 2—Pryima; 3—Shchyrets; 4—Vyniava-Horosno; 5—Stradch; 6—Melna; 7—Divychi Skeli; 8—Mala Ilovitsia; 9—Cholivs'ka Gora (Chortovets'); 10—Ostrivets'; 11—Chortkiv; 12—Horyshnya Vygnanka; 13—Syniakove, Syniakove-1; 14—Ozerna; 15—Borschiv; 16—Kryvchenska (Kryshtaleva); 17—Atlantyda, Ta Dirka; 18—Kasperivtsi; 19—Chun'kiv; 20—Tovtry; 21—Martynivka; 22—Balamutivs'ka; 23—Bukovynka; 24—Malimon-Canyon; 25—Trygolovatka. (B) Location of the Podillia-Bukovinian Karst-Speleological Area (СЄ-VI-Б) (highlighted in green) on the scheme of karst-speleological regionalization of the south of Eastern Europe according to Dublianskaya and Dubliansky (1992) with our changes.

causing the the erosional opening of the cave systems, they quite quickly became filled with allochthonous loose material, consisting mainly of the Quaternary loess and eluvium of the overlying Neogene clays and limestones.

4.1 Atlantyda Cave

The cave is situated on the left bank of the Zbruch River (left tributary of the Dniester River), near Zavallja Village, Kamianets-Podilsky Rayon, Khmelnytska Oblast (48°35′55.43″N, 26°20′42.90″E) (Fig. 1, *17*). The cave, with a total length of up to 8300 m, is of a maze type and has three levels. It is developed in the Miocene gypsum strata.

In the early 1980s, comprehensive research, including a detailed study of secondary deposits, was conducted under the leadership of O. Klymchouk in the Atlantyda Cave. In particular, a morphogenetic analysis of the cave together with cartographic, stratigraphic, granulometric, mineralogical, palynological, and paleomagnetic studies of the cave deposits were carried out (Bahmutov and Lagutin, 1985; Klimchouk, 1984; Klimchouk and Rogozhnikov, 1982; Rogozhnikov, 1984; Rogozhnikov and Lomaev, 1985). It was noted that bone and plant remains were not found in numerous exploration pits, and in 70 samples taken for palynological analysis, spores and pollen, even redeposited ones, were not found (Klimchouk and Rogozhnikov, 1982). However, a little earlier A. Lomayev indicated that the spore-pollen analysis of sediments in the Grotto of the Snow Queen in the cave yielded a "Mindel-Riss—Mindel spectrum" (Lomayev, 1979, p. 73). An attempt was made to conduct a paleomagnetic study of water-mechanical cave deposits (a 4.5-m section in one of the pits). It was established that the formation of deposits took place in the Brunes polarity era (Bahmutov and Lagutin, 1985). The more recent paleomagnetic research of the cave sediments established that the light-gray laminated aleuritic clays in the Globe Gallery, that are characteristic also to other galleries in the cave, were deposited below Matuyama/Brunhes boundary (Bondar et al., 2010).

A complete skeleton of a brown bear (*Ursus arctos* L.) was discovered in 2013 on the lower floor of the cave. The found skeleton lay along the narrow gallery, head to the suggested ancient entrance. It was bedded on the surface of the dense ancient clay, covered with a crust of gypsum crystals, iron, and manganese hydroxide, and dated to pre-Brunes.

The bones were covered with loose fluvial thin-layered loam sediments 25–40 cm in thickness, including also remains of Chiroptera, Rodents,

Lagomorphs, and Mollusks, and impure with charcoal fragments up to 4–5 cm in diameter. The occipital part of the cranium was accidentally partly destroyed by cavers, who discovered the skeleton, and some few bones were partly removed by flowing water from the initial position. The remains belong to a large old male individual with strongly worn teeth. It was dated to the Young Dryas (GS-1).

In other parts of the cave, numerous bones of small Carnivora like *Vulpes*, *Martes* sp., and *Felis silvestris* are bedded on the surface of the cave floor. Also, the tibia fragment of red deer (*Cervus elaphus*) with marks of gnawing by a large Carnivora was found.

4.2 Balamutivs'ka Cave

It is situated near the Balamutivka Village, Chernivtsi Oblast (48°32′40.92″N, 26°4′35.90″E) (Fig. 1, *22*). The cave is developed at the foot of a layer of cracked nodular cryptocrystalline gypsum of the Upper Badenian (Miocene). The lower part of the entrance grotto is cut into the underlying Middle Badenian calcareous sandstones with interlayers of sand underlying the sulfate bed.

The entrance to the Balamutivska cave is in an outcrop of gypsum rock at the slope of the Dniester River valley, which is limited on both sides by erosion basins, and has the appearance of an arch up to 4 m high and up to 6 m wide (Fig. 2). The entrance altitude is 235 m a.s.l. and 70–75 m above the Dniester River level. The cave begins with a large grotto 16 m long and up to 14 m wide. The total length of the grotto, together with several small branches, is 40.5 m, the area is 163 m^2, and the volume is 978 m^3. The average height of the grotto is 6–7 m, with a width of 8–12 m. At the end of the grotto, behind the large-block collapse, a gallery with a width of 1.5–2.0 m and a height of 1.0–1.5 m (sometimes up to 2.0 m) begins. A stream flows almost constantly at the bottom of the gallery, which in the hall of the entrance grotto gets lost among the accumulation of large blocks that have fallen from the walls and ceiling.

In 1951, during explorations of the Dniester Archeological Expedition of the Institute of Social Sciences of the Lviv Branch of the Academy of Sciences of the Ukrainian SSR, O. Chernysh discovered ancient petroglyphs in the Balamutivska Cave (in the entrance grotto). Based on analogies with the monuments of Kamiana Mogyla, eastern Spain and others, he attributed this drawings to the Mesolithic (Chernysh, 1953, 1959). An additional survey of the cave was carried out in 1968 by the same expedition

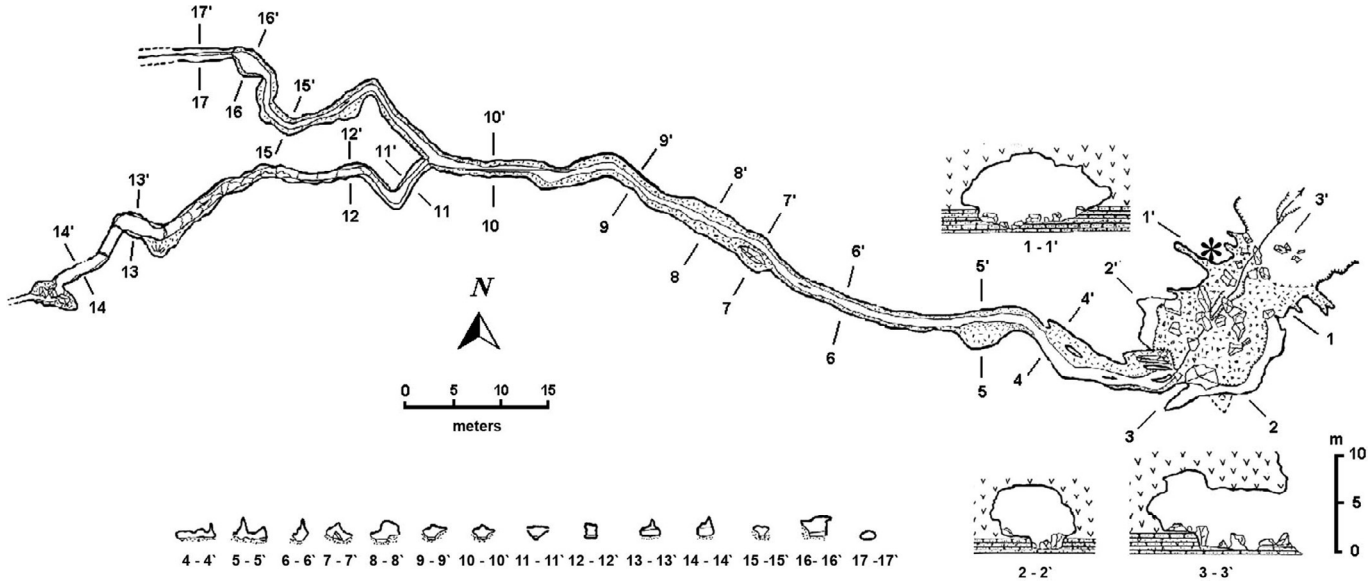

Fig. 2 Plan and cross sections of the Balamutivs'ka Cave (according to Ridush and Kuprich, 2003). *The place with the faunal remains.

(Chernysh, 1975). The drawings that were on the walls of the cave and partly on the ceiling were made on gypsum with black paint—soot mixed with fat and covered with a thin film of secondary gypsum. Areas with images in the form of various drawn lines carved in the gypsum surface were also noted. In total, more than 60 drawings were found in the cave, which were located mainly in groups. The dimensions of these black drawings did not exceed 25 cm. The ancient images consisted of anthropomorphic, animal, and linear geometric drawings. Among the drawings are images of hunting scenes, images of animals, human figures with a bow, etc. In the center is the figure of a shaman. According to O. Chernysh, this cave was a place where the ritual magical ceremonies of the Mesolithic tribes that lived nearby and for which hunting was the main branch of the economy took place (Chernysh, 1975).

In the following years, most of the drawings disappeared due to the collapse of sections of the walls and ceiling caused by frost weathering. When examining the grotto in 1985 O.P. Chernysh only found some fragments. Because of this, some authors doubted the age of the paintings in the Balamutivs'ka Cave, also due to the alleged impermanence of gypsum rocks, high humidity in the grotto, etc., they considered it "unlikely that the cave's destruction went at an accelerated pace only now, and that before the walls of the grotto were preserved the same appearance as in the Mesolithic" (Formozov, 1969, p. 143).

In our opinion, judging by the morphology of the cave and the ground relief around it, in the past (including in the Mesolithic) the cavity of the modern entrance grotto was at some distance (tens of meters) from the land surface. Due to this, the microclimatic conditions (temperature and humidity) in the grotto remained relatively stable for thousands of years, which contributed to the preservation of the drawings. Only over time, because of the slope regression, the grotto was opened and found itself in the zone of daily and seasonal temperature and humidity fluctuations, and as a result the progressive physical weathering was activated in it (Kochergan and Ridush, 2011; Ridush, 2004a).

The few small dead-end galleries adjacent to the main chamber contain slender-thick (up to 1.0 m) deposits of light-yellow loess-like loam and gypsum debris. The screening of the sediments resulted in finding the remains of Chiroptera, *Lepus* sp., *Vulpes* sp., Rodents, Aves, Reptiles, Amphibia, Pisces, Mollusca, and Diptera puparium. The species to be determined. A single little flint flake was also found.

4.3 Borshchiv

The bones of large and small vertebrates were discovered by workers in 1957–1958 and K.A. Tatarinov in 1960 in a large gypsum quarry located on the southern outskirts of the town of Borshchiv (Ternopil Oblast), on the way to the Vysichka village.

Tatarinov (1961) gives the following geological section of outcrop in the quarry:

(1) of burozem soil—0.3 m;
(2) yellowish-brown loess loam—7.0 m;
(3) yellowish-gray slightly cellular limestone—1.0 m;
(4) coarse-crystalline gray gypsum with inclusions of fine-crystalline white gypsum—19.0 m.

Numerous bones (about 10 vertebrae, individual teeth, fragments of limbs, ribs, fragments of the skull and lower jaw) of a woolly rhinoceros (*Coelodonta antiquitatis*) were discovered in a "cleft of gypsum sediments filled with loess loams." The bones were bedded about 8–9 m deep from the soil surface. Likewise, at a depth of 5 m from the surface, "in the gap between the gypsum deposits" were the remains (fragments of tubular bones, ribs, and fragments of teeth) of a mammoth (*Mammuthus primigenius*). A unique find is the jaw of a ram (*Ovis* sp.), which was bedded at the contact of loam with gypsum, 7–8 m deep from the soil surface. The other fauna, *C. elaphus*, *Cricetus*, *Ochotona pusilla*, *Apodemus* sp., *Microtus* sp., *Spalax* sp., are associated with the loam strata (Tatarinov, 1961). Since the remains of the rhinoceros and mammoth are represented by almost complete skeletons, there is reason to believe that they fell into a karst cavity in gypsum, where they died and were buried.

4.4 Bukovynka Cave

Geological and speleological conditions of the site. Bukovynka Cave is located near the. Stalnivtsi village of the Chernivtsi Oblast (48°17′9.00″N, 26°32′4.00″E). It is developed in the upper part of the Middle Badenian gypsum strata (N_1bd_2) with a total thickness of up to 35 m. In the area of the cave, above the gypsum are bedded "Ratin" limestones (up to 1 m) and gray and gray-green clays. Quaternary terrace deposits are represented by pebbles and loams. The modern entrances to the cave, of which there are several, are in an inactive gypsum quarry cut into the left side of the Matka River valley, 1.5 km southwest of the village. Two entrances are located at the foot of the quarry ledge, and another entrance, in the form of a vertical 5-m well, is on

the surface of the same ledge. The total length of the cave passages known today is 5460 m, the vertical amplitude is about 15 m. The altitude of the entrances at the foot of the escarpment is about 143 m a.s.l., which is about two meters above the bottom of the adjacent valley of the Prut River tributary, and 25 m above the level of the Prut River.

The cave was discovered and investigated by the Chernivtsi Speleological Club "Troglodite" since 1976 (Ridush and Kuprich, 2003; idush et al., 1998).

Bukovynka Cave is situated in the southeastern part of the Podillia-Bukovynian karst area (Ukraine), in the middle part of the Prut River valley, close to the Romania and Moldova borders (48°17′9.00″N, 26°32′4.00″E) (Figs. 1, *23*). The cave is developed in the upper part of the Upper Badenian gypsum strata (N_{1bd2}), which are up to 35 m thick. The gypsum deposit in this area consists of two lithofacies. The lower lithofacies are represented by stromatolitic gypsum with intercalations of clastic gypsum, and the upper one is represented by saber and crystalline gypsum (Peryt, 2001). The sulfate bed is underlain by few meters of sand (with 0.5 to 1.0 m sandstone cap) of Lower Badenian age. The top of gypsum layer is covered with up to 1 m of Ratyn Limestone and up to 8 m of the dark-gray clay of the Kosiv Formation (N_{1ks}), with abundant algae (*Lithothamnion*) limestone inclusions.

Quaternary deposits include river-terrace alluvium of the Prut River, composed of so-called "Carpathian Pebbles" of Early Pleistocene age, and gray sand, covered with Middle- and Late Pleistocene pale-yellow loess. Due to the different erosional opening of the massif, locally the Quaternary cover is directly on top of the Ratyn Limestone. The bedding of overlying deposits is strongly distorted by slope failures, which affect both Quaternary deposits and the upper Neogene clays.

Modern cave entrances are artificial. They are in the inactive gypsum quarry, cut in the foot of the left slope of the valley of the Matka River, a left tributary of the Prut River. Two cave entrances can be observed at the foot of the quarry bench, and another entrance is a 5-m vertical shaft on the surface of the same bench (Fig. 3). The total length of the presently known cave passages is 5155 m; the height is about 15 m, the total area is about 7000 m^2, and the volume is 11,250 m^3. The altitude of entrances at the foot of the bench is 135 m a.s.l., 2 m above the adjacent valley bottom, and 25 m above the Prut River (Ridush and Kuprich, 2003).

The cave is of a maze type. It was developed in three levels/floors. The main (middle) floor consists of a series of sub-parallel galleries (2–3 m wide), connected by narrow (up to 1 m) passages. The upper floor is represented by

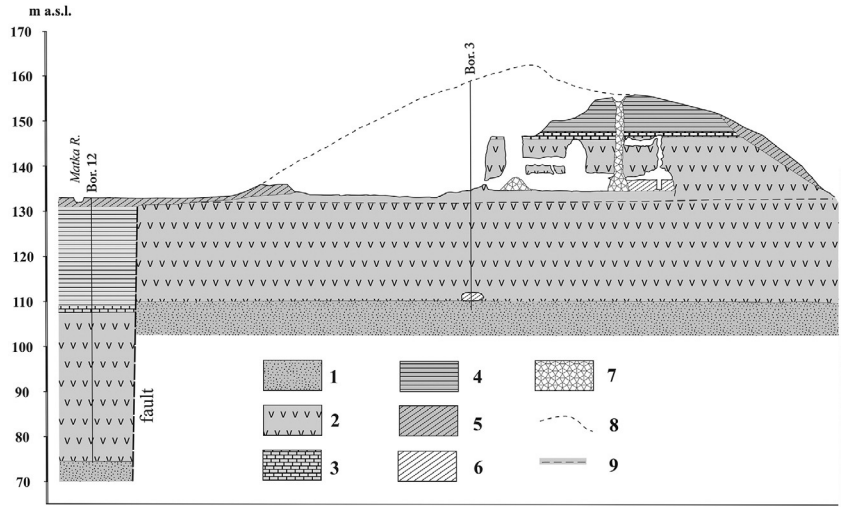

Fig. 3 Geological section of the gypsum karst massif, enclosing the Bukovynka Cave. Legend: 1—Lower Badenian sands; 2—Lower Badenian gypsum; 3—"Ratyn" Limestone; 4—clays of the Kosiv Formation (Miocene); 5—Quaternary terrace loamy deposits; 6—Quaternary loamy deposits in the cave; 7—collapse deposits in the cave; 8—surface line of the massif before gypsum developing; 9—the average groundwater table. Bor.—borehole (according to Bondar and Ridush, 2015).

mostly narrow fissures (0.5–1.0 m) of corrosive origin, narrowing upwards. Commonly, this floor is fragmented and is connected to the main floor by vertical pits/chimneys of 7–10-m in height. The lower floor is represented by mostly narrow (1.0–1.5 m) galleries with rounded vaults. They are partially filled with clay-loamy sediments. This floor is located at the zone of long-term groundwater table fluctuations, and therefore from time to time it is completely flooded. It connects to the main floor through short "windows" in the form of lakes-siphons (with areas to 1.3 m^2). Fluctuations of the water table in cave lakes and, consequently, aquifer varies within 0.2–1.0 m. There are both seasonal and longterm groundwater table fluctuations. The water temperature in the aquifer is 8.5 °C. Water is highly mineralized, with a hydrocarbonate-sulfate content of up to 2.0–2.5 g/L.

The bottom and partly the walls of corridors are covered with thick (up to 4 m) loam-clay deposits. Thin red and black interlayers can be observed in the cave lacustrine clay sequences, which correspond to the oxidizing and reducing hydrochemical conditions in underground paleoponds (Andreychouk, 2007). The upper unit of the Quaternary sequence usually is composed of light loam. It often includes fragments of

white, gray, and sometimes reddish calcite flowstone crusts that detached from the ceiling. Today, the interior parts of the cave are thermoconstant with a year-round temperature of 9–10 °C. At the entrance, because of the existence of several inputs, there is an active air exchange with the surface, and temperatures inside the cave depend on the temperature conditions outside. In the winter due to the cooling of the near-entrance galleries, the seasonal ice forms stalactite-like icicles, columns are formed, and clay-loamy sediments are frozen to 0.5 m depth (Ridush and Levytska, 2005).

Geological conditions of the cave location, galleries morphology, and the maze structure of the cavity indicate the hypogenic (artesian) origin of the cave (Klimchouk and Andreychouk, 2017). Most of the maze system was developed before the gypsum strata, and the cave became exposed by erosion.

The topographic relief above the cave is a high and ancient (Early Pleistocene) terrace of the Prut River, 70–80 m above the modern water level in the river. During Middle-Late Pleistocene, the local Matka River, a tributary of the Prut River, cut into this surface and exposed the gypsum strata. Sometimes the stream flowed underground, transiting through the cave chambers. The river stream was flowing through a ponor, which was located at the foot of board of the valley, to the north of the cave. Probably, the discharge of the cave stream on the surface occurred 100 m southwest from the present cave entrance, at the edge of the valley. This part of the cave, from the modern entrance to the place of former underground stream discharge, was destroyed by quarrying of gypsum deposits. The part of the Bukovynka Cave, which consists of the Entrance-, Trapeznyi- and Sukhyi (Dry) chambers, differ from other parts of the cave in morphology and Quaternary succession (Fig. 4). These three chambers were, in the past, a single gallery, which later was divided by collapses (Fig. 4B).

To characterize clastic deposits in the cave, three sections were selected in alignment with the paleostream riverbed. Sections 1 (Fig. 5A) and 2 (Fig. 5B) are situated in the Trapeznyi Chamber and can be observed in natural outcrops on the sides of the chamber. They became exposed due to the subsidence of sediments in the central part of the gallery-like chamber. The stratigraphic and granulometric data of these sections were published (Gerasimenko et al., 2019). The succession in both sections is similar but the description is given for Section 2 as it is the more complete one (Table 1 and Fig. 5B).

Unit T2 (Fig. 5A2), containing bones and coprolites, could be considered as alluvial because of the inclusions of individual gravel size clasts.

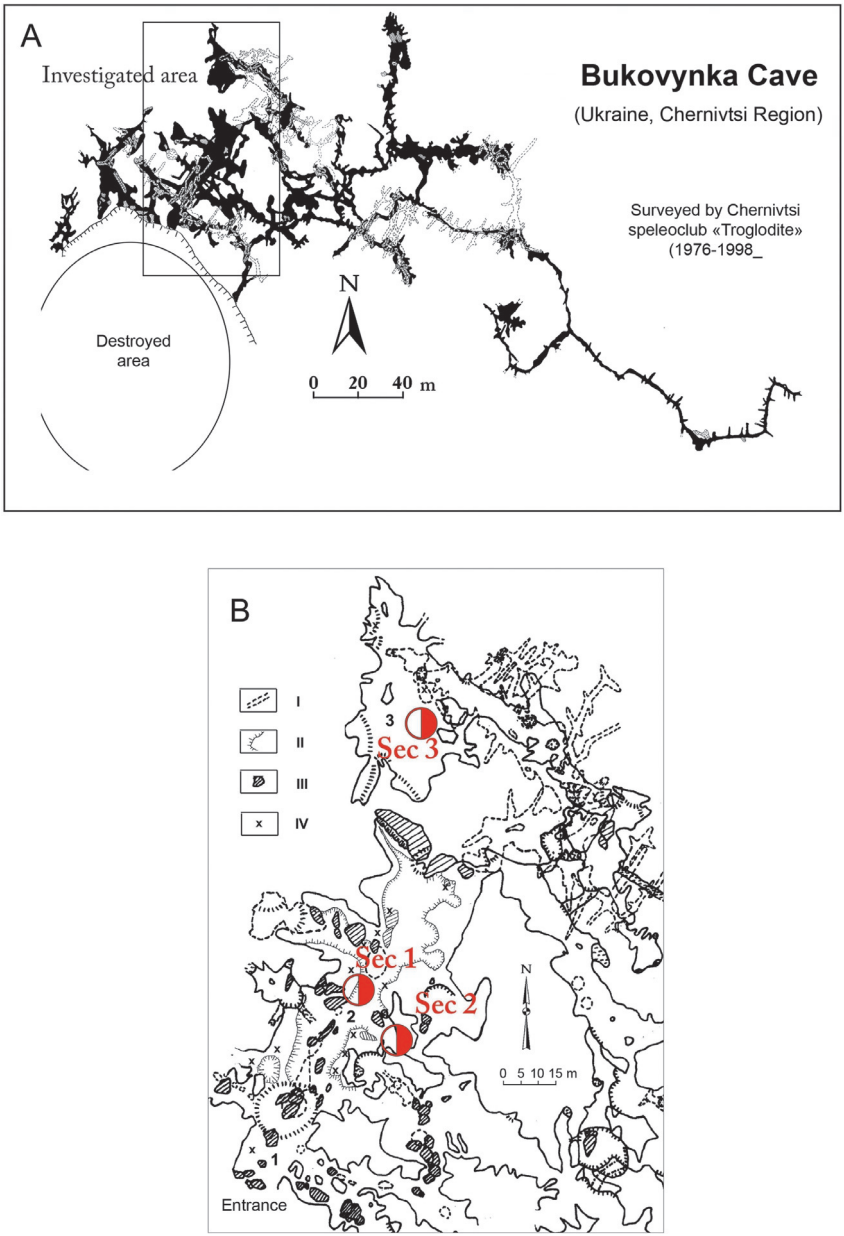

Fig. 4 Map of Bukovynka Cave with location of the sections studied. (A) general plan of the cave. (B) investigated area of the cave maze. I—upper level of galleries, II—inner benches formed by uncemented deposits, III—fallen rock blocks, IV—places of bone finds; 1—Entrance Chamber, 2—Trapeznyi Chamber, 3—Dry Chamber; "Sec 1"—places and numbers of Quaternary deposits section (according to Bondar and Ridush, 2015).

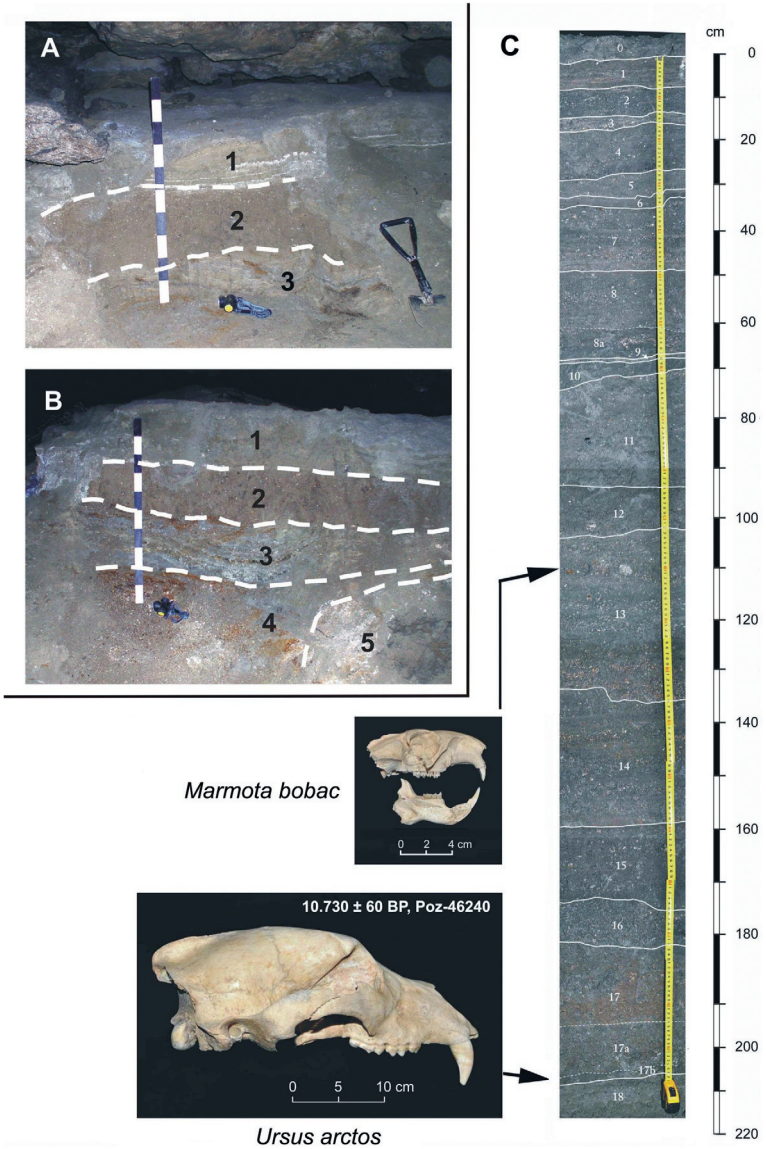

Fig. 5 (A and B) Late Pleistocene deposits of the Sections 1 and 2. 1—Unit T1, Eolian deposits ("cave less"); 2—Unit T2, zoogenic layer ("hyena layer"); 3—Unit T3, fine alluvial deposits of transit stream; 4—Unit T4, gravel alluvial; 5—Unit T5, gypsum bedrock. (C) Late Pleistocene—Holocene deposits in Dry Chamber. 1–18—Units S1–S18 (according to Bondar and Ridush, 2015; Gerasimenko et al., 2019).

Table 1 Section 2 of clastic sediments in Trapeznyi Chamber (Figs. 4 and 5) (according to Bondar and Ridush, 2015).

Unit	Depth, m	Description
T1	0.0–0.3	Light loam, loess-like, laminated, light yellow, with numerous inclusions of secondary gypsum crystals, with rare inclusions of coprolites, small bone fragments, with interbeds enriched with fine-crystalline gypsum (up to 1–2 cm).
T2	0.3–0.6	Light-brown loam, cloddy, with rare inclusions of gruss of limestone and gruss solid laminated (argillite-like) clay, occasionally inclusions of quartz gravel and Lithothamnion limestone debris, as well as coprolites and bone remains from small (up to 0.5e2.0 cm) to individual Mammals teeth and large bones fragments.
T3	0.6–0.9	Gray laminated sandy clay, sometimes as gruss of the same clay. In Section 2 the gravel interlayer (less than 10 cm) with a predominance of Lithothamnion limestone gruss and with inclusions of pebbles and gravel can be observed on top of the unit.
T4	0.96–1.2	Gravel-pebble deposits (predominance of gravel of quartz and sandstone rocks), with an admixture of limestone gravel (*Lithothamnion*) up to 30%, reddish, enriched with FeO2 (redeposited river terrace pebble)
T5	>1.2	Bedrock: macrocrystalline, grayish-brown gypsum

However, stratification was not observed, and all bones and coprolites found in it have no rolling traces, while most of the coprolites are quite fragile and would be destroyed if moved by water-flow. All these remains were found in situ and were not transported and redeposited by water flows. The genesis of these unit is probably almost entirely zoogenic, with only minor eolian input. The lower part of the Sections (units T3-T4) is composed of alluvial cave deposits containing redeposited Quaternary and Neogene sediments.

The ^{14}C age of Unit T2, based on an included cave hyena tooth is 41,300 (+1300/−1100) BP (VERA-2529), cal 12,765–12,621 yrs. BP, which corresponds with the warm Vitachiv Stage (MIS-3) (Gerasimenko, 2010). Zoogenic accumulation took place probably continuously during this phase. The overlying eolian sediments (Unit T1) could correlate to one of cold episodes during MIS-3 (Gerasimenko et al., 2019).

To avoid confusion in units from different localities, the lithofacies units in the Trapeznyi Chamber are designated "T," and units from the Dry

Chamber are marked "S." The characteristic features of sediments of Unit T1 (Fig. 5A1), such as silty composition, stratification, and lack of gravel inclusions, as well as the presence of gypsified intercalations, indicate that the top of Sections 1 and 2 (Unit T1) include airborne sediments (Gerasimenko et al., 2014b).

The sediments of Section 3 were studied by Bondar and Ridush, 2015; Gerasimenko et al., 2014a, 2019). They are represented mainly with grayish-brown loams with limestone grus inclusions (Fig. 5C). A prospecting shaft 2.5 m deep was excavated for this purpose. The screening of loams from Unit S17b showed impurities of travertine grus up to 5%. A similar type of travertine, which was formed underwater, can be observed on the walls and ceiling of the Zolushka Cave (7 km to the east (Andreychouk, 2007; Andreychouk and Klimchouk, 2017). The latter was drained by a quarry only a few decades ago, and preserved many subaquatic features, including this fragile travertine, only 1–3 mm thick.

There are five bone sites in the cave. The first (**Bukovynka-1**) contains the *Trapezny Chamber* and the adjacent galleries. It is the largest chamber in the cave. It is elongated for 40 m from SW to NE. From both ends it's limited by collapses. It can be considered as a wide gallery, that formerly was continued by the Sukhyi Chamber, that now is separated by the large collapse (Fig. 5). The palaeontological site consists of numerous cave hyena dens, located mainly close to the walls of the chamber and galleries, containing numerous coprolites and less numerous bone fragments. In the Unit T2, the remains of several genera and species of large Late Pleistocene mammals were found: cave hyena (*Crocuta spelaea*), woolly rhinoceros (*Coelodonta antiquitatis*), cave bear (*Ursus spelaeus*), brown bear (*U. arctos*), horse (*Equus caballus*), steppe bison (*Bison priscus*), red deer (*C. elaphus*), giant deer (*Megaceros giganteus*), wild pig (*Sus scrofa*), and red fox (*V. vulpes*). Cave hyena remains are represented mainly by numerous fragments of mandibles, maxillae, and separate teeth of at least 10 individuals. In the same unit that contains the bone remains, cave hyena coprolites are quite abundant. Some coprolite material forms continuous layers that apparently formed floors of the cave hyena den. The remains of most species, excluding fox, are the remnants of hyena prey, including old and young individuals of cave bear. Evidence of cave hyena activity as unidentified fragments of crushed bones and coprolites were found in a broad area of cave maze, more than 100 m from all possible ancient entrances (Ridush, 2004b; Vremir et al., 2000).

The second site (**Bukovynka-2**) is in the northern corner of the Sukhyi Chamber. It is represented by only one find—the proximal end of the radius of a bison (*Bison priscus*) of Pleistocene age. The bone was discovered in cone-shaped body made of loose collapsed roof material. A crust of secondary gypsum crystals 1–3 mm thick formed on the surface of the bone and in its internal canal. Judging by the conditions of the find and the regularities of cave-in formation above the gypsum caves (for details on the mechanism of cave-in formation in the gypsum caves of Bukovyna, see (Klimchouk and Andrejchuk, 2002), this bone did not enter the cave from the Quaternary terrace loams, since no traces of these loams were found within the collapse cone. The latter is composed of Neogene clays lying directly above the gypsum. The bone fragment was captured by a collapse from the upper floor of the cave, an unknown part of which is apparently located above the Sukhyi Chamber. Along with the bone, fragments of flowstone calcite formations were brought from the upper floor. In the Bukovynka Cave, this flowstone is mostly formed in the axial cracks on the ceiling of the galleries of the upper floor due to the redeposition of carbonates from the overlying Ratin limestones by condensation waters.

The third paleontological site **Bukovynka-3** (Section 3 according to (Bondar and Ridush, 2015)) is situated in the Dry (Sukhyi) Chamber (Fig. 5C). In the Dry Chamber and adjoining galleries, Holocene faunal remains were found. In the trench (Section 3) at a depth of 1.1 m in Unit S13 a partly preserved cranium and a mandible branch together with some postcranial bones of marmot (*Marmota bobac*) were found. In the same section at 1.8 m depth, at the bottom of Unit S17b, an almost complete cranium (without mandible) of brown bear (*U. arctos*) was excavated (Marciszak et al., 2015) (Fig. 5C). Direct ^{14}C dating provided an age of the Late Pleistocene to Early Holocene transition (10,730 ± 60 BP, Poz-46,240, cal 10,815 BP) (Ridush et al., 2012). At a depth of 2.2–2.5 m the "hyena layer" was found, that is similar to the one in the Trapeznyi Chamber. It is lithologically represented by pale-yellow loam including cave hyena coprolites and bone fragments.

The site of **Bukovynka-4** is on the upper floor of the cave. Here, in the Stolovyi Chamber, a partial skeleton of a red fox (*V. vulpes*) of the Holocene age was found in clay deposits at a depth of 20 cm. Lumps of burnt red clay and shells of terrestrial mollusks are found in the overlying layer. In another place on this floor, a humus layer (3–5 cm) with numerous

inclusions of small mammal bone fragments, which belong to foxes' prey (also of Holocene), is observed under a 5–10-cm layer of cave loam.

4.5 Cholivska Gora (Chortivets)

O.M. Adamenko together with D.O. Prunko and P.I. Arsenych examined in the gypsum quarry a karst dolina with bones of large mammals (Table 2). The site is on the north-eastern outskirts of the Chortivets village, Horodenka District, Ivano-Frankivsk Oblast, on the right slope of the valley of the Zagreblia Stream (Cholivska Gora) (Fig. 1A 9), at an altitude of 40 m on the bed of a stream, the valley of which is deeply cut into a plateau composed of Badenian gypsum and limestone (Fig. 6) (Adamenko, 1976).

The fauna from layer 3 was collected by D.O. Prunko and is stored in the Ivano-Frankivsk Museum. Parts of the collection has been taxonomically determined. Among the bones are *Bison priscus*, *Canis lupus*, *Crocuta spelaea*. The cultural layer belongs to the late Paleolithic with Aurignacian features. According to L. Matskevyi its faunistic content and flint artifacts make up a single complex (Matskevyi, 2005).

Table 2 Cross-section of the sediments of the buried cave in the Chortivets Village (according to Adamenko, 1976).

nn	Description	Depth, m
1.	Modern soil of the chernozem type	0.0–0.2
2.	Debris and boulder deposits with loamy filling	0.2–0.4
3.	Debris-clay deposits with a mass accumulation of large mammals' bones, which compose up to 60–70% of the sediment. Bones are badly destroyed, loose, and fall apart when trying to extract them (fauna of Chortivets)	0.4–1.2
4.	Loams are laminated, light brown and gray, dense, with rare fragments of mammal bones. At the bottom of the layer, traces of firing (the fireplace of ancient man) and several scrapers made of patinated flint were found	0.4–0.8
5.	gray to dark gray loams, earthy soil deposits	0.8–0.9
6.	Light brown and gray loams that fill the bottom of the karst dolina and therefore lie with different slopes towards the center of the funnel, parallel to its slopes	0.9–1.6

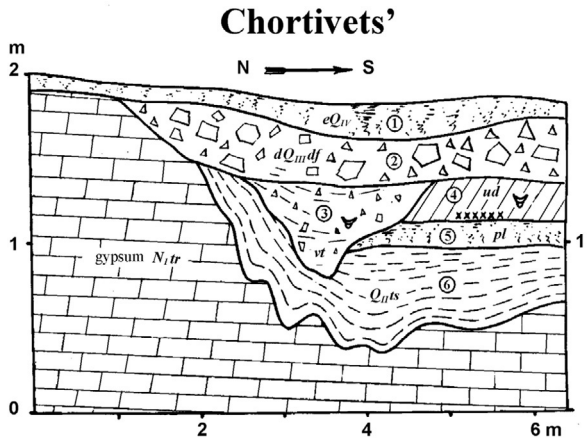

Fig. 6 Section of the filling of the buried karst dolina in the Chortivets village (Cholivska Gora) (according to Adamenko, 1976).

4.6 Chortkiv

In the western region, the oldest Quaternary fauna was recovered in 1953 near the town of Chortkiv, Ternopil Oblast (Fig. 1A, *11*), by participants of the paleontological expedition of the Institute of Zoology of the Academy of Sciences of the Ukrainian SSR. The location is located on a high terrace, on the left bank of the Seret River, in an ancient grotto, which was formed on the site of a karst dolina in calcareous sandstones of the Badenian (Miocene) and is filled with reddish-yellow medium-grained sands. The discovered fauna dates to the Eopleistocene ("early Homycene" according to I.H. Pidoplichko). The lens, where the fauna was found, was about 3 m long, 0.8 m thick and located at a depth of 3 m from the surface. Reddish loams and clays of colluvial origin are near the lens. The composition of the fauna was described by Pidoplichko (1955, 1956b) (Table 3). Recently, based on the fauna of Rodents the site was dated to the second half of the Odesian Fauna (Kryzhanivka Stage, MIS 41–62) (Krokhmal' et al., 2021).

4.7 Chortova Skelia (Lviv VII)

It is located on the eastern outskirts of Lviv, on the land of the "Pid Skeleyu" park which is part of the biosphere-landscape reserve Chortova (Chatova) Skelya (49°49′43.77″N, 24°7′2.74″E). The Marunka River flows to the south of the exposure, and the Poltva River to the north (Fig. 1A, *1*). The site is at an altitude of 65 m above the river level. The rock shelter is exposed to the north.

Table 3 The species composition and number of skeletal remains of mammals from Chortkiv site (according to Pidoplichko, 1956b).

Species	NISP	MNI
Sorex araneus L.	1	1
Sorex macropygmaeus Pall.	1	1
Blarina (ver. Beremendia) ucrainica Pidop.	1	1
Myotis sp.	1	1
Miniopterus sp.	4	3
Ochotona pusilla Pall.	4	3
Citellus cf. *undulates* Pall.	1	1
Citellus cf. *suslica* Guld.	1	1
Glis L.	4	2
Sicista sp.	1	1
Microspalax cf. *leucodon* Nord.	1	1
Cricetullus migratorius Pall.	2	2
Lemmus cf. *lemmus* L.	1	1
Mimomys sp.	23	5
Allophajomys sp.	219	60
Meles meles L.	1	1
Mustelidae	1	1
Hyaena sp.	2	1
Rhinoceros sp.	1	1
Cervus elaphus L.	1	1
Bos primigenius Boj.	4	1

The lowest cultural layer (A), with a thickness of 15–20 cm, is traced at a depth of 240–260–350–360 cm from the rapper. It consists of numerous blocks of light sandstone of Miocene, the spaces inbetween are filled with loess-like loam. About 6000 osteological remains were found in the layer, which were only partly determined by K.A. Tatarinov and V.V. Gumenyuk. The fauna is represented by the mammals *Mammuthus primigenius*, *Rangifer tarandus*, *Lepus timidus*, *C. cricetus*, *Arvicola terrestris*,

and birds, *Anser*, *Anas plathyrhyncha*, *Limosa*, *Vanellus*, *Anas guerguedula*, and *Turdus* sp. The Paleolithic industry is assigned by Matskevyi to Aurignacian tradition. This corresponds to the ^{14}C data of 27,200 ± 170 yrs. BP (Ki-5415) (cal 31,596–31,061 yrs. BP) (Matskevyi, 2001, 2005).

The middle layer (B), with a thickness of 15–20 cm, was traced at a depth of 190–210–270–320 cm. It is represented by loess-like loam, pale yellow in color, homogeneous, macroporous, and non-calcareous. There are large blocks that reach more than 50 cm over the long axis in the bedding. The contact to the underlyering bed is unclear and only sometimes discernible. More than 4000 bones were found in the layer. Only a part of the remains was determined (Matskevyi, 2005). According to radiocarbon dating, the layer dates to 13,500 ± 110 yrs BP (Ki-5412) (cal 16,635-15,933 BP).

The Upper Paleolithic layer (C), with a thickness of 20–25 cm, is traced in the third lithological horizon, at depths of 130 (140)–190 (210) cm. The deposits are represented by dark gray, homogeneous loam. There are inclusions of sandstone rock fragments, rubble, and debris in the layer. The lower contact with the underlying deposits is clear in color and uneven. More than 2000 osteological remains belong to the cultural layer. Only 36 bones from 3 individuals of *Mammuthus primigenius* and 52 bones from 6 individuals of *R. tarandus* were identified. Gnawing marks are visible on some bones. A piece of Paleolithic mobile art, an image of a reindeer antler, was found. Based on stratigraphy, osteological remains and industry, as well as radiocarbon dates, the layer is assigned to the Late Paleolithic with elements of the Late Aurignacian tradition, although recorded in Gravettian times. The radiocarbon dates of the animal bones provided an age of 11800 ± 90 BP (Ki-5414) (cal 13,991-13,466 BP), which corresponds to the Dryas 2 (Older Dryas), and possibly the beginning of the Allerød interstadial (Matskevyi, 2005).

Unfortunately, the list of fauna from this site in the text and in table by Matskevyi (2005) does not match, and therefore we will not include the table here. The faunistic material is partly stored in the Krypiakevych Institute of the Ukrainian Studies of the Ukrainian Academy of Science, in Lviv, and can be revised (Table 4).

4.8 Chun'kiv

In 2009, when digging a water supplement well in the Chun'kiv village of Zastavna District, Chernivtsi Oblast (Table 1, 19), the bones of a woolly rhinoceros (*Coelodonta antiquitatis*) were found. The bones were bedded at a

Table 4 The species composition and number of skeletal remains of animals from Divychi Skaly (according to Pidoplichko, 1956a, p. 128).

Species	NISP	MNI
Mammuthus primigenius	4	2
Equus	5	2
Bison priscus	7	2
Cervus elaphus	8	1
Rangifer tarandus	38	3
Marmota bobac	40	4
Ursus spelaeus	5	1
Citellus suskicus	1	1
Dicrostonyx torquatus	1	1
Microtus oeconomus	3	2
Microtus ex. gr. *arvalis*	4	2
Lepus sp.	12	1

depth of 5 m, obviously in the filling of a karst cavity, since the depth of gypsum in the surrounding area does not exceed 1.5–2.0 m. Few metapodials were collected, but the workers told us that it was a complete skeleton, that is still lying there. We are probably dealing with the fall of a heavy animal into the karst sinkhole.

4.9 Divychi Skaly

In 1953, I.H. Podoplichko conducted excavations at the site of Divochi Skeli (Divychi Skaly), situated in the rocky massif of the Kremenetski Mountain, to the NW from the Kremenets town, of Ternopil Oblast (50°7′5.54″N, 25°43′38.86″E) (Tables 1, 7). The bones were bedded in the loess-like loam that filled the karst cavity, at a depth of 1–2 m from the surface. As the researcher believed, the large bones were washed into the fissure from above, and the small ones came from the bird pellets (Pidoplichko, 1956a, p. 128). Since charcoal and ash stains were also found in the loam, it is possible that some of the bones were associated with the Paleolithic cave site.

To the list were added also some bones stored in the Kremenets Museum.

Also, in the Zhytomyr museum some bones of cave hyena and cave bear from Kremenets are stored (Pidoplichko, 1956a, p. 128). We consider it to be quite probable that these bones derived from the same locality.

4.10 Divychi Skaly—Cave Bear Grotto

In 1956, K. Tatarinov excavated a karst niche in the same place of Divychi Skaly, on its northeastern outskirts, which he called Cave Bear Grotto (Fig. 1A, 7). Under the large block that forms the rock shelter, in loess-like loams up to 1.5 m thick, filling a wide (up to 3–4 m) crack in calcareous sandstones, the remains of large mammals were concentrated (Fig. 7 and Table 5) (Tatarinov, 2000, pp. 70–74).

4.11 Horishnia Vygnanka

The site was in a sand quarry near the Ternopil—Chernivtsi highway, 0.5 km from the Gorishnya Vygnanka village near Chortkiv, Ternopil Oblast (Fig. 1A, *12*). It's represented by the infilling of an ancient grotto, formed in a layer of Lower Badenian white quartz sands, under a cornice of limestones of the same age (up to 1 m). The remains of 30 species of

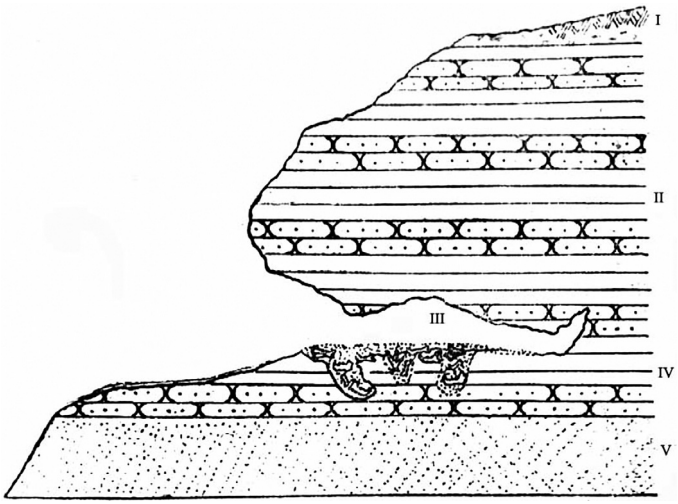

Fig. 7 Schematic section of the Divychi Skeli site, where the vertebrate fauna was found. I—modern soil layer, 0.3 m; II—porous calcareous sandstone (Sarmatian, Miocene), 7.5 m; III—a crack in the sandstone in which fauna was found; IV—bone-bearing layer—fissures in calcareous sandstone filled with terrestrial sediments containing vertebrate fauna; V—Badenian fine-grained quartz sand, visible thickness 1.5 m (according to Tatarinov, 1962).

Table 5 The species composition and number of skeletal remains of animals from Cave Bear Grotto (according to Tatarinov, 2000, p. 72).

Species	NISP	MNI
Dicrostonyx torquatus	1	1
Alopex lagopus	4	1
Ursus spelaeus	168	21
Crocuta spelaea	48	2
Mammuthus primigenius	3	1
Equus	12	1
Coelodonta antiquitatis	4	1
Megaloceros giganteus	2	1
Cervus elaphus	1	1
Rangifer tarandus	52	3
Bison priscus	7	2

mammals and other vertebrates were found here: mouse-eared bat (*Myotis* sp.), Pliocene bear (*Ursus* cf. *wenzensis*(=*minimus*) Stach.), forest cat (*Felis* cf. *silvestris* Schreber.), Pliocene badger (*Arctomeles* (= *Parameles*) *pliocaenicus* Stach.), fox (*Vulpes* sp.), jackal (*Canis* cf. *aureus* L.), eared hedgehog (cf. *Hemiechinus* sp.), small mole (*Talpa minor* Freudenberg), Ukrainian blarina (*Blarina ucrainica* Pidoplitshko), hypolagus hare (*Hypolagus* sp.), small pica (*Ochotona* cf. *pseudopusilla* Gureev et Schevtschenko), marmot (*Marmota bobac podolicus*), small shelf dormouse (*Glis minor* Kowalski), parapodemus mouse (*Parapodemus* cf. *coronensis* Schaub.), large hamster (*C. cricetus* aff. *Major* Woldrich.), Seret hamster (*C. cricetus seretensis* subsp. n.), Mimomys vole (*Mimomys intermedius* Newton.), Allophajomys vole (*Allophajomys pliocaenicus* Kormos.), mole-rat (*Spalax minor*), deer (*Cervus* sp.), bull (*Bos* sp. vel *Leptobos* sp.), Etruscan rhinoceros (*Dicerorhinus etruscus* Falconer) (Tatarinov, 2000; Tatarinov and Bachynskyi, 1968) (Table 6).

The site dates to the Late Pliocene (Villafranchian). Wagner identifies *Ursus wenzensis* Stach. with *Ursus minimus* Devéze et Bouillet, 1827, and notes that these bears survive the Ruscinian–Villanian boundary without changes and occur from MN 15b to MN 16b (Wagner, 2010). According to the fauna of small mammals, L. Rekovets, refers the site to the Zhevakhov phase of the Early Eopleistocene (Rekovetz, 1994, p. 13).

Table 6 The species composition and number of skeletal remains of animals from Horishna Vygnanka (according to Tatarinov, 2000).

Species	NISP	MNI
PISCES		
Cyprinidae gen. et sp.	1	1
AMPHIBIA		
Eopelobates cf. *bajeri* Spinar	6	1
Archipelobates giganteum	1	1
Hyla sp.	16	3
Rana sp.	34	3
Indet	82	–
REPTILIA		
Lacertilia	3	2
Serpentes	1	1
MAMMALIA		
cf. *Hemiechinus* sp.	1	1
Blarina ucrainica Pidop.	1	1
Talpa minor Freud.	2	2
Mytis sp.	1	1
Hypolagus sp.	5	1
Ochotona cf. *pseudopusilla* Yur. et Schev.	7	2
Marmota bobac podolicus	8	1
Glis minor Kowal.	17	7
Spalax minor Kowal.	1	1
Parapodemus cf. *coronensis* Schaub.	1	1
Cricetus cricetus cf. *major* Wold.	31	4
C. cricetus seretensis	12	1
Mimomys intermedius Newt.	7	3
Allopajomys pliocaenicus Korm.	4	1
Canis cf. *aureus* L.	1	1

Continued

Table 6 The species composition and number of skeletal remains of animals from Horishna Vygnanka (according to Tatarinov, 2000).—cont'd

Species	NISP	MNI
Vulpes sp.	14	2
Arctomeles cf. *pliocaenicus* Stach.	16	2
Ursus cf. *wenzensis* Stach.	34	2
Felis cf. *silvesrtis* Schreb.	1	1
Dicerorhinus etruscus Falconer	47	1
Cervus sp.	24	1
Bos sp. vel *Leptobos* sp.	55	1
Indet	212	–

In another work, K. Tatarinov wrote that the accumulation of faunal remains was found in two places: (1) in red-orange alluvial poorly sorted sands with an admixture of red clay; (2) in white medium-grained Lower Tortonian sands (redeposited, of course). The first fossil accumulation was located 25–30 m from the second, which gives reason to assume that these locations are of different ages (Tatarinov, 2000).

4.12 Kasperivtsi

In the 1920s, Yu. Polyansky investigated a Paleolithic site under a ruined rock shelter on the bank of the Seret River, in the Kasperivtsi village (Zalischytsky District, Ternopil Oblast) (Fig. 1A, *18*). The cultural layer was associated with a paleosol, covered by the layer of loess and modern soil. Bones of mammoth, woolly rhinoceros, bison, deer, horse, and wolf were found. Except for the mammoth's thick bones, all other remains were splintered, and some bore the marks of blows and cuts. Along with the bones, quartzite stone implements were found (in our opinion, this meant sandblasted flint, which is often found in Cenomanian sediments). The location dates to Mousterian times. Yu. Polyanskyi attributed the site to the interstadial of Würm I and Würm II. I.K. Ivanova believes that, according to modern ideas, this site belongs to one of the early Würm interstadials (Ivanova, 1969; Polians'kyi, 1929).

The exact location of this site is currently unknown. However, we assume that the mentioned rock shelter or grotto was formed in the massive calcareous sandstones of the Cenomanian (Cretaceous), which are common in the vicinity of Kasperivtsi village. Since these sandstones are karstified in some places, the cavity probably had a karst origin.

4.13 Kryshtaleva (Nyzhniokryvchanska) Cave

The Kryshtaleva (Nyzhniokryvchanska) cave is located near the Nyzhnye Kryvche village (Chortkiv District, Ternopil Oblast), on the narrow interfluve between the Tsyganka River and its tributary the Semeniv Potik River (Fig. 8); both are the tributaries of the Dniester River (48°41′20.30″N, 26°5′16.00″E) (Fig. 1A, *16*). The cave is developed in the 15-m-thick strata of Miocene gypsum, overlain by 1-m-thick crystallin Ratyn limestone. The total length of the cave is 22.6 km. The altitude of the entrances is 235 m a.s.l and 80 above the river valley bottom (Zimels, 2008).

There are four entrances to the cave. In two of them, Serednia (Middle) and Mala (Small) caves K. Tatarinov found some faunal remains. G. Bachynsky had found some bones also in the so-called Palaeozoological Labyrinth. According to these researchers, the bones overflowed the upper 20-cm layer of gypsum-clay debris covering the bottom of the cave gallery (Tatarinov and Bachynskyi, 1968). All these burials are associated with the marginal part of the Crystal Cave, where the cavities were occasionally open to the surface and therefore intensively filled with debris material. The remains

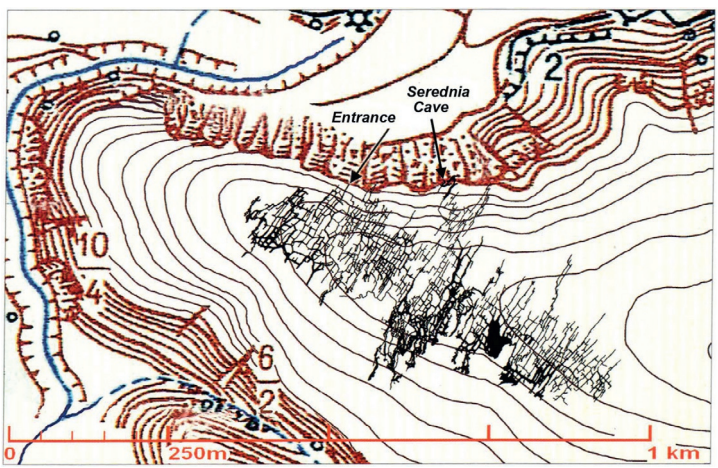

Fig. 8 The location of the Kryshtaleva Cave in relief, according to Zimels (2008).

of small animals predominate here, and among them the remains of pikas and bats. According to K. Tatarinov, the burial was formed mainly from the pellets of diurnal birds of prey. Osteological material was determined by G. Bachynsky, K. Tatarinov, V. Topachevkyi (mammals), M. Voinstvenskyi, I. Marisova (Marysova, 1962), and A. Umanska (birds).

The cave labyrinths near the entrance are almost filled with allochthonous loamy deposits. Remains of the Late Pleistocene (*L. timidus, O. pusilla, Vulpes lagopus, R. tarandus*) and Holocene fauna were found in the cave (Bachynskyi and Tatarinov, 1966) (Table 7), but their stratigraphical position was not known exactly.

Table 7 The species composition and number of skeletal remains of mammals from Nyzhniokryvchanske site (according to Tatarinov, 2000).

Species	NISP	MNI
Talpa europaea L.	2	1
Sorex sp.	2	1
Crocidura sp.	15	3
Myotis cf. *bechsteini* Kühl.	31	2
M. cf. *myotis* Borkhausen	4	1
M. cf. *nattereri* Kühl.	61	9
Myotis sp.	1240	30
Plecotus auritus L.	22	8
Lepus timidus L.	13	3
Ochotona pusilla Pall.	2607	1225
Ochotona sp.	134	100
Marmota cf. *bobak* Müller	15	4
Citellus cf. *citelloides* Kormos	46	15
Glis glis L.	12	4
Dyromys sp.	1	1
Apodemus sp.	2	1
Dicrostonys torquatus Pall.	26	14
Cricetus cf. *cricetus* L.	16	6

Table 7 The species composition and number of skeletal remains of mammals from Nyzhniokryvchanske site (according to Tatarinov, 2000).—cont'd

Species	NISP	MNI
Lagurus lagurus Pall.	3	2
Arvicola terrestris L.	202	66
Microtus oeconomus Pall.	58	17
Microtus cf. *arvalis* Pall.	3	2
Microtus gregalis Pall.	113	47
Clethrionomys glareolus Schreber	7	2
Spalax cf. *podolicus* Pennat.	7	3
Mustela cf. *nivalis* L.	35	6
Mustela nivalis minima	7	4
Mustela erminea L.	19	6
Meles meles sinjakovensis	3	1
Alopex lagopus L.	23	2
Felis sp.	13	1
Rangifer tarandus L.	16	2
Equus caballus L.	1	1

The taxonomical composition was complex. As picas are troglophiles, they probably arranged dens in the cave. Besides them, reliable troglophiles are bats (*Myotis* cf. *bechsteini*, *M.* cf. *myotis*, *M.* cf. *natterei,* and *Plecotus auritus*), badgers (*Meles* cf. *meles*), and probable weasels (*Mustela* cf. *nivalis*, *M. nivalis minima*), ermine (*Mustela erminea*) and several rodents.

On the other hand, the findings of a relatively large number of reindeer bones, represented by fragments of limb bones, phalanges, and the right mandible—a fragment with satisfactorily preserved teeth, are remarkable. In addition, cut marks of a flint tool were found on the jaw. The fossil horse is represented by one well-preserved tooth from the upper jaw, found on a rocky outcrop near the entrance to the Middle Cave (Tatarinov, 1965). Such finds may indicate the habitation of the cave by people.

Unfortunately, the entrance parts of the Serednia and Mala Caves were destroyed in the 1960s by a small gypsum quarry. K. Tatarinov believed that

the bones in the Middle Nyzhniokryvchanska cave were washed in by water because until 1959 (prior to the industrial gypsum production), the cave was isolated and therefore inaccessible to predatory mammals or birds (Tatarinov, 1965). We believe that in the late Pleistocene, not one but several entrances to the cave were accessible not only to animals but also to humans. Only later, due to the accumulation of loess layers and activation of slope processes, these entrances were blocked by colluvial deposits.

The new section is studied in the narrow gallery which forms the entrance to the Serednya-2 tunnel of the cave. This is a vertical fissure-like gallery, 0.8–1.0 m wide, 8–9 m high. It is almost completely filled with loose sediments. Only the upper 0.5 m of the profile, through which the gallery connects to the main labyrinth, is unfilled. Up to now, only the upper 4.5 m of sediments were subjected to cleaning. The upper ledge of loose sediments (cave colluvium), about 2.20 m in thickness, has a layered texture and is composed of limestone and gypsum debris and rubble, "crumbs," loam and contains bones of rodents and birds (not studied). The lower ledge, is formed by a 1.0–1.5-m layer of sediments with traces of human activity in the form of numerous charcoal inclusions throughout the layer and three distinct continuous charcoal layers, as well as burnt gypsum (Table 8 and Fig. 9). The profile of all horizons is strongly concave, and the difference in thickness between the central and lateral parts of the layer reaches up to 0.5 m vertically. Several brown bear bones were found in the 12-cm layer separating the anthropogenic sediment pack from the "silent" sandy sediments. The chronostratigraphic subdivision of the section (3 m in thickness) is based on the ^{14}C date of 12,240 ± 70 yrs BP (Poz-59413) obtained on the *U. arctos* bones (Ridush, 2014), and ^{14}C-dates 11,710 ± 60 BP (Poz-51431), 11,890 ± 60 BP (Poz-51430) yielded from charcoal (Nadachowski et al., 2015). The obtained pollen data indicate that the cave infilling was formed during the end of the Middle Pleniglacial, the Late Pleniglacial, the Late Glacial and the Early Holocene. Grain-size studies of the deposits have been also carried out in the section (Avdieienko et al., 2018). According to palynological data (Avdieienko et al., 2018), the bone bearing layer belongs to the Bølling interstadial (12,240 ± 70 yrs BP (14,6–14,1 cal ka BP)).

4.14 Mala Ilovytsya (Lypa IX, Mount Pustelnya)

In the 1960s, the Lypa IX (Mount Pustelnya) site, located on Mount Pustelnya near Mala Ilovytsya Village (Kremenetsky District, Ternopil

Table 8 Section of the sediments of the lower (Pleistocene) ledge of the excavation in the cave Serednya-2 (Kryshtaleva, Nyzhniokryvchanske Site) (Fig. 9D).

N of layer	Layer description	Depth of the layer base, *m*	Layer thickness, *m*
1	gray loam with inclusions of limestone and gypsum debris ("crush"), transitional to the upper ledge of the section	0.0–0.2	>0.20
2	dark gray loam (gley?), with inclusions of charcoal and debris of burnt gypsum; in the roof there is a carbonaceous layer (1 cm), above and below it—1 cm—interbeds of reddish burnt loam	0.2–0.4	0.1–0.2
3	white and soft burnt gypsum	0.4–0.6	0.15–0.2
4	gray-brown loam, with inclusions and interbeds (up to 1 cm) of charcoal, and debris of soft white gypsum	0.6–0.8	0.1–0.2
5	debris of white soft burnt gypsum with an admixture of loam and with rare carbon inclusions	0.8–0.95	0.1–0.15
6	light brown loam, with the inclusion of charcoal, burnt white gypsum, debris of gypsum and limestone	0.95–1.1	0.1–0.15
7	light yellow sandy loam, with a 1 cm carbonaceous interbed in the roof (layer 7a)	1.1–1.5	0.03–0.06
8	brownish-gray loam, coarse-grained, with inclusions of debris of bedrock clays, gypsum, and limestone	1.15–1.25	0.07–0.1
9	is light brown loam, with inclusions of gypsum eluvium, carbonates, and individual gypsum crystals, with bone remains of *Ursus arctos*, *Rangifer tarandus*, Aves sp. etc. Late Glacial, Bølling interstadial	1.25–1.45	0.15–0.2
10	brownish-yellow loam, with rare inclusions of gypsum debris	1.45–1.6	>0.2

Oblast), was investigated. Mount Pustelnya is a part of the Kremenets Mountains and is located in the border zone between Podillia and Volyn (50°11′49.78"N, 25°59′49.03″E) (Fig. 1A, *8*). The top of the mountain is flat, covered with a layer of loess. On the north-western edge of the

Fig. 9 Section of Upper Pleistocene sediments in the Middle Cave (Nizhniokryvchanske site). (A) The general view of the entrances: on the left—the Serednya Cave, on the right—the newly discovered section in the Serednya-2 Cave; (B) the upper (Holocene) part of the section; (C) the general view of the Serednia-2 entrance; (D) the lower (Pleistocene) part of the section.

mountain is a quarry. A cavity 1.5 m high, filled with sand, silty deposits, and sandstone fragments, was discovered during industrial the limestone production. Animal bone fragments and three flint plates were also found in the filling of this cavity. In 1962 and 1963, M.I. Ostrovsky collected flints (more than 70 specimens) and bone remains of animals there. Most of the material,

apart from one point and one lithic core, was picked up at the surface during the pit inspection. According to Grigoriev and Ostrovsky, the site can be attributed to the local Lipska Upper Paleolithic Culture (Ostrovskiy and Grigoriev, 1966), which dates back to the end of the Mologa-Sheksnya interglacial (MIS 3) and the beginning of the Ostashkiv Glaciation (MIS 2) (30–20 ky BP). It is obvious that the tools collected during the inspection of the quarry could have come from the destroyed part of the buried cave.

The taphonomic study of the location was conducted by I.V. Marisova and K.A. Tatarinov. According to K.A. Tatarynov, the fossil bones were in brown loam with inclusions of fragments of oolitic limestone and sandstone in a niche of the southern wall of the quarry at a depth of 7 m from the surface. The thickness of the bone-bearing lens reached 0.8 m with a length of 5–6 m. The species identified are: cave bear (*Ursus spelaeus*)—14 individuals; reindeer (*R. tarandus*)—4 individuals; brown bear (*U. arctos*), and Norway lemming (*Lemmus* cf. *lemmus*)—2 individuals each; wolf (*C. lupus*), arctic fox (*Alopex lagopus*), *cave lion* (*Panthera spelaea*), horse (*E. caballus*)—1 individual each (Tatarinov and Bachynskyi, 1968). The 1966 publication mentions the findings of the cave hyena (*Hyaena spelaea*) and the Arctic lemming (*Dicrostonyx torguatus*), but the 1968 publication does not list these species anymore. K. Tatarinov and G. Bachynsky believed that since the remains of cave bears predominate in the cave, they and some other predators lived in this cave, and also that for a particular time, the cave served as a shelter for Late Paleolithic people who possibly hunted cave bears (Tatarinov and Bachynskyi, 1968).

4.15 Malimon-Canyon Cave

The cave is an artificially opened isolated part of the huge karst system of the Zolushka (Popeliushka) Cave (located on both sides of the border—near the village of Podvirne, Novoseltsky District, Chernivtsi Oblast, Ukraine, and the village of Kryva, Brychany District, Republic of Moldova). It is developed within the gypsum of the middle Badenian (N_{1bd2}). (More details about the Zolushka Cave and the regional karst are provided by Andreychouk (2007) and Andreychouk and Klimchouk, (2017). Gypsums, like other bedrocks, are not exposed in the river valley, as they are covered by a 2–3 m thick colluvium. The entrance to the cave is through an artificial well 15 m deep, located near the Podvirne village of Chernivtsi Oblast (Fig. 1A, *24*), on the left bank of the Patsak River (a left tributary of the Prut), 10 m above the river level. The cave consists of two wide (up to 2–3 m) sub-parallel galleries

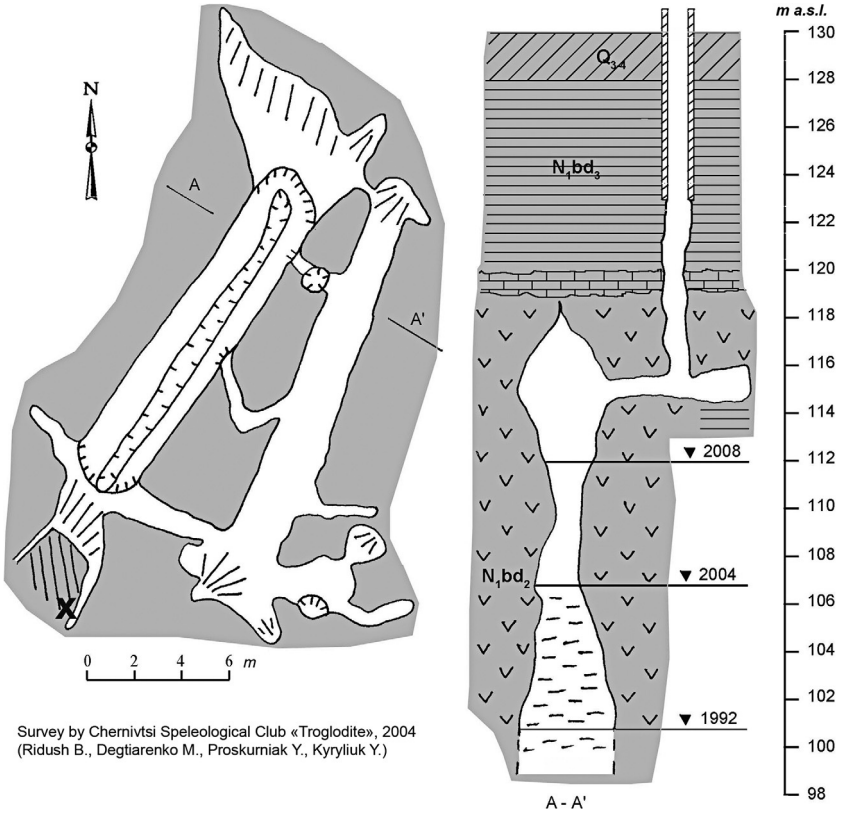

Fig. 10 Plan and cross section of the Malimon-Canyon Cave (according to Ridush and Kuprich, 2003). X—the place of Pleistocene bones bedding.

running south-west and north-east, connected by four narrow passages approximately perpendicular to the main galleries (Fig. 10) (Ridush and Kuprich, 2003). In fact, the cave is a part of the more extensive labyrinth, but it is bounded on all sides by landslides. The north-western gallery through a cracked well (feeder) connects with the cavities of the lower tier, which is located 15 m below, and is now beneath the groundwater table. (In general, the groundwater table in the massif has been lowered to 28 m due to water-pumping from a gypsum quarry located nearby on the territory of Moldova). The upper level of the cave is located in the upper part of the gypsum stratum, but almost 5–6 m below the current water table of the Patsak River. Some of our observations in the sediments inside the Zolushka Cave provide evidence for the active descending of this tectonic block at the end of Late Pleistocene.

During speleological excavations, a woolly rhinoceros (*Coelodonta antiquitatis*) humerus was discovered in one of the galleries of the upper level of the cave. A thin (4–5 cm) layer of brownish loam was found under the landslide deposits, which can be correlated with the humus layer in the Bukovynka Cave (see above). It is covered with moist, light loam, close to the eolian "cave forest" from the Dining Hall in the Bukovynka Cave. The geological analysis of the roof of the cavity in this place showed that the collapse had, so to speak, an internal nature and affected only the rocks containing the cave. Therefore, it remains to assume that the bone got into the cave by the large predators (*Crocuta splelaea*), and the cave used to have a horizontal entrance. The radiocarbon data of the bone is 38.000 ± 800 BP (Poz-47727). Therefore, the site can be dated to the Late Pleistocene, particularly the Vytachiv Stage (MIS-3), like the cave hyena den in the Bukovynka cave, located just 6.5 km away.

4.16 Martynivka Cave

It is a karst cave developed in the upper part of the Miocene gypsum strata. It is situated between Pogorylivka and Chornyi Potik villages of the Chernivtsi region, in the Middle Dniester area (48°32′45.49″N, 25° 59′32.19″) (Fig. 1A, *21*). The two cave entrances have human height and are in the gypsum cliff, 30 m above the valley bottom, on the right bank of the Chornyi Potik River, a right tributary of the Dniester River. This area's 10 m thick gypsum strata is represented by white and light-gray microcrystalline nodular gypsum. Initially, it had a hypogenic origin but was later strongly modified by the weathering processes. The total length of all galleries is 80 m, but the main gallery is just 25 m long, 2–5 m wide, and 2–3 m high (Ridush and Kuprich, 2003). The gallery ends with the accumulation of rock blocks formed by the ceiling collapse.

Since 1960s the archeological layers of the 7–8th, 13th, and 17th centuries are known (Ridush, 2000). The up to 1.0 m thick cultural layer of the 17th century overlaps the rock-fall. The natural sediments in the entrance part of the cave were removed in the 13th century when the cave was inhabited. The cultural layer of this epoch developed directly on the rock floor. In the 17th century, most of the 13th-century cultural layer was also removed. The small fragments of undisturbed sediments were preserved only below the large blocks in the inner part of the gallery. The excavation of the gypsum blocks produced numerous faunal remains of small mammals wich were enclosed in the loose sediments between the blocks and the cave

wall as well as between the blocks themselvs. The bone-bearing sediments are represented by 0.3–0.6 m thick alevritic loess-like yellow and light brown sediment and fine cryogenic gypsum debris, with inclusions of coarse debris. There are three taxonomical orders represented: Insectivora, Chiroptera and Rodentia. Pikas (*O. pusilla*) and hamsters (*C. cricetus*) dominate; fewer water voles (*Arvicola amphibius*) and voles (*Alexandromys oeconomus = Microtus oeconomus*). Forest forms are sporadic: dormice (*Glis glis*), squirrels (*Sciurus vulgaris*), and red forest voles (*Clethrionomys glareolus*). Very few voles (*Microtus arvalis*). The presence of lemmings (*Dicrostonyx henseli*), steppe lemming (*Lagurus lagurus*) and narrow-headed vole (*Lasiopodomys gregalis*) is unique. The species assemblage indicates the ecologically mixed nature of the fauna with the dominance of the species of mesophilic habitats and the predominance of steppe species over cold-loving species (lemmings and narrow-headed voles) (Ridush et al., 2021).

Nowadays, the site is situated in the semi-aphotic part of the cave. Considering the regular slope regression that is characteristic for the area, 20–30 kys BP, the site was further from the entrances, in the aphotic zone. The bone accumulation could be related to the activity of troglophilic small carnivores like foxes or mustelids, which are inhabiting the cave or visiting it. Animals such as picas and dormice are also troglophilic species and could die during winter hibernation. The nesting of birds of prey in this place is very unlikely because of the low ceiling of the gallery.

4.17 Melna

This is the first paleontological cave site in Western Ukraine. It was revealed in a deep valley, 7 km east of the Melna village (Rohatyn District, Ivano-Frankivsk Oblast) (Fig. 1A, *6*). Here, beneath the layers of Miocene sandy limestones, in the upper part of the fine-grained Miocene sands, caves were formed by suffosion. The latter are filled almost to the ceiling with yellowish sandy loam. In 1879, M. Lomnytskyi discovered here a significant number of remains of a cave bear (*Ursus spelaues*), a cave hyena (*Crocuta (Hyena) spelaea*), their coprolites, as well as the remains of other unidentified mammals (Łomnicki, 1881) (Fig. 11). The materials were transferred to the Dzieduszycki Museum in Lviv (now it is the State Museum of Natural History), but Tatarinov notes that the fate of this material is unknown, since it is not in the museum's collections (Tatarinov, 1958).

In addition, Podoplichko notes for the Melna village three other finds: (1) in Quaternary deposits (?)—*C. lupus, Ursus spelaeus*; (2) skull of *Crocuta*

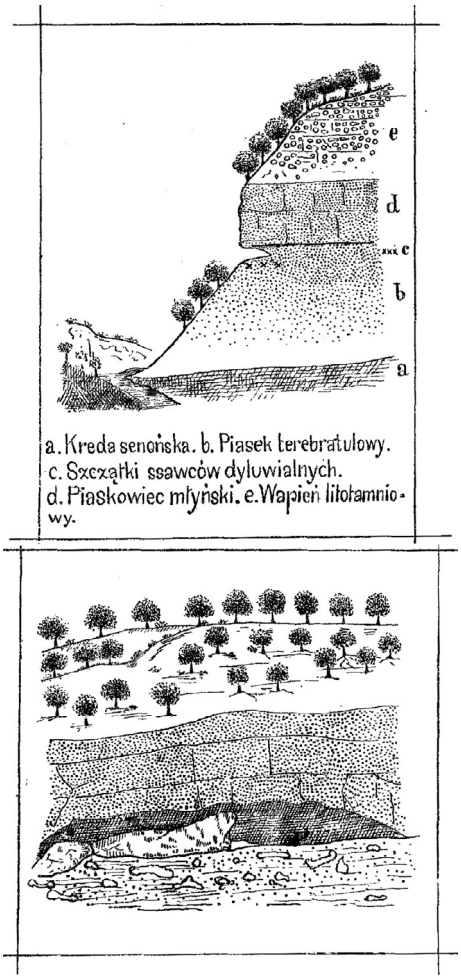

Fig. 11 The geological sections of the Melna Cave paleontological site (according to Łomnicki, 1881).

(*Hyaena*) *spelaea*; (3) skulls, teeth, limb bones, sacrum, vertebrae, and other bones from five individuals of the cave bear *Ursus spelaeus* (Pidoplichko, 1956a, p. 120). Again, it is unknown whether we are talking about Łomnicki's or other finds.

4.18 Ostrivets'

The Late Pleistocene fauna was described by Tatarinov (1959) near the Ostrivets' village of the Stanislav Oblast (now Horodenka District,

Ivano-Frankivsk Oblast) (Fig. 1A, *10*): *Bison priscus, E. caballus*, *Coelodonta antiquitatis*, *Lepus europaeus*, *Hyaena* (*Crocuta*) *spelaea*, and Aves. The bones were discovered in May 1958 during the production of sandstone for building stone. The sandstone quarry is located on the Masyok Mountain. A typical karst landscape can be observed in the vicinity of this village. Fossil animal bones were found in two shallow karst dolinas, which were uncovered because of the clearing the sandstone slab. The geological section of the quarry is as follows: soil—0.5 m; weathered *Lithothamnia* limestone (Miocene)—0.3 m; sandstone (lithified)—3–5 m. The karst dolina was filled with soil and fragments of weathered rock. The bones of fossil animals lay on the contact of the soil and weathered fraction with the sandstone slab (Tatarinov, 1959).

This region is an area of gypsum karst, where Miocene gypsum is underlain by limestones and sandstones of the same age. Judging the description by Tatarinov, the site was associated with a destroyed and buried karst cave in gypsum, in which, during the Late Pleistocene, there was a cave hyena's den.

4.19 Ozerna (Popova Yama) Cave

The giant labyrinth, with a total length of 144 km, is located near the village of Strilkivtsi, Borschiv District, Ternopil Oblast, at the confluence of the Seret and Nichlava rivers (48°45′51.47″N, 25°57′56.99″E) (Fig. 1A, *14*). Like other giant labyrinths of the region, it is formed within Miocene gypsum (Klimchouk, 2012; Klimchouk and Andreychouk, 2017). The modern entrance is located at the bottom of a large karst dolina that cuts into the labyrinth in its farthest northwestern part (Fig. 12A).

In 2009, in the southeast of the cave system, speleologists from Ternopil discovered a new part of a labyrinth with numerous bones of a cave bear (*Ursus spelaeus* or *U.ingressus*) (Fig. 12B–D). According to speleologists, the bones lie both on the surface of the floor and inside the clay aggregate. The taphonomy and faunal composition of the location require a special study, but certain conclusions can be drawn from the already available data.

Due to the surface bedding of the examined bones, the collagen content was insufficient for the radiocarbon analysis. A significant number of remains of cave bears indicate that this part of the cave served as a winter den for bears during certain stages of the Late Pleistocene (not later than MIS-2). Since the site today is too far from the modern entrance, it is logical to conclude that in the Late Pleistocene, another entrance or a few entrances to the labyrinth existed. In this area, the roof of the gypsum layer is bedded at the level of

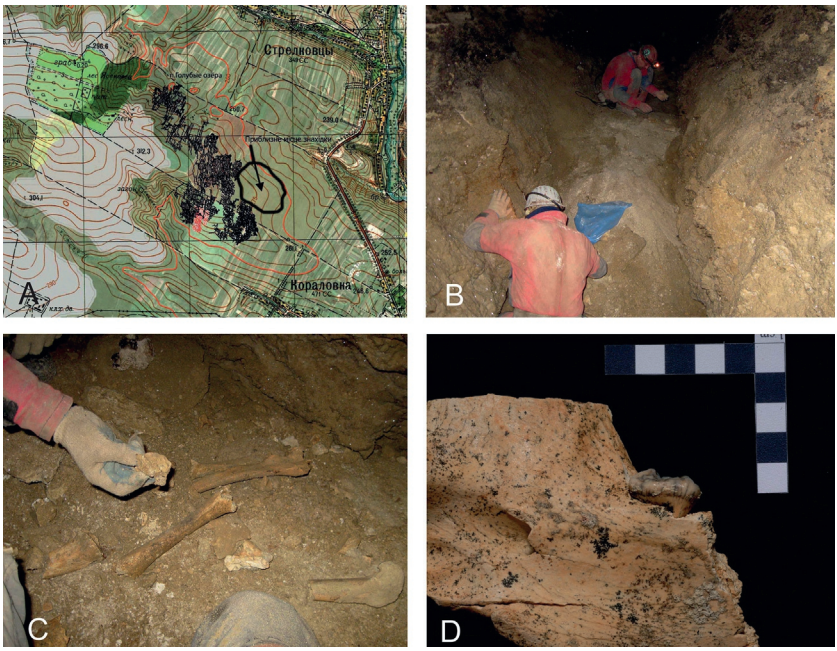

Fig. 12 The site with *Ursus spelaeus* L. in the Ozerna Cave. (A) Location of the cave; the arrow points to the location of the new area of the cave; 260 m isohypse, which approximately matches with the level of the roof of the gypsum layer, is highlighted in red. (B) The nature of the galleries where the bone remains were found; (C) bones of *Uloborus spelaeus* lying on the bottom of the gallery; (D) a fragment of the cave bear mandible with a molar (M2) (based on the materials by V. Apostoliuk and V. Andrash).

the basement of the high river terrace of the Dniester valley, dated to the Early Pleistocene. However, the continuation of the gypsum roof over the nearest adjacent drain, the Nichlava River, is only 30 m. Therefore, the erosive dissection of the labyrinth took place only in the Late Pleistocene. Also, complete drainage of the cave system has not occurred yet, as the cave experience multiannual fluctuations of the groundwater table. Therefore, the closing of the entrances exposed by denudation could have taken place during the Last Glacial Maximum (LGM, MIS 2, Bug Stage), when an intensive loess accumulation was characteristic of this area.

4.20 Pryima I (Nimecha)

Up to now, Pryima I is the oldest archeological site in the caves of the Western Ukraine. It was investigated by L. Matskevyi in the upper grotto of the multi-tiered cavity. The site is located 1 km southwest of the Pryima village,

Mykolaiv District, Lviv Oblast, in the Nimecha tract (Fig. 1A, *2*). The rock with the grottoes is located on the valley shoulder, on the left (northern) slope of the deep valley of the drying Nameless stream, the left tributary of the Dniester. The site is located 2.3 km east of the Dniester, and 1.2 km east of the Mykolaiv—Rozdol highway, in the area between the villages of Rozvadiv and Veryn. This rock has the local name Diryava (the other name is Biny Cave). The cave is of the karst-sufossion type, and developed in the residual composed of Neogene sandstones. The relative altitude of its fifth floor (grotto) above the thalweg of the stream is 45 m, the absolute altitude is 372 m a.s.l. In addition to the grotto (which, judging by the section given by L. Matskevyi, is now almost destroyed), the cave complex has four more levels—the upper (I) and lower (II) caves, as well as two rock shelters—the upper (I) and lower (II) (Fig. 13).

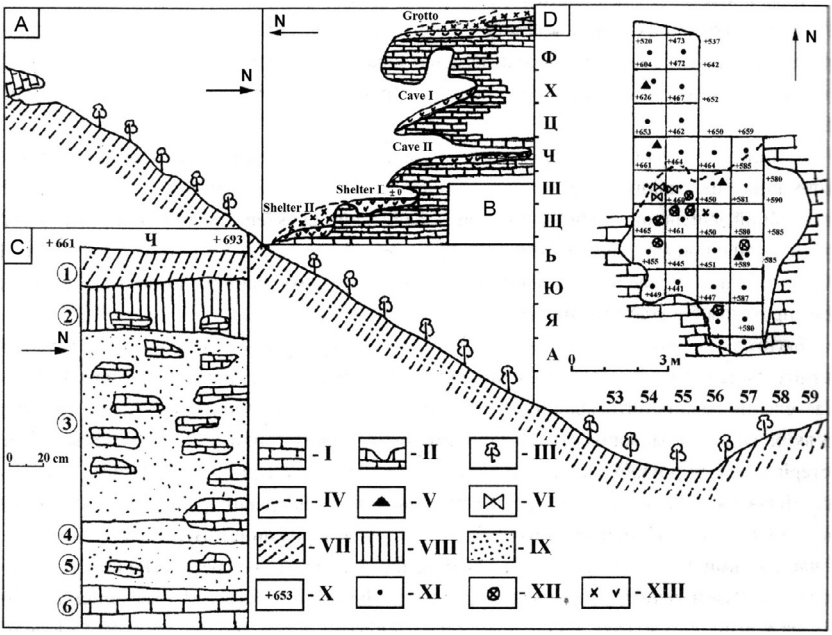

Fig. 13 Settlement in the multi-tiered cave-rock ensemble of Priyma I (Niemecha): (A) section of sediments from south to north between squares 53 and 54; (B) scheme of the ensemble; (C) stratigraphic column of the western wall of square Ч-54; (D) grotto plan; I—bedrock; II—cavities in bedrock; III—forest massif; IV—the overhang limit of the rock cavity (drip line?); V—point; VI—bear tooth; VII—modern soil; VIII—loess-like loams; IX—sand; X—mark from the zero point (reference); XI—excavated squares; XII—*Homo* sp. bones; XIII—colluvium and cultural layer (according to Matskevyi, 2005).

The cave sediments included several cultural layers, including Middle Paleolithic, Late Paleolithic, Mesolithic, Eneolithic, Early Bronze, Early Iron, and Middle Ages layers. Here we discuss only layers related to Pleistocene. The fauna on the site contains up to two thousand specimens, which were determined by K. Tatarinov. The bone collection is stored in the Krypiakevych Institute of Ukrainian Studies of the Ukrainian Academy of Science. Unfortunately, the detailed list of determined bones was lost.

The **Mousterian Cultural Layer** has a thickness of 10–20 cm and is located in the base of the cave deposits, at 160–185 cm deep in front of the cave and 120–145 cm deep in the grotto. The layer comprises fine-grained clayey dark gray to black sand and yellow loam. The latter is of medium phosphorus and low humus. Among the two thousand specimens of osteological remains, the bones of the cave bear (*Ursus spelaeus*) prevail. Also, the bones of the European hare (*L. europaeus*) and other animals are present. A significant number of teeth of the cave bear was located at the entrance to the grotto, and the main number of human remains was embedded nearby. The complex is dated to 45,600 ± 450 yrs. BP (Ki-4583) (cal 49,079–46,775 BP), and may possibly relate to the Moershoft episode (OIS 3) (Matskevyi, 2005).

The numerous human bones, including fragments of the occipital bone of the skull and an "upper part of the skull, accompanied by a flit point, were claimed to be found in this layer. Another five Neanderthal bones, including the radius, were found closely packed near the north-western part of the grotto, on the rock floor near the three points, the teeth of the cave bear, and the remains of a fireplace, in situ within the cultural layer (Matskevyi, 2005). Unfortunately, no special publications about these human remains are available, except for some interviews in the press. So, we strongly doubt and question the taxonomical determination of these remains. Also, we do not know where these bones are stored now, after L. Matskevyi passed away in 2019.

The **Upper Paleolithic Layer** is 15–20-30 cm thick, at a depth of 280–350 cm. The materials embedded in light gray and brownish loamy sand with elements of hygromorphic paleosol. The layer contains the most numerous bones (see Table 9). Seven bones are suggested to be human (*Homo* sp.). The Paleolithic culture was identified to be Gravettian. However, several ^{14}C dates, for the layer (13,900 ± 130 (Ki-4145), 13,600 + 120 (Ki-4146), 14,100 ± 105 (Ki-4147), 14,200 ± 90 (Ki-4163), 13,800 ± 105 (Ki-4178)), indicate the end of the Pleistocene, the Younger Dryas (Matskevyi, 2005). Archeological and faunistic material from the LP Layer suggest some earlier

Table 9 The species composition and number of skeletal remains of mammals from Pryima I, composed (according to Matskevyi, 1998, 2005).

	Mousterian		Late Paleolithic		Late Paleolithic–Mesolithic	
Species	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**
Mammuthus primigenius			9	7		
Coelodonta antiquitatis			42	6		
Alces alces			377	6		
Cervus elaphus			112	5	17	1
Rangifer tarandus			2650	26	21	2
Cervus sp.			14	1		
Capreolus capreolus			83	16	16	1
Bison priscus			90	5		
Bison sp.			287	2		
Equus equus (ferus)			1197	23		
Sus scrofa			61	4	11	1
Ursus arctos			462	12		
Ursus spelaeus	56	1	3063	22		
Crocuta spelaea			531	8		
Panthera spelae			73	5		
Vulpes vulpes			67	4	2	1
Vulpes corsac			1	1		
Alopex lagopus			139	6		
Meles meles			198	6		
Lutra sp.			165	14		
Putorius putorius			23	1		
Martes martes			8	1		
Lepus timidus			33	5		
Lepus europaeus	12	1	70	4	6	1
Ochotona pusilla			11	3		
Marmota bobac			41	5		

Table 9 The species composition and number of skeletal remains of mammals from Pryima I, composed (according to Matskevyi, 1998, 2005).—cont'd

	Mousterian		Late Paleolithic		Late Paleolithic–Mesolithic	
Species	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**
Dycrostonyx torguatus			39	13		
Microtus subterraneus			1	1		
Microtus arvalis					4	2
Microtus gregalis			1	1		
Arvicola terrestris			38	5		
Cricetus sp.			14	1		
Cricetus cricetus			36	4		
Sciurus sp.			51	1		
Erinaceus europaeus			8	1		
Talpa europaea			1	1		
Homo sp.			7	2		

time. The presence of *Ursus speleus* and *Crocuta spelaea* indicates the time not later than the beginning of the LGM. Such species as *S. scrofa* and *Capreolus capreolus* usually indicate interglacials, although the wild pig could be present also in interstadials. That is why we believe that the fauna from this layer accumulated during the several paleoclimatic stages.

4.21 Shchyrets (Tserkovna Gora)

In the Shchyrets village (Nemyriv District, Lviv Oblast) in 1950, employees of the Lviv Museum of Natural History of the Academy of Sciences of the Ukrainian SSR investigated the bone site with Quaternary mammals in a karst sinkhole (ruined cave?) during work in a gypsum quarry located on Tserkovna Gora (Church Mount) (Fig. 1, *3*). The bones were embedded in yellowish-gray loam at a depth of 4–4.5 m from the land surface. The bony horizon of about 0.5 m in thickness located on the gypsum and was covered by loess about 1 m thick. During the excavations, the remains of the following animals were found (Table 10). Among 387 bone fragments, there were ten mammoth molars. The teeth of a woolly rhinoceros, teeth

Table 10 The species composition and number of skeletal remains of mammals from Shchyrets site after (Pasternak and Tatarinov, 1952; Pidoplichko, 1956a, 1956b; Tatarinov, 2000).

Species	NISP	MNI
Mammuthus primigenius	60	5
Equus equus	1	1
Ursus spelaeus	1	1
Equus equus	?	?
Bison priscus	?	?
Coelodonta antiquitatis	?	?

and bones of a horse, a cave bear, and a bison were also found (Pasternak and Tatarinov, 1952; Pidoplichko, 1956a; Tatarinov, 2000, pp. 68–70).

4.22 Shchyrets-1

In 1949, 2 km south of Shchyrets (Fig. 1A, *3*), the remains of *Equus, Alces, Bison priscus, Ursus spelaeus* were found in loams filling a karst dolina in gypsum (Pidoplichko, 1956a).

4.23 Stalactite (Lokitka) Cave

The cave is situated near the Lokitka village, Tlumach District of the Ivano-Frankivsk Oblast (Fig. 1A, *26*). In former times the cave has numerous stalactites because of the 2-m thick limestone strata overlaying the gypsum. It was first described by Łomnicki (1896). The cave has an epigenic origin and was developed in Miocene gypsum by the small underground stream (Dublianskyi and Smolnikov, 1969). I. Pidoplichko collected in the cave some faunistic remains: Rodents—*O. pusilla, A. amphibius, M. oeconomus, M. arvalis,* small Carnivora—*Mustela nivalis,* Chiroptera—*Vespertilio,* large and small birds (*Aves*) (Pidoplichko, 1956a). The most numerous remains of pika (30 bones of 15 individuals) indicate a Pleistocene age of the assemblage. The collection is kept in the Lviv Natural History Museum of the National Academy of Sciences of Ukraine. At present the entrance to the cave is obliterated.

4.24 Stradch

It was discovered in 1949 by Goretskiy (Goretskiy, 1957). From 1953 to 1955, under his leadership, excavations of this location were carried out,

in which also Bachynsky took part. Remains of cave bear (*Ursus spelaeus*), cave hyena (*Crocuta spelaea*), wolf (*C. lupus*), horse (*E. caballus*), woolly rhinoceros (*Coelodonta antiquitatis*), red deer (*C. elaphus*), giant deer (*Megaloceros* sp.), *reindeer* (*R. tarandus*), mammoth (*Mammuthus primigenius*, early form) and gopher (*Citellus* sp.) were found. The remains of the cave hyena and the taphonomic features of the burial were studied by G. Bachynskyi (1967).

The site is in the vicinity of the Stradch village of the Lviv Oblast (15 km from Lviv) (Fig. 1A, *5*), in the precipice of the steep left bank of the Vereshchytsia River, 25 m above its level. The fossil bones were found in a small niche filled with medium-grained white quartz sand under the cornice formed by a layer of sandstone. Both the sand layer and the overlying sandstone layer are sediments of the Badenian Stage (Miocene). The main accumulation of bones had the shape of a lens with a width of up to 1.5 m and a thickness of about 0.5 m which continued below a slight slope, deepunder the sandstone cornice. In this lens, isolated limb bones, jaw fragments, teeth, and even whole skulls (4 hyena skulls), together with clusters of coprolites of various sizes and fragments of sandstone and limestone, were embedded in the main mass of sandy material. Isolated fossil bones were also found in the sand on either side of the main cluster beneath the cornice. Most bones were light yellow and white in color. The cavities of tubular bones are filled with calcified sand, and the surface of many bones is covered with a thin limestone crust. Examination under a microscope showed that the marginal areas of the bone tissue of some remains are partially mineralized with calcite. The site was formed mainly during the Late Pleistocene (Riss-Würm) (Bachynskyi, 1967, pp. 14–15).

4.25 Syniakove

In the period between 1936 and 1939, during the paleontological research of Siniakove Cave (Fig. 14), animal remains of the Pleistocene fauna were found (now stored in the Lviv Natural History Museum). Podoplichko identified the taxonomical composition of this fauna (Table 11). The exact location of the cave is unknown. It is very possible that it was in the same place, where the Syniakovo-1 Cave is located (see below) (Fig. 1A, *13*).

4.26 Synyakove-1

The site was discovered in a sand quarry near the Synyakovo Village, which is near the town of Chortkiv, Ternopil Oblast, 500 m east of the Synyakove bus station (49°0′14.58″N, 25°48′41.09″E) (Fig. 1, *13*). Now it is within

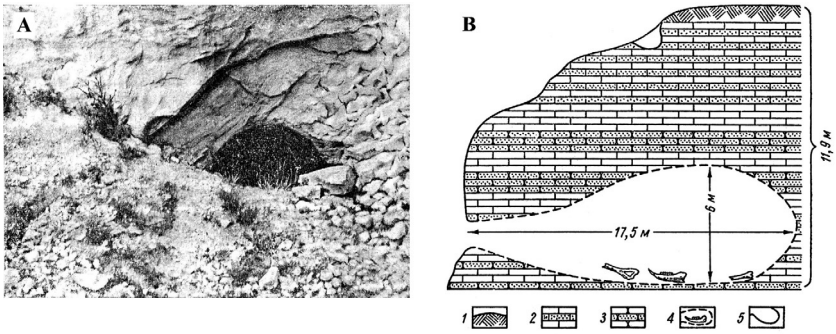

Fig. 14 (A) The entrance to the cave (photo by K. Tatarinov); (B) Schematic geological section of deposits in the cave near the Syniakove Village: (1) soil horizon; (2) limestones; (3) carbonate sandstones with cracks filled with loams with animal remains; (4) a cave where the remains of Pleistocene animals were found; (5) a niche that contained the remains of fossil fauna (according to David et al., 1990).

Table 11 The species composition and number of skeletal remains of mammals from Syniakove site (Pidoplichko, 1956a, p. 130).

Species	NISP	MNI
Coelodonta antiquitatis	16	1
Bison priscus	1	1
Cervus elaphus	93	5
Capreolus capreolus	2	1
Ursus arctos	34	3
Meles meles	13	3
Putorius sp.	2	1
Crocuta spelaea	3	1
Canis lupus	8	2
Desmana moschata ternopolitana	6	1
Talpa europaea	2	2
Vespertilionidae	1	1
Lepus europaeus	1	1
Ochotona pusilla	4	2
Castor fiber	2	1
Cricetus cricetus	25	5
Cricetulus migratoris	2	1
Arvicola amphibious	1	1
Microtus arvalis	3	1

Chortkiv limits. It is located at an altitude of 295 m above sea level, at the level of a Pliocene terrace of the Dniester. The material was collected in 1962 by A.B. Bogutsky and in 1963 K.A. Tatarinov.

The geological section of exposed sediments is as follows: a) thin soil layer—0.1–0.2 m; (b) highly weathered (to the state of fragments) Ratyn limestone—1 m; c) Lower Tortonian (middle Badenian?) gray with a yellowish tinge quartz layered sands of different densities—more than 10 m. The Badenian sandstones have not only vertical (6–8 m deep and up to 0.5 m wide), but also horizontal cracks-niches, reaching 0.5 m in height. The cracks are filled with white quartz sand and clastic material (sandstone, Ratin limestone). The accumulation of bones of large animals and their coprolites is connected with the filling of an ancient grotto (12 m long, 10 m wide and 1.5 m high), which was formed in Middle Badenian white quartz medium-grained skewed sands, under the cornice of calcareous sandstones (Fig. 15). The remains of animals (separated limb bones, phalanges, individual teeth and fragments of skull bones) were scattered in a layer of yellow unlaminated sand that completely filled the ancient grotto (David et al., 1990; Tatarinov, 2000, pp. 65–68) (Table 12).

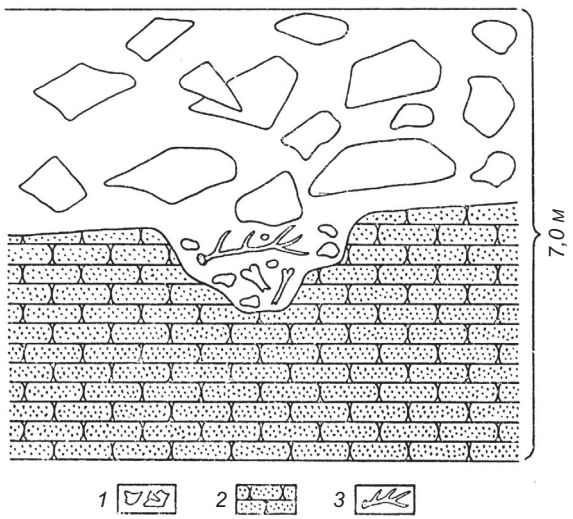

Fig. 15 Schematic section of sediments in the Synyakovo-1 quarry: 1—heavily destroyed limestone; 2—medium- and fine-grained quartz sandstones; 3—karst dolina filled with sand, limestone fragments and remains of Pleistocene animals (David et al., 1990).

Table 12 The species composition and number of skeletal remains of mammals from Syniakove-1 site (according to David et al., 1990; Tatarinov, 2000).

Species	NISP	MNI
Insectivora		
Desmana moschata ternopolitana Pidop.	1	1
Chiroptera		
Myotis cf. *danutae Kowal.*	8	6
Plecotus sp.	7	4
Pipistrellus sp.	4	1
Lagomorpha		
Lepus sp.	4	4
Ochotona pseudopusilla Gur. *et* Schev.	7	2
Rodentia		
Marmota sp.	1	1
Citellus sp.	3	1
Castor fiber L.	8	3
Dyromys sp.	5	1
Rattus sp.	1	1
Apodemus sp.	1	1
Parapodemus cf. *coroneris* Schaub.	3	3
Cricetus cricetus major L.	6	1
Allocricetus sp.	6	3
Cricetulus sp.	3	3
Arvicola cf. *hintoni* Ahar.	4	1
Microtus (Pitymys) arvaloides Hint.	5	2
Microtus ex gr. *arvalis* Pall.	5	5
Spalax sp.	1	1
Carnivora		
Canis sp.	12	1

Table 12 The species composition and number of skeletal remains of mammals from Syniakove-1 site (according to David et al., 1990; Tatarinov, 2000).—cont'd

Species	NISP	MNI
Vulpes vulpes L.	12	1
Cuon sp.	11	3
Mustela erminea L.	2	2
Mustela nivalis minima Tatar.	2	2
Putoris sp.	1	1
Lutreola lutreola L.	1	1
Martes foina homizeniensis Tatar.	2	1
Gulo sp.	1	1
Meles meles sinjakovensis Tatar.	34	10
Lutra lutra L.	1	1
Ursus spelaeus rossicus Bor. (U. savini Andrews)	61	7
Crocuta cf. *spelaea* Gold.	6	2
Felis sp.	2	1
Panthera spelaea Gold.	11	3
Equus cf. *mosbachensis* Reich.	5	3
Dicerorhinus aff. Mercki Jager	10	2
Megaloceros sp.	4	2
Capreolus sp.	8	3
Cervus cf. *elaphus* L.	31	5
Bos sp. vel *Bison* sp.)	3	1

Tatarinov believed that various predators lived in the ancient grotto at different times and died there themselves. Their remains were mixed with the bone material of their prey. The bones at the bottom of the grotto were covered with sand that gradually fell from the walls and ceiling of the grotto and were buried under slabs that fell from the ceiling. Burials in vertical cracks were formed mainly from the pellets of birds of prey, in particular

owls, which settled in the cracks before they were filled with sand (Tatarinov, 2000, pp. 65–68).

Bachynskyi and Tatarinov believed that the fauna corresponds to the Tiraspol faunal complex and the burial was formed over a long period (Bachynskyi, 1965; Tatarinov, 1966a; Tatarinov and Bachynskyi, 1968). Later Tatarinov recognized that this fauna is close to the "middle anthropogenic" (Tatarinov, 2000), i.e. middle Pleistocene according to current concepts. David considers this fauna to be similar to that of Tiraspol, with which he considers the common species to be a cave lion, a horse close to Mosbach, a Kirchberg rhinoceros, a red deer, etc., noting the absence of Late Pliocene forms in it (David, 1977). In fact, this fauna is mixed with rather heterogeneous elements, some of which are characteristic of the Singilian Fauna of the Middle Pleistocene. So, *U. spelaues rossicus* Bor. today is confidently identified with *Ursus savini* Andrews, which appears at the very beginning of the Middle Pleistocene (Baryshnikov and Foronova, 2001). It is possible that the given list contains mixed assemblages from the filling of various cavities and fissures at different times, and fauna from different times was included in the list. Recently, based on the fauna of Rodents, the site was related to the last stage of the Tiraspolian Fauna (Tiligul-Lubny Stages, MIS 14—MIS 15) (Krokhmal' et al., 2021).

Unfortunately, now the site does not exist anymore since the sandstone bank of the terrace is strongly destroyed by the local development of sand (Fig. 16).

4.27 Tadirka Cave

This recently discovered small cave is close to the Atlantyda Cave (48°35′52.14″N, 26°20′42.67″E) (Fig. 1A, *17*). Evidently, it is one of the ancient entrances to the Atlantyda Cave system, just separated from it by sediment infill. It was partly destroyed by the industrial gypsum production in the 1960s. The remains of at least two individuals of brown bear (*U. arctos*) and rodents were found. In the narrow gallery where bones were embedded, the walls were partly burnt, and charcoal fragment were found in the sediments. As the cave is too narrow for continuous human habitation, it is very probable that it was temporarily inhabited by humans during the hunting seasons and that open fire was being used. The faunal material is currently being studied.

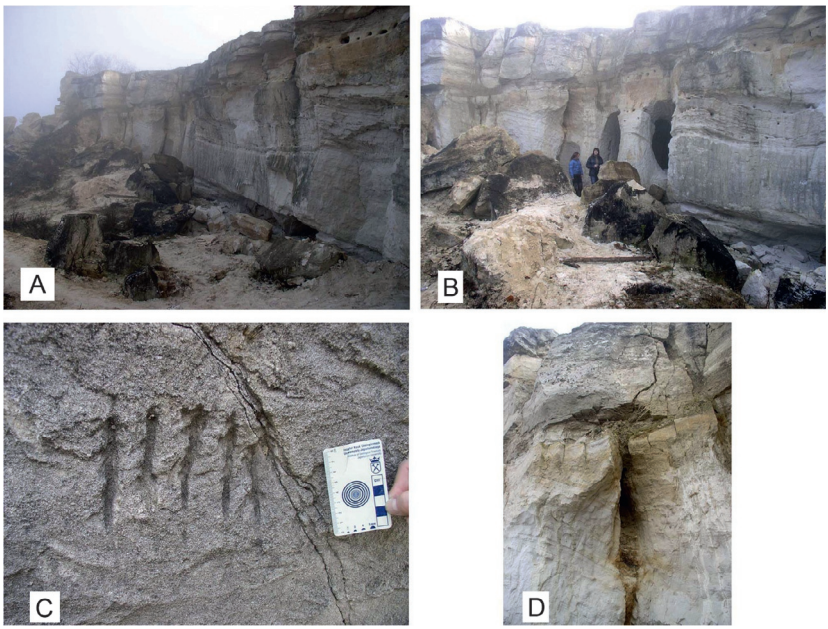

Fig. 16 The current state of the Synyakovo-1 site. (A and B) Sand quarry with entrances to arbitrary tunnels; (C) scratches from the claws of a bear (?) on the wall of a ruined cave; (D) vertical cracks widened by sufossion, cutting both sandstones and the upper part of the sands, with patches of reddish paleosol.

4.28 Trygolovatka Cave

The cave is located in the rocky Trigolovatka Mount, near the Khotymyr village (Tlumatsky District, Ivano-Frankivsk Oblast) (Fig. 1A, *25*). A. Kirkor mentions it for the first time. In the big cave there was a lake with a stream deriving from it. The entrance to the cave, a few years before A. Kirkor's exploration, was destroyed due to the industrial production of gypsum stone from this mountain. During gypsum stone production from the cave itself, human skulls and bones were found at a depth of 3 m. The bones found during the gypsum exploration, some already fossilized, were transferred by A. Kirkor to the museum in Krakow. The researcher suggested that a Stone Age burial could have existed in this cave (Kirkor, 1876, p. 8).

As our research has shown, in fact, this massif is composed of coarse-crystalline gypsum. The mentioned stream is a karst spring with clean

transparent water and a flow rate of ≈10 L/s, flowing out from under the gypsum blocks. In the alluvium of the stream, a few meters far from its exit from the underground, we discovered several fragments of strongly fossilized bones of large mammals.

The significant fossilization of the bones extracted from the cave in the 19th century, together with the fragments we found, may indicate their rather ancient, at least Late Pleistocene, age. It is possible that these human remains are still stored in the collections of one the Krakow museums.

4.29 Tovtry Cave

The cave is situated at the northern outskirt of the Tovtry village in Chernivtsi Oblast (48°34′6.86″N, 25°52′3.13″E) (Fig. 1, *20*). It is 26 m in length and near 8 m in height (Ridush and Kuprich, 2003). This small cave forms part of an ancient hypogenic labyrinth developed at the base of the 30-m thick Miocene gypsum strata. Initially, this part of the cave was filled with loose sediments consisting of light-brown loam with numerous inclusions of debris-like large gypsum crystals. In the 1960s, the cavity was transected by a small gypsum quarry, and the cave filling became exposed. The sediments from the depth of 1–4.1 m were examined for their pollen content, which resulted in their dating to the Last Interglacial, Early Glacial stadials, and interstadials (Avdieienko, 2018, 2019). Only at a depth of 6.3–7.5 m rare bone fragments and bones belonging to bison (*Bison priscus*) and horse (*Equus ferus*) were recovered from the cave infill. Some bones exhibit traces of gnawing by carnivores.

4.30 Vyniava—Horosno

The site is situated in a sand quarry, between the Vyniava and Horosno villages, about 25 km to SW of Lviv (49°39′44.77″N, 23°57′52.59″E). It includes several buried niches and small grottoes inhabited during different episodes of Pleistocene, that are discovered from time to time because of sand quarrying (Fig. 17). The first finds of *Crocuta spelaea* from this site were published by K. Tatarinov (Tatarinov, 1958) (Table 13). Later the list of species was added (Tatarinov, 2000, pp. 76–78) (Table 14). Some bones from this quarry got into private collections. One of the cave hyena teeth was dated to 40,770 ± 350 BP (MAMS 31302) (Westbury et al., 2020) (Table 15), that place the site in the timescale of the Late Pleistocene, MIS 3. The recent investigation of the small mammals from a cave in this quarry revealed the next list of species (a number means the MNI): *Sorex*

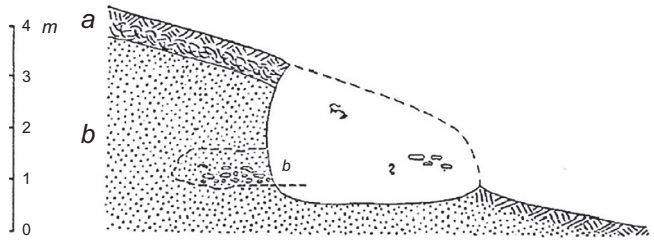

Fig. 17 The section of the Vyniava site (according to Tatarinov, 1958).

Table 13 Geological section of the Vyniava site (according to Tatarinov, 1958).

Unit	Thickness, m	Description
1	0.6	colluvial deposits containing sand, *Lithothamnion* limestone fine debris, and humified loam
2	1.2	grayish-white quartz sand of lower Badenian (Miocene)
3	0.5–0.7	greenish glauconite sand (Miocene?) with the bone remains

Table 14 The species composition and number of skeletal remains of animals from Vyniava (according to Tatarinov, 2000).

Species	NISP	MNI
AVES		
Lyrurus tetrix	1	1
MAMMALIA		
Spalax cf. *polonicus*	3	1
Apodemus sp.	17	2
Microtus sp.	34	2
Canis lupus	5	2
Ursus spelaeus	4	1
Crocuta crocuta spelaea	62	17
Mammuthus primigenius	7	2
Equus equus	87	6
Coelodonta antiquitatis	51	5
Cervus elaphus	7	3
Bison priscus	2	1

sp.—1; *Crocidura* sp.—1; *Ochotona* sp.—2; *Sicista* sp.—2; *Spermophilus odessanus*—10; *Lemmus* sp.—1; *Arvicola chosaricus*—9; *M. oeconomus*—2; *M. gregalis*—11; *M. arvalis*—1. This fauna was dated to the Middle Pleistocene (first half of MIS 6) (Popova et al., 2019).

From the taphonomical point of view it becomes apparent that the faunistic remains of large mammals are associated with the cave hyenas' dens and are represented by the bones of hyenas and their prey. Small mammals relate to nests of birds of prey. The cavities inhabited by the predators can be of suffusion and weathering origin, as well as zoogenic. They were developed in low cemented sandstone under a cover of strongly cemented calcareous sandstones.

5. Discussion and conclusions

The region is specific for its karst and caves. But the very long gypsum labyrinths contain not too many bone sites. At the same time numerous caves in sandstones of suffosional and even weathering origin contain quite old fauna, like Chortkiv, Synyakove, Horishnia Vygnanka, Melna and others. Paleolithic cave sites, up to now, are known only from the suffosional cavities and rock shelters of Pryima and Chortovi Skeli. The evidence of human presence in form of charcoal in sediments and burnt walls or stones, were noted in the Kryshtaleva and Tadirka caves. The investigated sections of cave sediments are usually quite short and do not cover long periods. Only Kryshtaleva and Tovtry have a potential for successions covering more than 50 kyr. There is a lack of radiocarbon dates in the region, especially for the direct dating of the fauna (Table 15), as well as other physical dating.

The character of the bone accumulations can usually be related to the activity of large and small carnivores. The sediments contain the bones and remains of their prey. Accumulations of small vertebrates (Rodents, Reptiles, Amphibia) usually are related also to the activity of the birds of prey.

The typical inhabitants of caves, so-called troglophiles, are cave hyenas, cave and brown bears, foxes, badgers, mustelids, and red foxes. Among Rodents, the most troglophilic are picas (*Ochotona*) (Ridush, 2004c).

Table 15 Results of AMS radiocarbon dating of Quaternary paleontological cave sites in Podillia-Bukovinian Karst-Speleological Area (Ukraine).

Site	Bone	Species	Lab code	%C	%N	14C	cal BP	Source
Horosno-Vynjava	tooth	*Crocuta spelaea*	MAMS 31302			40,770 ± 350	44,430–43,125	Westbury et al. (2020)
Bukovynka Cave, Trapeznyi Chamber	tooth	*Crocuta spelaea*	VERA-2529			41,300 +1300/−1100	46,629–42,660	Ridush (2009)
Bukovynka, Sukhyi Chamber	tooth	*Ursus arctos*	Poz-46240			10,730 ± 60	12,765–12,621	Ridush (2012)
Malimon-Canyon Cave	humerus	*Coelodonta antiquitatis*	Poz-47727	5.5%C,	1.2%N	38,000 ± 800	43,145–41,276	Nadachowski et al. (2015)
Kryshtaleva (Kryvchenska) Cave	fibula	*U. arctos*	Poz-59413	6.4%C	2.4%N	12,240 ± 70	14,812–13,894	Nadachowski et al. (2015)
Chortova Skelia, Layer A		*Unknown*	Ki-5415			27,200 ± 170	31,596–31,061	Matskevyi (2005)
Chortova Skelia, Layer B		*Unknown*	Ki-5412			13,500 ± 110	16,635–15,933	Matskevyi (2005)
Chortova Skelia, Layer C		*Unknown*	Ki-5414			11,800 ± 90	13,991–13,466	Matskevyi (2005)
Pryima I, Middle Paleolithic		*Unknown*	Ki-4583			45,600 ± 450	49,079–46,775	Matskevyi (1998)
Pryima I		*Unknown*	Ki-4145			13,900 ± 130	17,302–16,485	Matskevyi (2005)
Pryima I		*Unknown*	Ki-4146			13,600 + 120	16,868–16,059	Matskevyi (2005)
Pryima I		*Unknown*	Ki-4147			14,100 ± 105	17,419–16,891	Matskevyi (2005)
Pryima I		*Unknown*	Ki-4163			14,200 + 90	17,479–17,026	Matskevyi (2005)
Pryima I		*Unknown*	Ki-4178			13,800 ± 105	17,038–16,407	Matskevyi (2005)

All the14C ages are calibrated with 95.4% probability using the IntCal20 atmospheric curve (Reimer et al., 2020) in the OxCal 4.4 software (Brock et al., 2013). Abbreviations: cal BP—calibrated before present.

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