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QUATERNARY IN THE KARST AREAS OF THE WEST CARPATHIANS

INTRODUCTION

The Quaternary of karst areas is characterized by a wide variety of fossil-rich sediments enabling both main groups of zoofossils — *Mollusca* and *Vertebrata* to be mutually correlated, and by the occurrence of peculiar sedimentary environments such as caves, chasms, sinkholes, karstified crevasses and rock-shelters. Thus, in karst areas well-differentiated depositional sequences with fossils can be found even in positions, where erosion generally predominates, e.g. on steep slopes and tops including high mountain areas. In karst environments prehistoric sites are also concentrated so that animal remains come often from archaeological contexts (L o ž e k 1960a).

On the other hand, it must be considered that the great majority of karst areas is situated in mountain regions, where Quaternary deposits are mostly preserved only in fragments of comparatively small areal extent. For this reason, they have received relatively little attention and Quaternary geologists have mostly neglected important informations on the faunal development, local environment and regional climate based on evidence from karst areas.

This is true also of the West Carpathians, where a number of karst areas occurs within a broad altitudinal scale from the foothills to the alpine zone. Although also here attention has been concentrated on the Quaternary of lowlands, i.e. of non-karst areas, at present so many diverse records from our karstlands are available that it may be useful to evaluate them and to draw several conclusions (L o ž e k 1978b).

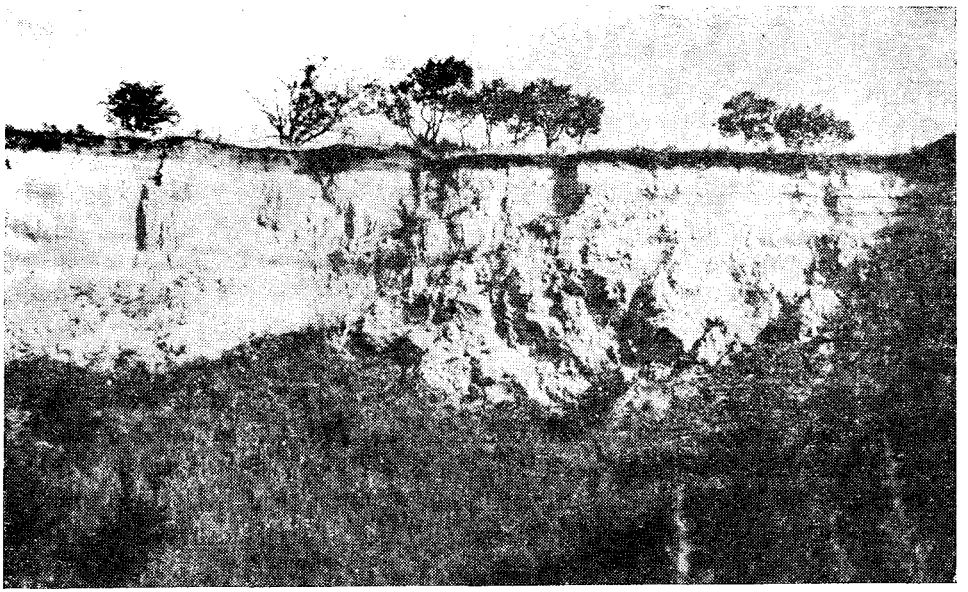
POSSIBILITIES OF INVESTIGATION OF KARSTLAND QUATERNARY IN THE WEST CARPATHIANS

As pointed out before, the karst is particularly characterised by sedimentary fills of various cavities providing palaeontological and archaeological findings. Besides them further kinds of biostratigraphically im-

portant sediments occur in karst areas. These are first of all slope and floodplain sediments as well as tufas which in response to high $CaCO_3$ content also use to be rich in fossils and become important in sites, where they can be correlated with climatically controlled Quaternary deposits such as terraces or loesses. Such a possibility is given mostly in the Carpathian foothill zone, e.g. in the mountain ranges of Pálava, Malé Karpaty, Považský Inovec, Tríbeč, Slovenský kras etc. as well as in karst areas bordering the valleys of large rivers, particularly of the Váh, Hron and Hornád. Some formerly glaciated districts also are favourable, e.g. the Demänová karst at the northern side of the Nízke Tatry Mts., but they have remained mostly unexplored as far.

Great altitudinal differences in the West Carpathian karst areas enable the facies development of Quaternary deposits in various altitudinal zones to be traced — from the chernozem zone in the Pálava Mts. and the lower Váh valley through the humid forest zone in intramontane basins and lower mountain regions to the alpine zone of the high limestone Carpathians.

Well-stratified sequences of diverse types of slope deposits have been investigated in detail only in karst areas. For instance, the following



Phot. 1. In the foothill zone the karst phenomena are associated with loess sequences. A section near Hlohovec (Považský Inovec Mts.) showing karstified dolomitic limestones being covered by a complicated loess sequence with several fossil soils (Photo V. Ložek)

Fot. 1. W strefie podgórskiej zjawiska krasowe są powiązane z sekwencjami lessowymi. Przekrój koło Hlohovec (góry Považský Inovec) pokazuje krasowiejące dolomityczne wapienie pod złożoną pokrywą lessów przegrodzonych kilkoma glebami kopalnymi

sites may be mentioned: Middle Pleistocene slope sequence of the Mních Hill near Lisková (Vaškovský, Ložek 1972), Early Pleistocene scree conglomerates in the Muráň and Slovak karsts (Ložek 1960b; Ložek, Záruba 1965; Ložek, Horáček 1987) or Late Vistulian proluvial cones in the glaciated area of Nízke Tatry Mts. (Ložek 1986).

As far as caves and rock-shelters are concerned, particular attention has been concentrated upon several characteristic types of sedimentary fills, first of all of those in mountain rock-shelters, where loose sinter, the so-called foam sinter, is intensely precipitated (Ložek 1965). In addition, spring tufas have been investigated, since their depositional sequences reflect the changes of water regime as well as the proportion of different sedimentary processes in biostratigraphically well-subdivided profiles. Moreover, certain types of tufas give the possibility of a direct comparison between molluscan assemblages and plant remains (Kovanda 1971).

In most of the karst sites a correlation between molluscan and vertebrate faunas can be made which has stimulated the advancement of Quaternary biostratigraphy. Accordingly, as mentioned above, in some tufa deposits a comparison between *Mollusca, Ostracoda* and vegetational changes is possible, as demonstrated by the fossil records from the thick sequence in the valley Slovanská dolina near Valča in the Turiec region (Vaškovský, Ložek 1976; Šilar, Ložek 1988). Comparative studies of sedimentary fills of cave entrances and rock-shelters in various altitudinal and morphological positions considerably contributed to the knowledge of Late Pleistocene and Holocene palaeoenvironments providing results applicable within broad mid-European context (Ložek 1975, 1980b; Horáček, Ložek 1988ab; Jánossy 1986; Kordos 1978).

The above data show that the karstlands provide very favourable conditions to reconstruct the development of whole Quaternary ecosystems because of the possibility to correlate both main components, i.e. the abiotic environments (sediments, soils, erosional processes) and the biocoenoses (mutual correlation of different animal groups and their relation to the vegetation).

REVIEW OF BIOSTRATIGRAPHICALLY INVESTIGATED SITES

EARLY AND MIDDLE PLEISTOCENE

In several karst areas of Slovakia, particularly in the Slovak Karst (Plešivec, Gombasek, Včeláre, Jabloňov, Honce etc.), but also in the lower Váh valley (Ivanovce, Skalka near Nové Mesto) and at the foot of the

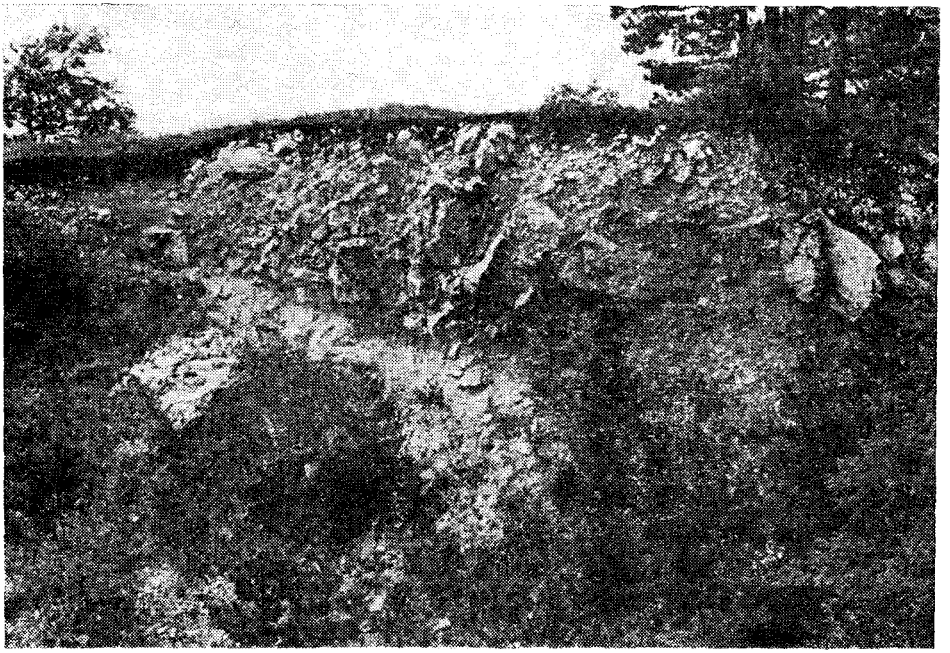
Tríbeč Mts. (Málok near Koliňany, Žírany) relict sedimentary fills of karst cavities are preserved which include a rich Pleistocene fauna, mainly the mammals. Its analysis has largely contributed to the knowledge of the succession of particular faunal assemblages during the Late Pliocene and Early Pleistocene (Fejfar 1961ab, 1976; Horáček 1981; Ložek, Horáček 1984; Horáček, Ložek 1988b) as well as to the recognition of molluscan index species characteristic of this time span (Ložek 1969; Horáček, Ložek 1988b).

In this connection it is worth noting that in the Spiš Basin, particularly in the Late Pliocene and Early Pleistocene travertines of Dreveník and Pažica near Spišské Podhradie, karst pipes are developed which provided rich faunas from several phases of the Pleistocene (Ložek 1964b).

Of particular interest are screes cemented by $CaCO_3$ with variable admixture of terra rossa material. For the first time they were described from the foot of the karst plateau Muránska planina as the Muráň breccia (Ložek 1960b), but they are more common in the Slovak Karst, where they are best exposed near Slavec and Hrhov. Further occurrences are known from the Hornád valley and from the foot of the Rokoš Range in the Nitrica valley. The incorporated malacofauna indicated that the minimum age of these scree breccias is an early phase of the Middle Pleistocene (Ložek, Záruba 1965) which was recently confirmed by records of small mammals (Ložek, Horáček 1987). Due to this age the breccias are locally karstified in such a way that they include rather large caves (Piecky near Muráň). Screes formed in later phases are generally not cemented and their loamy matrix is different.

Deposits of demonstrable Mid-Pleistocene age occur in karst cavities rather seldom (cp. Lais 1941), but they are well developed on the surface as screes with a loamy matrix forming complex sequences whose particular members are characterized both by the consistence of their matrix and by the form and size of stone fragments. The best example of such a sequence are the slope deposits overlying the 18 m terrace of the Váh river exposed in the slope of the Mních Hill near Lisková in the Liptov Basin. The river gravels are covered by loamy humus-deficient sediments corresponding to a late glacial phase. This basal member is overlain by a thick scree sequence including in its lower part a complete interglacial and higher the following early glacial. This sequence is discordantly covered by scree deposits from a later cycle showing a different development. Thus, the above interglacial is younger than the comparatively low-lying river terrace, but older than at least one full Pleistocene cycle, and consequently it is post Early Pleistocene age (Vaškovský, Ložek 1972).

An important site is the Turold Hill near Mikulov in the Pálava Mts., where the sedimentary fills of various karst cavities are represented by



Phot. 2. One of the numerous karst pipes in the Turold Hill near Mikulov (Pálava Mts.) filled up by a scree sequence, with a Mid-Pleistocene interglacial horizon at the basis of the coarse scree (Photo V. Ložek)

Fot. 2. Jedna z wielu krasowych rynien na wzgórzach Turold koło Mikulova (góry Pálava) wypełniona rumoszem, z interglacjalnym, środkowoplejstoceńskim horyzontem grubego rumoszu w spągu

thick sequences of screes with a loamy matrix including rich interglacial faunas of Middle Pleistocene character (Bosák *et al.* 1984; Ložek 1957).

Another site to be mentioned is the Kočkovská skala in Záskalie near Púchov in the middle Váh valley. At the side of a karstified Jurassic rock a Mid-Pleistocene terrace relic is preserved. It is overlain by a complicated sequence of screes, soil sediments and loesses including a palaeontologically documented interglacial at the basis (Smolíková, Ložek 1962; Mazúr, Kalaš 1963). In this context it is worth noting that through the Dudlavá Skala Cave at the foot the Nízke Tatry Mts. penetrates a stream of proluvial gravels underlying a scree sequence which includes at the basis an interglacial with Drobacia banatica-fauna (Ložek 1962).

LATE PLEISTOCENE AND HOLOCENE

The great majority of Quaternary depositional sequences exposed in the karst areas of the West Carpathians is, however, of Late Pleistocene and Holocene age, like in other mid-European karstlands (Lais

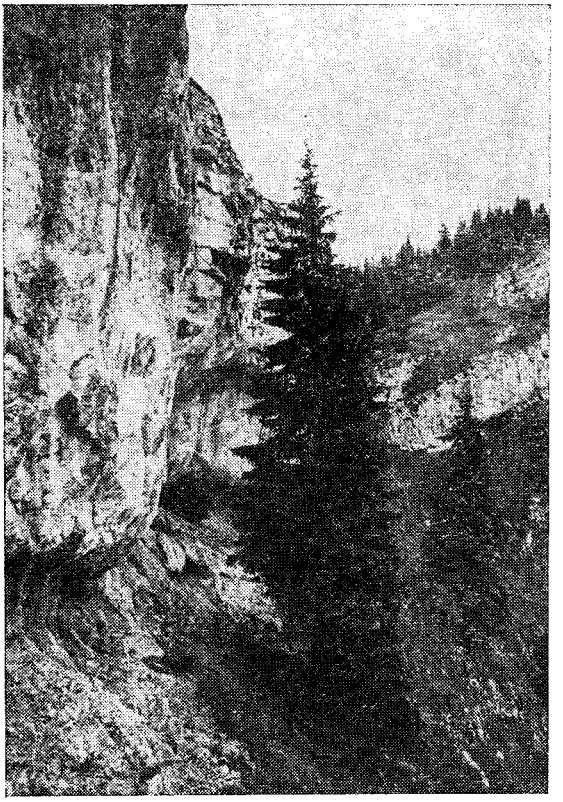
1941). Particularly the time period post-dating the culmination of the Vistulian pleniglacial is represented in numerous sites situated in all altitudinal zones as well as relief contexts (Ložek 1980b).

First of all sedimentary fills of large horizontal caves may be mentioned, since they are in many cases important localities of prehistoric man. Modern comprehensive investigations were made in the caves Dzeravá and Tmavá skala in Malé Karpaty Mts. (Prošek 1951), Velká Jasovská (Ložek *et al.* 1957), Maštalná (Ložek, Horáček 1988), Kvapľová and Hámorská caves (Horáček, Ložek 1988a) in the Slovak Karst, further in the Čertova Pec near Radošiná, apart from preliminary archaeological investigations in many other cave sites (Bárta 1965, 1975 etc.).

Among caves inhabited by palaeolithic man the cave Prepoštská jaskyňa in Bojnice is of particular interest, due to the fact that it is situated within a travertine body at the mouth of a spring which deposited the travertine, but later formed in its own travertine deposit and underground cave system (Bárta 1972).

Several karst areas are characterized by numerous rock-shelters which frequently developed in series bordering the foot of vertical limestone and locally also dolomite cliffs (Ložek 1965; Mitter 1988). Most favourable conditions for the forming of such rock-shelters occur in mountain areas consisting of Middle Triassic limestones which are exposed in steep slopes as vertical rock steps („radovice" in Slovak). Under the humid climate of the montane and subalpine zones a peculiar form of loose sinter, the so-called foam-sinter, is precipitated as incrustations on mosses and lichens covering the moist walls and ceilings of the rock-shelters. These incrustations fall off during dry or frost periods and accumulate on the rock-shelter floor. At present the main sedimentation of foam-sinter is confined to altitudes between 800 and 1400 m, occurring at lower elevations only exceptionally. However, the foam-sinter was deposited here since the Late Boreal to the Epiatlantic, so that it forms a considerable, locally a major part of Holocene depositional sequences (Ložek 1964a, 1965). In the xerothermic foothill areas its deposition is restricted to a comparatively short phase spanning the Late Boreal and Early Atlantic, declining with the immigration of Neolithic man (Ložek 1984, 1985).

Since Late Pleistocene and particularly Holocene deposits were investigated at numerous sites at various elevations, it was possible to formulate certain regularities of their development, first of all to date the beginning of this sedimentation cycle into the Late Vistulian pleniglacial (Ložek 1980b). In low-lying warm hilly countries as well as in the lower submontane zone the Holocene sequences consist of loamy screes and the foam-sinter either forms only one rather thin horizon or is absent. This horizon, well-known from a number of mid-European



Phot. 3. At the foot of limestone cliffs in the high limestone Carpathians numerous rock-shelters with fossil-rich foam sinter fills are developed. Rock walls („radovice") in the top part of the Ohnište Mt. in the Nízke Tatry Mts. near Liptovský Mikuláš (altitude 1500 m) (Photo V. Ložek)

Fot. 3. U podnóża urwisk wapiennych w wysokich wapiennych Karpatach występuje wiele schronisk wypełnionych faunonośnymi naciekami. Ściany skalne („radovice") w górnej części gór Ohnište w Niskich Tatrach koło Liptowskiego Mikulasza (wysokość 1500 m npm)

caves (L a i s 1941), can be assigned to the Early Atlantic (L o ž e k 1985). With increasing altitude the foam-sinter sedimentation continues up to later phases and the sinter forms a whole sequence beginning at the Boreal/Atlantic boundary, but declining during the Epiatlantic or even later — according to the altitudinal and morphological position of the site in question (L o ž e k 1984). The underlying beds consist of scree with yellowish brown matrix poor in humus, whereas the sinter sequence is overlain by loose humus-rich loams with coarser scree (Fig. 1).

Tripartite profiles of this developmental pattern are common at middle elevations of the Mid- and North-Slovak Carpathians. As a typical example the sedimentary fill in the entrance of the Mažarná Cave may be mentioned (L o ž e k 1980a). In the higher and cooler areas the pre-

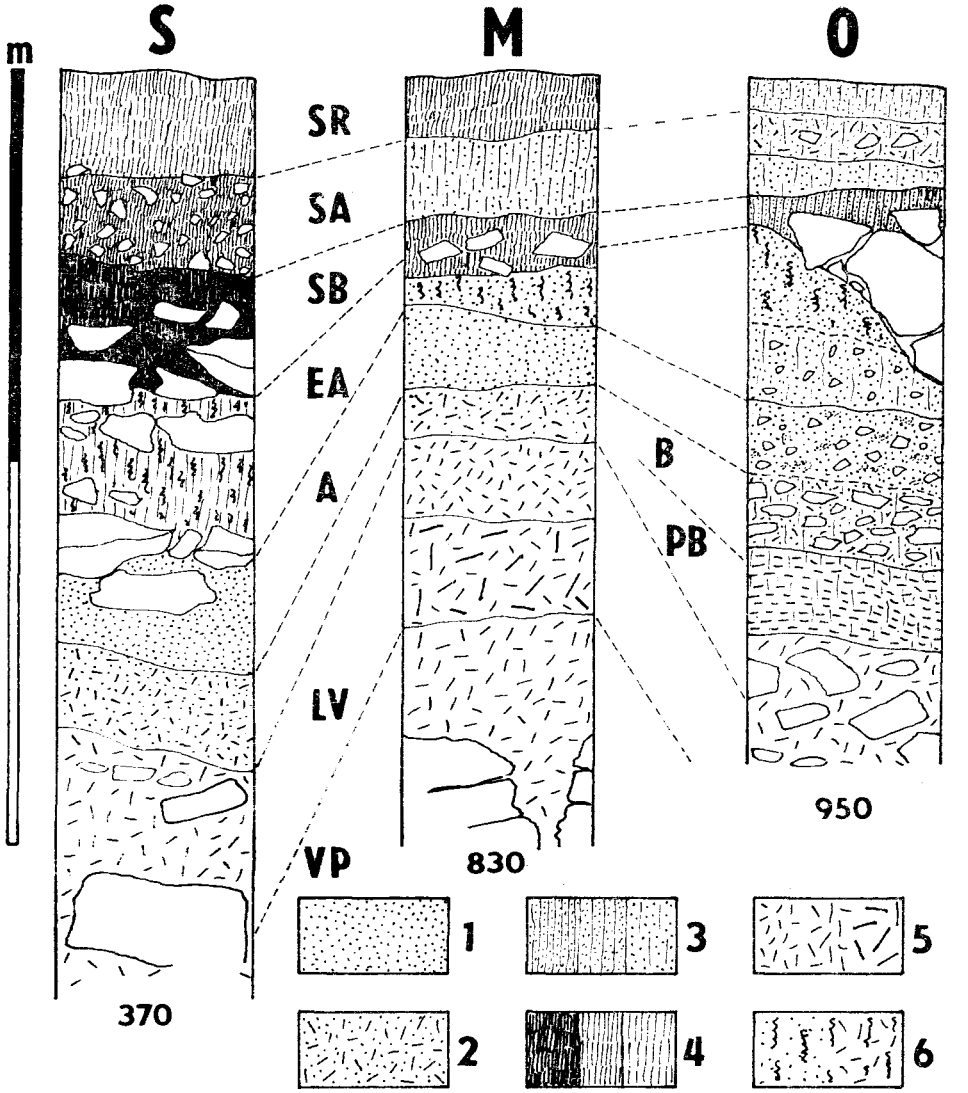


Fig. 1. Late Pleistocene-Holocene depositional sequences with foam sinter horizons at different altitudes. 1 — foam sinter, 2 — rock debris with foam sinter admixture, 3 — foam sinter with variable admixture of humic rendzina material, 4 — rendzina material with variable humus content, 5 — small-sized to coarse scree, 6 — humus infiltrations; 370 — altitude (in m); VP — Vistulian pleniglacial, LV — Late Vistulian (= Late Glacial), PB — Preboreal, B — Boreal, A — Atlantic, EA — Epiatlantic, SB — Subboreal, SA — Subatlantic, SR — Subrecent; sites: S — Soutěska (Pálava Mts.), M — Mažarná Cave (Velká Fatra Mts.), O — Ohnište, Sokol (Nízke Tatry Mts.)

Ryc. 1. Późnoplejstoceńskie i holoceńskie sekwencje osadów z poziomami nacieków na różnych wysokościach. 1 — nacieki, 2 — rumosz z domieszką nacieków bezwęglanowych, 3 — nacieki z różną domieszką humusowych rędzin, 4 — rędzina o zmiennej zawartości humusu, 5 — rumosz drobny do grubego, 6 — nacieki humusowe; 370 — wysokość bezwzględna (w m), VP — vistulian — pleniglacjał, LV — późny vistulian (= późny glacjał), PB — preboreał, B — boreał, E — atlantyk, EA — epiatlantyk, SB — subboreał, SA — subatlantyk, SR — subwspółczesny; stanowiska: S — Soutěska (góry Pálava), M — jaskinia Mažarná (Wielka Fatra), O — Ohnište, Sokol (Niskie Tatry)

cipitation of foam-sinter continues up to the present as shown e.g. in the rock-shelter Ružový previs in the Vrátna Valley near Blatnica (Ložek 1964a). It is of interest that at the upper timber line and in the dwarf-pine zone the foam sinter deposition starts gradually later and declines within the alpine zone (Ložek 1978a, 1981, 1984).

Of prime importance from the viewpoint of Holocene climatic development is the foam sinter horizon occurring in the caves of the xerothermic hilly countries, since it documents the most humid Holocene phase in the early Atlantic. It is worth noting that it formed in certain cases even at the foot of high overhanging cliffs as in the Soutěska in Pálava Mts. If we consider that the site in question is situated in the centre of the dry chernozem area of South Moravia (Vienna Basin), it is obvious that this moist oscillation was extraordinarily intensive (Vašátko, Ložek 1971; Ložek 1972, 1985).

As for slope sedimentation dynamics in mountain areas, the biostratigraphic analysis of the proluvial cone at the mouth of the valley Pivková dolinka at the northern foot of the formerly glaciated Ďumbier Massif may be mentioned. The evidence provided by fossil molluscs demonstrates that during the Late Glacial and earliest Holocene an intense denudation at high elevations took place leading to a rapid accumulation of thick screes in footslope areas and of proluvial cones at the mouth of steep dry valleys (Ložek 1986). Also the climatically unstable period of the Subboreal sensu Jäger (1969) resulted in a mighty destruction of solid rock outcrops and consequently to accumulation of very coarse screes, as documented at the foot of the Kozel Mt. in Lúčanská Fatra (Ložek 1986) and in the Maštalná Cave in the Slovak Karst (Ložek, Horáček 1988).

As pointed out earlier, the karstlands are characterized by numerous deposits of spring limestones, mostly in the facies of Holocene tufas. First of all, we must mention several sites in the Slovak Karst which are known for many years and were several times described in the literature: Gombasek, Jabloňov, Hrhov, Háj, Jasov (Němejc 1937; Petrbok 1937; Ložek 1958; Kovanda 1971; Vaškovský, Ložek 1976; Horáček, Ložek 1988a, etc.). Tufas, however, also occur in a number of other areas and mostly provide rich palaeontological findings, particularly molluscs and locally plant imprints.

In many cases they include buried soil horizons, particularly a well-developed rendzina containing in a number of sites Late Bronze ceramics and corresponding to the dry oscillation which characterizes the Subboreal sensu Jäger (1969), (Hrhov, Jabloňov, Háj, Gombasek, surroundings of Plavecký Mikuláš etc.). The occurrence of buried soils corresponding to phases of restricted spring discharge (when the tufa surface dried up), and thus to dry periods, enables the Postglacial climatic development to be traced in correlation with biostratigraphic and ar-

Phot. 4. In a number of West Carpathian karst valleys tufa deposits are developed. A tufa sequence with scree intercalations (Middle and Late Holocene) exposed in the upper part of the Manín Gorge near Považská Bystrica (Photo V. Ložek)

Fot. 4. W wielu krasowych dolinach Karpat Zachodnich są rozwinięte utwory martwicowe. Sekwencja martwic z wkładkami rumoszu (środkowy i późny holocen) odsłonięta w górnej części wąwozu Manín koło Považskiej Bystricy

chaeological records (Ložek 1958, 1964b; Jäger, Ložek 1968, 1978; Šteffek 1986). For this reason, the tufa sequences in the Slovak karstlands played an important role in establishing the newly proposed Holocene phase called Epiatlantic (Jäger 1969; Ložek 1982).

Within tufa deposits also different sedimentation processes can be examined, particularly at sites, where tufa horizons alternate with clastic slope or alluvial deposits. In the Slovak Paradise at several places tufa intercalations in proluvial cones occur allowing to date the proluvial accumulation which formed very intensely even during certain phases of the Holocene as is demonstrated by the section at the mouth of the gorge Nižný Bajan in the Lesnica Valley (Ložek 1976).

Behind travertine dams across the valley floors shallow lakes or calcareous swamps became established in which the Holocene deposition reaches its maximum thickness. Such deposit is exposed in the valley Slovänská dolina near Valča to a depth of 12 m. It consists not only of tufas but also of calcareous muds with fen peat intercalations. For this reason it includes besides molluscs and ostracods also numerous plant

remains, particularly wood fragments and fruits. In view of the fact that this site gives the possibility of a direct comparison between palaeozoological and palaeobotanical biostratigraphy in correlation with radiometric and magnetometric data from a number of horizons, it is predestinated to become one of the standard Holocene profiles not only in the Czechoslovak but also in a broad Mid-European context (Vaškovský, Ložek 1976; Šilar, Ložek 1988).

MAIN RESULTS OF QUATERNARY RESEARCH IN THE KARST OF THE WEST CARPATHIANS

Even though only a restricted number of Quaternary sites in the West Carpathian karstlands has been investigated in detail, some conclusions can be drawn which may contribute to the knowledge of the Quaternary in Middle Europe.

The records of *Vertebrate* faunas from Early Pleistocene sites are sufficiently numerous to characterize the sequence of chronologic phases ranging in date from Late Pliocene to Late Biharian (Horáček 1981). Besides this they enabled characteristic mammalian and molluscan assemblages to be mutually correlated and chronostratigraphically important species of *Mollusca* to be recognised. This concerns particularly the faunas with *Gastrocopta serotina* Lžk corresponding to the Plio/Pleistocene boundary, whereas those with *Helicigona capeki* (Pbk) and *Zonitoides sepultus* Lžk are associated with the Late Biharian faunal complex, i.e. with the later phase of the Early Pleistocene (Ložek 1969; Horáček, Ložek 1988b).

Dated scree sequences enable the development of clastic climatically controlled deposits to be traced with increasing altitude, i.e. even in mountain areas where loesses and loess-like deposits are absent. They show that loesses are generally replaced by fine-sized angular debris which in certain places, e.g. in the vineyards of Pavlov or near Oravská Krivá, as well as in several caves, are developed without loamy matrix and thus correspond to the „grèzes litées" of French literature. By contrast, the warm periods are represented by coarser screes with matrix consisting of various soil sediments or cemented by sinter. For a comparison of this facies with loess sequences the section on the Mních Hill near Lisková may be of particular importance (Vaškovský, Ložek 1972).

Detailed research on karstland Quternary largely contributed to the knowledge of the Late Glacial and Holocene. A comparison of sedimentary fills of cave entrances and rock-shelters with tufas enabled different sedimentation and soil-forming processes to be studied in mutual

Table 1

Review of the Quaternary in West Carpathian karstlands
Zestawienie czwartorzędu w obszarach krasowych Karpat Zachodnich

Chronology	Clastic sediments		$CaCO_3$ — deposition (sinters, tufas, travertines)	Major erosional and climatic events
	Surface deposits	Underground deposits (entrance facies)		
HOLOCENE Subatlantic	Coarse screes with loose humus-rich matrix		Restricted tufa sedimentation Foam sinter only higher than 800 m	Increasing erosion (partly due to man's activities)
Subboreal	Very coarse screes — in many cases poor in loose humus-rich matrix		Interruption of tufa deposition — buried soils in tufa sequences	Humidity minimum Continental climate
Epiatlantic	± Coarse screes — loamy matrix with increasing humus contents and variable foam sinter admixture in caves at higher elevations		Grey intercalations in foam sinter sequences Thick tufas with several feeble soil or scree horizons	Humid phase, with short dry oscillations
Atlantic	Brown clayey generally ± decalcified loams	Locally sinter admixture	Foam sinter in mountain caves Foam sinter horizons in xerothermic foothill zones Maximum foam sinter sedimentation	Standstill phase Humidity maximum
	Restricted clastic sedimentation Pedogenesis			

Boreal Preboreal	Yellowish brown comparatively compact calcareous loams with medium-sized scree $CaCO_3$-infiltrations	Increasing tufa and foam sinter deposition	Rapid increase in humidity
LATE PLEISTOCENE Late Glacial	Yellowish loams with scree, mostly rich in $CaCO_3$ Intense accumulation of proluvial cones in mountain areas	Beginning of tufa deposition	Increasing scree deposition
Late Pleniglacial	Loesses in the foothill zone Cryoclastic debris and small-sized scress with loess-like matrix at higher elevations (Cave loess in the caves Dzeravá skala and Peskö)		Minimum scree deposition within the loess zone
Early Pleniglacial	Angular medium-sized screes with loess-like matrix		Maximum erosion and denudation (slope and cave entrance retreat)
Early Glacial	Medium-sized to coarse screes with moderately humic matrix		

Last Interglacial	Reddish brown clayey partly decalcified loams with scree (and sinter intercalations) Pedogenesis		Cave sinters Stalagmites etc.	
MIDDLE PLEISTOCENE	Horizons of loesses and loess-like loams with scree Scree sequences with matrix consisting of humic rendzina sediments (Scree sequences overlying the Váh terraces at Mnich and Kočkovská skala)	Sedimentary fills of karst pipes (Turold in the Pálava Mts., Pažica — in Early Pleistocene travertines)	Younger interglacial travertine in Hradiště pod Vrátnom	Intense erosional processes towards the end of this period (probably due to neotectonic movements)
	(In most of the West Carpathian karstlands Mid-Pleistocene deposits are not recorded!)			
EARLY PLEISTOCENE PLIO-PLEISTOCENE	Cemented screes with matrix containing terra rossa material Terra rossa sediments (Slovak Karst, Muráň Karst Hornád Valley, foot of the Rokoš Range)	Sedimentary fills of karst pipes and vertical cavities (karstified crevasses etc.) containing terra rossa material — partly cemented (Slovak Karst, Drevenik, Ivanovce, Chalmová, Málok near Nitra)	Sinter formations Older interglacial travertine in Hradiště pod Vrátnom	Intense vertical karstification

(In this table travertines at mineral springs are not included!)

correlation and, consequently, new important data on the regularities of Postglacial climatic development in different climatic zones to be obtained. Among major results, primarily, the evidence of a very moist phase in the Atlantic may be mentioned, which has been best recorded in the depositional sequence exposed at the foot of the Soutěska Cliff in the Pálava Mts. (Ložek 1985). In addition, the following two observations have to be noticed; firstly, the evidence of the chronologic range of the humid Holocene phase in mountain areas, and secondly, dating of the most intensive accumulation of proluvial cones in the Late Glacial and Early Holocene (Ložek 1986). Moreover, it is possible to distinquish the development of both sedimentation and fauna in the forest zone representing the mid-European climax from that in the subalpine and alpine zones, where glacial conditions are partly persisting, irrespective of very high humidity (Ložek 1978a). The above results from Pálava give valuable information on the conditions in the chernozem area which represents also a separate facies zone being characterized by the absence of the Forest Optimum in the Middle Holocene (Ložek 1980c, 1982).

In this connection it was possible to study some particular problems as e.g. the oscillations of the upper timber line during the Postglacial, especially its elevation in the climatic optimum assumed above all by several Polish research workers (Kotarba 1972 etc.). Analyses of Holocene molluscan assemblages from rock-shelters in the top area of Velký Rozsutec, at the foot of the Muráň Cliff in the Belianske Tatry and in the rocks of Kopenčie in the Velká Fatra Mts. give evidence that a closed forest reached towards the end of the Middle Holocene at least 200 m higher than today. This means that both the Velká and Malá Fatra were at this time for the most part wooded, with exception of large rocky areas (Ložek 1978a, 1981).

Finally, we must mention the profile of the rock-shelter at Svinská úlina in the Dunajec Gorge in the Pieniny Mts., where a phase of temporary low level of Dunajec floods was recorded, evidently corresponding to the Subboreal sensu Jäger (1969), Ložek (1977). This confirms analogous observations from Lepenski Vir in the Danube Valley (Brunnacker 1971).

CONCLUSIONS

The purpose of this paper was to review some of the progress that has been made in recent years in our knowledge of the Quaternary in karstland environments. It has become evident that the karst areas of the West Carpathians give favourable possibilities to study and solve

various problems of the Quaternary past providing results of relevance to the region of whole Middle Europe.

It should be stressed that our field work has been conducted rather occasionally, so that the results presented might be considered only as a basis for future systematic research which could largely contribute to the knowledge of the Quaternary, and particularly of the interaction between organisms including man and the abiotic environments. This is of prime importance to scientists dealing with environmental problems of today.

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STRESZCZENIE

V. Ložek

Czwartorzęd obszarów krasowych w Karpatach Zachodnich

Utwory czwartorzędowe obszarów krasowych obfitują w kopalne szczątki zwierzęce. Występują one w różnych typach osadów, a w szczególności w osadach wypełniających jaskinie, schroniska i poszerzone krasowo szczeliny. Formy te spotkać można na stokach górskich i wierzchołkach pozbawionych utworów powierzchniowych. W większości stanowisk główne grupy kopalnych zwierząt (mięczaki i kręgowce) mogą być wzajemnie skorelowane. W Karpatach Zachodnich liczne obszary krasowe występują od piętra pogórskiego po piętro alpejskie, co umożliwia analizę piętrowego rozmieszczenia różnych sekwencji czwartorzędowych. Charakterystyczne osady, zawierające znaczące zespoły mięczaków i kręgowców, odzwierciedlają wahania klimatyczne. W południowej strefie pogórskiej, a w szczególności w Krasie Słowackim szczątki zwierzęce występują we wczesnoplejstoceńskich osadach jaskiniowych i scementowanych rumoszach. W dolinie dolnego Wagu istnieją możliwości ich korelacji z seriami lessowymi. Środkowy plejstocen jest reprezentowany przez sekwencje powierzchniowego, faunonośnego rumoszu okrywającego środkowe terasy w dolinie środkowego i górnego Wagu. Osadów tego wieku nie stwierdzono w jaskiniach. Sekwencje późnoplejstoceńskie i holoceńskie spotykamy we wszystkich piętrach. Szczególne znaczenie mają poziomy nacieków dokumentujących holoceńskie maksimum zwilgotnienia klimatu, tudzież podstokowe martwice z wkładkami rumoszu i gleby kopalne świadczące o zmianach dynamiki sedymentacji stokowej. Okazuje się, że zachodniokarpackie obszary krasowe umożliwiają prowadzenie studiów nad różnymi zagadnieniami czwartorzędu. Wyniki tychże badań są reprezentatywne dla całej środkowej Europy.

РЕЗЮМЕ

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ЧЕТВЕРТИЧНЫЙ ПЕРИОД КАРСТОВЫХ ТЕРРИТОРИЙ ЗАПАДНЫХ КАРПАТ

Четвертичные образования карстовых территорий изобилуют ископаемыми остатками животных. Они выступают в отложениях разных типов, в частности — заполняющих пещеры, укрытия, расширенные карстовые щели, ущелья. Эти формы встречаются и на горных склонах и лишенных поверхностных образований вершинах. На большинстве становищ основные группы ископаемых животных (моллюски и позвоночные) могут коррелироваться друг с другом. В Западных Карпатах многочисленные карстовые территории вы-

ступают от предгорного яруса до альпийского, благодаря чему возможно проведение анализа размещения различных четвертичных секвенций по ярусам. Характерные отложения, содержащие значительные комплексы моллюсков и позвоночных, отражают климатические колебания в южной предгорной зоне; в частности, в Словацком карсте животные остатки встречаются в раннеплейстоценовых пещерных отложениях, сцементированных россыпях. В долине нижнего Вага имеются возможности их корреляции с лессовыми сериями. Средний плейстоценовый период представлен секвенциями поверхностной фауноносной россыпи, покрывающей центральные террасы в долине среднего и верхнего течения Вага. Отложения этого возраста не были обнаружены в пещерах. Позднеплейстоценовые и голоценовые секвенции встречаются во всех ярусах. Особое значение имеют уровни натеков, являющих собой доказательство голоценового максимума увлажнения климата, а также подсклоновые туфы с прослойками россыпи и ископаемые почвы, свидетельствующие об изменениях в динамике склоновой седиментации. Оказывается, что западнокарпатские карстовые территории дают возможность вести исследования по разным проблемам четвертичного периода и что результаты этих исследований представительны для всей центральной Европы.