bedeckung (Grasflächenboden - Bedeckung) potschwenno - dernowyi oder einer zusammengeschwemmten Bodendecke. Diese, mit Rasen oder Boden bedeckten sadernowannye Karstgebiete unterscheiden sich von denen des eigentlichen bedeckten Karstes durch das Vorhandensein von Trichtern, Wannen und anderen Formen, die d i r e k t auf dem Wege der Auslaugung und der Auswaschung entstanden sind, aber sie haben nicht die typischen Merkmale des nackten Karsts (Gwozdeckij, 1954, S. 166—167, Sokolow, 1962, S. 34). Wir haben daher zum Unterschied vom eigentlichen „bedeckten" den Terminus „bodenbedeckter Karst" (Sadernowannyi Karst) (Karst mit Boden und Pflanzenbedeckung) vorgeschlagen (Gwozdeckij, 1954, S. 331)[1]).

Dieser Karst, der eine sehr große Verbreitung hat, kommt häufig in Begleitung des nackten Karstes mit Karren vor. Wir beobachteten ihn in vielen Gebieten Kaukasiens, im Gebirge „Peter I." in Mittelasien, in einigen Gebieten der Russischen Ebene, er ist ferner auch typisch für einige Gebiete des Urals.

Den beiden charakteristischen Typen des Karstes — dem eigentlichen „bedeckten" und dem „mit einer Pflanzendecke (fast immer Gras) (Sadernowannyi Karst) zugedeckten" folgt, — wenn man nach den Untergliederungsmöglichkeiten Ausschau hält — der „Merokarst" oder der „unvollkommene Karst" (Cvijic, 1925) im Unterschied zum klassischen Karst des Dinarischen Gebietes — dem „Nacktkarst" oder „Vollkarst".

Der Nacktkarst weist in der UdSSR ebenfalls eine weite Verbreitung auf; besonders auf der Krim, im Kaukasus und in einigen Gebieten des zentralasiatischen Berglandes.

[1]) Vorschlag des Chairmann: „Grasnarbenkarst".

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FOSSIL KARST IN POLAND

1 map, 10 figures and 1 table

Sylwia Gilewska

Karst phenomena are developed in the Middle Polish belt of old mountains and of uplands (Sudety Mtns, Silesian Upland, Cracow Upland, Nida Basin, Świętokrzyskie Mtns, Lublin Upland), and in the Carpathians (Tatra Mtns, Klippenzone, Carpathian Upland). Karst features also occur at several sites in lowland areas.

Recent studies of karst phenomena have been restricted to particular karst areas. A. Wrzosek (59) discussed the karst of the Tatra Mtns. Z. Cietak (7) studied the caves in the southern part of the Cracow Upland. S. Z. Rozycki (40, 41) recognized depressions due to solution subsidence on the northern fringe of the Świętokrzyskie Mtns. J. Flis (13) investigated the gypsum karst in the Nida Basin, and K. Kowalski (25) published an inventory of Polish caves. Finally, M. Klimaszewski (23) summarized and discussed the modern views on karst evolution, and R. Gradzinski (16) studied the fossil subsurface karst features in the southern part of the Cracow Upland. Karst phenomena have been the subject of numerous references by geologists, archeologists, geographers botanists and zoologists. Despite the abundance of works on this subject, however, a paper summarizing the observations has not been published. The brief descriptions of the karst regions in Poland, together with the reconstruction of the various stages in their evolution were therefore, the principal object of the present paper.

The Sudety Mtns (Map, I)

Karst features are developed in hard Lower Paleozoic limestones which have undergone crystallization and in softer Upper Permian limestones. The soluble rocks form thin layers or lenses within the mass of igneous and metamorphic rocks. Karst features including karren, dolines and caves (21) are, therefore, poorly developed. Dolines are important in the vicinity of caves as at the Miłek in the Kaczawskie Mtns (at Wojcieszòw/Kauffung). M. PULINA suggested that these dolines date from Pliocene times. Today they begin to function again. Caves are found in the Kaczawskie Mtns (Katzbach-Gebirge), Orlickie Mtns (Adler-Gebirge), Bystrzyckie Mtns (Habelschwerdter Gebirge), Snieżne Mtns (Glatzer Schneegebirge) and in the Złote Mtns (25 c). The Kaczawskie Mtns contain the larger number of caves. The longest cave so far discovered in the Sudety was about 350 m., and occured in a quarry at Rogòżka. The caves developed by corrosion by through flowing streams and by water percolating downward.

Caves lying in the Kaczawskie Mtns occur at different levels (35). The upper caves were formed during the Neogene as deduced from the Upper Pliocene fauna remnants that have been found in the Southern Cave (Kitzelhöhle) at the Połom at Wojcieszòw (Kauffung). Caves have originated during several phases of rapid corrosion and of deepening which were separated by phases of fluvial accumulation (sand, pebbles, breccia) and of calcium carbonate deposition. The lower caves were formed during the Quaternary (25c). Caves above the present river level are now dry. Enlargement is taking place only in the lower part of the Radochowska Cave near Lądek which is occupied by a small lake (25c).

The Silesian Upland (Map, II)

In Upper Silesia the Lower and Middle Triassic limestones and dolomites have well developed dolines, pipes and joints widened by solution. Caves are rare. The dolines range up to 100 m. or more in diameter and 30 m. in depth. They are common in the vicinity of Tarnowskie Gòry, Bytom/Beuthen and Mierzęcice (1, 11, 14, 17, 18, 22, 42, 50). The features discussed date from different periods, i. e. the Upper Trias and Lower Jura, the Tertiary and the Quaternary. The fossil karst landforms developed on the polycyclic and polygenetic surface of degradation whose initiation is regarded as Lower Tertiary (14). The karst depressions contain deposits of different age and origin. The infill consists of pre-Tortonian crystalline formations, of deep-red residual clays rich in kaollinite, of halloysite and allophane, of residual iron and zinc ores, of Liassic bauxite, fireclays, sand and pebbles, and of Lower Tortonian marine or brackish clay containing lignite *(Glyptostroboxylon tenerum)*. Fossil karst hollows filled with Upper Miocene freshwater clay and sand with lignite also occur in the Cretaceous marly limestone and marl near Opole (Oppeln) and bones of *Mastodon augustidens* have been found in them (4).

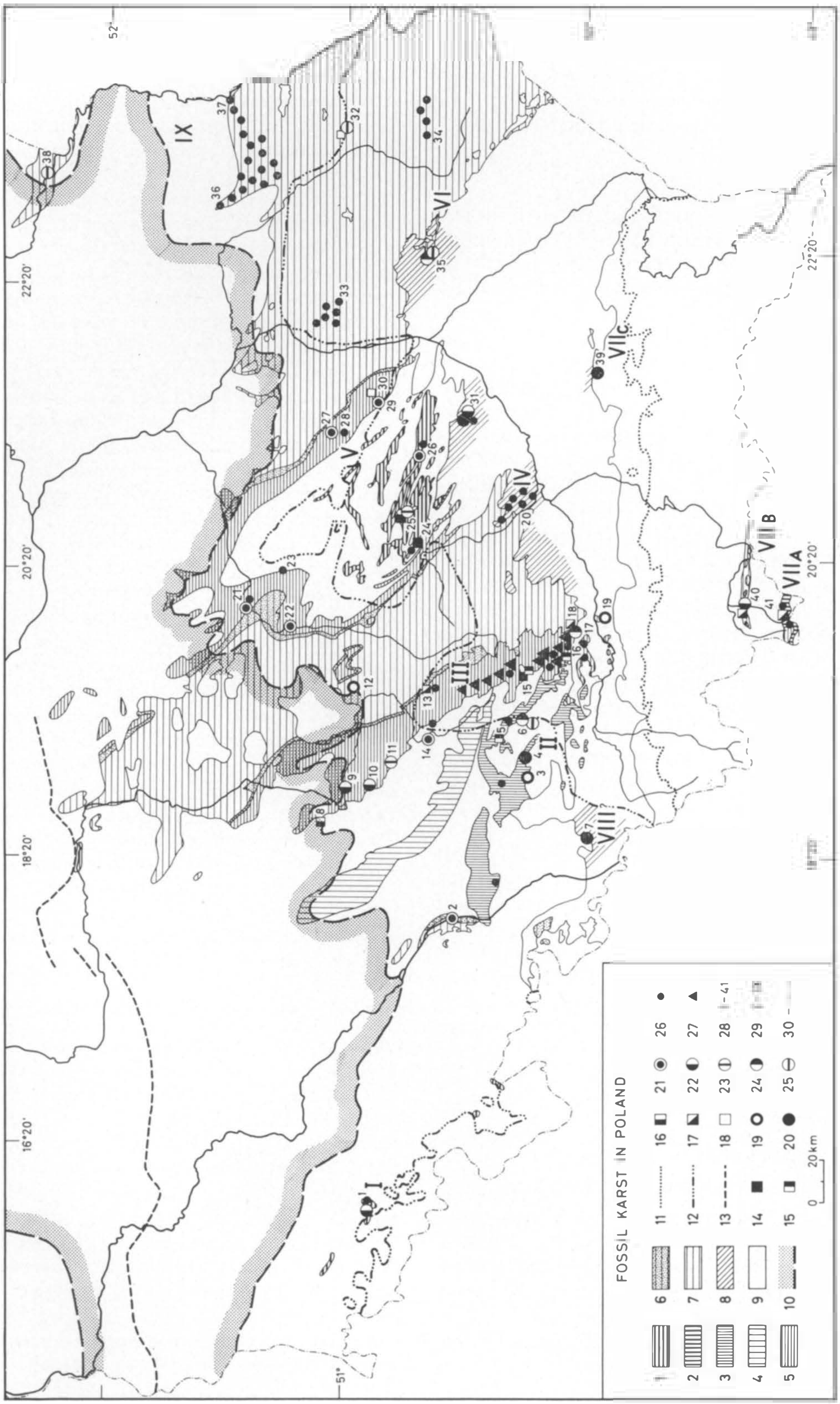
Karst features continued to develop during the Pleistocene (14). This is indicated by caves, pipes and karren buried under Würm deposits. The Silesian Upland was twice invaded by the Scandinavian inland ice. Hence, the karst processes were interrupted during the glaciations (Mindel, Riss I) and re-energized during the later phases of the glacial periods at which the powerful pro-glacial streams disappeared in the jointed limestones and dolomites. Consequently the caves were enlarged. During the last glacial period at which periglacial conditions prevailed constriction rather than enlargement of the caves was taking place. Caves were filled with calcite dripstone, varved clay and brown clay rich in quartz and illite.

At present the former karst depressions partly revive. Recent karst landforms are poorly developed. There occur stepkarren and small dolines. These can form under a shallow cover of pervious sand, which subsides into the depression as it grows. Powerful springs and streams disappearing over a portion of their courses (17) and underground circulation of the karst waters have also been recorded.

The Cracow Upland (Map, III)

In the Cracow Upland all composed of limestones karst phenomena have their most comprehensive development. Surface drainage is poorly developed. Dry valley systems predominate. Vauclusian springs are common. The few rivers (Prądnik, Racławka, Będkòwka, together with their tributaries, and Wiercica) flow in narrow valleys with steep sides. The streams are actively depositing calc-tufa at their bottom (25a, 36, 53).

In the Cracow Upland there occur residual mogotes, dolines, shafts, caves, blind valleys, pipes, pinnacles, clefts and joints widened by solution. These features have originated during different periods, i. e. the Lower Trias (28), the Jura (25a, 28, 36), the Cretaceous (6, 15, 36, 39), the Terti-


FOSSIL KARST IN POLAND
0 20 km
52°
51°
22°20'
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I
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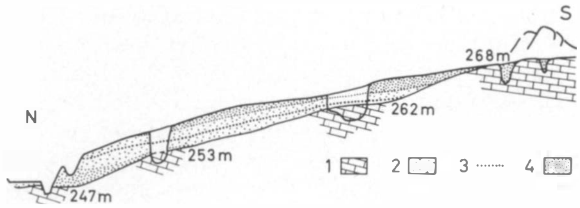


Fig. 1: Lower Cretaceous dolines at Złoty Potok (after S. Z. Rȯzycki)

1. Jurassic limestones; 2. Albian sandstones; 3. Lower Cenomanian glauconite sand containing a phosphorite bed; 4. Middle Cenomanian glauconite sand with phosphorite.

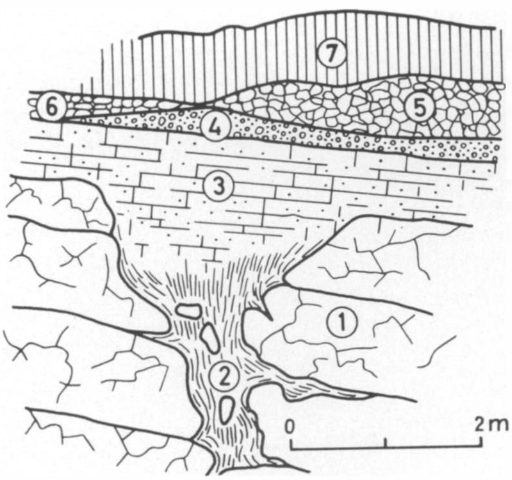


Fig. 2: Shaft of Cretaceous date at Trojanowice in the Pradnik Valley (after S. Bukowy)

1. Rauracien limestone; 2. green limy clays with limestone fragments passing into marl at top; 3. sandy limestone; 4. Upper Turonian conglomerate; 5. Upper Turonian nodulous limestone; 6. Pradnik gravels; 7. loess.

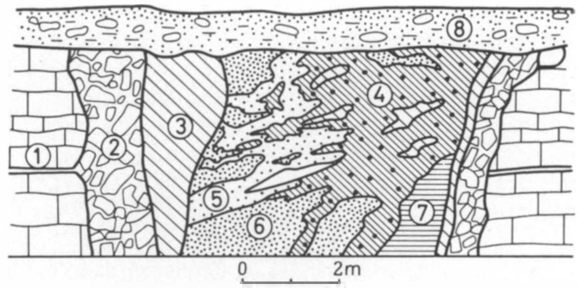


Fig. 3: Tertiary doline near Grodziec north of Katowice (after S. Doktorowicz-Hrebnicki)

1. Triassic limestone; 2. coarse limestone debris with yellow marly clay; 3. green-grey clay; 4. brown ferruginous clay with ochre and bean ores (limonite); 5. fine yellow sand; 6. fine red sand; 7. deep-brown ferruginous limestone block; 8. Quaternary clay.

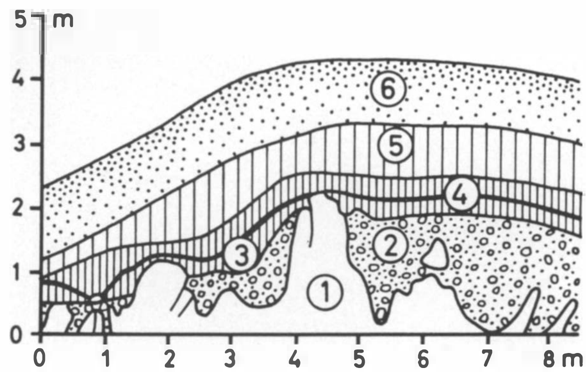


Fig. 4: Pre-Tortonian karst surface at Kurdwanȯw near Krakȯw (after M. Tyczynska)

1. Upper Jurassic limestone cut by fissures; 2. Pre-Tortonian residual clay with flints; 3. Lower Tortonian marine clay with oyster shells; 4. limonitic sand; 5. Lower Tortonian sand; 6. Quaternary sand.

Map: Fossil karst in Poland

1. Paleozoic limestones and dolomites; 2. Triassic limestones, dolomites, shales and sandstones (in the Tatra Mtns); 3. Muschelkalk limestones, dolomites and marl; 4. Keuper sandstone, conglomerate, limestone and dolomite; 5. Jurassic limestones, marl and dolomite; 6. Middle Cretaceous sand, sandstone, clay, marl and limestone; 7. Upper Cretaceous marl and limestones; 8. Miocene limestone, sandstone, sand, clay and gypsum; 9. insoluble rocks; 10. limit of the Pliocene clay facies; 11. limit of Cracow (Mindel) glaciation; 12. limit of Middle Polish (Riss) glaciation; 13. limit of Baltic (Würm) glaciation; Karst features dating from: 14. Permo-Trias; 15. Keuper-Lower Jura; 16. Jura; 17. Cretaceous; 18. pre-Oligocene; 19. pre-Tortonian; 20. Tortonian; 21. Miocene; 22. Pliocene; 23. Tiglian; 24. early Pleistocene; 25. Upper Pleistocene; 26. recent times; 27. residual mogotes; 28. localities referred to in text: (1. Wojcieszȯw/Kauffung, 2. Nowa Krȯlewska Wieś/Bolko near Opole/Oppeln, 3. Bytom/Beuthen, 4. Dołki north of Katowice, 5. Mierzęcice, 6. Ząbkowice Będzińskie, 7. Czernica near Rybnik, 8. Wieluń, 9. Węże I and II near Działoszyn, 10. Rembielice Królewskie, 11. Kamyk near Kłobuck, 12. Radomsko, 13. Złoty Potok, 14. Błeszno near Częstochowa, 15. Klucze north of Olkusz, 16. Czernka Valley, 17. Trojanowice and 18. Jerzmanowice north of Cracow, 19. Kurdwanȯw south of Cracow, 20. Wiślica, 21. Tomaszow Mazowiecki, 22. Sulejow, 23. Opoczno, 24. Zelejowa near Chęciny, 25. Kadzielnia at Kielce, 26. Łagȯw, 27. Iłża, 28. Starachowice, 29. Kąty near Ostrowiec, 30. Sudoł, 31. Smerdyna, 32. Rejowiec, 33. Chodel, 34. Zamość, 35. Janȯw Lubelski, 36. Siemień, 37, Włodawa, 38. Mielnik, 39. Broniszȯw in the Wielopolka Valley, 40. Szaflary south of Nowy Targ, 41. Mała Rȯwień Valley in the Tatra Mtns);

29. Karst regions: I - Sudety Mtns, II - Silesian Upland, III - Cracow Upland, IV - Nida Basin, V - Swietokrzyskie Mtns, VI - Lublin Upland, VII - the Carpathians (VII A - Tatra Mtns, VII B - Klippenzone, VII C - Carpathian Upland), VIII - promontory rift valley, IX - Polish Lowland;

30. limits of the field of study.

ary (16, 18, 22, 23, 30, 33, 34, 36, 39, 42, 45, 47, 52) and the Quaternary (Fig. 1—3). The fossil karst depressions and caves contain residual clays with flints (Fig. 4) or bean ores, manganese and calcite formations, redeposited Cretaceous sand and gravels, bone breccia, gyttja, and marine sand and gravels, conglomerates, clay, marl and marly limestone.

The residual mogotes (Fig. 5) rising above the Lower Tertiary Karstverebnungsfläche of 450 m. above sea level are characteristic of the southern part of the Cracow Upland (23, 33, 34, 42). The mogotes are separated by wide depressions. Their bottom shows numerous pinnacles, pipes and deep clefts widened by solution and buried under a mantle of impermeable pre-glacial deep-red residual clays with flints being up to 10 m. thick. Active dolines and uvalas unconnected by surface drainage also occur. They develop under the covering loess (in the vicinity of Cracow) (53) or glacio-fluvial sand (near Częstochowa and Złoty Potok) (3, 36) which is extremely permeable. Bare limestone surfaces commonly show a widening of joints by solution, small karren and a few dolines and blind valleys. Caves are some of the best developed morphological features of the Cracow Upland. There occur 508 caves and cliff hollows (25a), the longest being the Wierzchowska Gòrna Cave (640 m.). Cavern passages occur at different levels. Unfortunately, nothing is known of their relation to erosion benches and alluvial terraces. Most of the caves were formed during the Neogene. The geological date of their formation is given by cave deposits in which bones of Pliocene (18b, 30, 36, 45, 47) and of early Pleistocene animals (18b, 30) (Fig. 6, 7) as well as Lower Paleolithic implements (Fig. 8) have been found. Caves continued to develop during the Pleistocene under a shallow layer of permafrost. Caves are now dry. Enlargement is taking place only in the Kryspinowska Cave (25a).

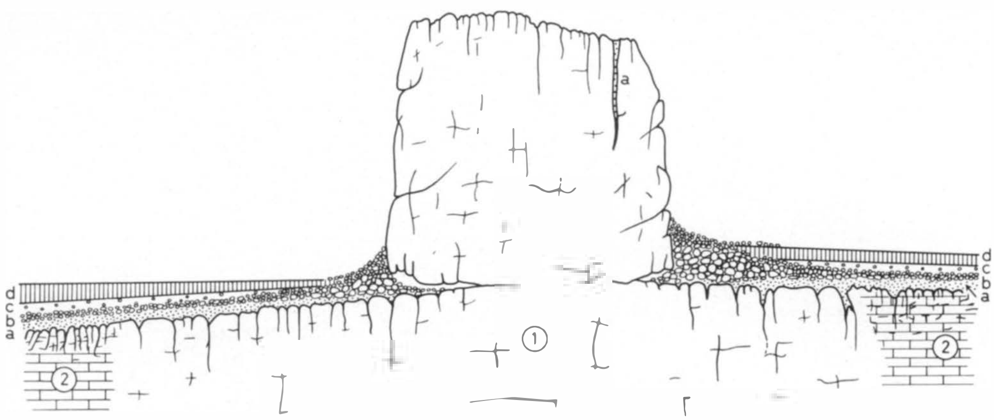


Fig. 5: Residual mogote north of Krakòw (after J. Pokorny)
1. Biohermal limestone; 2. Plattenkalk; a) Tertiary residual clays rich in kaollinite, b) limestone debris, c) interglacial waste, d) loess.

The Nida Basin (Map, IV)

In the Nida Basin karst phenomena occur in the Miocene gypsum and limestone (13). The gypsum has well developed collapse dolines, uvalas, blind valleys, karst basins (small poljes) with residual humus, and caves. Most of the caves are occupied by lakes. The collapse dolines may have either convex, inclined or concave floors (Fig. 9). Pipes, solutional dolines and shafts are rare. The caves and dolines generally are controlled by horizontal bedding planes. The gypsum karst is of recent age. No erratic material has been found in neither the caves nor the closed karst depressions. It is, therefore, concluded that the gypsum karst has originated after the retreat of the Mindel inland ice.

The Świętokrzyskie Mtns (Map, V)

Karst phenomena are found in the Paleozoic limestones and dolomites in the centre of the Świętokrzyskie Mtns, and in the Mesozoic and Upper Miocene marl, limestones and conglomerates on the northern and southern fringes of the mountains. Fossil karst features predominate. They date from the Permo-Trias (8, 10, 24, 37) and the Tertiary (2, 5, 9, 20, 22, 24, 25, 31, 37, 38, 44). There occur caves, dolines, shafts, pipes, joints and clefts widened by solution. Fossil dolines are very common in the vicinity of Łagòw, Tomaszòw Mazowiecki, Opoczno, Sulejòw and Iłza, and in the Opatòw Upland. These closed depressions are buried under a covering of Miocene residual flints (being up to 19 m. thick), and

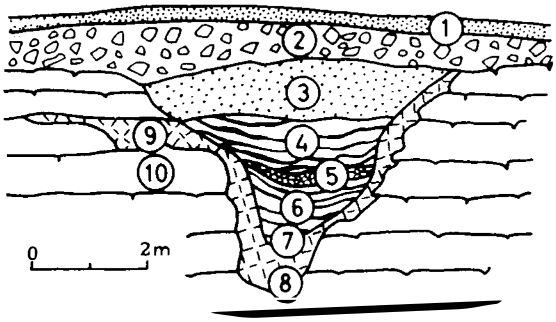


Fig. 6: Middle and Upper Pliocene cave breccia at Weze near Działoszyn (after J. SAMSONOWICZ and Z. MICHALSKA).

1. Sandy soil; 2. limestone debris and residual clay; 3. red crystalline calcite breccia containing chemically weathered limestone fragments and bones; 4. grey bone breccia; 5. red sandy clay with bones of Vertebrata; 6. bone breccia interbedded with crystalline calcite and thin layers of red residual clays; 7–8. red residual clays; 9. crystalline calcite; 10. Upper Jurassic limestone.

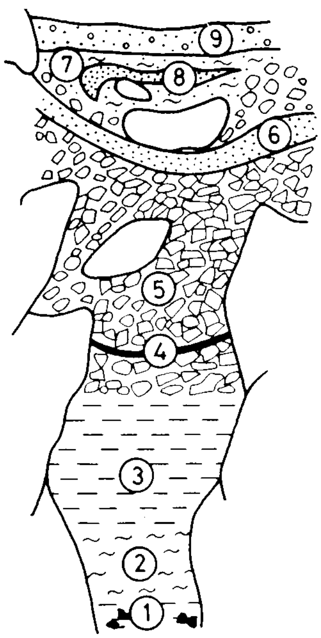


Fig. 7: Pleistocene infill of a cleft widened by solution at Rembielice Kròlewski (after Z. MOSSOCZY).

Residual clay of terra rossa type containing bones of Upper Pliocene animals was covered by 1. grey-brown clay with remnants of early Pleistocene animals; 2. silt; 3. clay; 4. fossil soil layer; 5. limestone debris mixed with clay, gravels and a few erratics; 6. light brown stratified sand with gravels; 7. grey sand containing limestone debris and erratics; 8. brown clayey sand; 9. forest soil.

of fireclays, fluviatile sand, gravels and silt containing remnants of *Glyptostroboxylon tenerum* (at Katy), and, probably, of Oligocene marine sand (55). The dolines and shafts were partly reactivated during the advance of the Mindel inland-ice and in recent times.

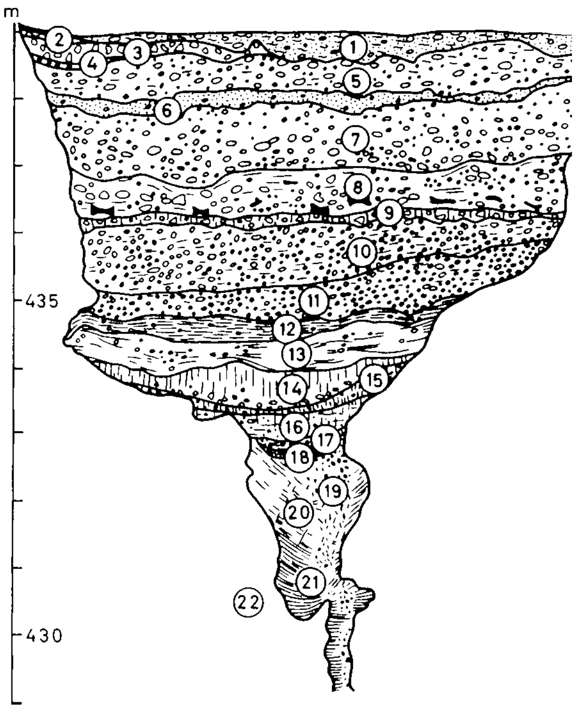


Fig. 8: Deposits covering the floor of the Nietoperzowa Cave at Jerzmanowice north of Cracow (after W. CHMIELEWSKI).

Recent times:
1. Grey clay with smoothed limestone fragments, neolithic and mediaeval artifacts.

Baltic glaciation:
2. limy silt and sand; 3. coarse and sharp-edged limestone fragments mixed with yellow clay (thermal and rainfall minimum); 4. grey clay containing smoothed limestone fragments, charcoal silt and chert artifacts; 5. smoothed limestone fragments mixed with red clay which includes Jerzmanowice chert artifacts at bottom; 6. Lower layer of Jerzmanowice artifacts which gave a C_{14} age of 38 160 ± 1260 years; 7. well smoothed limestone fragments mixed with grey clay and 8. brown clay containing both smoothed and sharp-edged limestone debris, limy sand and numerous bones of *Ursus speleus* (interstadial oscillation); 9. sharp-edged limestone debris mixed with brown clay (thermal and rainfall minimum); 10. smoothed limestone debris mixed with red clay; 11. smoothed limestone debris (chemically weathered on the surface) mixed with brown clay.

Eemian interglacial period:
12. deep-brown clay containing a few heavily decomposed limestone fragments; 13. grey and greyish-blue clay containing heavily decomposed limestone fragments, ash, charcoal and remnants of forest animals.

Middle Polish glaciation:
14. loess containing sharp-edged limestone debris at bottom and Lower Paleolithic implements; 15. grey-green clay with quartz pebbles and decomposed limestone fragments showing a manganese coating; 16. grey-brown nodulous silt containing fine limestone fragments, well rounded quartz pebbles and red clay balls; subaquatic deposits; 17. light-brown silty clay with quartz gravels and red clay balls; 18. quartz gravels mixed with yellow and red clay; 19. red clay containing a few quartz gravels and chert fragments at bottom; 20. yellow-red intercalations of sand and clay; 21. brown-red clay with lenses and lamines of yellow-green clay and sand; 22. Upper Jurassic limestone.

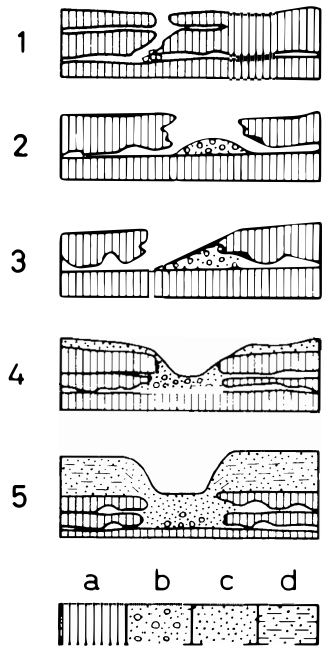


Fig. 9: Recent dolines developed in gypsum (after J. Flis). 1. shaft; 2. convex floored doline; 3. doline with an inclined floor; 4. concave floored doline; 5. doline developed in the covering sandy deposits; a) gypsum, b) gypsum fragments and fine waste material, c) soil, d) sand or standstone.

Active dolines, uvalas, dry basins (small poljes) are characteristic of limestone areas covered with boulder clay (in the vicinity of Starachowice — Fig. 10a) or glacio-fluvial sand (in the vicinity of Tomaszòw Mazowiecki and Opoczno — Fig. 10b). Solutional dolines, uvalas and ponores occur on

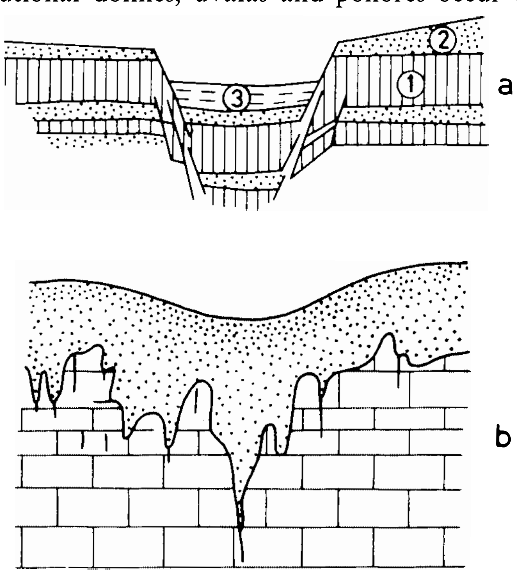


Fig. 10: Hollows due to solution subsidence (after S. Z. Ròzycki); a) in clayey deposits (1. boulder clay, 2. sand, 3. loam); b) in sand.

bare limestone surfaces in the area around Łagòw. Karren are locally developed at the Zelejowa near Chęciny. Caves are less well developed, the largest being the Łagowska Cave (80 m. long). It contains actively forming small straw stalactites.

The Lublin Upland (Map, VI)

Karst landforms occur in the Cretaceous and Upper Miocene limestones, Fossil karst features are poorly developed in the Lublin Upland (29, 43). Both dolines of pre-Oligocene age and Würm pipes have been recorded from Rejowiec, and pipes of pre-glacial date observed at Janòw Lubelski[1]). Actively forming dolines and uvalas also occur. Caves are absent because the thickness of soluble rock above the karst water table is small. Karst depressions unconnected by surface drainage are very common in the Chodel and Zamość Basins. Dolines chiefly develop under the covering permeable Pleistocene deposits and tend to occur in groups. Numerous hollows are water-filled, many of them silted up. By the coalescence of neighbouring groups of dolines flat karst surfaces arise on the floor of the Chodel and Zamość Basins[1]).

The Carpathians

Karst phenomena occur in the Tatra Mtns, in the Klippenzone together with the Pieniny Mtns, and in the Carpathian Upland.

The Tatra Mtns (Map, VII A)

In the Polish Tatra the limestone and dolomite area in which underground drainage and active karst phenomena are displayed extends as a belt from the Hala Gąsienicowa in the east to the Chochołowska valley in the west. The morphology of this region shows several specific features. Cave formation is closely linked with the allogenic streams draining from the crystalline rocks which cover the Mesozoic series. These through-flowing rivers have formed most of the caves that open out from the valley-sides. Both the caves and the karst landforms are associated with structural features in the Mesozoic strata. Most of the caves and dolines occur in the limestones showing well developed joints, whereas the dolomites rarely have dolines, and caves are smaller. The evolution of the Tatra karst has been affected by their glaciation. The existing karst landforms are of recent age. They were formed after the melting of the tjäle. Finally, the development of the karst landforms is closely dependent upon the zones of vegetation[2]) reflecting the prevailing climatic conditions. Typical rillenkarren (up to 2100 m.), ver-

[1]) The writer is indebted to Assist. Prof. Dr. H. Maruszczak of Lublin for information about the area.

tical shafts (avens) and deep caves may be found all over the higher parts of the dwarf pine — and pasture zones. Karren also occur on the bare surfaces of the roches moutonees at the bottom of former glacial troughs (at 1050 m.). Dolines are common in the forest zones. The dolines are broad and rather shallow and tend to develop under a mantle of glacial deposits. Caves are fairly common. In the Polish Tatra Mtns there occur about 80 caves. The deepest cave so far discovered is 620 m. or more (Śnieżna Cave) (18 c). The caves are relatively simple unbranching narrow passages following well developed joints. Potholes and flutes are significant. Moon-milk formations are typical of the Polish Tatra caves whereas crystalline dripstone is rather rare. River gravels and sand occur in most cave passages and bones of Upper Pleistocene animals have been found in them. Large scale collapse has taken part in many caves. The cave galleries occur at two main levels, at 100—120 m. and at 180—210 m. above present river level in the Kościeliska Valley. These levels are to be regarded as evidence of phases of reduced stream erosion associated with the Upper Tertiary phases of tectonic stability.

The Klippenzone (Map, VII B)

The Klippenzone consists of Mesozoic limestones which show a complicated structure and contain numerous intercalations of insoluble rocks. Karst phenomena are, therefore, poorly developed. Fossil karst hollows of Cretaceous age and typical lapies of preglacial date have been found at Szaflary (58). Small solution caves and cliff hollows open out from the valley-sides in the Pieniny Mtns. Underground drainage occurs in the Białka gap across the Klippenzone (25 c).

The Carpatian Upland (Map, VII C)

Fossil karst hollows developed in the Lower Tortonian gypsum have occasionally been found in the Wielopolka Valley (46). Fossil dolines of similar age also occur in the promontory rift valley at Czernica near Żory (Map, VIII).

[2]) Forest zones in the Tatra Mtns (according to J. Fabijanowski):

700—1250 m. above sea level — lower forest zone (beech, fir, spruce)
1250—1550 m. above sea level — upper forest zone (chiefly spruce)
1550—1800 m. above sea level — dwarf pine zone
1800—2300 m. above sea level — pasture or alpine zone
above 2300 m. above sea level — summit zone

[3]) The DTA of the infilling clays show that the Tertiary residual clays formed under warm and humid climatic conditions are rich in koallinite, whereas illite predominates in the Quaternary clays. By analysing the mineralogical composition of the clays it becomes possible to give both upper and lower limiting dates for the formation of the clays concerned. The DTA of the residual clays were carried out by Prof. J. P. Bakker in Amsterdam.

The Polish Lowland (Map, IX)

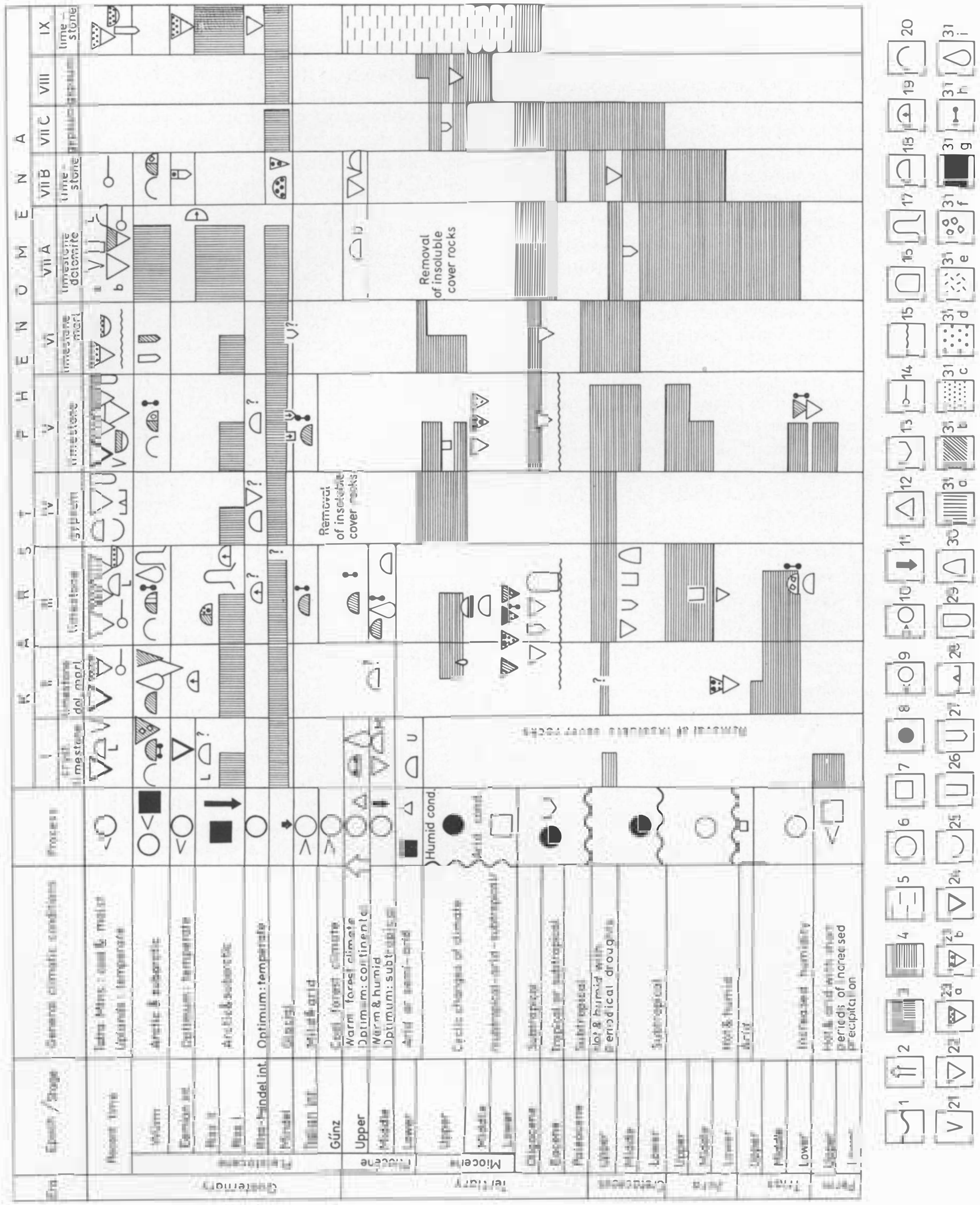
In lowland areas the soluble rocks are covered by Tertiary and Pleistocene clay and sand. In consequence karst phenomena are confined to the buried ridges where the Cretaceous limestone is at, or slightly beneath the surface of the covering permeable deposits. Numerous water-filled depressions due to karst processes are best seen between the rivers Bug and Tyśmienica around Siemień, Cycòw and Włodawa (Podlasie) (55, 56). The initiation of these depressions is regarded as pre-Riss (19). They were renewed in post-Riss times. Small karst hollows and pipes also occur at Mielnik on top of the buried limestone ridges. M. Drzal (12) suggested that these depressions were formed during the late phases of the last glaciation (Würm) and continued to function in the early Holocene.

The examination of the karst regions in Poland shows that the limestones, dolomites, marl and gypsum have well developed widened joints, karren, pinnacles, pipes, dolines, uvalas, vertical shafts, blind valleys, karst basins (small poljes) with residual hums, planated surfaces due to karst processes, mogotes and caves containing local and allogenic deposits. These features were formed under different climatic conditions prevailing at different times. The chronological position of the various stages in the evolution of the karst regions is shown in the following table.

Conclusions

In Poland there occur regions which have passed through more than one former cycle of karstic development and regions which show signs of only one cycle of karsting. The polycyclic karst features are characteristic of the Middle Polish uplands. Their morphological evolution took place in several stages separated by transgressions of the epicontinental seas which deposited a thick sheet of limestones, dolomites and marl. One cycle of karstic development has taken place in areas that emerged from beneath the sea in Upper Tertiary times (the Nida Basin), and in the mountains where the limestones have been completely buried under an insoluble rock mantle. After removal of the cover, the surface and subsurface solution in limestones has given rise to different karst features.

Karst phenomena developed during all periods of emergence of the land masses when the limestones were already exposed (16,25). In Poland we can recognize four major continental periods of karstic development (the Permo-Trias, the Upper Trias — Lower Jura, the Lower Cretaceous, the Tertiary, together with the Quaternary) — also a number of minor periods of karsting. These are


Era
Epoch / Stage
General climatic conditions
Process
K A R S T P H E N O M E N A
I
II
III
IV
V
VI
VII A
VII B
VII C
VIII
IX
gypsum
limestone
limestone marl
limestone dolomite
lime-stone
Quaternary
Tertiary
Cretaceous
Jura
Trias
Perm
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Recent time
Würm
Riss II
Riss I
Riss-Mindel int.
Mindel
Günz
Upper
Middle
Lower
Tatra Mts.: cool & moist
Uplands: temperate
Arctic & subarctic
Optimum: temperate
Arctic&subarctic
Glacial
Mild & arid
Cool forest climate
Warm forest climate
Optimum: continental
Warm & humid
Optimum: subtropical
Arid or semi-arid
Humid cond.
Arid cond.
Cyclic changes of climate
Subtropical
Tropical or subtropical
Hot & humid with periodical droughts
Hot & humid
Arid
Increased humidity
Hot & arid with short periods of increased precipitation
Removal of insoluble cover rocks

short periods of re-emergence of relatively small land tracts, and the recurrent interglacial periods. In addition, there is plentiful evidence of successive phases of either moist or arid climatic conditions (27, 48, 49). During phases of high humidity (wether tropical, subtropical, temperate or cool) strengthened karstic development took place. During phases of arid climate (wether warm or cold) mechanical weathering (scree formation) dominated over the chemical weathering. These data clearly indicate that the development of karst was not a rare occurence in the history of the relief of Poland, but a systematic phenomenon. Karst developed always under humid climatic conditions (wether warm and humid or cool and humid) at periods following the phases of earth movements (producing jointing systems and a high relative relief).

The inventory of the karst features varies from region to region. Well developed caves are characteristic of the mountains and of the Cracow Upland where the limestone is pure, the surface stands high, and the valleys are deep. In the remaining upland areas, by contrast, the total vertical scope for karsting is less because the soluble cover is relatively thin and contains less soluble (chiefly marly) elements. Dolines and uvalas predominate. Shallow cave systems being controlled by the horizontal bedding planes occur only in the gypsum of the Nida Basin. In other areas caves are rare (Silesian Upland) or absent (Lublin Upland).

The fossil karst features ceased to function at various stages of evolution. They are now buried under deposits of different origin. Such conditions are exactly realized in the Silesian Upland where dolines containing only Tortonian sediments with lignite (14) occur in the close vicinity of dolines that are completely filled with residual clays and covered by deposits of the Tortonian sea (1). The conclusion is that the long — continued karst processes lead to development of a flat land — surface. This k a r s t e q u i p l a n a t i o n takes place through lowering the ridges that separate the neighbouring groups of hollows, and filling the karst depressions a) with the insoluble residual clays and coarse debris — chiefly flints (e.g., the planation surface with the mogotes in the southern part of the Cracow Upland), and b) with the redeposited loams, sand and gravels, and organic matter (e.g., the karst surfaces actively forming on the floor of the Chodel and Zamość Basins).

Both the fossil karst landforms and their infill suggest that the optimum conditions for the development of karst prevailed during the Tertiary continental period representing about 60 million years. In the Oligo — Miocene times several successive phases of tectonic movement took place producing well developed jointing systems. This fact favoured the development of underground drainage and of cave formation in limestone areas. Furthermore, both the rich vegetation and the prevailing humid tropical or subtropical climate provided conditions for wide-spread chemical weathering which resulted in the formation of a thick mantle of residual clays with flints and of a great number of huge karst hollows.

At the present time the development of karst is less perfect in the belt of the Middle Polish uplands and old mountains. Most of the karst landforms are actively formed under a covering of the Pleistocene deposits. The disappearence of springs has also been observed. But it is not known if this is a consequence of revival of the former karst features, or of the progress in karsting. Caves are now dry. In the Tatra Mtns, by contrast, karstic development is still continuing under cool and humid climatic conditions.

Table: The Evolution of Karst Phenomena in Poland.

Karst phenomena occuring in the I - Sudety Mtns, II - Silesian Upland, III - Cracow Upland, IV - Nida Basin, V - Swiętokrzyskie Mtns, VI - Lublin Upland, VII - Carpathians (VII A - Tatra Mtns, VII B - Klippenzone VII C - Carpathian Upland), VIII - promontory rift valley, IX - Polish Lowland.

1 - Major phases of mountain building and jointing, 2 - major phases of uplift, 3 - glaciations; 4 - marine transgressions; 5 - extensive lakes and swamps.

Processes: 6 - Chemical weathering, 7 - mechanical weathering; 8 - intensified weathering; 9 - predominant weathering; 10 - reduced weathering; 11 - intensified subsurface corrosion; 12 - wind action; 13 - intensified erosion; 14 - underground drainage.

Karst phenomena: 15 - Formation of karst planation surfaces; 16 - initiation of mogotes; 17 - mechanical destruction of mogotes; 18 - cave formation; 19 - enlargement of caves; 20 - mechanical destruction of cave mouths; 21 - karren (lapiés) formation; 22 - sink-hole formation on bare rock surfaces; 23 - active formation of karst depressions under a shallow cover of a) sand; b) gravel (see 31); 24 - renewed modelling of Tertiary karst depressions; 25 - uvala formation; 26 - shaft formation; 27 - pipe formation; 28 - active formation of small poljes with hums; 29 - active formation of blind valleys; 30 - formation of isolated limestone hills; 31 - constriction or fossilization by accumulation of a) loess; b) clay; c) sand; d) gravel; e) huge masses of flint; f) angular rock fragments; g) organic matter (lignite, gyttja); h) bone breccia; i) dripstone. Cave levels: L - lower, M - middle, U - upper. a) Pasture and dwarf-pine zones; b) forest zones (in the Tatra).

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NEUE DATEN UND BEOBACHTUNGEN ZUR KENNTNIS DER PALÄOKARSTERSCHEINUNGEN IN UNGARN

Mit 7 Abb. und 3 Bildern

P. Z. Szabó

Die Untersuchung der in Ungarn durchweg bedeckten Paläokarstformen ist nicht nur eine morphologische Aufgabe, sie ist auch mit dem Studium der Füllsedimente in den Hohlformen verbunden und darüber hinaus mit einer stets schwer zu lösenden Frage des Bergbaus: Der Ermittlung der wahrscheinlichen Stellen von Karstwassereinbrüchen. So kann sich der Karstmorphologe im Verein mit dem Geologen, Paläoklimatologen und Geochemiker an der Lösung praktischer Probleme nützlich beteiligen.

Die Korrosion schafft im Bereiche der Karbonatgesteine einen äußerst vielfältigen Formenschatz. Die Formausbildung und Formänderung ist außer von den klimatischen Faktoren in hohem Maße von der Gesteinsbeschaffenheit abhängig. Dazu schreibt H. Lehmann (1): „Keineswegs aber ist das Kegelkarstgebiet identisch mit der Verbreitung der Kalke überhaupt. Es gibt sowohl auf Kuba, wie auf Jamaica mehr oder minder ausgedehnte Kalkgebiete, die nicht den Formenschatz des tropischen Kegelkarstes aufweisen, sondern nur die gewöhnlichen Karsterscheinungen. Wo dies nicht der Fall ist, kann das Fehlen der sonst typischen Kegelkarstformen in ursächlichem Zusammenhang mit der unreinen, kreidigen oder mergeligen Beschaffenheit der Kalke gebracht werden."

In Ungarn lenkte die Bauxit- und Steinkohlenforschung die Aufmerksamkeit auf die Karstreliktformen aus der Kreidezeit (2, 3). Heute können wir schon mit Recht die bedeckten Karstformen der Kreidezeit und des Paläozäns als ein Ergebnis eines tropischen Vorzeitklimas betrachten (4, 5). Dennoch zeigen diese Formen nicht in jedem Falle die charakteristischen Merkmale des Tropenkarstes. Im norischen Dolomit und rhätischen Kalkstein der oberen Trias, weiterhin im Kalk vom Dachsteintyp des unteren Lias, und schließlich in den Obermalmkalken finden wir typische, unverkennbar tropische Karstformen. Dagegen