UNIWERSYTET ŚLĄSKI KATOWICE 1982

Kras i speleologia

tom 4 (XIII)

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Preface

Karst and caves of Poland

Abstract: Karst and cave areas of Poland are briefly presented. The aim and scope of this volume are revieved.

Introduction

In honour of the 8th International Speleological Congress (Bowling Green, Kentucky, USA, July 1981) the Editorial Board of *Kras i Speleologia* is pleased to present papers ilustrating the present state of Polish speleology. This is the first time in the eight congresses that such set of papers has been devoted to the actual congress and this idea has been attained by an effort of the Publishing Office of the Silesian University. Papers were restricted to around 15 pages in length. The contributions were written by prominent Polish specialists in different branches of speleology. For reasons of complete presentation of the Polish speleological activity the majority of papers presents a review of individual problems or the summary of the current research problems of greater interest for colleagues from other countries.

Karst areas with their specific features cause practical problems and are widespread throughout Poland's territory (see below). Polish karstologists and cavers have had broad activity since the XIX century (see Wójcik's review). Caves of Poland were throughly described in early fifties by K. Kowalski (1951, 1953, 1954) in his monumental *Inventory of Polish caves*. But since this time many discoveries twice enlarged the number of known caves. Recent work on new inventory is reported by J. Grodzicki and R. Kardaś (see pp. 98), as well as the longest and dipest caves of Poland are listed by R. Kardaś (see pp. 103). Every day new data are collected and new theories are put forth. The role of hydrothermal karst processes in the origin of zinc-lead deposits is elaborated by S. Dżułyński and his collaborators (see pp. 21), new discoveries of fossil karst of early Mesozoic age are reported by M. Paszkowski and J. Wieczorek (see pp. 32) and broad studies of Late Pleistocene cave deposits are summarized by T. Madeyska (see pp. 43). However, new data and theories often do not reach the popular professional journals or are published only in Polish (see review of Mikuszewski); therefore, they are not readily available to all who are interested in them. This fact led to the publishing of this issue which presents karst relations within Poland's territory and the problems of various branches having advanced results. Information on speleological organization and scientific institution dealing with speleological problems are given by J. Mikuszewski (pp. 118).

Till present, the widely available general review of karst in Poland was presented by J. Głazek, T. Dąbrowski and

R. Gradziński (1972), of caves by M. Pulina (1969), of fossil karst by S. Gilewska (1964) and of biospeleology by A. Skalski (1976). However these reviews are considerably outdated.

Karst and cave areas of Poland

The karst rocks in Poland are widely distributed throughout the country, but most are covered with Cenozoic loose deposits. Although the surface karst regions in Poland occupy the area of only about 8000 square kilometers (i.e. 2,5% of the country surface) in the southern part of the country (Fig. 1), karst waters and features constitute great problems in mining operations and water supply in some other regions.

The Carpathians

The Tatra Mountains on the southern boundary of the country are the highest and northernmost massif in the Inner Carpathians (highest peak in Slovakia — 2663 m a.s.l.). It consist of a crystalline core covered on the northern slope with sedimentary cover and several nappes. Structural units are directed approximately east-west dipping towards the north. The carbonate rocks of the Middle Triassic, Upper Jurassic and Lower Cretaceous form narrow belts cutted by N-S valleys. The alpine folding took place twice in the Upper Cretaceous and in the Miocene, while the uplift movements started in the Late Miocene and caused strong erosion. During the Pleistocene the Tatra Mts. were glaciated several times. The present-day Tatra Mts. acquired an Alpine character with a cold and humid periglacial climate. Karst processes have developed within carbonate rocks since the Neogene. Altogether there are over four hundred caves known so far, among them the longest cave of Poland (Miętusia Cave — 9,040 m long) and the deepest one (Śnieżna Cave — 768 m deep). A storied arrangement of horizontal passages (Phot. 1, 2 and 3) connected by vertical shafts and scanty dripstone are characteristic features of the Tatra caves. Numerous underground water flows were traced (Dąbrowski, 1967), and many investigations were carried there (cf. Głazek et al., 1979). Whole karst area lies within the Tatra National Park and caving is restricted by the National Park Code (special permission is required). Only four caves are accessible for tourist, among them only one — Mroźna Cave — has electric light.

The Pieniny Klippen Belt represents a narrow tectonic zone between the Inner and External Carpathians with Mesozoic limestone scales among Cretaceous marls and Cretaceous-Paleogene flysch. Fifteen small caves are known, up to 170 m in length and 60 m in depth.

The External Carpathians are built up of Cretaceous-Paleogene flysch deposits overthrusted in the form of extensive nappes on the foreland structures. Karst forms are absent there, but over fourty caves were created in sandstones due to stress relaxation and slope creeping. The longest cave reaches 400 m of length and the deepest one 45 m in depth.

The Carpathian Fore-Deep

The extensive Carpathian Fore-Deep is filled with thick Miocene silty-clayey deposits with rock-salt, gypsum-anhydrite and detrital limestone in the bottom part of the sequence, which outcrop on the gentle northern slope. Within the limestone minute karst forms are known, while in the largest gypsum area (Nida river basin) fourteen caves (the longest one is 280 m long) and many surface karst forms (dolines, ouvalas, blind valleys) are known. Beneath clayey overburden, the gypsum was karstified, and in phreatic conditions was reduced by bitumens carried with water into the sulphur deposits (Osmólski, 1976). Rock salt deposits are squeezed up in front of the Carpathians overthrust and form famous deposits, which have been exploited since the medieval ages. In the old salt mine in Wieliczka a Crystal Cave was encountered and recently a speleotherapeutical sanatorium has been built there.

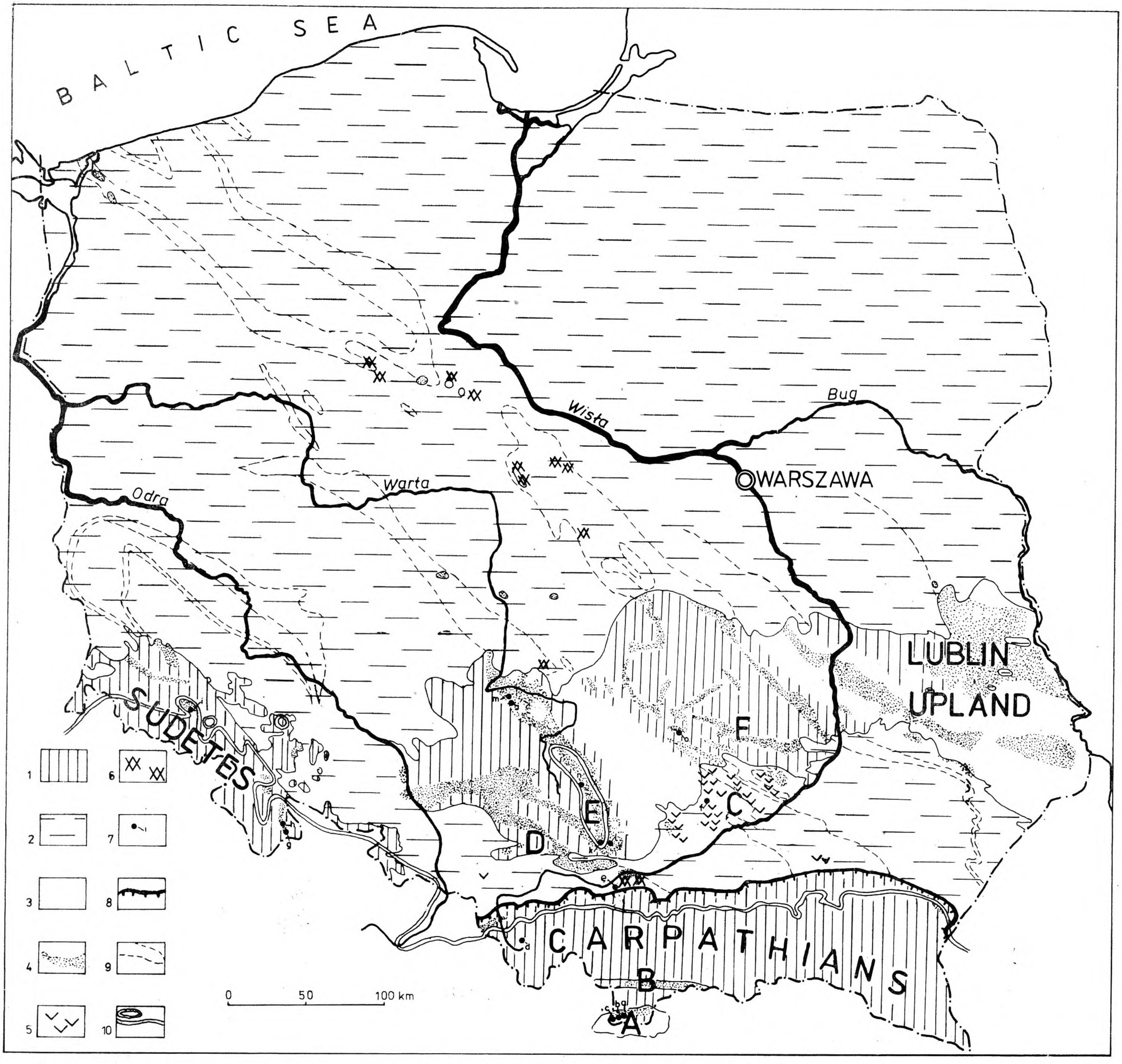
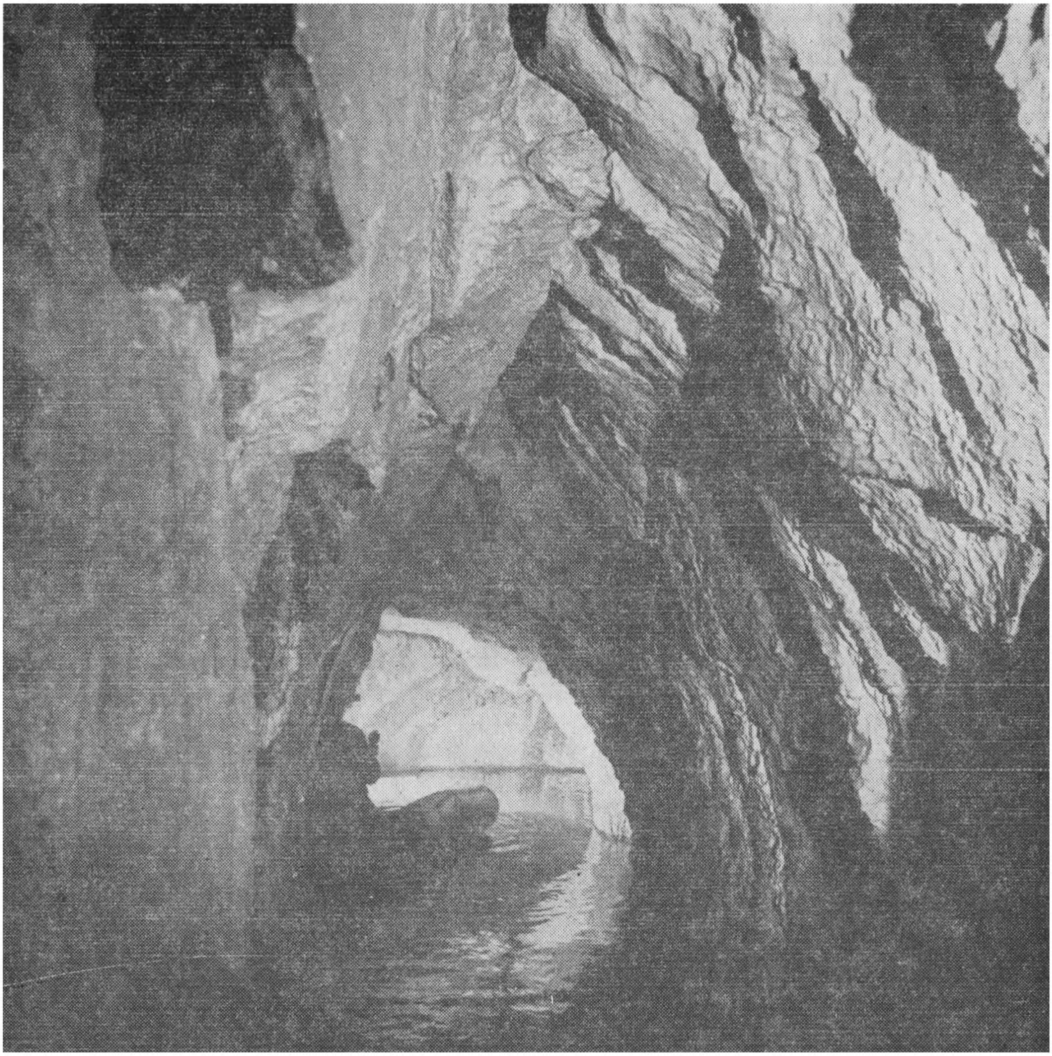
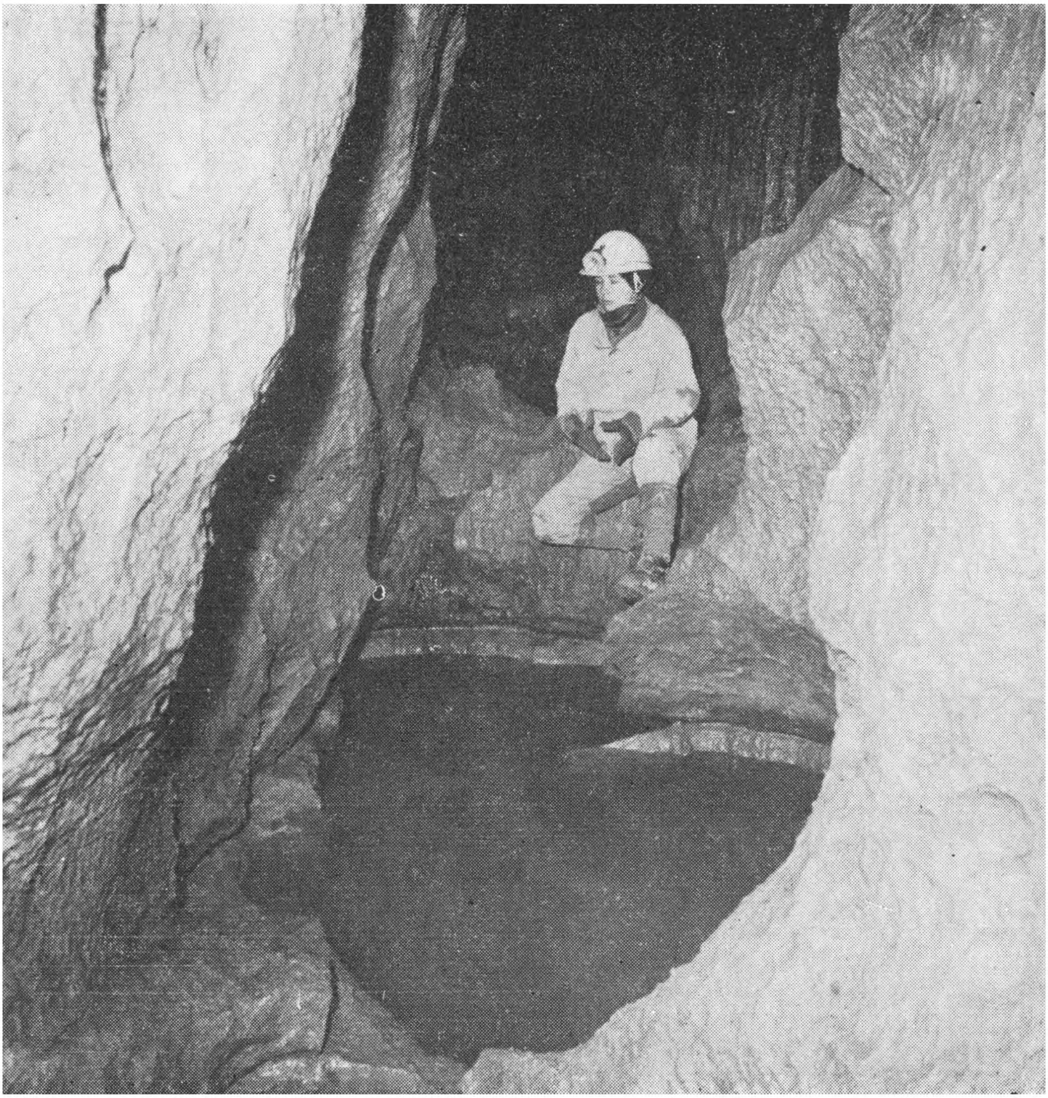


Fig. 1. Map showing the distribution of karst in Poland on the geological background:

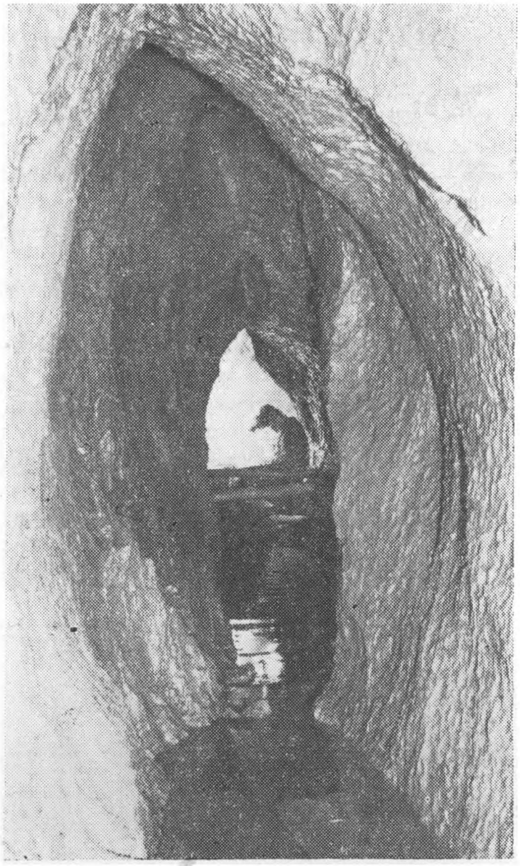
A — Tatra Mts., B — Pieniny Klippen Belt, C — Nida river basin, D — Silesian Upland, E — Cracow—Wieluń Upland, F — Holy Cross Mts.; 1 — Pre-Neogene unkarstifiable rocks, 2 — Neogene clayey-sandy deposits covered karst in older rocks, 3 — karst rocks, 4 — carbonate karst near the surface, 5 — gypsum karst near the surface, 6 — saline-gypsum karst in the salt structures (domes etc.), 7 — important caves (a — Śnieżna, b — Miętusia, c — Mroźna, d — W Trzech Kopcach, e — Wieliczka Crystal Cave, f — Skorocicka, g — Niedźwiedzia, h — Radochowska, i — Jasna, j — Szachownica, k — Wierzchowska Górna, l — Łokietkowa, m — Głęboka, n — Ewy, o — Raj), 8 — Carpathian overthrust, 9 — boundaries of karst rocks beneath the Neogene deposits, 10 — maximal extent of the Pleistocene continental glaciations



Phot. 1. The Lake in the Main Passage of the Miętusia Cave, Tatra Mountains
(Phot. W. Burkacki)

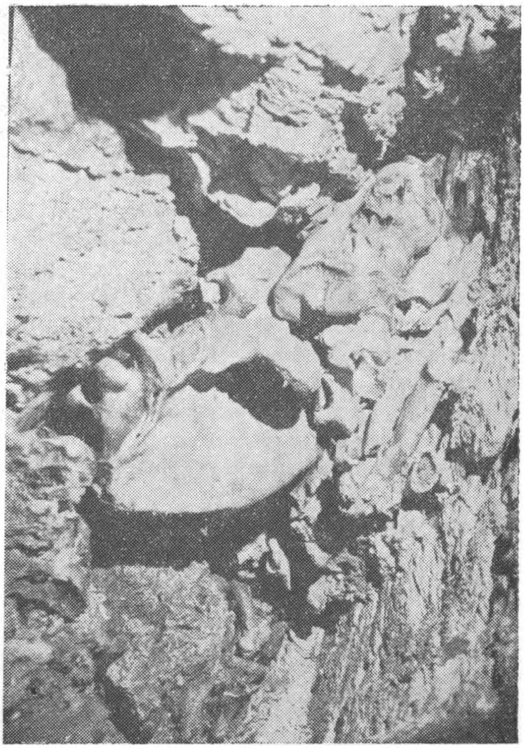


Phot. 2. Pothole in the Main Passage of the Miętusia Cave, Tatra Mountains
(Phot. W. Burkacki)



Phot. 3. „Z Zapałkami" Lake in the Kasprowa Niżnia Cave, Tatra Mountains

(Phot. W. Burkacki)



Phot. 4. Bones of cave bear in Niedźwiedzia (Bear) Cave, Sudetes

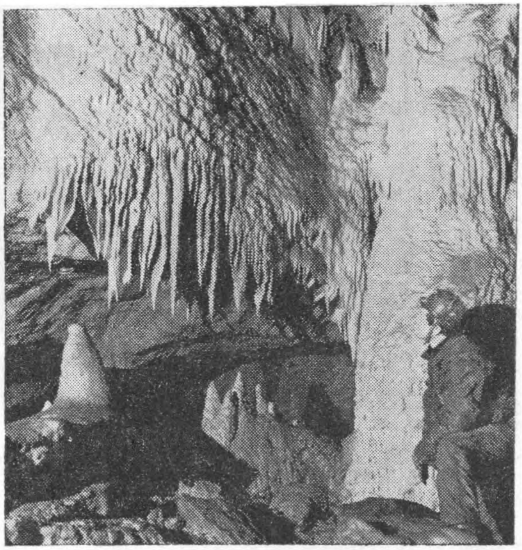
(Phot. J. Mikuszewski)

Meta Carpathians Arch

Outside the Carpathian Fore-deep a belt of uplands was elevated during the Neogene.

The Sudetes in the west consist of Precambrian and Paleozoic metamorphic rocks. Among them small lenses of marbles are strongly karstified. Over fourty caves are known there, among them Niedźwiedzia (Bear) Cave reaches over 2 km in length and Jasna Cave is about 80 m deep. Two caves Niedźwiedzia (Phot. 4 and 5) and Radochowska are accessible for the tourist.

The Silesian Upland consists of Carboniferous coal-measures covered here and there by flat-lying Triassic marly—carbonate deposits. Numerous surface karst forms, among



Phot. 5. Speleothems in Niedźwiedzia Cave

(Phot. M. Pulina)

them, large infilled Tertiary dolinas are known here. Underground karst water circulation has caused great difficulties in the exploitation of the zinc-load deposits and in dam construction (cf. Głazek, Szynkiewicz, 1979), but caves are unknown there. The origin of the Upper Silesian zinc-lead deposits is explained by hydrothermal karst processes (see pp. 21). On the north-eastern margin of the Upper Silesian coal basin the substratum of coal-bearing formations is composed of Middle Devonian through Lower Carboniferous carbonates and is unconformably covered by Triassic or Jurassic deposits. On this angular unconformity Early Mesozoic infilled karst forms containing fossil vertebrates were found (Tarlo, 1959; Lis, Wójcik, 1960; see also pp. 32).

The Cracow-Wieluń Upland is composed of Upper Jurassic limestones which form a vast monocline, dipping nartheast at law angle. This area forms the most prominent karst region of Poland with numerous residual hills (Phot. 6) separated by extensive cockpit karst depressions (to 110 m deep) filled with kaolinized sandy-clayey deposits of Tertiary age. During the Pleistocene glaciations, this area (elevated to 504 m above sea level) was never completely covered by the ice-sheets. A concave nunatak was formed and covered with outwash sands up to 410 m elevation (Różycki, 1965). Caves and karst channels already existing were repeatedly blocked and filled with sediments during the Badenian transgression on the south-eastern edge of the upland and during Pleistocene glaciations. The Pliocene uplift and during the retreat of the Pleistocene glaciations these karst conduits were reexcavated like at present time. Numerous studies of cave sediments gave evidences of such processes and dated them by paleontological and other methods. Over six hundred smaller caves are known in this area. These caves (Phot. 7) represent preserved fragments of partially destroyed older Tertiary caves, or accessible portions of infilled cave systems. The longest cave system — Szachownica Cave — reaches one kilometre in total passage length and the deepest one — Januszkowa Szczelina Cave — exceeds 50 m in depth. Deep karst water circulation is present there and the karst aquifer in Jurassic limestones is the main source of water in this area. Eight caves

Phot. 6. Residual hills in the Cracow—Wieluń Upland, view from the ruins of Ogrodzieniec Kastle (Phot. T. Zapaśnik)

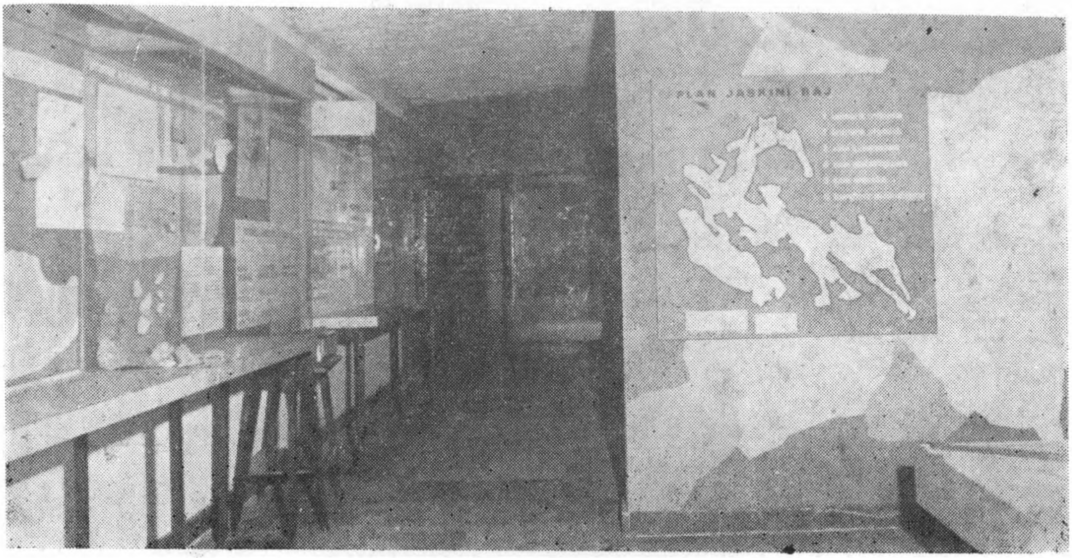
Phot. 7. Entrance to the Wierzchowska Górna Cave

(Phot. J. Mikuszewski)

are accessible for the tourist (two of them has electric light).

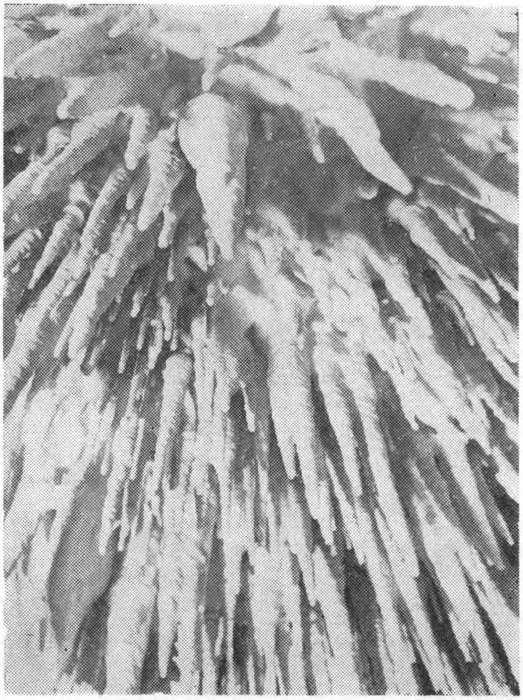
The Holy Cross Mountains represents an anticlinorium elevated by Laramian movements. In the centre Devonian carbonates and on the peripheries Upper Jurassic limestones are the main karst formations. The paleogeographic conditions of karst development in this area were similar to those presented for Cracow-Wieluń Upland. Over fifty smaller caves are known in this area, the longest one is Raj Cave (240 m in length) and the deepest one (Jaworznicka Cave) is 21 m deep. Two caves are accessible to tourist, but the Raj cave is fully adopted and floodlit (Phot. 8 and 9).

The Lublin Upland is built up of flat-lying Upper Cretaceous chalk intercalated by limestones and marls, and exhibits gentle surface corrosional depressions and a lack of underground forms. This peculiar karst is the result of the low permeability of weakly lithified microporous rocks and their low mechanical resistance (Maruszczak, 1966). Upper Crotaceous rocks are underlain by Upper Jurassic limestones resting on Carboniferous coal measures. Deep karst water circulation in this Jurassic limestones cause graet difficulties in coal mine operations in **this area.**



Phot. 8. Exhibition Hall at the entrance to the Raj Cave

(Phot. J. Mikuszewski)



Phot. 9. Stalactite Room in the Raj Cave, Holy Cross Mountains
(Phot. J. Mikuszewski)

Lowland area

To the north of the Meta-Carpathian Arch the lowland is covered by Cenozoic deposits up to 200 m thick. Karst rocks (Upper Permian salt, gypsum and carbonates, Upper Jurassic limestones) occur near the surface in the buried anticlinorium trending north-west from the Holy Cross Mountains. Karst cavities (infilled or open) and deep circulation of karst waters were encountered in some salt domes, coper mines, brown-coal strip-mines and deep limestones quarries.

Closing remarks

The Editors wish to apologize for the scope of this issue is not complete because some of the invited papers were not submitted in time, and then must be omitted. The Editors would like to inform our readers that in the near future, we intend to publish a review of such important subject as biospeleological research in Poland or Polish caving and scientific investigations in other countries. The paper of M. Pulina (pp. 67) may serve as an example of investigations carried abroad.

Acknowledgements

The Editors wish to thank numerous authors for their willing co-operation. The English translations have been briefly looked over by Michael Kamiński, B. Sc.; we cordially thank him. Finally this volume could not have been appearing without the co-operation of Silesian University Publishing Office, particulary Miss Barbara Woźnica, M.Sc. and Mrs Wiesława Piskor, M.Sc.

*Jerzy Głazek, Ryszard Gradziński, Marian Pulina**

Translated by Jerzy Głazek

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* Jerzy Głazek, Institute of Geology, Warsaw University, Żwirki i Wigury 93, PL 02-089 Warszawa, Poland

Ryszard Gradziński, Institute of Geological Sciences, Polish Academy of Sciences, ul. Senacka 3, PL 31-002 Kraków, Poland

Marian Pulina, Laboratory of Karst Geomorphology, Silesian University, ul. Mielczarskiego 58, PL 41-200 Sosnowiec, Poland

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Jerzy Głazek, Ryszard Gradziński, Marian Pulina

WSTĘP

KRAS i JASKINIE POLSKI

Streszczenie

Omówiono pokrótce krasowe i jaskiniowe regiony Polski. Przedstawiono zawartość tego tomu przygotowanego z okazji 8 Międzynarodowego Kongresu Speleologicznego (Bowling Green, Kentucky, USA, lipiec 1981).

Jerzy Głazek, Ryszard Gradziński, Marian Pulina

INTRODUCTION

LE KARST ET LES GROTTES DE POLOGNE

Résumé

Dans l'introduction sont discutées les régions karstiques et caverneuses de Pologne. Est également présenté le contenu du volume présent préparé à l'occasion du VIIIième Congrès International Spéléologique (Bowling Green, Kentucky, USA, juillet 1981).

Traduit par Teresa Korba-Fiedorowicz

RESEARCH PAPERS

Stanisław Dżułyński
Maria Sass-Gustkiewicz*

The role of hydrothermal karst processes in the emplacement of sulfide ores

A b s t r a c t: Zn-Pb sulfide ores belonging to the category of Mississippi Valley type deposits are associated with underground karst structures. Arguments presented here indicate that these structures and the ores resident in them can be interpreted in terms of hydrothermal karst processes.

Introduction

The association of Zn-Pb sulfide ores with karst cavities is among the diagnostic features of so called „Mississippi Valley" type deposits (see glossary). The disputable question here is the relationship between the karst cavities and the ores resident in them. In general, the association of sulfide ores with underground karst structures is interpreted in terms of three possible explanations (W a l k e r, 1928): 1 — the karst structures and the ores contained in them are products of cold-water processes, 2 — the karst structures resulted from the action of cold meteoric waters before the introduction of hot, ore-bearing solutions and, 3 — the karst structures and the ores were formed more or less simultaneously by the action of ascending hydrothermal solutions. The first explanation is advanced by geologists who favor the sedimentary and exhalative-sedimentary origin of ores (e.g.: R o u v i e r, 1971; B e r n a r d, 1971; L a g n y, 1975). The second and third ones are accepted by exponents of the hydrothermal-epigenetic hypotheses of ore formation (e.g.: H o a g l a n d at al., 1965; R i d g e, 1968; B o g a c z et al., 1970; S a s s - G u s t k i e w i c z, 1975; D ż u ł y ń s k i, 1976; D ż u ł y ń s k i, S a s s - G u s t k i e w i c z, 1977, 1978).

The above three explanations are not mutually exclusive (C a l l a h a n, 1974). The growing evidence, however, points out the third explanation as the most plausible one. Under such explanation considerable parts of the sulfide ores assigned to Mississippi Valley type deposits can be interpreted in terms of hydrothermal karst processes.

The aim of this paper is to discuss the premisses and criteria whereby the ores resident in karst cavities can be interpreted in terms of hydrothermal karst processes, and to give examples of such ores. The examples presented come from the Cracow-Silesian ore district, a representative of Mississippi Valley type deposits. In this district, the mineralized karst structures occur in the ore-bearing dolomite which is a crystalline neosome produced by replacement of Middle Triassic limestones and recrystallization of early-diagenetic dolostones (for references and details see: B o g a c z et al, 1975).

General premisses

The terms „underground karst" as used in this article applies essentialy to underground forms, structures and deposits produced by the action of agressive watery so-

* Stanisław D ż u ł y ń s k i, Polish Academy of Sciences, Institute of Geology, Jagiellonian University, ul. Oleandry 2a, PL 30-063 Kraków, Poland
Maria S a s s - G u s t k i e w i c z, Institute of Geology and Mineral Deposits, Academy of Mining and Metallurgy, al. Mickiewicza 30, PL 30-059 Kraków, Poland

lutions of any origin and temperature. The underground karst features involve not only solution caverns but also various rock deformations resulting from stress redistribution consequent upon the solutional removal of soluble rocks. Such deformations, indicated as „karst tectonics" (B a l w i e r z, D ż u ł y ń s k i, 1976) include: solution collapse breccias, sag fissures, minor gravity faults, tilting of layers towards areas of maximum dissolution, etc. The deformations mentioned are products of brittle failure and involve dilatancy which is manifested in the appearance of deformation voids. Such voids, too, are included into karst cavities.

It may be added, at this place, that all the dilatant zones, whatever their origin, are regions of low fluid pressure. Consequently, any available fluid will move towards such zones to fill voids (M e a d, 1925). This has a profound bearing upon the mineralization of deformation voids (B o y l e, 1970).

The underground karst features produced by the action of hydrothermal solutions fall into the category of „hydrothermal" or „thermomineral karst" phenomena (K u n s k y, 1957; M a k s i m o v i c h, 1969). As introduced, the above mentioned terms referred to the present day karst features effected by the action of hydrothermal but not ore-bearing solutions.

The concept of hydrothermal karst has been only recently applied to paleokarst structures containing Zn-Pb sulfides (B o g a c z et al., 1970). In ore geology, however, this concept is not new insofar as the general thought is concerned. It has been touched upon, although by implications rather than assertion, throughout a number of papers in which the solution cavities and the ores resident in them are assigned to the same formative processes (e.g.: P o š e p n y, 1894; O h l e, 1959; R i d g e, 1968 and others).

The case of the hydrothermal-karst concept as applied to Zn-Pb sulfide ores rests on the following general premisses: 1 — the voids serving as ore receptacles are of karstic origin, 2 — the sulfides infilling the karst determined voids are products of hydrothermal solutions and, 3 — the karst determined voids and the ores resident in them resulted synchroneously from the action of the same formative solutions.

Karst determined ore receptacles

Ore-filled solution caverns virtually riddle the ores and the host dolomite. The caverns, generally small, show network, anastomosing or spongework patterns and their geometry is very similar to that of ordinary meteoric karst cavities (Fig. 1). In most instances this geometry is indicative of freatic conditions (Fig. 2). The ore-filled caverns are bedding and fracture controlled. Among the controlling factors are also the metasomatic boundaries of secondary dolomites (Fig. 3), the boundaries of „sanded" i.e. solutionally disaggregated crystalline dolomites (Fig. 4) and diffussion bandings in ores.

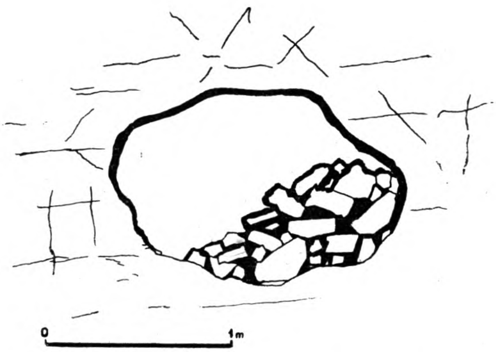


Fig. 1. Ore lined solution cavern partly filled with ore-cemented collapse breccia (black areas — ores)

The fractured character of the dolomites hosting the sulfide ores prevents the development of large solution caverns with intact ceilings. Such a character promotes the formation of extensive zones of solution collapse breccias and fractures which constitute the most important ore receptacles in the Cracow-Silesian district and in many other ore districts.

The solution-collapse breccias under consideration take the form of highly irregular, tabular and commonly branching, bedding-parallel bodies. The horizontal extension of such bodies amounts to several hundreds of meters and their maximum height may reach several tens of meters.

The karstic origin of the breccias under consideration is shown by the following features (Fig. 5): 1 — the lowermost boundaries

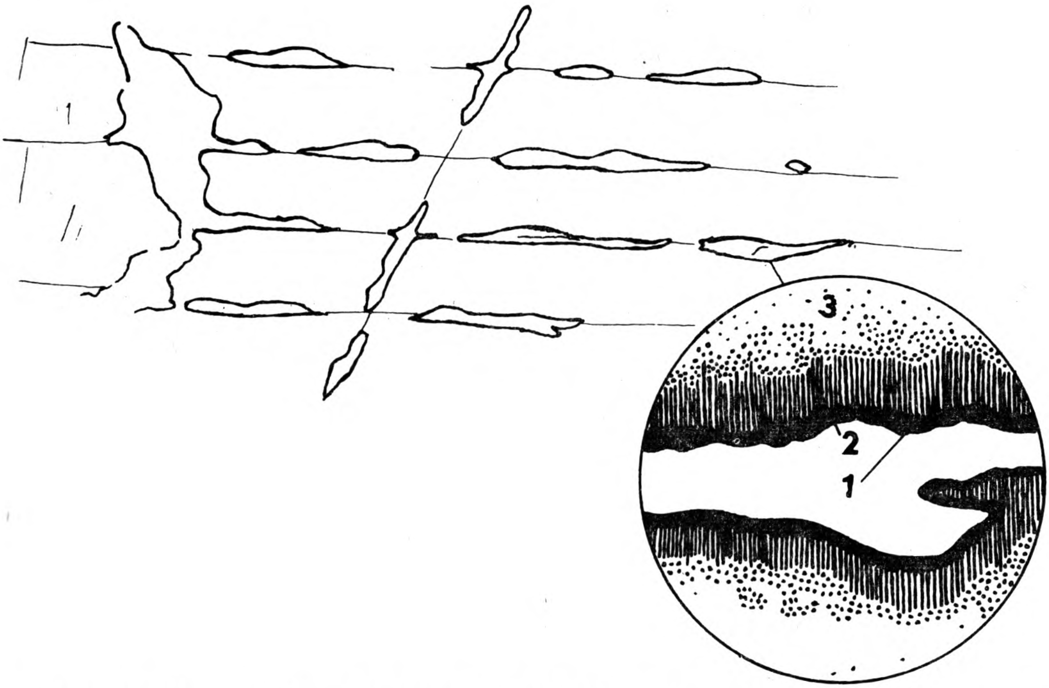


Fig. 2. Bedding- and fracture-controlled ore-lined solution caverns (schematic presentation). Detail of cavern (circle, lower right):
1 — incrustations, 2 — massive sphalerite replacement rims, 3 — aureole of sphalerite impregnation

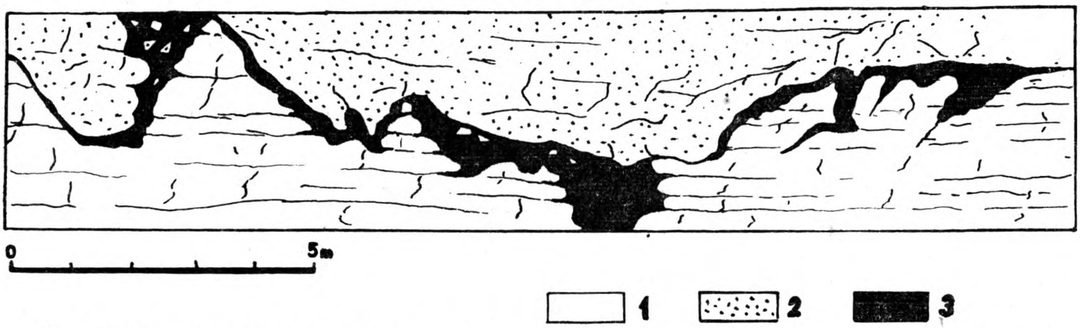


Fig. 3. Mineralized solution caverns (**3**) developed along the metasomatic contact between ore-bearing dolomite (**2**) and limestone (**1**)

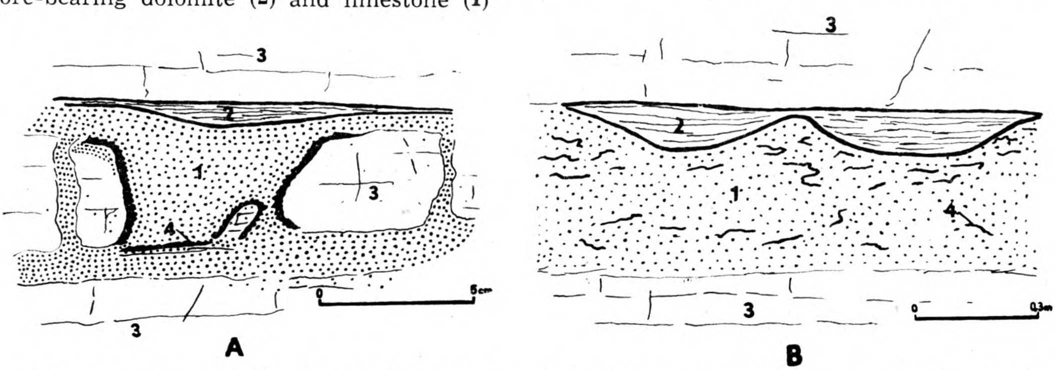


Fig. 4. Caverns (**A, B**) developed along upper boundaries of disaggregated dolomite (**1**), **2** — clastic internal sediment, **3** — hard dolomite, **4** — galena (after B o g a c z et al., 1973)

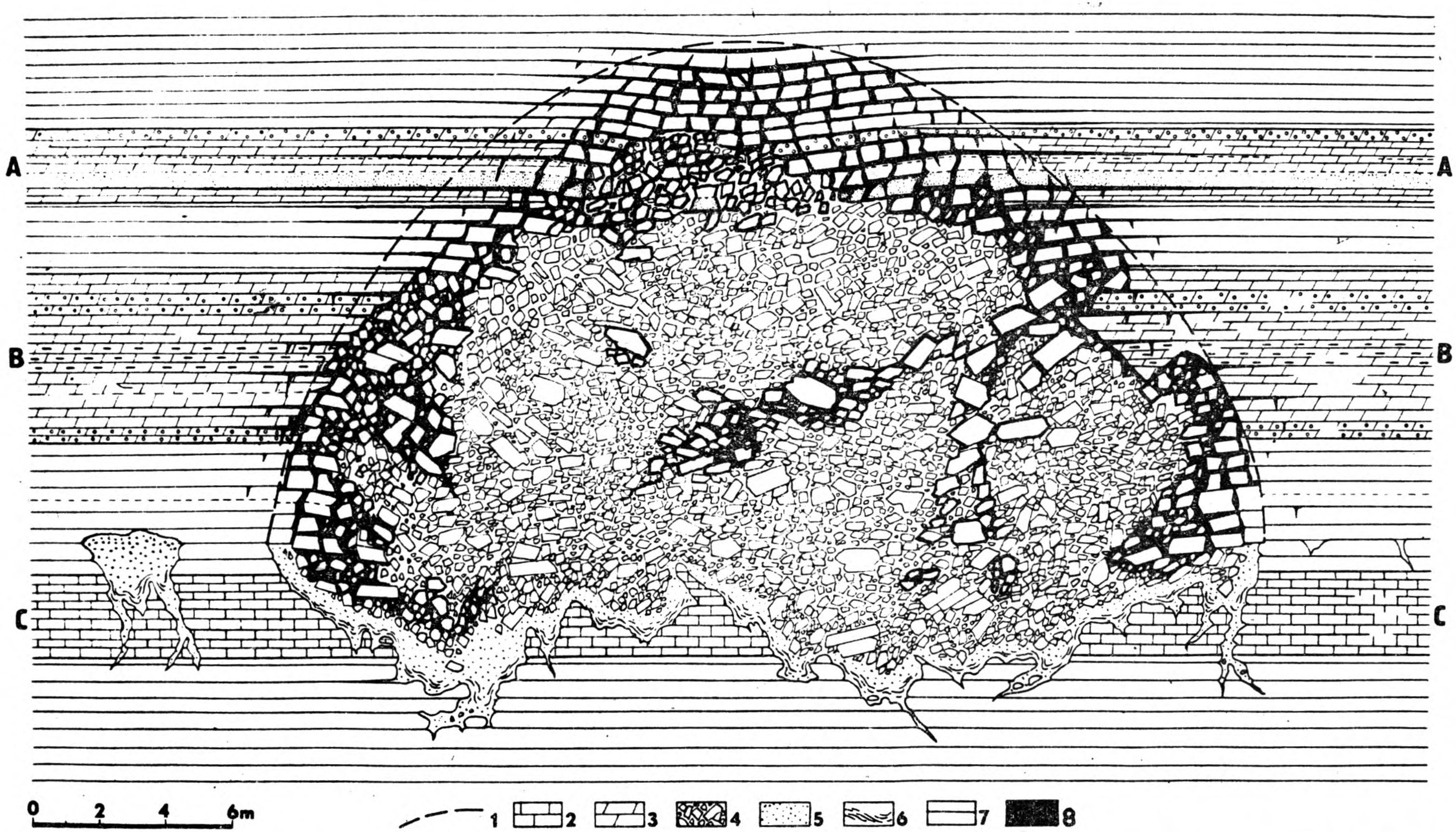


Fig. 5. Reconstruction of solution collapse breccia based upon exposures (**A**, **B**, **C**) in mine workings (after Sass-Gustkiewicz, 1974):
1 — presure arch, **2** — limestone, **3** — dolomite, **4** — brecciated dolomite, **5** — fine-grained clastic material, **6** — laminated internal sediments, **7** — reconstructed parts, **8** — ore

of the breccia bodies are solution surfaces representing the former floors of caves, 2 — the solution surfaces are covered with internal clastic cave sediments grading upwards into a mass of angular blocks and, 3 — the upper and lateral boundaries of the breccia bodies are commonly gradational and the chaotic rubble of angular blocks is seen to pass through crackle breccias into a network of cracks and fissures cutting the adjacent and overlying strata in various directions (for details and references see: Sass-Gustkiewicz, 1974, 1975b; Dżułyński, Sass-Gustkiewicz, 1978). In some transverse sections through the breccia bodies the above mentioned fissures may approximate the pattern of tension dome (McCormick et al., 1971; Sass-Gustkiewicz, 1974). The breccias are also associated with extensive, bedding controlled sag fissures in the overlying strata (Fig. 5).

The breccias described tend to occur along specific horizons within the ore-bearing dolomite. In many instances, however, the incipient caverns are located along the lower, metasomatic boundary of this dolomite. Such breccias are seen to expand laterally and upwards with little or no downward expansion (Fig. 3).

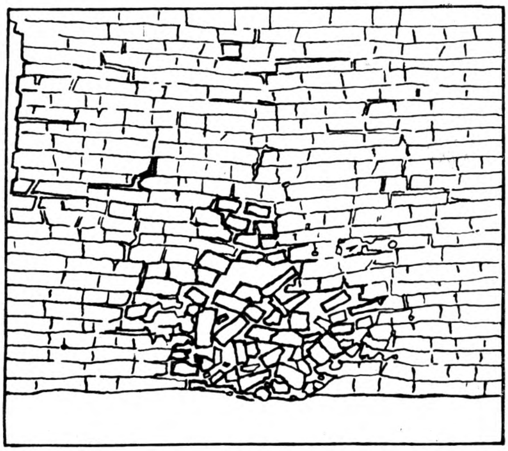


Fig. 6. Experimentally produced solution collapse breccia (after Balwierz, Dżułyński, 1976)

The formation mechanism of solution collapse breccias is known from observations (Davies, 1951; White and White, 1969) and experiments (Balwierz and Dżułyński, 1976, see also fig. 6 in this article). Accordingly, only few comments are here needed. The breccias originate under phreatic, vadose or combined phreatic-vadose conditions. They develop through progressive fracturing and differential settling of detached blocks concurrently with the solutional removal of rocks in the lower portions of the breccia bodies. A prolongued transfer of agressive solutions is the primary requirement for the development of large breccias bodies. By cessation of solution transfer and jamming of broken fragments, the development of breccias may be temporarily arrested. It is, however, reactivated with the resumption of the solution transfer.

Although cave collapse is among the most important factors promoting the development of breccias it is realized that the incipient caverns might have never grown to any sizable vertical dimensions. As it is shown by experiments (Balwierz and Dżułyński, 1976), the breccias may also result from piecemeal derangement of layers overlying the strata which are subject to simultaneous dissolution along a great number of transmissive fissures („polycentric solution derangement breccias" — Balwierz and Dżułyński, 1976).

Infilling of karst determined voids

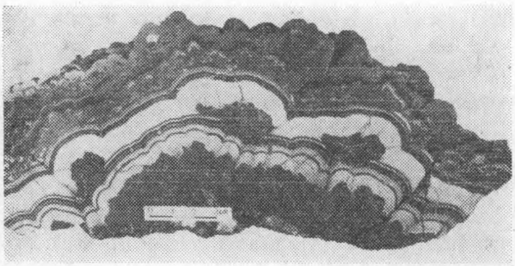
The solution caverns and deformation voids here discussed are partly or entirely filled with sulfide precipitates (Phot. 1) and/ /or internal clastic sediments of specific composition.

The precipitates consist chiefly of galena, sphalerite and iron sulfides. The sulfides have been emplaced by hydrothermal solutions. This is evidenced by fluid inclusion investigations. For the Cracow-Silesian ores such investigations indicate temperatures of deposition ranging from 90 to 135°C (Karwowski et al., 1979) which is consistent with temperatures of sulfide deposition reported from other Mississippi Valley type deposits.

The morphologies of the precipitates approximate closely the morphologies of calcareous and/or aragonite speleothems of non-

Phot. 1. Typical example of mineralized solution collapse breccia — Olkusz Mine

-mineralized hydrothermal caves. Among the common forms are drusy and finely crystalline or „colloform" banded encrustations of diverse configurations — Phot. 2. Such pre-



Phot. 2. Typical example of sulfides lining rock fragments in solution collapse breccias

cipitates are indicative of phreatic conditions and, in most instances, have crystallized directly on walls of solution caverns or open fractures and on the sides of rock fragments in breccias. Some of these sulfides, however, appear to have nucleated in solution and settled under gravity control to form caps and overhangs on the upper horizontal or sub-horizontal sides of the rock fragments. Sulfide dripstones indicative of vadose conditions are relatively rare (S o b c z y ń s k i and S z u w a r z y ń s k i, 1975).

The internal clastic sediments consist of various solutions residues, disaggregated dolomitic grains, clastic fragments of ores and autigenic sulfide crystals (for details see H o r z e m s k i, 1962; B o g a c z et al., 1973; S a s s - G u s t k i e w i c z, 1975a). The internal sediments may reveal a fine lamination and „soft-rock-deformations" — Phot. 3. In

Phot. 3. Fragment of laminated internal sediment

some instances the amount of clastic ore fragments is so high that the internal sediments infilling the solution caverns and deformation voids deserve the name of „sedimentary ores" (Sass-Gustkiewicz, 1975a).

Essential simultaneity of brecciation and mineralization

It is realized that the mere presence of hydrothermal ores in karst cavities cannot be regarded as a criterion of hydrothermal karst processes. The convincing evidence in this respect is provided by essential simultaneity of brecciation and mineralization.

The breccias discussed resulted from a succesion of mineralization and brecciation processes, whereby succesively younger sulfide minerals enclose and envelope the clastic products of earlier brecciation and mineralization (Sass-Gustkiewicz, 1975b). The brecciation and mineralization phases were not interrupted by any significant time intervals and were partly overlapping in time and space. Mineralogically there is hardly any distinction between the specific sulfides belonging to different stages of mineralization. There is also no evidence of the interference of any oxidizing waters between the stages of sulfide mineralization. In addition, the breccia bodies, as seen in plan view, show a zonal and concentric arrangement which reflects the lateral growth of such bodies. The successively younger stages of mineralization and brecciation cover progressively more extensive areas (Sass-Gustkiewicz, 1975b). These relationship suggest that the ores and their host breccias were produced by the action of essentially the same transfer of solutions. These solutions, however, were hydrothermal solutions as it is shown by the previously mentioned fluid inclusions in ore minerals and by other geologic evidence which need not be ennumerated here (see Dżułyński, 1976). Accordingly, a further inference and the next logical step is the conclusion that the mineralized breccias under consideration represent hydrothermal paleokarst features. The above conclusion can be extended to cover the earlier described „roofed", ore-lined solution caverns which are seen to pass into the collapse structures. Consequently, the whole assemblage of the underground karst structures here discussed may be interpreted in terms of hydrothermal karst phenomena or more precisely „thermomineral" karst phenomena adopting the name coined by J. Kunsky (1957) for the mineralized karst structures. In this connection, we mention that the mineralized karst cavities under consideration are associated with wall-rock alterations which include the replacement of dolomite by sphalerite and solutional disaggregation of dolomite. Such alterations provide yet another, complementary, argument in favor of the hydrothermal-karst origin of the structures discussed.

It should be borne in mind, however, that the hydrothermal karst phenomena, although of primary importance for the Mississippi Valley type deposits, represent only a part of the processes which have led to the formation of the ore bodies in question. These bodies include also mineralized tectonic fissures, extension breccias not related to the solutional removal of rock and, finally, large bodies of metasomatic ores.

Horizontal distribution of karst ores

Although the origin of hydrothermal solutions is a conjectural question, their flow pattern can always be resolved into two components: the vertical ascent and the horizontal spread. The first component is preserved in the form of vertical, fissure-controlled ore veins (Dżułyński and Sass-Gustkiewicz, 1977 and 1980). Such veins however, constitute only a minor part of Mississippi Valley type deposits. The bulk of these deposits is made up of ore bodies which are disposed more or less parallel to the bedding surfaces of host carbonates. Such disposition reflects also the original horizontal position of ore bodies which, as it is shown by ample evidence, predate major tectonic disturbances and were emplaced into nearly flat-lying carbonate rocks. In such a situation, the horizontal extension of the karst determined ore receptacles may arise from the fact that in flat-lying carbonate rocks the bedding surfaces and specific transmissive layers serve as primary routes for groundwater movement. It should also be noted that many of the mineralized karst breccias are located not far beneath unconformities marking the position of ancient land surfaces. Under such conditions, the karst water-table might have been among the factors controlling the spread of ascending hydrothermal and mineralizing solutions. Evidence supporting such a possibility is found in the behavior of some present-day hot waters (Müller and Sárváry, 1977).

As noted at the outset of this article, the three explanations with respect to the association of Mississippi Valley type deposits with karst structures are not mutually exclusive. The near surface location of many sulfide deposits provides opportunities for mutual interference of hydrothermal and cold water karst processes (mixing of solutions differing in composition and temperature is among the factors promoting the development of karst cavities and the precipitation of sulfide ores). This is in agreement with what is known of recent hydrothermal karst phenomena (Jakucs, 1977). Consequently, it is possible that the hydrothermal solutions, working their way upwards, have also deposited sulfide ores in the pre-existing karst structures of meteoric origin. This question requires further investigations. However, in the present writers opinion, only a small part of the sulfide ores can be accounted for in this manner.

A further consequence of the near-surface location of many sulfide ores is the alteration effected by the circulation of cold meteoric waters. The sulfide ores are particularly sensitive to such alteration which includes oxidation, local remobilization i.e. reprecipitation of sulfides and the superposition of newly formed meteoric karst structures upon the earlier hydrothermal ones. Most of the Mississippi Valley type deposits bear a clear record of such supergene alterations. Only a passing reference is, however, given to this question which, although of interest for the karst sciences, is beyond the scope of the present article.

English text by the authors

Glossary

„Mississippi Valley type" deposits or, rarely, „Upper Silesia — Mississippi Valley type" (Danham, 1950): chiefly bedding controlled Zn-Pb sulfide ores in carbonate rocks.

Dilatancy: the property of expanding in bulk with the change of shape, due to the increase in space between individually rigid particles or parts as they change their relative position.

Metasomatism: replacement of an older parent rock by newly formed minerals.

Neosome: newly formed part of rock consequent upon metasomatic processes.

Metasomatic boundaries: term referring to the boundaries of rocks that are formed by metasomatic processes.

Cracle breccia: one whose fragments are slightly disjointed with little or no displacement.

Solutional disaggregation: transformation of hard crystalline carbonates (mostly dolomites) into weakly cemented or incoherent mass of grains through the action of slow nonintegrated transfer of aggressive solutions.

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Stanisław Dżułyński, Maria Sass-Gustkiewicz

ROLA HYDROTERMALNYCH PROCESÓW KRASOWYCH W POWSTAWANIU ZŁÓŻ KRUSZCOWYCH

S t r e s z c z e n i e

Występowanie bogatych nagromadzeń rud cynkowo-ołowiowych w strukturach krasowych jest znamiennym zjawiskiem w złożach typu Mississippi Valley, stanowiąc jedną z ważniejszych ich cech diagnostycznych. Problemem wzbudzającym kontrowersje jest związek między formami krasowymi a znajdującymi się w nich rudami. Rozpatrywane są trzy możliwe przypadki (W a l k e r, 1928):

1 — struktury krasowe i kruszce są produktem krasu meteorycznego,

2 — struktury krasowe powstały w wyniku działania krasu meteorycznego, poprzedzając depozycję rud z roztworów hydrotermalnych,

3 — struktury krasowe i kruszce utworzyły się mniej więcej równocześnie jako rezultat działalności ascenzyjnych roztworów hydrotermalnych. Na przykładzie złóż Zn-Pb rejonu śląsko-krakowskiego przedyskutowano przesłanki wskazujące na trzecią z wymienionych możliwości i udowodniono, że zjawiska krasu hydrotermalnego, w przypadku złóż typu Mississippi Valley, odegrały rolę czynnika złożotwórczego. Wykazano mianowicie, że:

— struktury będące siedliskiem kruszców są pochodzenia krasowego;

— siarczki wypełniające formy krasowe są produktem roztworów hydrotermalnych;

— struktury krasowe i znajdujące się w nich kruszce utworzyły się synchronicznie pod wpływem tych samych roztworów. Praca omawia szczegółowe przesłanki geologiczne stanowiące podstawę przedstawionego rozumowania.

Stanisław Dżułyński, Maria Sass-Gustkiewicz

LE RÔLE DES PROCESSUS KARSTIQUES HYDROTHERMAUX DANS LA FORMATION DES GISEMENTS MINERAUX

R é s u m é

La présence de riches accumulations de minerai plombo-zinci-fère dans les structures karstiques est un phénomène significatif de gisements de type de Mississippi Valley, ce qui constitue un de leurs importants trait diagnostiques. Cependant le rapport entre les formes karstiques et les minerais y apparaissant suscite les controversions. Ainsi sont pris en considération trois cas possibles (W a l k e r, 1928):

1 — structures karstiques et minerais sont produits du karst météorique,

2 — structures karstiques formées au cours de l'action du karst météorique ont précédé la sédimentation de minerai provenant des solutions hydrothermales,

3 — structures karstiques et minerais se sont formés à peu près simultanément comme résultat de l'action des solutions hydrothermales.

Sur l'exemple des gisements de Zn-Pb de la région de Silésie-Cracovie ont été discutées les prémisses indiquant la troisième des possibilités citées ci-dessus. A été prouvé que les phénomènes du karst hydrothermal, en cas des gisements de type de Mississippi Valley, ont joué le rôle très important dans la formation du gisement. A été notament démontré que: les structures étant le site de minerai sont de l'origine karstique; les sulfides remplissant les formes karstiques sont produits des solutions hydrothermales; les structures karstiques et les minerais y apparaissant se sont formés synchroniquement sous l'influence des mêmes solutions. L'étude présenté discute les premisses géologiques particulières étant la base du raisonnement en question.

Traduit par Teresa Korba-Fiedorowicz

Mariusz Paszkowski
Józef Wieczorek*

Fossil karst with Mesozoic bone breccia in Czatkowice (Cracow Upland, Poland)

Abstract: The preliminary results of geological studies on newly found fossil karst forms with vertebrate faunas at Czatkowice (Cracow Upland) are presented in this paper. Two phases of karstification have been established — the first phase began during the Late Carboniferous and ended in the Early Triassic (before Röth) and the next phase began during the Late Triassic and ended in the Middle Jurassic (before the Callovian).

Introduction

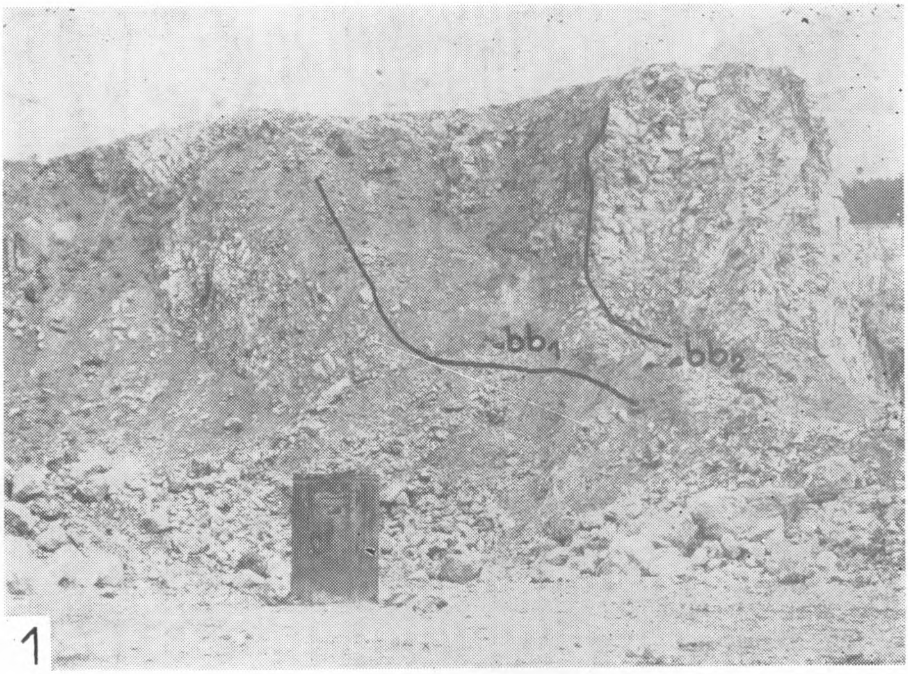
Cainozoic karst phenomena are well studied in the Cracow Upland (Gradziński, 1962; Madeyska-Niklewska, 1969; Madeyska, 1977) while Mesozoic and Late Paleozoic karst forms, though mentioned in this area (Siedlecki, Wieser, 1948; Lis, Wójcik, 1960; Gradziński, Wójcik, 1966; Głazek et al. 1972) have not yet been closely examined. New information about the fossil karst of the Cracow Upland is provided by the author's preliminary observation at the Czatkowice quarry. Karst forms have developed here in Lower Carboniferous limestones. Bone breccias with fossils of fishes, reptiles and/or amphibians occur in some of them. This bone material enables one to establish more precisely the ages of the karstification phases in this area. The bone breccias were discovered in July 1978 by Marek Michalik and Mariusz Paszkowski, teaching assistants at the Institute of Geological Sciences, Jagiellonian University, during geological mapping. At that time, large blocks of the bone breccia could be found on the waste-heaps of the Czatkowice quarry. Later, some localities containing the bone material were discovered mainly by M. Paszkowski in the fillings of the karst forms in the quarry. Preliminary investigation of the bone-bearing karst forms were made by the authors with the help of research workers and students of the Institute of Geological Sciences to whom the authors would like to express their gratitude. In 1979 workers of the Polish Academy of Sciences began to take part in the exploration of the bone breccia. Dr T. Maryańska (Museum of the Earth of the Polish Academy of Sciences, Warsaw) and Dr H. Osmólska (Institute of Paleobiology of the Polish Academy of Sciences, Warsaw) in collaboration with co-workers, undertook the task of paleontological investigation.

The authors thank Prof. S. Dżułyński and Dr. J. Głazek for field discussion, Prof. Z. Kielan-Jaworowska and Dr. T. Maryańska for information on the preliminary identification of the vertebrate fauna and to Dr. M. Krysowska-Iwaszkiewicz for preliminary analysis of heavy minerals. The authors also express special thanks to Dr. T. C. Atkinson, Dr. J. Głazek, Mr M. A. Kamiński and Mrs R. Paszkowska for their help in the preparation of the English text.

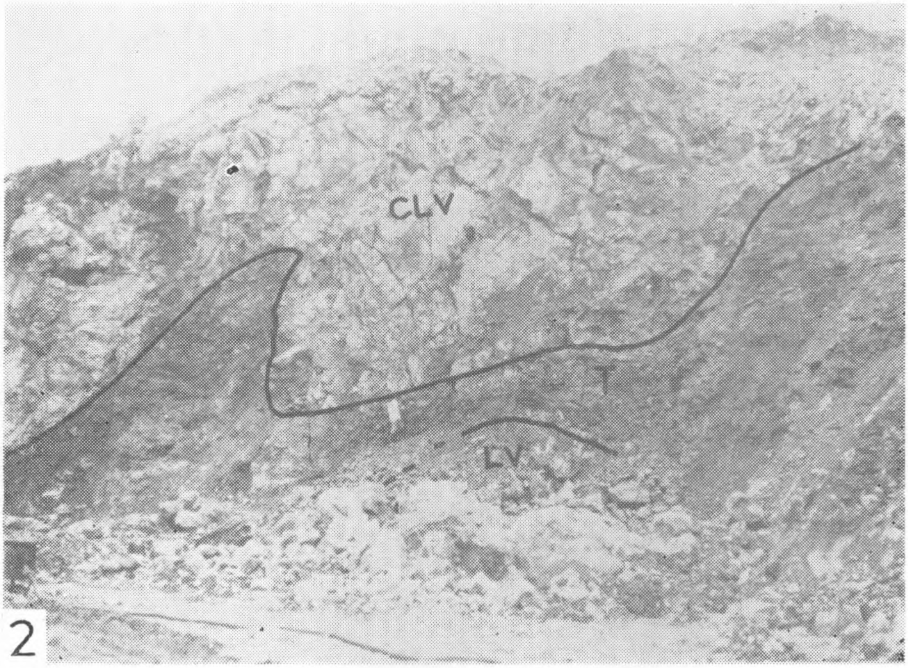
Geological setting

The Lower Carboniferous rocks which occur in the Czatkowice quarry (Figs. 1, 2) form the western limb of the Dębnik anti-

* Jagiellonian University, Institute of Geological Sciences, ul. Oleandry 2a, PL 30-063 Kraków, Poland

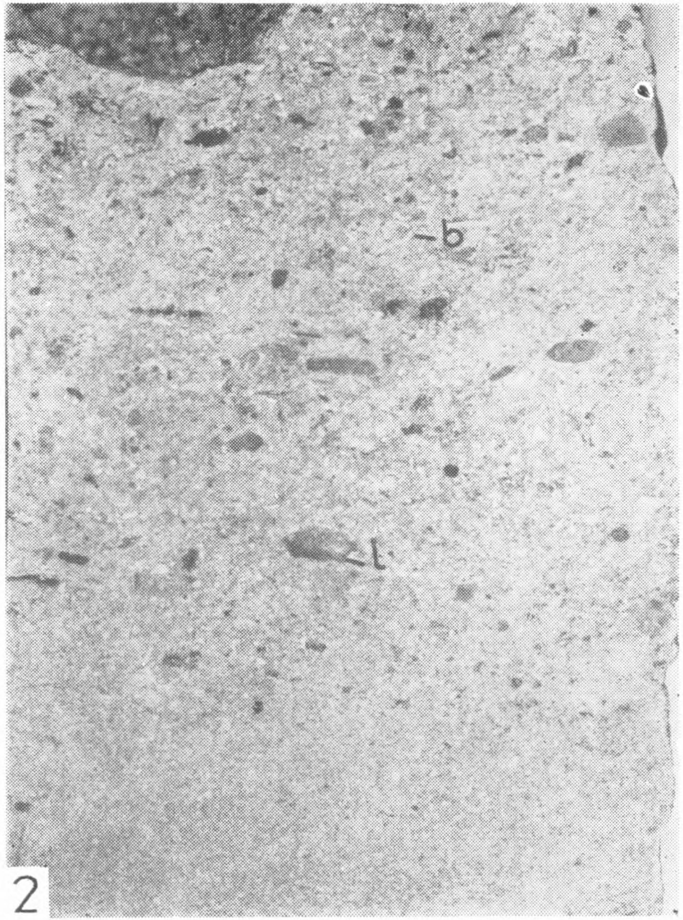


Phot. 1. View of the north wall at Czatkowice quarry (level 310). Outline indicates a preserved fragment of cave (locality 1) with bone breccia in the lower part — arrow bb_1; bb_2 — place covered by rubble heap, fragments of bone breccia were chaotically distributed in greenish loams and gypsum (Phot. J. Wieczorek)



Phot. 2. View (October, 1979) of quarry wall (level 370), locality T. Fragment of a cave filled mainly by tuffites (T) is marked, LV — Visean limestones forming the floor of the cave, CLV — Visean limestones coming from the collapse of the cave roof

(Phot. J. Wieczorek)

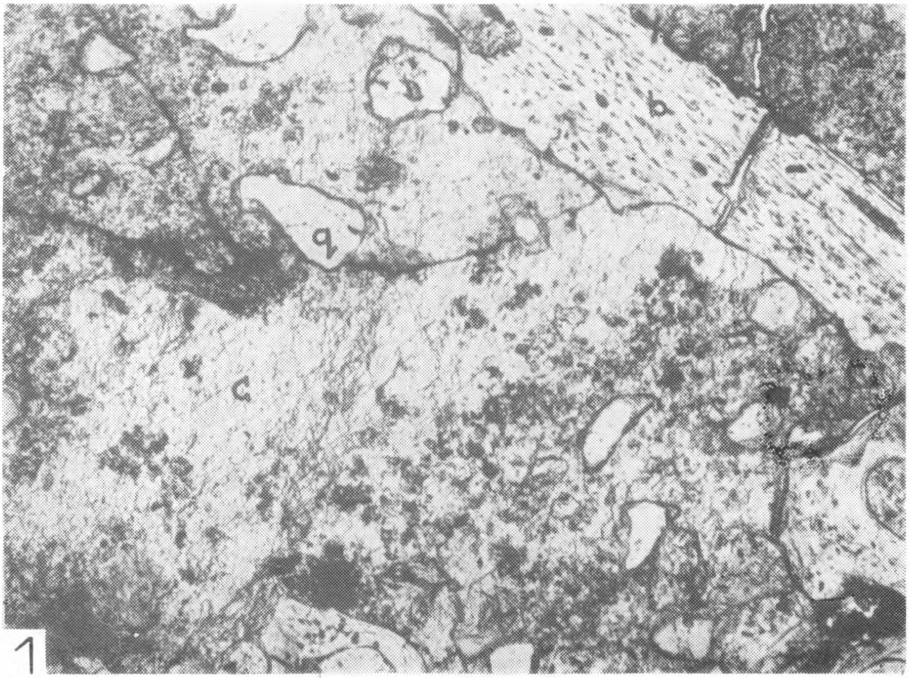


Phot. 2. Cross-section through block of bone breccia (locality 1): 1 — fragments of Lower Carboniferous limestones, b — fragments of bones (× 1)

(Phot. K. Fedorowicz)

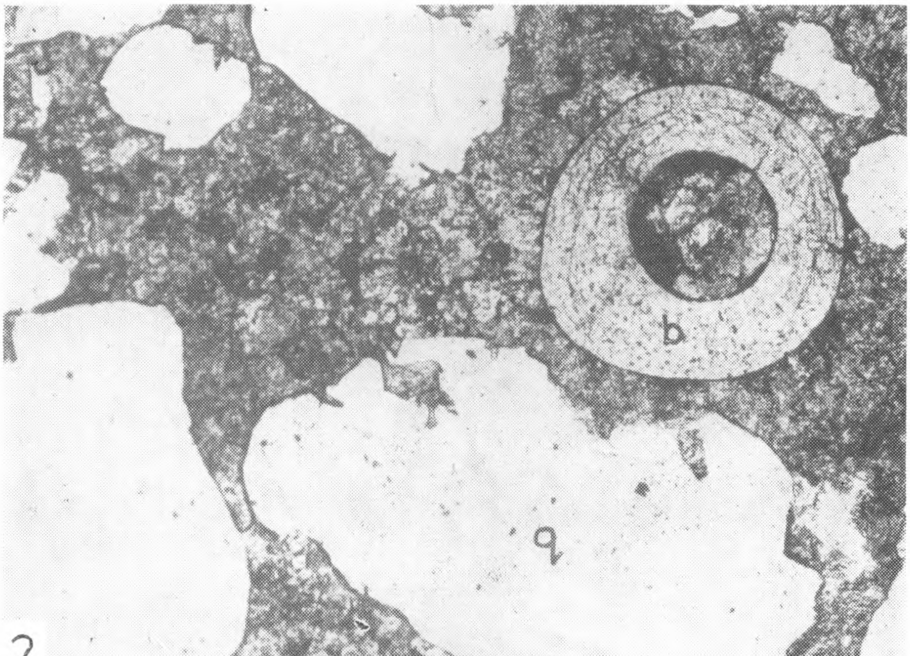
Phot. 1. Upper part of locality 1 filled with sandy non-cemented deposits (s). Calcite flowstones are preserved on the walls

(Phot. J. Wieczorek)



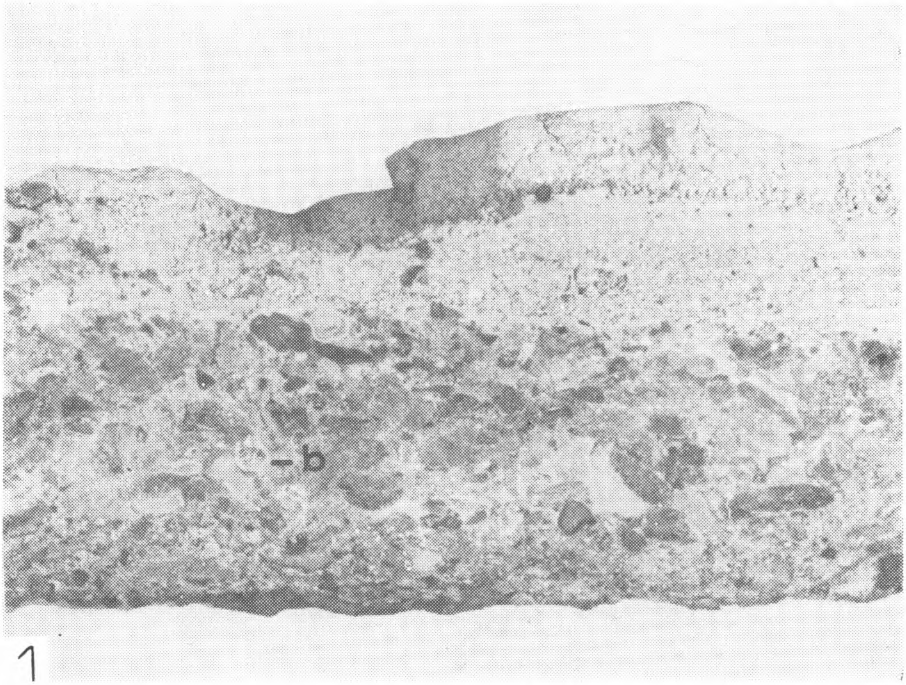
Phot. 1. Thin-section of bone breccia, locality 1: b — bones, q — quartz, c — calcite, (× 75)

(Phot. J. Wieczorek)



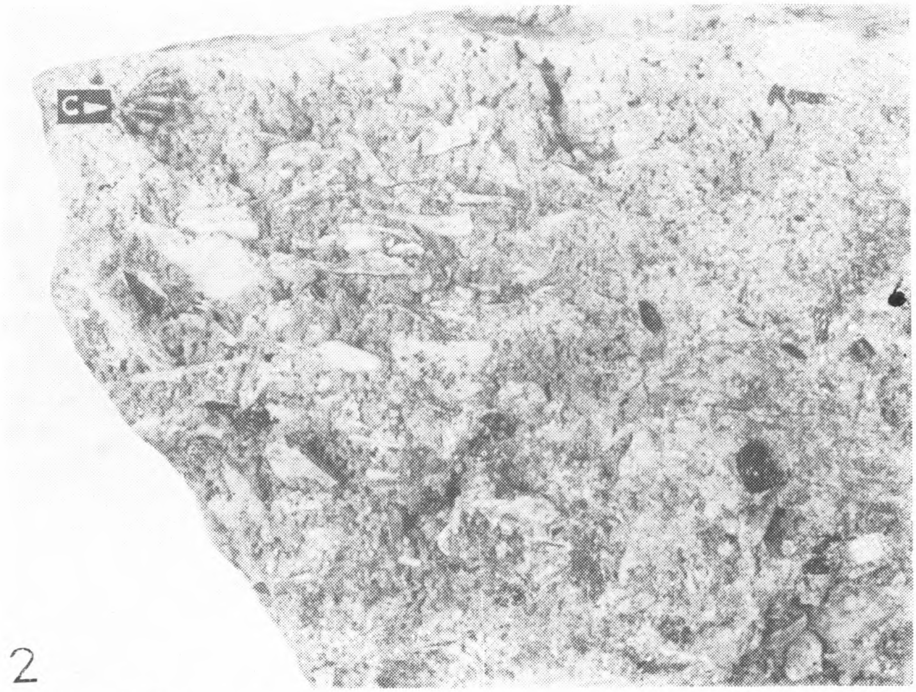
Phot. 2. Thin section of bone breccia, locality H: b — bones, q — quartz, (× 75)

(Phot J. Wieczorek)



Phot. 1. Cross-section through conglomerate block with pebbles of Lower Carboniferous limestones and bones (b), locality 1, (× 1)

(Phot. K. Fedorowicz)



Phot. 2. Fragment of bone breccia, locality H (× 1). Fragments of bones and a tooth of *Ceratodus phillipsi* can be seen (C)

(Phot. K. Fedorowicz)

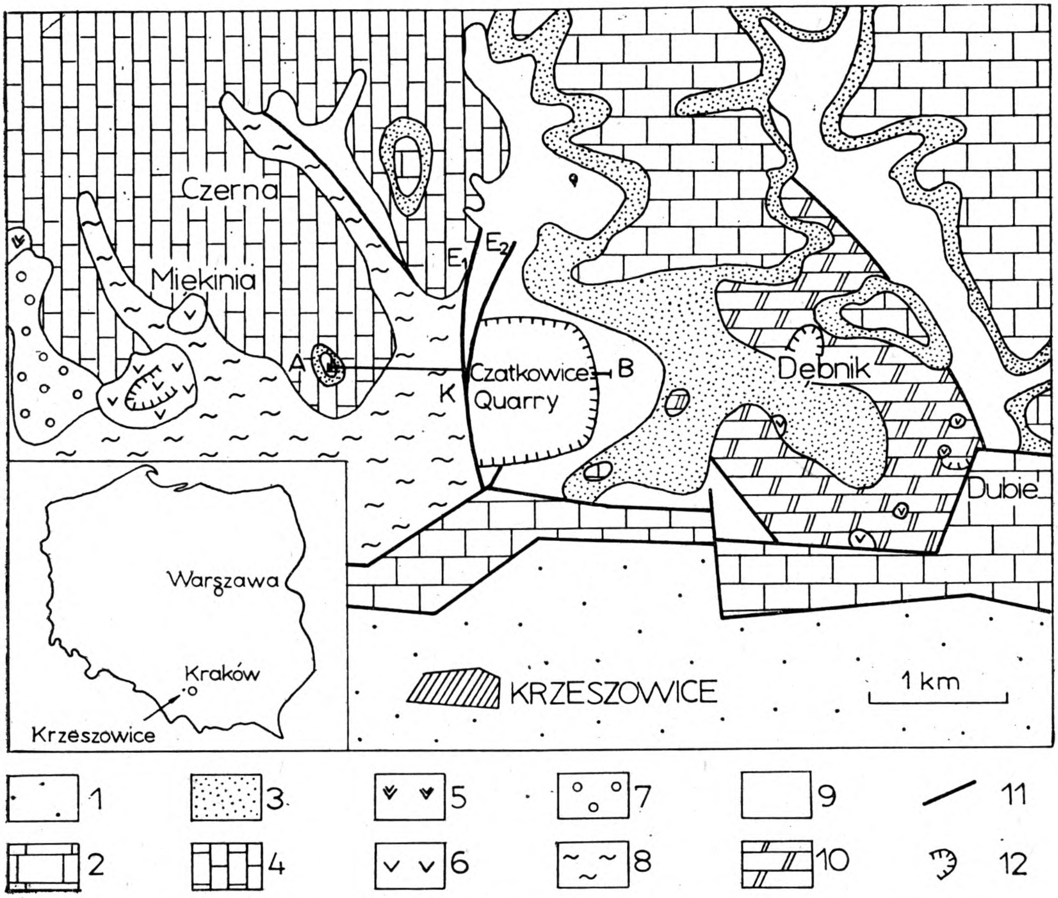


Fig. 1. Geological sketch-map of Czatkowice area, modified from R. Gradziński (1972):

1 — Tertiary, 2 — Upper Jurassic, 3 — Middle Jurassic, 4 — Triassic, 5—7 — Permian (5 — Filipowice Tuffs, 6 — porphyries, 7 — Myślachowice Conglomerates), 8 — Upper Carboniferous (together with Malinowice beds — Upper Visean-Namurian A), 9 — Lower Carboniferous, 10 — Devonian (Givetian through Famennian), 11 — main faults, 12 — quarries; A—B — line of the geological cross-section presented at Fig. 2

cline (vide Siedlecki, 1954; Bogacz, 1977). Within the quarry there is a change of dip of the beds, from 50—60°, in the eastern part of the quarry, to about 90° in the central part, and in the most western part the beds dip in the Eastern direction (Fig. 2) The strike of the beds is approximately meridional. This western limb of the Dębnik anticline is called the Czatkowice flexure (Bogacz, 1977).

The central part of the Dębnik anticline is composed of dolomites and limestones of Givetian to Famennian age (Siedlecki, 1954; Baliński, 1979). However in the Czatkowice quarry the upper part of the Tournaisian and Lower and Middle Visean are exposed. The Tournaisian is represented by dark, bituminous well-bedded limestones. The thickness of beds varies from 20 to 100 cm. Usually calcirudites form the thick layers, while thinner one consist of calcarenites and calcilutites. In some layers flints are present. The Visean is represented chiefly by well-bedded calcarenites and calcilutites, usually lighter in colour than the Tournaisian ones, but in the we-

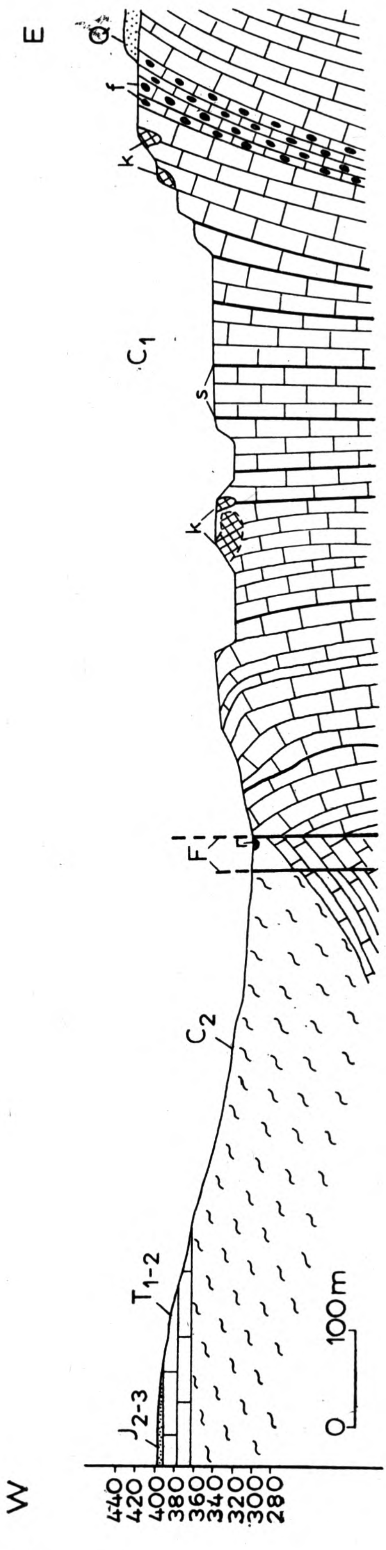


Fig. 2. Cross-section through the Czatkowice quarry, modified from K. B o g a c z (1977): C_1 — limestones of the Upper Tournaisian (the most eastern part of the profile) and the Lower and Middle Visean, C_2 — Malinowice beds (Upper Visean-Namurian A), T_{1-2} — Triassic (Röth and Muschelkalk), J_{2-3} — Jurassic (Callovian and Oxfordian), **f** — flints, **k** — karst forms, **s** — slates, **F** — faults, **r** — river

stern part of the quarry limestones (chiefly calcirudites) which are almost white in colour. Visean limestones contain more than 90% $CaCO_3$ by weight and their porosity is about 1% (K a m i e ń s k i, R u t k o w s k i, 1975). In some parts limestones are dolomitized.

The Middle Visean rocks are in faulted contact with the Malinowice Beds (Upper Visean-Lower Namurian) along the Krzeszówka fault, to the west of the Czatkowice quarry (Fig. 2). In the area to the west of Krzeszówka and Eliaszówka faults the Carboniferous rocks (Lower Carboniferous and lower part of the Upper Carboniferous) are covered by Triassic (Röth and Muschelkalk) and Jurassic (Callovian and Oxfordian) deposits. Bunter Sandstone was found only at Czerna, in clastic dykes (A l e x a n d r o w i c z, 1957). Further to the west, in the area of the Miękkinia and Karniowice, Carboniferous rocks are covered by the Permian continental Myślachowice Conglomerates, locally by the Karniowice Travertine, by porphyries and locally by melaphyres, and also by Filipowice Tuffs and tuffites also of Early Permian age (see S i e d l e c k i, 1954, B o g a c z, 1967). However, there are no Permian and Triassic deposits to the east of the Krzeszówka and Eliaszówka faults, and the older Paleozoic rocks (Lower Carboniferous and Devonian) are directly covered by Middle Jurassic deposits (see J u r k i e w i c z o w a, 1974). Only in localized infillings of karst forms can the Lower or Upper Triassic and Jurassic, pre-Callovian deposits be found.

Characteristics of the karst localities

Numerous karst forms can be observed in the Czatkowice quarry (Fig. 3). They have developed in almost vertically bedded Lower Carboniferous limestones. Such an arrangement of beds caused the development of very deep karst forms. The fossil karst forms are filled with clayey, silty and sandy sediments and in some fillings remnants of vertebrates were found occuring either seperately or in bone breccia. In addition to the recorded bone-bearing localities within quarry, a number of blocks with bone

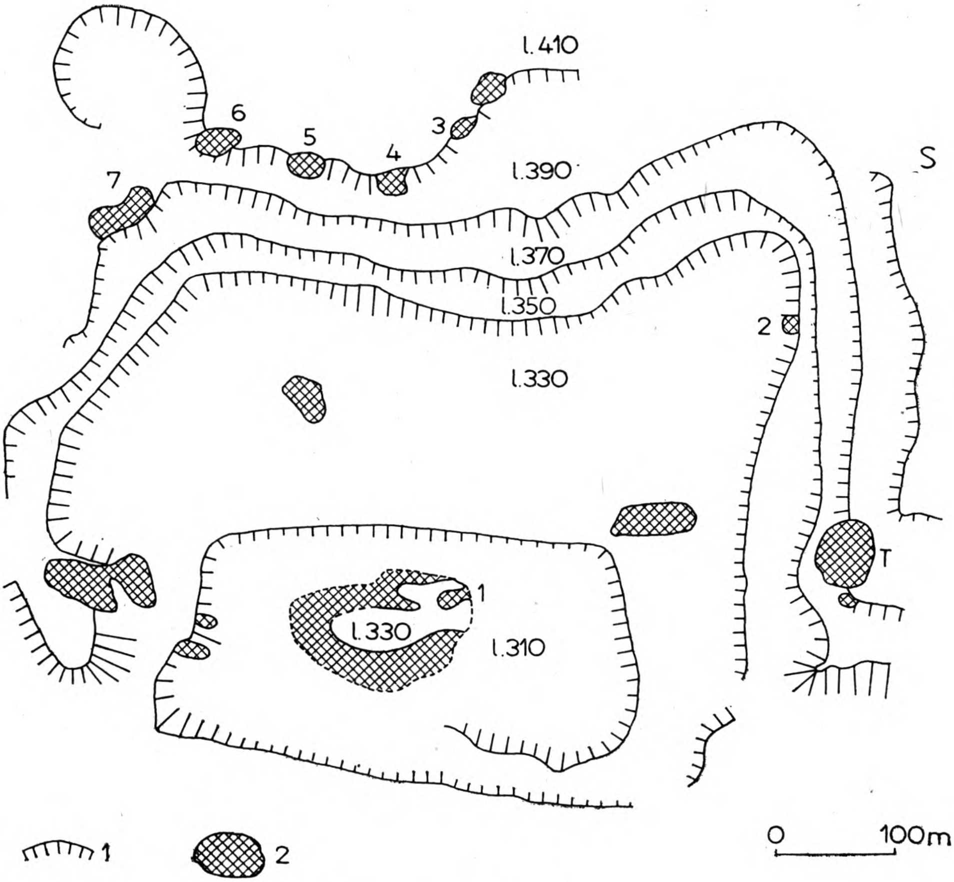


Fig. 3. Sketch map of the Czatkowice quarry (in 1979):
1 — escarpments, 2 — fossil karst forms. Bone-bearing karst forms are marked by numbers; T — a cave filled mainly with tuffites. Symbols l. 310 etc. indicate levels of exploitation and their heigh above the sea-level

material were found on the waste-heaps of the quarry (localities H and D). Undoubtly these blocks came from the infillings of karst forms which have been quarried away but their primary localization is problematic.

Locality Czatkowice 1

This is a fragment of a cave, preserved at 330 m above sea level (Fig. 3, Pl. 1, Phot. 1) which has developed along the bedding planes of Visean limestones. The walls of the upper part of the cave are „pock-marked" covered in places by calcite flowstones 20—30 centimeters thick (Pl. 2, Phot. 1). The upper part of the cave is filled with a 2 meter thick sequence of yellow sands, and the lower part contains green-brownish cave loams with gypsum intercalation and calcite flowstones. In this 6 m thick sequence, numerous fragments of calcite flowstones and Lower Carboniferous limestone occur. The lowest part of the cave is filled with bone breccia layers (Pl. 1, Phot. 1, Pl. 2, Phot. 2, Pl. 3, Phot. 1) totalling about 70 cm thick. The lower bone breccia bed, about 40 cm thick is penetrated by calcite flowstones and cave loams from the upper breccia bed, about 25 cm thick. The bone breccia is vertically cracked and the cracks are filled by cave loams. Similar loams occur below the bone breccia. The adges of separated blocks of the bone breccia are slightly rounded. In the eastern part of the cave (bb_2 in Phot. 1 on Pl. 1) smaller and separated blocks of bone breccia occur in cave loams. The bone breccia material from the locality Czatkowice 1 contains numerous fragments of reptile bones of the *Prolacertillia* and *Proterosuchia*. These bones are not abraded and are completely or partly filled by calcite and in this latter case show geopetal structures. The prolate fragments of bones show a discernible directional arrangement. In the bone breccia containing calcite cement, 15—20% of the rock is composed of well rounded quartz grains having an average diameter of 0,2 mm but sometimes reaching 1,0 mm in size. In one of the loose blocks of breccia (consisting mainly of well rounded, slightly silificed pebbles of Lower Carboniferous limestones) occasionaly fragments of tuffites and broken bones were stated (Pl. 4, Phot. 1). The bone breccia sediments were mechanically deposited in depressions in the cave floor. Layers of breccia may possibly have been broken into blocks and smaller fragments redeposited in deeper parts of the cave.

Text-Phot. 1. Block of bone breccia, locality H

(Phot. K. Fedorowicz)

Locality Czatkowice 2

This was a small fragment of a cave, now completely destroyed. It was filled mainly with cave loams and silty and sandy sediments as well as numerous remnants of vertebrate bones, fish scales and *Ceratodus* teeth. Bones accumulated in sandy laminae, a few cm thick, which were also rich in quartz grains. It is possible that bone breccia material found on the waste--heaps of the quarry (locality Czatkowice H) was derived from this cave.

Locality Czatkowice H

The blocks of bone breccia (Pl. 3, Phot. 2, Pl. 4, Phot. 2, text-Phot. 1) which were found during the Summer of 1978 on the quarry dumps are full of *Ceratodus* teeth. The majority of them most probably represent the species *Ceratodus phillipsi* Agassiz (det. J. Wieczorek). They also contain numerous squama and bone fragments of fish *Pycnodontidae, Semionotidae* and *Pholidophoridae* and fragments of amphibians — probably *Capitosauroidea* (det. T. Maryańska) bone. The vertebrate remains occur in lamine which obliquely contact the beds of the dolomitized Lower Carboniferous limestones (text Phot. 1). Individual laminae differ slightly in respect to the quantity, state of preservation and taxonomic composity of bone material and to the quantity of quartz grains. Angular and subangular quartz grains having a diameter of about 0,5 mm occur in laminae and represents up to 50% of the rocks. Idiomorphic quartz cristals also occur occasionaly. The heavy mineral composition of the bone breccia is as follows — zircon — 68,5%, tourmaline — 12,0%, garnet — 11,0%, rutile — 6,0%, epidote — 2,0%, staurolite — 0,5%. This is similar to sandy the Middle Jurassic deposits of the Krzeszowice region (see Krysowska, 1960). The vertebrate bones and teeth are unabraded which testifies to the short mechanical transport and quick deposition of unlithified fragments.

Other localities

Numerous remnants, mainly the bones of reptiles were found in the dolomitized bone breccia (locality Czatkowice D). Blocks of this breccia were found on the waste-heaps in the quarry. Remnants of vertebrates were also found in several other fillings of the karst forms (localities 3—7 in Fig. 3) which have not been yet investigated in detail. A some specimens of teeth of theromorph reptiles (preliminary det. Prof. Zofia Kielan-Jaworowska) were found in localities 4—5 which represent large karst forms filled with clays and silts.

Locality T. This is a large cave (Pl. 1, Phot. 2) filled mainly with porphyritic tuffs and tuffites containing fragments of porphyries and Lower Carboniferous limestones. The infillings also contain a 40 cm thick calcite flowstone layer, pink limestone laminae and a layer of red jasper. In the tuffites ripplemarks, graded bedding and sedimentary dykes filled with laminated pink limestone are all visible indicating that the tuffites were washed in the large karst forms which were at least partly filled with water. On the basis of the spatial relations between cave material and the Carboniferous host limestone one can conclude that the roof of the cave collapsed and because of the pressure of the collapsed rock layers of cave infillings were broken.

Age of the karst forms

From analysis of the geological history of Cracow Upland and from the known age of bone material filling karst forms in Czatkowice quarry one may assume that two phases of karstification took place in the area during the Late Paleozoic and Early Mesozoic:

— between the Late Carboniferous and Röth,

— between the Late Triassic and Callovian.

The first phase began after the development of the Dębnik anticline during the Late Variscan movements in the Late Carboniferous. The warm climate was favourable to the development of the karst processes in the Lower Carboniferous limestones which were exposed after the erosion of the thin cover of the Upper Carboniferous clastic deposits. The origin of the cave filled with tuffites at Czatkowice (locality T) may be correlated with this phase of karstification. The lack of allochtonous younger material in the tuffites suggests that the filling of the cave was probably simultaneous or almost simultaneous to the Early Permian volcanic activity which took place in the Cracow Upland.

Karst processes may possibly continued in the Late Permian as the Zechstein transgression never reached the region. Likewise, during the Earliest Triassic the paleogeographic conditions were also favourable for continental processes, including karst. This continental phase was ended by the Röth transgression. The development of locality Czatkowice 1 is associated with this Permo-Triassic karst phase. Sediments infilling this cave are somewhat younger than those filling locality T. This is evident because of the presence of rare redeposited fragments of tuffs as well as the occurence of an Early Triassic and perhaps Upper Permian vertebrate fauna (*Prolacertillia* and *Proterosuchia*). The remnants of these small terrestrial creatures were swept into the cave before they underwent fossilization on the surface. Presumably the cave was completely filled with sediments before the Röth transgression. There is, however no reason to believe that these karst processes persisted into the Middle Triassic, as was the case in the area of Klucze-Gliny, where karst processes still took place on isolated islands (Głazek et al., 1972). In the Czatkowice region, the Röth Sea transgresses upon a land surface of very low relief (Siedlecki, 1955: Łydka, 1956). In the Cracow Upland, karst processes could have been renewed after the regression of the Muschelkalk Sea and before the advance of the Callovian Sea. In this phase karst features were developed on the Middle Triassic limestone in the western parts of the Cracow Upland, whereas in the eastern part, east of the Krzeszówka and Eliaszówka faults, on the Paleozoic basement, karstification affected Upper Devonian and Lower Carboniferous limestones. The Krzeszówka--Eliaszówka fault line was undoubtedly active during Late Triassic tectonic movements. The uplifted eastern block of the Cracow Upland was erosionally stripped of its cover of Muschelkalk limestone. In this region, the cover of the Keuper and Rhaetic is also missing, exept in isolated localities where deposits of this age are preserved as infillings of karst forms. This Keuper and Rhaetic formations are more fully preserved in the region of Chrzanów (Siedlecki, 1952; Bilan, 1976). A subtropical climate during the Late Triassic and Early Jurassic is evidenced by the occurence of coal, kaolinite clays and a diagnostic flora (Znosko, 1955). Such climatic conditions were favourable to the development of karst processes in the Cracow-Silesia Upland (see also Gilewska, 1971). Karst forms associated with this phase have already been described in the literature (Siedlecki, 1955: Górzyński, 1963; Lipiarski, 1971; Głazek et al., 1972; Głazek, 1973; Grodzicka-Szymanko, 1978) but they have not been adequately dated paleontologically. The localities Czatkowice 2 and H infilled by the ceratodus bone breccia can be correlated with this phase of karstification. The age of these infillings is documented by the occurence of numerous specimens of *Ceratodus phillipsi*, cited by L. Agassiz (1833) from Lower and Middle Jurassic sediments, as well as by the occurence of fishes — *Pycnodontidae*, *Semionotidae* and *Pholidophoroidae* which suggest an age no older then the Late Triassic. These organisms inhabited fresh water (personal communications — Dr. T. Maryańska).

It is interesting to note that such a large accumulation of terrestrial Early Mesozoic vertabrate remnants has not been found in Poland before. Individual reptiles and *Ceratodus* have been reported from the Rhaetic Lisow Breccia (Roemer, 1870) and remnants of *Labyrinthodonts* have been reported from Lower Triassic (Labirinthodont Beds) from the Holy Cross Mts. (*Senkowiczowa*, 1976). Vertebrate remains are also known from the Muschelkalk Limestone from the Cracow region (Siedlecki, 1952) and from the Holy Cross Mts (Liszkowski, 1973) as well as from the Upper Triassic of the Miechów synclinorium (Pawłowska, 1978). These represent marine forms like those found in many „bone-beds" described from the Upper Triassic of Germany and England (see Reif, 1971; Sykes, 1977; Antia, 1979). Marine as well as terrestrial reptiles of Middle Triassic age (see Tarlo, 1959) were found in cave bone breccia from the Stare Gliny quarry (Lis, Wójcik, 1959, 1960; Głazek, 1973).

This article contains only the preliminary results of investigations of karst forms in the Czatkowice region. The authors intend to continue further work on this subject with the cooperation of other specialists.

English text by the authors

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Mariusz Paszkowski, Józef Wieczorek

KOPALNY KRAS Z MEZOZOICZNYMI BREKCJAMI KOSTNYMI W CZATKOWICACH KOŁO KRZESZOWIC (WYŻYNA KRAKOWSKA)

Streszczenie

W wapieniach dolnego karbonu odsłaniających się w kamieniołomie Czatkowice (ryc. 1, 2) rozwinięte są liczne formy krasu kopalnego (ryc. 3). Wypełnienia niektórych form zawierają szczątki kręgowców (ryb, płazów lub gadów) występujące pojedynczo lub tworzące brekcje kostne. Na podstawie analizy historii geologicznej rejonu Czatkowic oraz uwzględniając wstępne dane paleontologiczne i petrograficzne o wypełnieniach form krasowych można sądzić, że istniały na tym obszarze dwie fazy krasowienia podczas późnego paleozoiku i mezozoiku. Pierwsza faza rozpoczęła się w późnym karbonie po wypiętrzeniu antykliny Dębnika i usunięciu znad wapieni dolnokarbońskich pokrywy klastycznych utworów karbonu górnego. Zakończenie tej fazy nastąpiło po przykryciu obszaru Wyżyny Krakowskiej przez morze retu. Warunki klimatyczne w tym okresie sprzyjały rozwojowi procesów krasowych, a silne nachylenie warstw karbonu uwarunkowało rozwinięcie się w Czatkowicach głębokich form krasowych, sięgających sto kilkadziesiąt metrów poniżej powierzchni terenu. Tę fazę krasowienia dokumentuje duża jaskinia (stanowisko Czatkowice T — ryc. 3, pl. 1, fot. 2) wypełniona głównie tufami i tufitami podobnymi do dolnopermskich tufów filipowickich. Można sądzić, że wypełnienie tej formy krasowej materiałem tufitowym było synchroniczne lub niemal synchroniczne z erupcjami wulkanicznymi, jakie miały miejsce w rejonie Krzeszowic podczas wczesnego permu. Również z tą fazą można wiązać powstanie i wypełnienie formy krasowej (stanowisko Czatkowice 1 — ryc. 3, pl. 1, fot. 1, pl. 2, fot. 1) zawierającej w spągowej partii brekcję kostną (pl. 2, fot. 2, pl. 3, fot. 1, pl. 4, fot. 1). W brekcji obecne są liczne szczątki drobnych lądowych gadów z grupy *Prolacertillia* i *Preterosuchia* (det. dr T. Maryańska). Sposób występowania i stan zachowania szczątków kręgowców wskazuje na namycie ich do formy krasowej, nim zostały pogrzebane w osadzie na powierzchni terenu. Druga faza krasowienia na obszarze Czatkowic rozpoczęła się w późnym triasie po ustąpieniu morza wapienia muszlowego, a zakończyła definitywnie wraz z transgresją morza kelowejskiego. Podczas późnego triasu rejon Czatkowic był wynoszony tektonicznie wzdłuż uskoków Krzeszówki i Eliaszówki, co doprowadziło do intensywnej erozji i usunięcia pokrywy wapienia muszlowego. Procesom krasowym na tym obszarze podlegały ponownie odsłonięte wapienie dolnego karbonu. Ten okres krasowienia dokumentowany jest w Czatkowicach formami krasowymi zawierającymi w wypełnieniach brekcje kostne (text fot. 1, pl. 3, fot. 2, pl. 4, fot. 2) z bardzo licznymi szczątkami ceratodusów (głównie gatunek *Ceratodus phillipsi* — det. dr J. Wieczorek), a także innych słodkowodnych ryb (głównie z grup *Semionotidae, Pycnodontidae, Pholidophoridae* — wstępne oznaczenia dr T. Maryańskiej) oraz labiryntodontów.

Mariusz Paszkowski, Józef Wieczorek

BRÈCHES OSSEUSES MÉSOZOÏQUES DANS LE KARST FOSSIL À CZATKOWICE PRÈS DE KRZESZOWICE, LE HAUT-PLATEAU DE CRACOVIE (POLOGNE)

Résumé

A Czatkowice dans la carrière des calcaires du Carbonifère inférieur ont été constatés quelques sites du karst fossil avec des ossements de vertébrés (poissons, amphities, reptiles) formant des accumulations de type de brèches osseuses. L'analyse de l'histoire géologique de la région étudiée et les déterminations préliminaires des ossements de vertébrés permettent de constater que ces formes karstiques se sont formées au cours des phases de karstification dans le Carbonifère supérieur — le Triasique inférieur (avant le Roeth) et dans le Triasique supérieur — le Jura moyen (avant le Callovien).

Traduit par Teresa Korba-Fiedorowicz

Teresa Madeyska*

Late Pleistocene cave deposits in Poland

Abstract: A review of archaeological, palaeozoological and geological methods and results of investigations of Late Pleistocene sediments in caves and rock shelters in Poland is presented here, with a particular description of the Cracow—Wieluń Upland. A reconstruction of a natural environment during Late Pleistocene and an estimate of its influence on colonization by Palaeolithic people recapitulate the multidisciplinary natural and archaeological investigations.

Studies up to recent times

Late Pleistocene cave and rock-shelter deposits are interesting because of their noted habitation traces and artifacts of ancient man, accompanied by animal remains. The first excavations in Poland were located in the Cracow—Wieluń Upland at the end of the XIXth century. The same area has been to date the most interesting one from the point of view of possible complex investigations as it was the main area of recognized traces of Middle and Late Palaeolithic cave colonization (Fig. 1, 2, 3).

In the Holy Cross Mts., a single Middle Palaeolithic site has been noted — the Raj Cave (Studies..., 1972). Detailed investigations of sediments of the Niedźwiedzia Cave in the Kłodzko Basin (Pulina, 1970; Wiszniowska, 1970, 1976, 1978) have not supplied us with undisputable traces of men. In the caves of the Tatra Mts. no traces of ancient man have been found and spurious finds of a so-called culture of cave bear hunters in the Magura Cave (Jura, 1955) should be ignored.

In the Cracow—Wieluń Upland about 40 caves and shelters have been investigated over the last hundred years (Fig. 2 and 3). These sites are of varying value for prehistoric and natural studies; on the one hand it is an effect of varying standard of investigations, dependant on the progress of excavating methods, on the other hand it depends on types of sediments.

Among the investigated sites there are large passage caves as well as small shelters of the narrow-passage type, seldom cutting the rock right through but also shallow rock niches and small preserved fragments of larger caves.

There are various types of sediments in caves and shelters. A general regularity: in large caves the sediment sequences could be deposited without a remarkable sedimentary break since the end of the Last Interglacial until Holocene; in shelters and close to the cave entrances the sediments could be more easily destroyed — their preserved fragments usually correspond with a younger part of that period (Madeyska, 1972b, 1977).

Comprehensive studies after the last world war have been carried out in 22 sites; thirteen of them enclosed the habitation traces of Palaeolithic man and many — of Neolithic man. In 13 sites a fossil fauna was analyzed completely or fragmentarily and in 12 sites — detailed analyses of sediments were done. The excavations were carried out by archaeologists of Warsaw, Cracow and Częstochowa centres (institutes of

* Institute of Geology of the Polish Academy of Sciences, Laboratory of Quaternary Geology, al. Żwirki i Wigury 93 PL 02-089 Warszawa, Poland

Fig. 1. General location map, showing (**A**) the Cracow—Wieluń Upland (for details — see Fig. 2) and other investigated localities of cave deposits in Poland

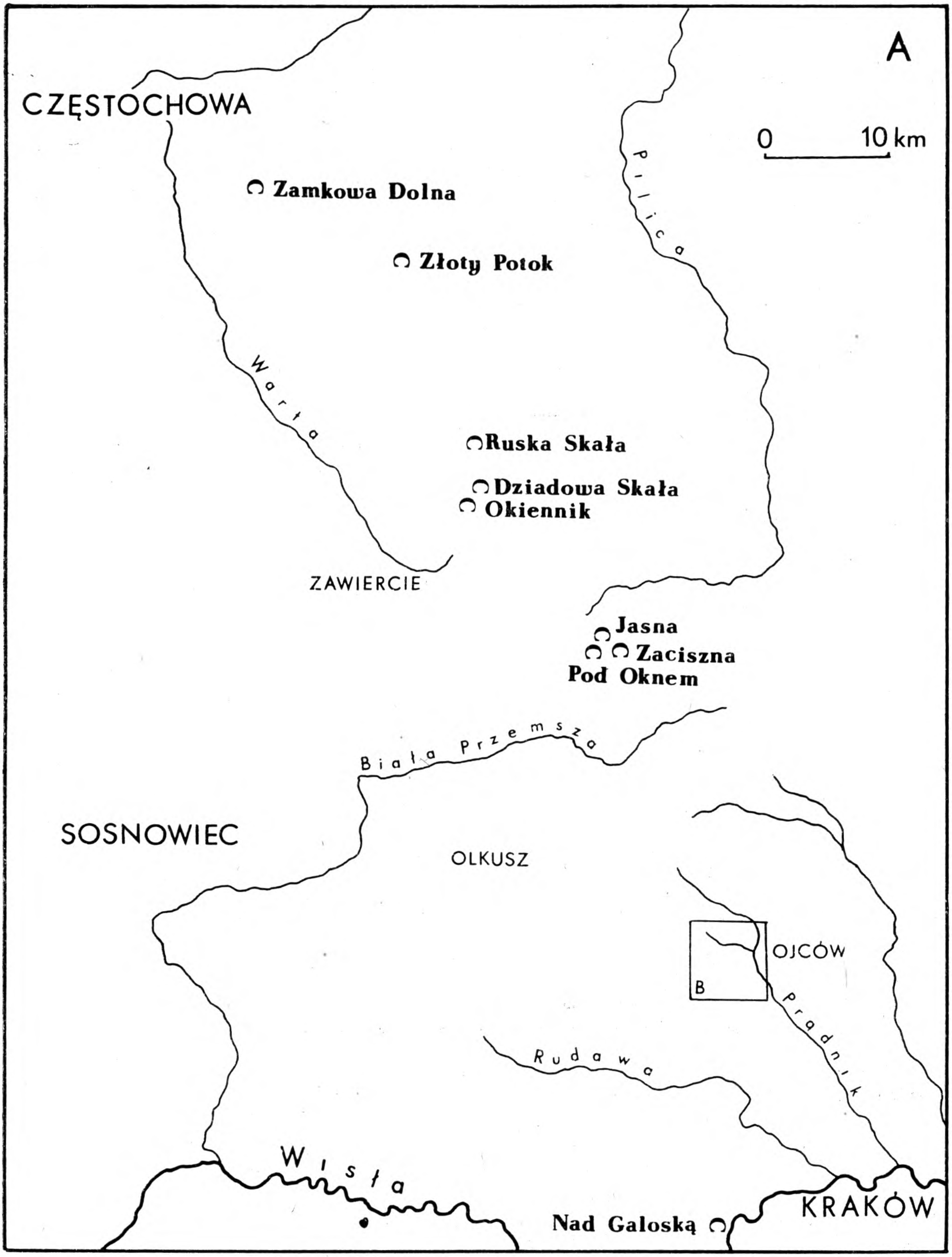


Fig. 2. Location map showing investigated localities of cave deposits in the Cracow—Wieluń Upland (inset **B** is presented at Fig. 3)

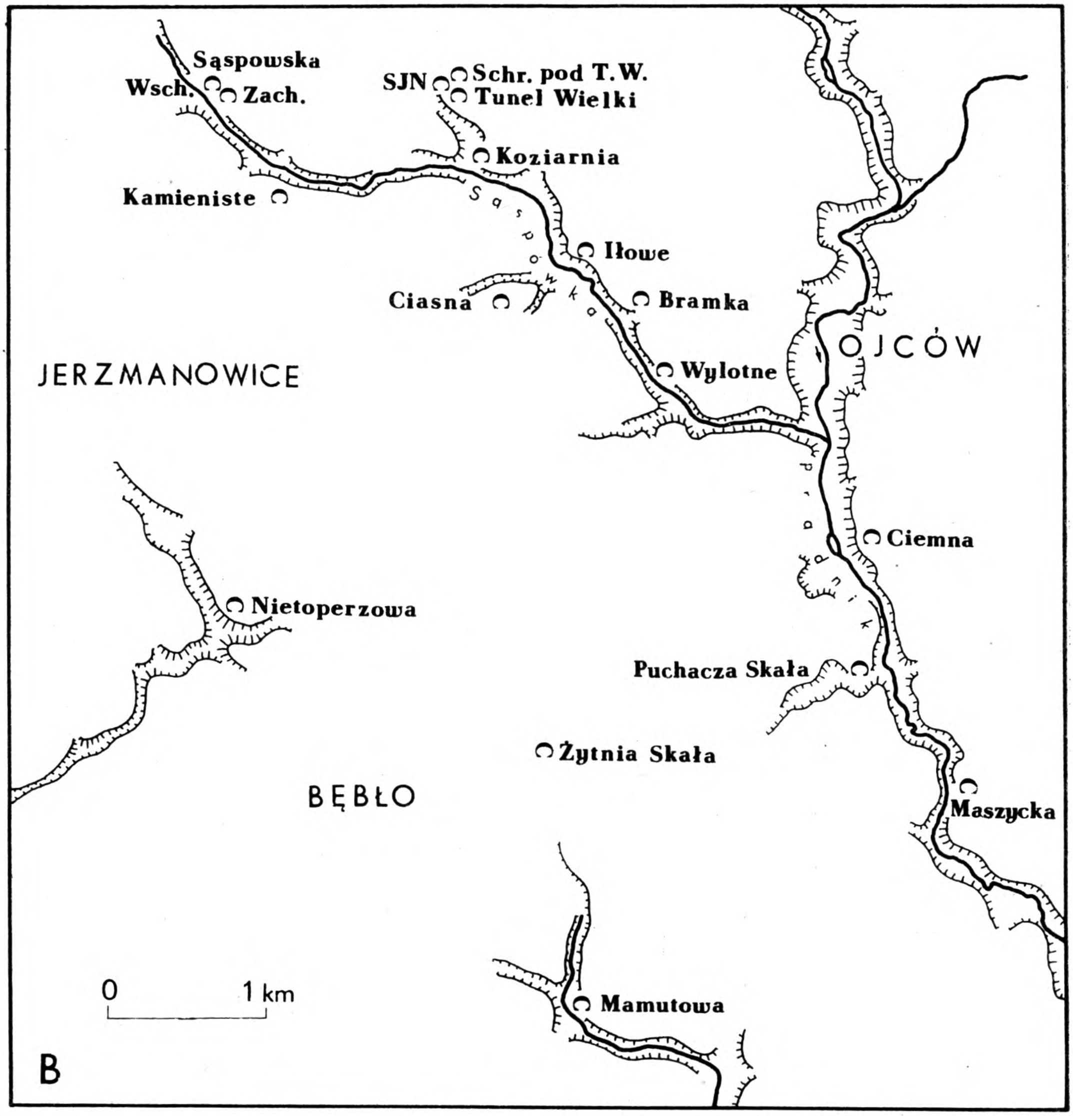


Fig. 3. Location of cave localities near Ojców: SJN — Shelter above the Niedostępna Cave, Schr. pod T. W. — Shelter beneath the Tunel Wielki Cave

Archaeology of the Jagiellonian and Warsaw Universities, Institute of History of Material Culture — Polish Academy of Sciences — in Warsaw, Archaeological Museum in Cracow, Regional Museum in Częstochowa), several ones with collaboration of geologists (Institute of Geological Sciences, Polish Academy of Sciences in Warsaw) and of zoologists (Laboratory of Systematic and Experimental Zoology, Polish Academy of Sciences in Cracow). Many of these sites are described in full monographs whereas others are known from papers dealing with some problems only.

Main directions of archaeologic investigations

Typologic-chronologic direction of investigations before World War II

In the first phase of investigations in the cave sites there was a tendency to collect as many archaeologic implements as possible; the material was then interpreted by a typologic analysis, applying the connections with Paleolithic cultural units defined in Western European countries. Results of these investigations are now scattered in many papers. An analysis of archaeological investigations of that period was done by J. Kostrzewski (1949), whereas a history of cave explorations — in a monograph of K. Kowalski (1951—1954); so I would like to mention the most important papers only.

W. Demetrykiewicz (in: Demetrykiewicz, Kuźniar, 1914) described the most ancient assemblage known at that time of Paleolithic flint tools from the Okiennik Cave near Skarżyce; he noted there the similarities with assemblages from la Micoque in France and with Mousterian of the La Quina type. S. Krukowski (1921) published the results of investigations of the caves near Złoty Potok; there, only Neolithic archaeological evidence has been found.

First recapitulation of investigations on the Paleolithic in Poland was presented by L. Kozłowski (1922, 1925). He compiled all the few stratigraphical and paleontological evidence of him and of other authors known at that time and collected in Mamutowa Cave (Zawisza, 1874, 1877), Nad Galoską Cave (Ossowski, 1881), Maszycka Cave (Ossowski, 1884, 1885), Nietoperzowa and Koziarnia Caves (Römer, 1883, 1884) and others, but also some of information published later on, collected by S. J. Czarnowski (1924) in the Puchacza Skała Shelter.

L. Kozłowski correlated an assemblage of flint artifacts from the Okiennik Cave with so-called Late Acheulean Epoch (in agreement with a contemporary interpretation of archaeologic cultures as the chronologic units) and the assemblages from the Nad Galoską Cave and the Mamutowa Cave — with the Mousterian Epoch. The Upper Paleolithic in many caves was connected with Solutrean and Magdalenian Epochs. At the same time he analyzed the relation of Paleolithic cultures with periods and phases of a glacial epoch describing the contemporary natural conditions and refering to paleoclimatic curves.

The recognition and definition of new cultural units and investigations of their evolution

A comprehensive monograph of S. Krukowski (1939—1948) contains information from numerous original authors studies. On the basis of his own investigations he defined a so-called „Dupice" industry of the Okiennik site. In the Ciemna Cave (Krukowski, 1924) an assemblage older than that one from Okiennik was distinguished and correlated with the Riss Glaciation. To the beginning of the Last Glaciation was ascribed the younger assemblage named the „Ojców" industry of the Ciemna Cave. The author also described the Aurignacian assemblages, among others of the Mamutowa Cave. The monograph had been for many years the principal synthesis and handbook of the Paleolithic in this country. The next synthesis was published over 35 years later (Chmielewski, 1975).

As a result of more and more precise excavating methods a possibility arose to study the evolution of every culture, and also, to prepare their more exact stratigraphy e.g. monographs of Jerzmanowician (Chmielewski, 1961) and the Micoquo-Prondnikian (Chmielewski, 1969a) cultures.

The Upper Paleolithic Jerzmanowician culture was distinguished on the basis of three assemblages from Nietoperzowa Cave. Similar assemblages have also been found in the Koziarnia and Mamutowa Caves. Among the flint artifacts of this culture the leaf-like points predominate; they are considered to be the spearheads. These tools, as well as remains of fire-places located across the cave support the interpretation of the site in Nietoperzowa Cave as a temporary hunters' camp, and the thesis of driving animals away from the cave with use of a smoky fire. Separate assemblages of the Jerzmanowician Culture from the

Nietoperzowa Cave differ from one another in the various ratio of particular tool types (scrapers, burins) which is an effect of slightly varying characteristics of every camp site. Instead, a change in the preparation of points is interpreted as an evolution of the flint tool assemblages. In earlier one the points possess bilateral surface flakings whereas in the later ones — the points have fragmentary surface flakings or flaking only at the ends and edges (Fig. 4).

A monograph of the Micoque-Prondnikian Culture (Chmielewski, 1969a; Madeyska-Niklewska, 1969b), based on data from the Wylotne Shelter and the Ciemna Cave, provides another example to study the evolution of a flint assemblages (Fig. 5). In the Wylotne Shelter three cultural layers, several centimetres thick, have been found; they were rich in flint artifacts and noted due to precise excavating methods. The latter included exploration in 5 cm thick layers and a detailed localization (on maps) of all tools and the limits of slightly differing beds. Thus in spite of an intensive deformation of the original bed arrangement, the separate assemblages could be distinguished without any admixtures. The tool composition of these assemblages changes considerably. These changes were evaluated as indices — e.g. so-called Total Acheulean Index gradually decreases from 33.9% in the lower cultural horizon, through 30.1% in the middle one, to 17.7% in the upper horizon. The values of a Biface Index differ from one another in 20% whereas an Index of knives of the Prondnikian type — in 4%.

Paleontologic investigations

During the first excavations in the caves collecting of paleozoological data included only a separation of bone remains of large animals. The application of sediment sieving methods with a use of a sluice enahlod to collect a rich analytic material — bone remains of small animals.

Animal remains got into the cave by different ways (K. Kowalski, 1962). The first group is composed of the remains of animals that lived or took shelter in the caves (cave bear, bats; rarely cave hyena, cave lion, here and there fox and badger; in winter some reptiles and amphibians sheltered themselves there; close to the entrances of caves the birds occurred: owls, swallows, swifts, jackdaws, starlings — Bocheński, 1974a).

The other most abundant animal group consists of the prey of man and beasts — mammals and birds. Among them there are large mammals (ungulated) as well as particularly significant remains of rodents and also of birds, fish, etc.

A rich paleozoological collection gathered from caves and shelters, examined by experts, has been the basis for investigations in several fields.

Changes of fauna composition in separate site layers

The investigation of these changes gives us very valuable information concerning fluctuations of climatic-environmental conditions. This problem is to be discussed below, together with a description of methods of environmental reconstruction. These data are also used for a reconstruction of hunters' methods and hunter specialization of ancient man.

The results of these investigations are published as separate chapters in monographs of individual sites (Chmielewski et al., 1967; Studies... 1972; K. Kowalski et al., 1965, 1967) or in separate papers (K. Kowalski, 1958, 1961, 1964; Nadachowski, 1976, in press).

Investigations of particular systematic groups of animals

Bone material collected during excavations in caves is so rich that it could have been analyzed in papers dealing with individual systematic faunal groups. Therefore, among the mammals the rodents (K. Kowalski, 1966), the cave bear (Wójcik, 1971; Wiszniowska, 1976), the weasels (Wójcik, 1974), the family Canidae (Bigaj, 1963) have been separately described. Among other things the papers supply interesting information about the evolutional changes of a particular species, in dependence according to environmental conditions.

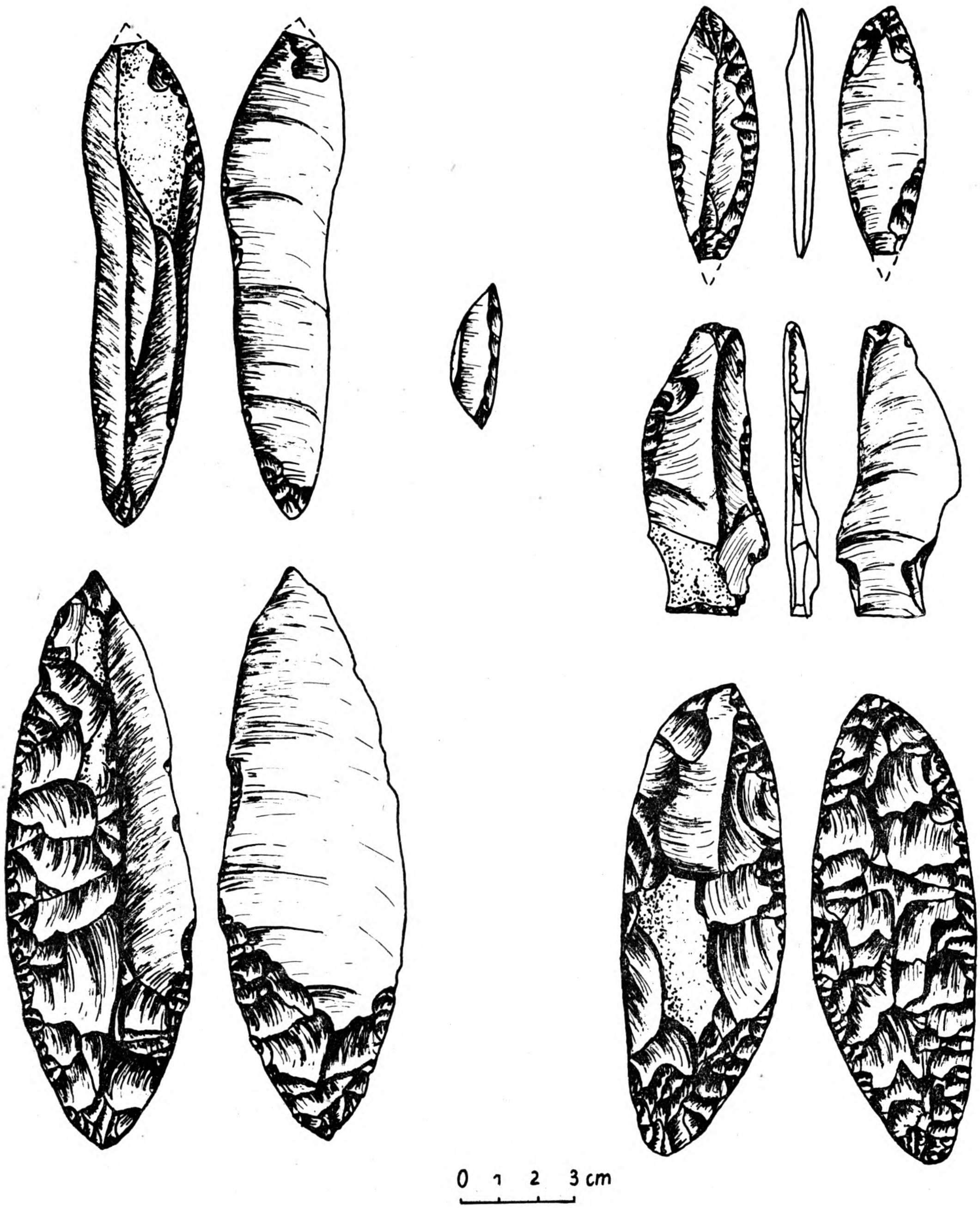


Fig. 4. Flint artifacts of the Jerzmanowician Culture

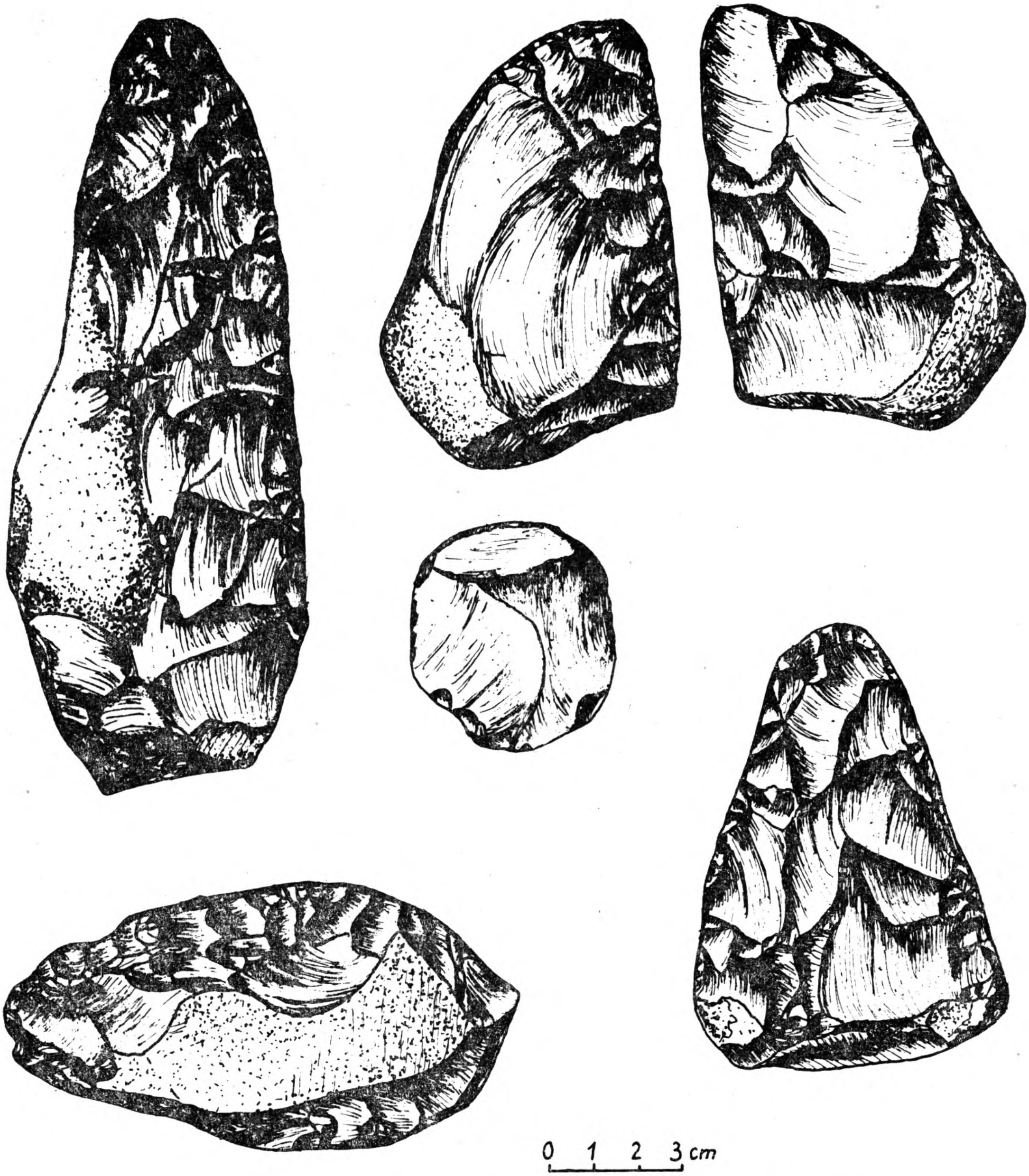


Fig. 5. Flint artifacts of the Micoque-Prondnikian Culture

Numerous bird remains have been analyzed and described in a valuable monopragh by Z. Bocheński (1974a) and in other papers of the same author (Bocheński, 1974b, in press). Z. Bocheński described about 80 bird taxons at a species or a genus level. Among them there are mainly birds that occupy vast areas of Europe now but also those that occur to the north or to the south of Poland.

In the cave sediments there are also numerous reptile and amphibian remains (Młynarski, 1977).

The molluscs are less abundant in caves than other animal remains as their shells are usually badly preserved in stony sediments. In some of the sites, however, the material for analyses could be obtained after a delicate washing of the sediment with a use of a sieves. The molluscs in the caves and shelters of the Sąspowska Valley were described by E. Stworzewicz (1973, in press), and those in the shelters in Puchacza Skała and in Żytnia Skała — by A. Wiktor (in: K. Kowalski et al., 1965, 1967). All the described species live in Poland at the present day and only some of them do not occur near Ojców.

Botanical analyses

Botanical data are unfortunately rare and limited only to determinations of charcoal wood coming from Paleolithic fireplaces (Kozłowska, 1921; Zabłocki, 1956; Reymanówna, in: Chmielewski et al., 1961). Attempts to do a pollen analysis have been thus far unsuccessful.

Lithologic and sedimentologic investigations

First simple sedimentologic informations and general data on the lithologic composition of cave fillings come from the investigations at the end of the XIXth century. The first stratigraphic subdivision of cave sediments was prepared by G. Ossowski (1881, 1884, 1885), who distinguished „diluvial" beds (composed of Pleistocene sediments and Paleolithic treated altogether) and „alluvial" beds (corresponding to the Holocene and containing Neolithic material). The papers published at the beginning of this century usually contain only scanty information on the sediment composition. S. Krukowski (1921, 1924, 1939—1948) introduced a new method to excavating works based on investigations of sediment changes in longitudinal as well as in transverse sections and on collection of archaeological and paleontological data of individual beds. This method was the very beginning of precise stratigraphic investigations continued after the World War II (Sawicki, 1953) and later expanded by a summary of sedimentologic observations (Chmielewski, 1958b).

Elaboration of a method for studies of cave sediments

The laboratory analyses of granulometric and chemical composition of cave sediments (begun in the Sudetic caves — Rode, 1928; Utescher, 1939), have been introduced on a large scale during investigations of caves of the Cracow—Wieluń Upland in the sixties when a period of complex studies was started.

The laboratory analyses of cave sediments are to establish the changeability of their lithologic features and, with detailed observations of changes in the sections, create the basis for a reconstruction of the sedimentary environment.

The methods of laboratory analyses were proposed by T. Madeyska basing her investigations on methods applied in France, Germany and Switzerland and also on her own experience. They form a series of simple physical and chemical analyses, applied during investigations of several sites (Madeyska-Niklewska, 1969a, 1971; Madeyska, in: Studies..., 1972; in press).

The analyses include a determination of a grain size composition — of an autochtonous (rubble) fraction as well as of an allochthonous fraction (loam, sand, silt). An estimation of a humus content i.e. of organic matter, seems to be valuable for a description of the evolution of vegetation on the surface or for defining the settlement phases (Fig. 6).

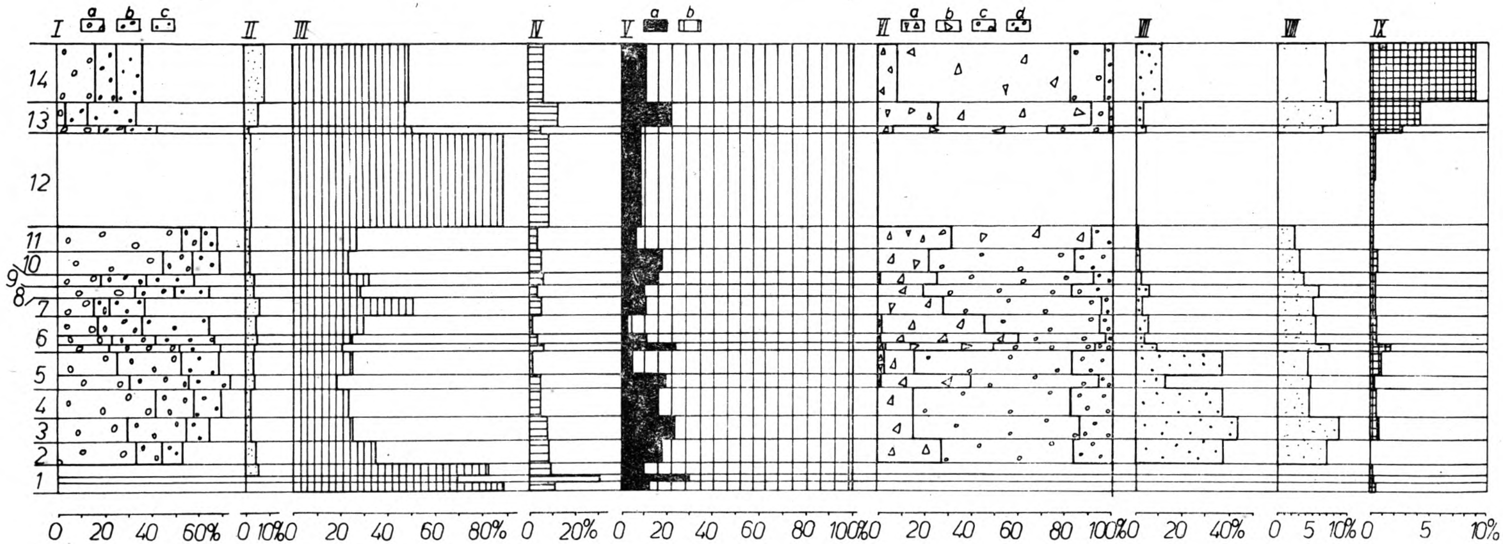


Fig. 6. Diagram showing results of the analyses of the sediments from the Tunel Wielki Cave:

I—IV: grain-size composition: **I** — limestone rubble: a — > 40 mm, **b** — 20—40 mm, **c** — 2—20 mm; **II** — fraction 0,5—2,0 mm, **III** — fraction 0,5—0,005 mm, **IV** — fraction < 0,005 mm in diameter, **V** — proportion of a clay fraction a — < 0,005 mm to a silty fraction b — 0,005—0,5 mm, **VI** — rubble roundness of a fraction > 10 mm in diameter: a — angular pieces, **b** — subangular, **c** — subrounded, **d** — rounded, **VII** — pieces with corrosive hollows, **VIII** — porosity of a surface of limestone pieces, **IX** — humus content

The most interesting results are obtained by an analysis of the morphology of a limestone rubble. A roundness degree is defined by the percentage contribution of rounded, slightly rounded and sharp-edged pieces; it proves the degree of weathering of the rubble caused by humidity and temperature increase. Sometimes this value is cited as roundness coefficient based on the calculation of detailed data — as a single number. If there are only sharp-edged pieces in a layer then the coefficient equals 0 and increases with the increase in quantity of rounded pieces. So, it well points out the layers with sharp-edged, cryoclastic rubble, typical of the coldest climatic conditions. As temperature and humidity increase then the quantity of rounded pieces and degree of their roundness increase, which is well proved by the increase of the coefficient. The pieces with pitted corrosive hollows are distinguished separately, for their quantity suggests the intensity of chemical weathering in connection with considerable aggressiveness of water; in the condition of high humidity of the sediments the diluted matter can be taken away. This is also possible in cool climatic conditions. Sometimes fragments having various preservation states of the surface are distinguished as well as ones which have cracked within the sediment.

The porosity of the surface of limestone particles is still another effect of chemical weathering connected with warm climatic conditions and probably with a lower sediment moisture, than in the case of pitted weathering. Porosity is indirectly defined by a weight estimation of the water absorbed by the rock fragments immersed in it, compared to the sample weight.

The above method was used during investigations of 12 sites. Figure 6 is an example of confrontation of analytic results.

Age differentiation of caves and their earliest sediments

The determination of the origin of the earliest cave sediments has been a side problem during investigations. These sediments fill the bottom channels and other depressions in walls and bottoms of caves. Studies of their differentiation (dependent on their position above the valley bottoms and their relation to rock terraces, for example at Sąspowska Valley) resulted in conclusions on the age of every rock level and the caves connected with them. It has also been found that almost the whole system of terraces of the Sąspowska Valley has been formed during Quaternary (M a d e y s k a, 1977).

Datings of fossil bones by the fluorine-chlorine-apatite and collagen method

Bones from the Nietoperzowa and Koziarnia Caves, collected during excavations, have been the basis for the dating method elaborated by T. Wysoczański-Minkowicz. The method is based on a proportion of collagen to mineral matter, and also of fluorine and chlorine to phosphorus. An index of collagen losses indicates climatic changes. The fluorine-chlorine-apatite index of T. W y s o c z a ń s k i - M i n k o w i c z (1969) enables to date the bones and, indirectly, the sediments as well.

Reconstruction of changes in the natural environment — a recapitulation of detailed investigations of cave and rock-shelter sediments

Rich geological, paleontological and archaeological data on the sediments of caves and rock-shelters have been collected and analyzed to reconstruct the natural environment and its changes during the Late Pleistocene. These data, supplemented with sedimentologic and palaeopedologic investigations of open sites, have been the subject of a monograph on the natural environment during Middle and Upper Palaeolithic in the Polish territory (M a d e y s k a, 1981).

The most valuable data come from the sites that have been studied over the last twenty years, mainly with the author's help. She used published informations as well as that in press but presented to the author in manuscript form.

The most significant sites are: the Nietoperzowa Cave (C h m i e l e w s k i et al., 1961; C h m i e l e w s k i, 1958a, 1961; B o c h e ń s k i, 1974; K. K o w a l s k i, 1961, 1964; M a d e y s k a-N i k l e w s k a, 1969a; R ó ż y c k i, 1972), the Koziarnia Cave C h m i e l e w s k i, M a d e y s k a, 1961; C h m i e l e w s k i et al., 1967; B o c h e ń s k i, 1974a); the Tunel Wielki Cave, the Shelter above the Niedostępna Cave, the Sąspowska Zachodnia Cave, the Bramka Shelter (S t w o r z e w i c z, 1973; B o c h e ń s k i, 1974a, in press; M a d e y s k a, in press; N a d a c h o w s k i, in press); the Wylotne Shelter (C h m i e l e w s k i, 1969a, 1970, 1975; M a d e y s k a-N i k l e w s k a, 1969a, b, 1970); the Ciemna Cave (K r u k o w s k i, 1939—1948; S. K o w a l s k i, 1967a; 1971); the Mamutowa Cave (S. K o w a l s k i, 1967b, 1969; B o c h e ń s k i, 1974a; N a d a c h o w s k i, 1976); the Raj Cave (Studies..., 1972; B o c h e ń s k i, 1974a); the Żytnia Skała shelters (K. K o w a l s k i et al., 1967; B o c h e ń s k i, 1974a).

The other group includes caves and shelters of less differentiated sediment sequences or those which were investigated a longer time ago, with the use of less precise methods: the shelter in Puchacza Skała (K. K o w a l s k i et al., 1965); the Maszycka Cave (L. K o z ł o w s k i, 1922; J.K. K o z ł o w s k i, 1962, 1963; S.K. K o z ł o w s k i, 1969); the Cave in Skała Okiennik (D e m e t r y k i e w i c z, K u ź n i a r, 1914); the Shelter in Dziadowa Skała (C h m i e l e w s k i, 1958b; D y l i k et al., 1954); the Jasna Cave, the Zaciszna Cave and the Shelter by Okno (S a w i c k i, 1953); the caves at Złoty Potok (K r u k o w s k i, 1921) the Shelter at Podlesice (C h m i e l e w s k a, P i e r z c h a ł k o, 1956; K r y s i a k, 1956; Z a b ł o c k i, 1956) and the Zamkowa Dolna Cave (K o p a c z, 1975; K o p a c z, S k a l s k i, 1971).

In the mentioned monograph (M a d e y s k a, 1981) the most significant results of analyses are confronted in a uniform way to illustrate changes in lithologic features for paleoclimatic interpretation (an example in Fig. 7).

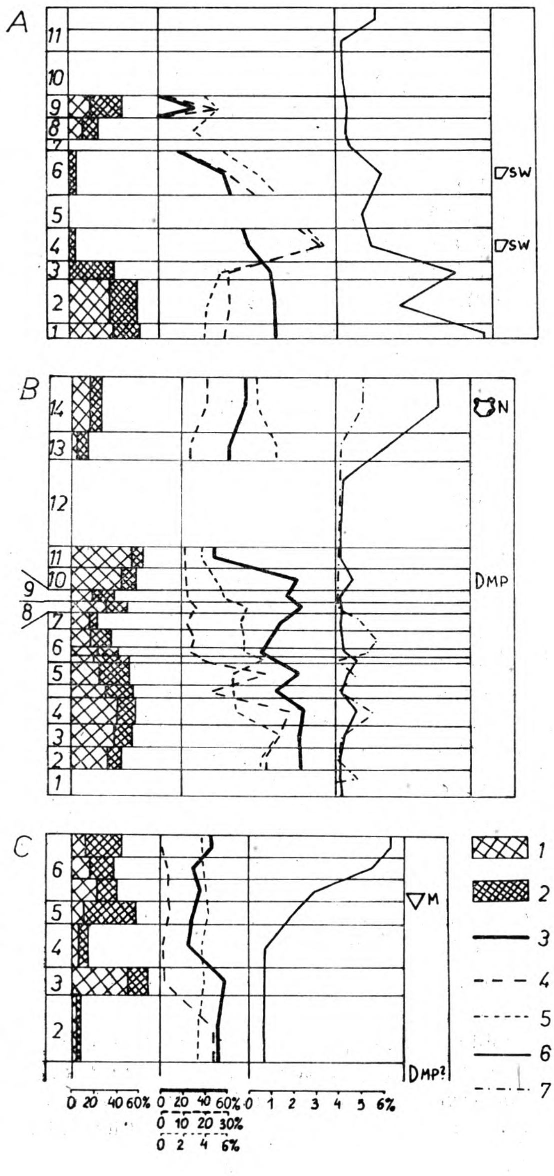


Fig. 7. Examples of simplified lists of results of lithologic analyses from the Raj Cave (**A**), the Tunel Wielki Cave (**B**) and the Bramka Shelter (**C**):

1 — limestone rubble with a diameter of pieces over 40 mm, 2 — rubble 20—40 mm in diameter, 3 — roundness coefficient, 4 — number of pieces with corrosive hollows calculated for the fraction over 20 mm in diameter, 5 — porosity of a surface of limestone pieces of the fraction 10—20 mm, 6 — humus content in a fraction < 1 mm, 7 — contents of ferruginous-phosphate aggregates in a silty fraction; **M** — horizon with Mesolithic remains, **N** — Neolithic cultural layer, **MP** — Micoque-Prondnikian cultural layer, **SW** — horizons with south-east-Charentian assemblages

A fossil fauna of mammals is compiled for an ecological interpretation of the assemblages of particular layers. For this purpose sets of species which are typical for their similar ecological needs were distinguished. Basing on information in the literature (K. Kowalski, 1961, 1966, in: Studies..., 1972, 1976; Nadachowski, 1976) the following ecological groups of species were distinguished:

Tundra species:

Rodentia: *Dicrostonyx torquatus, Lemmus lemmus, Microtus gregalis, Microtus nivalis.*
Lagomorpha: *Lepus timidus*
Proboscidea: *Mammuthus primigenius*
Perissodactyla: *Coelodonta antiquitatis*
Artiodactyla: *Ovibos moschatus, Rangifer tarandus*
Carnivora: *Alopex lagopus*

Steppe and steppe-tundra species:

Rodentia: *Citellus superciliosus, C. citelloides, Citellus* ex. gr. *major, Cricetulus migratorius, Cricetus cricetus, Lagurus lagurus*
Lagomorpha: *Ochotona pusilla*
Perissodactyla: *Equus caballus*
Artiodactyla: *Bison priscus*

Forest species:

Rodentia: *Apodemus flavicollis, Apodemus silvaticus, Castor fiber, Clethrionomys glareolus, Eliomys quercinus, Glis glis, Muscardinus avellanarius, Sciurus vulgaris, Sicista betulina.*
Insectivora: *Crocidura* sp., *Talpa europea*
Chiroptera: *Myotis bechsteini, Pipistrellus pipistrellus*
Artiodactyla: *Alces alces, Bos primigenius, Capreolus capreolus, Cervus elaphus, Sus scrofa.*
Carnivora: *Felis silvestris, Gulo gulo, Lynx lynx, Mertes mertes, Meles meles, Ursus arctos*

Eurytopic species:

Rodentia: *Arvicola terrestris, Micromys minutus, Microtus agrestis, Microtus arvalis, Microtus oeconomus, Pitymys subterraneus*
Insectivora: *Neomys fodiens, Sorex araneus, Sorex minutus*
Chiroptera: *Barbastella barbastellus, Eptesicus nilssoni, Myotis brandti, Myotis dasycneme, Myotis daubentoni, Myotis emarginatus, Myotis myotis, Myotis mystacinus, Myotis nettereri, Plecotus auritus*
Lagomorpha: *Lepus europeus, Orystolagus cuniculus*
Carnivora: *Canis lupus, Crocuta spelaea, Mustela erminea, Mustela nivalis, Mustela putorius, Panthera spelaea, Ursus spelaeus, Vulpes vulpes*

Some remains described with precision to a genus level as Cervidae or Bovidae are included into the eurytopic group since they contain species that live in various environments.

Independently from the above subdivision a group of mammals connected with an aquatic environment was distinguished: *Arvicola terrestris, Microtus oeconomus, Neomys fodiens, Myotis dasycneme, Myotis daubentoni, Castor fiber.*

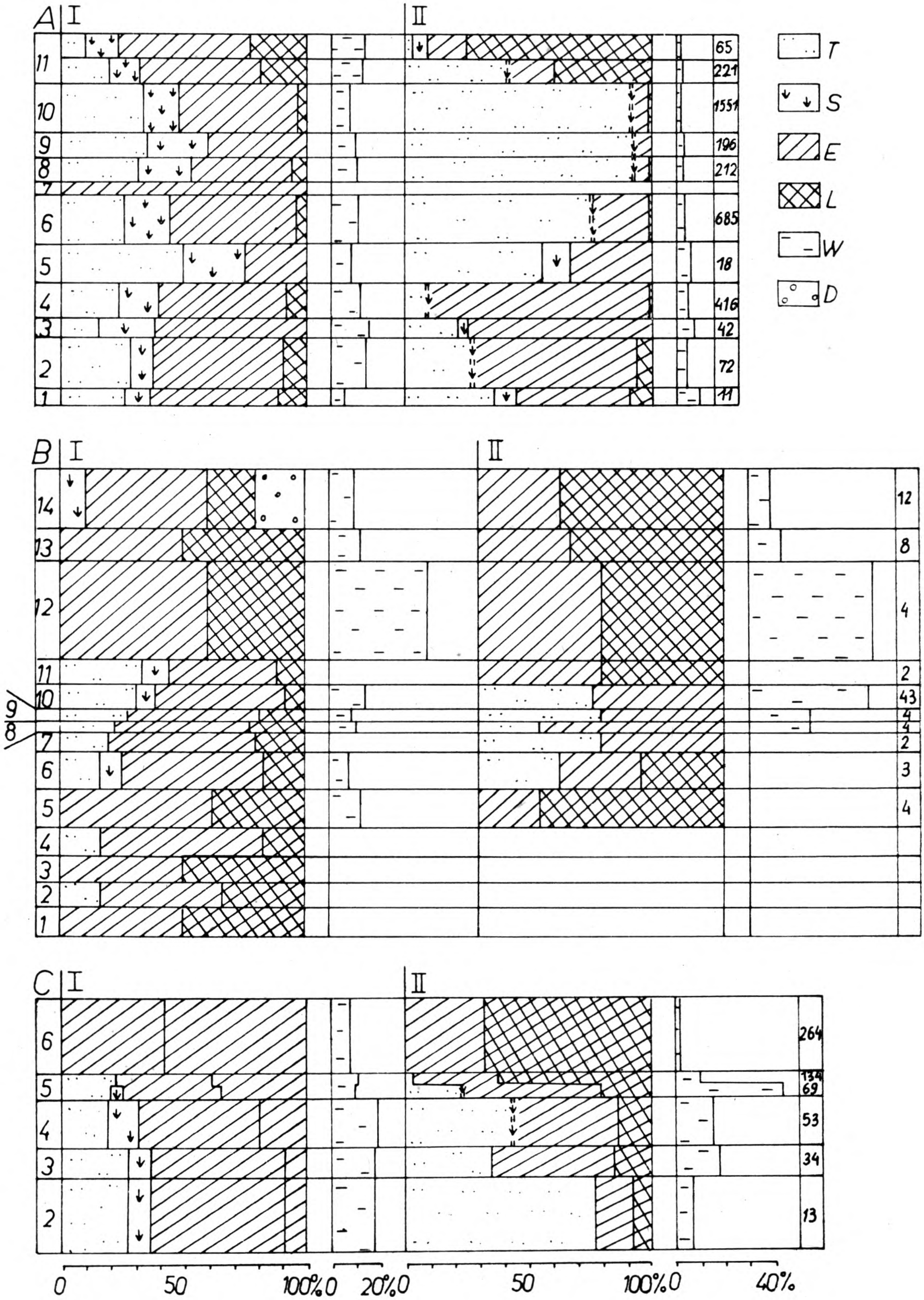
Within the Holocene layers the domestic mammals have been also noted as: *Bos taurus, Capra* sp., *Ovis* sp., *Sus scrofa domestica, Felis catus.*

Results of the ecologic analysis of fauna are presented in diagrams that show the contents of mammal assemblages of every layer, in a subdivision into the mentioned groups of different ecologic demands (Fig. 8). The first part of a diagram shows the species composition changes whereas the second one — the changes in a number of rodent individuals content against the same subdivision into groups. In separate columns there are the specimens connected with a water environment.

A specification presented at Fig. 9 recapitulates the detailed data and is based on a correlation of sections of various sites localized in the southern part of the Cracow—Wieluń Upland. It illustrates the trends of changes of fauna assemblages, a weathering degree of a limestone rubble and occurrence of archaeologic horizons against a background of Vistulian stratigraphic units.

As mentioned before the cave sediments of the Cracow—Wieluń Upland come from a period starting from the Last Interglacial until Holocene so, they comprise the whole last cold period (Vistulian).

In the post-Eemian parts of the sequences there are two distinct horizons, typi-


A I II
11 10 9 8 7 6 5 4 3 2 1
65 221 1551 196 212 685 18 416 42 72 11
T S E L W D
B I II
14 13 12 11 10 9 8 7 6 5 4 3 2 1
12 8 4 2 43 4 4 2 3 4
C I II
6 5 4 3 2
264 134 69 53 34 13
0 50 100% 0 20% 0 50 100% 0 40%

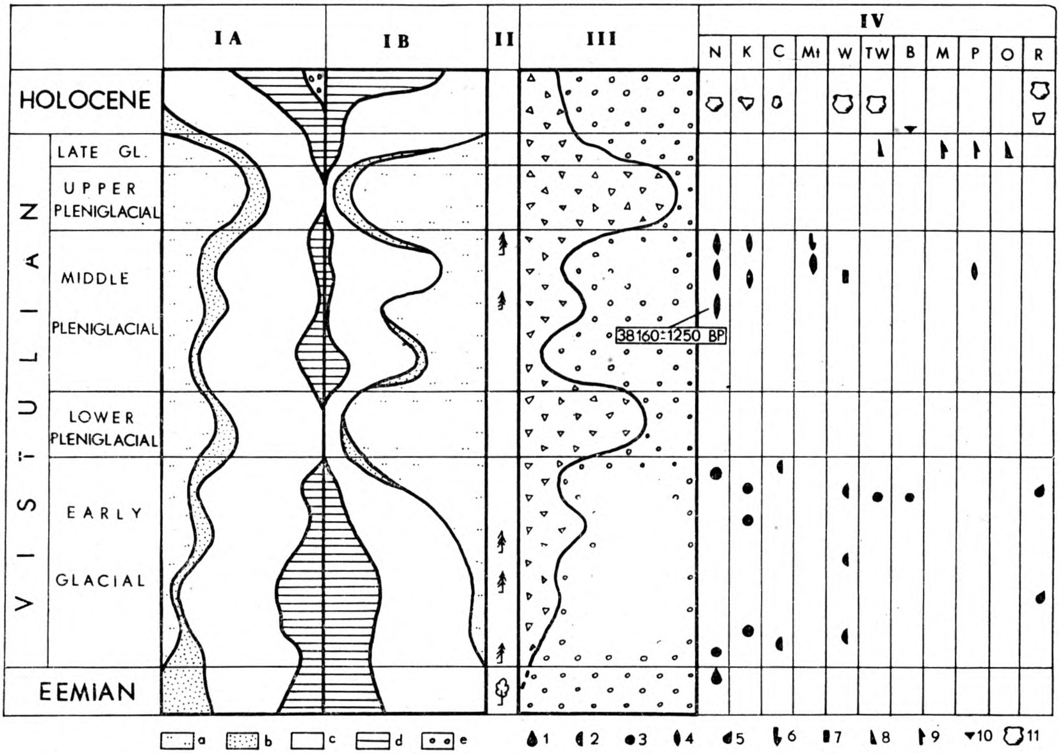


Fig. 9. Schematic stratigraphic specification of data of sediments from various caves and shelters of the southern part of the Cracow—Wieluń Upland:

I — list of mammals compiled according the groups of various ecologic demands: a — tundra, b — steppe and steppe-tundra, c — eurytopic, d — forest, e — domestic mammals; IA — list of a number of mammal species, IB — list of a number of rodent specimens; II — presence of coniferous and deciduous trees found on the ground of a charcoal analysis; III — roundness coefficient of a limestone rubble; IV — presence of archaeologic material in particular localities: N — Nietoperzowa Cave, K — Koziarnia Cave, C — Ciemna Cave, Mt — Mamutowa Cave, W — Wylotne Shelter, TW — Tunel Wielki Cave, B — Bramka Shelter, M — Maszycka Cave, P — Shelter in Puchacza Skała, O — other shelters of the Polish Jura, R — Raj Cave; Archaeologic cultures: 1 — Levallois-Mousterian, 2 — Micoque-Prodnikian, 3 — other Middle Palaeolithic assemblages, 4 — Jerzmanowician, 5 — East-Charentian, 6 — East Gravettian assemblage, 7 — other Upper Palaeolithic assemblages, 8 — Epipalaeolithic, 9 — Magdalenian Culture, 10 — Mesolithic assemblage, 11 — Neolithic assemblages

cal for effects of intensive physical weathering characteristic for extremely cold climatic conditions and containing numerous remains of the Arctic animals. A significance of these horizons for a stratigraphy of Palaeolithic cultures and a problem of corresponding phases of the Arctic climate in evolution of the cultures were presented by W. Chmielewski (1969b). He proved an absence of traces of man occupation in both these periods but their initial or final phases, during extremely severe cli-

Fig. 8. Composition of animal remains in sediments of the Raj Cave (A), the Tunel Wielki Cave (B) and the Bramka Shelter (C), divided into groups of different ecologic demands:

I — specific composition of mammalian fauna, II — composition of rodent fauna according to number of individuals; T — tundra, S — steppe and steppe-tundra, E — eurytopic, L — forest, D — domestic, W — water species. The numbers at left side designate the successive layers, the numbers at right side — a number of rodent specimens in the layer matic conditions in our territory the human groups displaced to the south from Poland.

The cave sediments corresponding with these two Arctic phases (i.e. with Lower and Upper Pleniglacial) are composed generally of sharp-edged, non-weathered limestone rubble connected with a pale yellow loess, containing a slight admixture of humus matter. In deeper parts of large caves these layers are rather thin but their thickness increases towards the cave entrance. In small shelters there is usually a single layer of this type. It is an effect of destructive processes, resulting in the removal of some sediments from the vicinity of cave entrances or even, from the whole shelters. The main intensification of these processes occurred in the phase between both Arctic phases.

The most typical rodent species found within the layers corresponding with the Arctic phases are: *Dicrostonyx torquatus*, *Lemmus lemmus*, *Microtus gregalis*. Within the sediments of the Raj Cave, the Holy Cross Mts., *Lepus timidus*, *Alopex lagopus*, *Coelodonta antiquitatis*, *Rangifer tarandus* and *Ovibos moschatus* have been also noted, accompanied by the species typical for a Pleistocene steppe-tundra: *Lagurus lagurus*, *Ochotona pusilla*, *Citellus* and *Equus caballus*. A forest element is represented during both these phases almost exclusively by *Clethrionomys glareolus* — now it is an exclusively forest species but during Pleistocene it had a wider environmental nitch (N a d a c h o w s k i, 1976).

Among the birds of Lower Pleniglaciel *Lagopus lagopus* and *Lagopus mutus* greatly predominated over the other species; *Larurus tetrix* and *Falco columbarius* were also numerous. Among the birds nesting in tundra *Squatarola squatarola*, *Calidris testacea*, *Nyctea scandiaca* occurred whereas among the water-marshy ones — *Capella media*. In Upper Pleniglacial there were: *Squatarola squatarola*, *Lyrurus tetrix* and *Numenius phaeopus* — nested by the tundra lakes, among the aquatic species: *Porzana porzana* and *Asio flammeus*.

The cultures od Middle Palaeolithic have developed in the Polish territory since the Eemian Interglacial, through Early Vistulian until the beginning of Lower Pleniglacial. According to the cultural subdivision of W. C h m i e l e w s k i (1975) the Levallois-Mousterian Culture is the earliest one of the Middle Palaeolithic; its traces have been noted in the Nietoperzowa Cave. During Early Vistulian the Micoquo-Prondnikian Culture has appeared and lasted until the Pleniglacial cooling (M a d e y s k a - N i k l e w s k a, 1969b). The East Charentian Culture was noted only in the Raj Cave where it was dated for the later phase of Early Vistulian.

The sediments corresponding with the Eemian Interglacial comprise the weathering loams, preserved in large caves. They are brown, red-brown or grayish, in places tinted with cultural remains. They contain a small amount of a strongly weathered limestone rubble and pieces of calcite sinters; in the Nietoperzowa Cave also a stalactite column was found in this horizon. Within a loam of interglacial layers considerable quantity of humus was found. All these features suggest warm and humid conditions, favourable for a chemical weathering, development of vegetation at the surface and also, for soil formation.

The sediments of Early Vistulian are characterized by less intensive chemical weathering in comparison to the interglacial ones; at the same time several fluctuations of a smaller order can be noted in the sections. The sediments of that age compose of light-brown or brown loams with a considerably but greatly variable humus content, with a less chemically weathered limestone rubble than the rubble of interglacial layers. The roundness coefficient of the rubble is high and shows two or three fluctuations within the whole series. On the basis of the above mentioned features one should accept that during the warm phases of Early Vistulian the temperature was high but lower than during the interglacial and humidity was high.

Among the mammals of the interglacial layers there are about 30% of forest species (among others: *Talpa europea*, *Apodemus silvaticus*) but the steppe ones (*Ochotona pusilla*, *Cricetus cricetus*, *Equus caballus*).

Almost all Early Vistulian layers contain a fossil fauna of all the five ecologic groups but their quantitative differentiation is more distinct in the case of rodent individuals than in the case of all mammal species. A tundra element appears at the beginning of the Early Vistulian. An appearance of *Microtus gregalis* and *Lepus timidus* is followed by *Dicrostonyx torquatus* and *Lemmus lemmus*. Forest element is poorer and less numerous than in the interglacial layers. At many sites a number of species connected with water environment increases at the end of the Early Vistulian what suggests probably a more humid climate.

Among the birds Z. Bocheński (1974) found *Aegithalos caudatus* and *Regulus regulus* within the interglacial layers whereas within the Early Vistulian layers *Lagopus lagopus* and *Lagopus mutus* as well as *Lyrurus tetrix* predominated. In the sediments of the Raj Cave there were also forest and water-marshy species.

On the ground of charcoals a presence of *Fraxinus* was noted during the interglacial and only of Coniferae (*Pinus silvestris, Larix* vel *Picea*) during the Early Vistulian.

The Early Vistulian is to be described then as the period with a great variety of vegetation in time as well as in the space. The climatic fluctuations resulted in changes of the areas occuppied by tundra, steppe-tundra, forest-tundra and forest (taiga or birch-pine woods) communities. During warmer periods the forests probably occuppied a large part of the area but a continuous stay of tundra and steppe animals proves that locally, e.g. in valleys at foot of slopes exposed to the north, patches of tundra vegetation have been preserved whereas in dry places — e.g. at valley edges — the patches of a steppe vegetation. In turn, during cold phases, the tree communities occurred in relic habitats favourable from a microclimatic point of view — at valley slopes of southern exposition, in places protected from the wind.

The Upper Palaeolithic cultures developed in our territory during the interval between the two above mentioned arctic fluctuations (Lower and Upper Pleniglacial) i.e. during the Interpleniglacial. This warming, comprises several climatostratigraphic units of lower order. Two distinct warm fluctuations, corresponding with interstadials distinguished as Denekamp and Hengelo, are seperated by a cooling trend (Hammen et al., 1967). W. Chmielewski (1975) distinguished in the territory of Poland the following cultural units of the Upper Palaeolithic: Jerzmaniwician Culture, Szeletian Culture, Aurignacian assemblages and Fast Gravettian assemblages. J.K. Kozłowski and S.K. Kozłowski (1977) distinguished several smaller units based on a typologic analysis. The stratigraphic data generally prove that the Jerzmanowician and Aurignacian cultures are followed in the southern Poland by a development of East Gravettian assemblages which lasted until the beginning of the Upper Pleniglacial.

The sediment series deposited during the Interpleniglacial in large caves are composed generally of smoothed limestone rubble and light-brown or pale yellow silty loam, containing a considerably smaller (in comparison with the sediments of the Early Vistulian amount of residual clay and organic matter. A limestone rubble is much less chemically weathered; it is expressed by a small perosity although a roundness coefficient is high. This series are best developed in the Nietoperzowa Cave where it is 2 m thick. A distinct fluctuation of the roundness coefficient is noted there what proves to be a cool phase that separates the series into two parts.

In the rock-shelters the destructive processes that deformed the original position of layers, occurred during the Interpleniglacial. This was caused by humid climatic conditions. At that time the sediments have been fraquently removed from shelters due to washing and slope creap near the entrance.

Among the mammal remains tundra element is represented by lemmings, and *Microtus gregalis* occurs in the whole sequence. *Microtus nivalis* and *Coelodonta antiquitatis* are noted only during the above mentioned cold oscillation. At that time also *Lepus timidus, Alopex lagopus* and *Rangifer tarandus* appeared also and lasted until the end of this period.

A steppe element is mainly represented by *Lagurus lagurus, Ochotona pusilla* and *Equus caballus*. A forest element is very poor. Besides *Clethrionomys glareolus*, common during the whole Late Pleistocene, in the later part of the Interpleniglacial *Sicista betulina* and *Gulo gulo* occur, the species typical for coniferous forests although the latter species is also noted in the forest--tundra zone.

An aquatic element, represented mainly by *Microtus eoconomus* that is usually more abundant than *Arvicola terrestris*, is noted in all interpleniglacial horizons but it is more common in its lower and upper parts.

A rich bird community of the Mamutowa Cave (Bocheński, 1974) proves similar fluctuations and enables the author to draw a similar conclusion on the natural environment. *Lagopus lagopus* and *Lyrurus tetrix* are most common whereas a cold--resistant *Lagopus mutus* appears during a cold fluctuation. A single bone of *Alauda arvensis* has been also found and within the sediments corresponding to the later part of this period — two water-marshy species: *Anas crecca* and *Rallus aquaticus*.

An overview based on animal remains, presents of a steppe-tundra with patches of coniferous trees (forest-tundra). During the middle interval the climate is cooler and tundra predominates. An analysis of charcoals proved the presence of *Pinus silvestris, Pinus cembra, Larix* vel *Picea*.

The Upper Palaeolithic cultures, noted in the Polish territory during the Late Glacial, are represented in the caves by small assemblages of the Magdalenian Culture (an assemblage best preserved comes from the Maszycka Cave). Habitational remains of Neolithic communities are quite frequently noted in the caves.

Late Glacial sediments occur mainly in small rock-shelters and locally, close to the entrances of larger caves. Inside the caves, the clastic sediments of the Late Glacial and Holocene are not more than several centimetres thick. Such a small thickness of these sediments in an effect of the short duration of this period in comparison with the preceding ones and of a mild climate of Holocene which has not been favourable to physical weathering.

Inside the shelters, the sediments of this age are considerably variable and depend on individual characteristics of a site such as: entrance exposition, slope steepness outside an entrance, thickness of the rock cap above a cave. These features influence the physical weathering of rocks and also a quantity of washed (at that time) fine sediment, mainly composed of redeposited loess. In result, the rubble series are deposited inside the shelters; the rubble consists of various fractions, from fine-grained ones up to large blocks. A washed loess locally creates as much as almost 100% of the whole sediment and frequently, it has streaks caused by washing. The upper parts of Late Glacial layers, localized at shelter entrances, are usually transformed by Holocene soil processes.

The Holocene sediments possess a similarly differentiated grain-size composition but usually contain much humus, and also locally distinct cultural layers with remains of fires of Neolithic communities.

The Holocene sediments are typical for an occurrence of various kinds of speleothems. In deeper parts of caves the flowstone crusts cement the upper part of the sequence, locally with cave pearls (Raj Cave, Nietoperzowa Cave), creating the layers several centimetres thick. Such a flowstone has cemented in the Nietoperzowa Cave corn grains and Neolithic pottery; it contained also prints of leaves of deciduous trees.

Inside smaller caves and shelters no typical speleothems are noted but there are common silty carbonate precipitations that cement the sediments, locally to a depth of several dozen centimetres, forming conglomerations of loam or loess. If the layers compose of quite a loose rubble, the carbonates precipitate at lower sides of the fragments as fine-crystalline covers or a moonmilk. They are easily weathered.

The palaeofauna of Late Glacial sediments in the rock-shelters is typified by the coexistence of species from all the ecologic assemblages. For the relatively small thickness of these layers and the fact, that they are usually composed of loose sediments or at least they were loose at the beginning of Holocene, a mixing of the animal remains of both these periods is distinct and common.

Late Glacial and the beginning of Holocene start with the appearence of new thermophilous animal species, absent in the underlying layers (Bocheński et al., 1968). Particularly many new species are noted among the birds which seem to be connected not only with an increase of its population at that time but also, may be an effect of more favourable conditions of preservation for fragile bones in younger sediments. Simultaneously, in the Late Glacial layers the tundra species are still noted but a considerable number of aquatic and marshy animals. The tundra species disappear during Holocene but they are replaced by stenothermal forms, among them also the ones that are relict or absent now in the Polish territory: the species of the Holocene climatic optimum i.e. *Lacerta viridis, Elaphe longissima, Eliomys quercinus, Myotis bechsteini, Aegypius monachus.*

Conclusions

Interdisciplinary investigations of Late Pleistocene cave fillings enabled the author to draw interesting conclusions on the palaeocology and phases of ancient colonisation.

1. In the caves of the Cracow-Wieluń Upland there are sediment sequences corresponding in time to the last cold period (Vistulian); their lithologic features allow to distinguish the climatic fluctuations of a second order too. The latter are noted by a varying degree weathering of the limestone rubble and by changes of composition of the cave loam.

2. An alkaline environment of the cave sediments favours a good preservation of animal remains. The composition of the palaeofauna does not correspond exactly with natural communities that lived close to the cave but is a result of selection caused by the means of emplacement of the animal remains into the cave sediments. In spite of that, an investigation of the changes in the fauna composition from a point of view of ecologic demands of every species is, besides lithologic studies, the basis for reconstruction of environmental-climatic conditions.

3. The caves were used by an ancient man as shelters which is evidenced by habitation traces, usually fire-places and flint tools. These finds are of the Middle and Upper Palaeolithic but also, of the Neolithic and younger ages. Due to detailed stratigraphic investigations the cultures of the Middle Palaeolithic were found to have developed in the Early Vistulian, Upper Palaeolithic — during the so-called Interpleniglacial; during both Pleniglacial Arctic fluctuations no colonisation is noted is southern Poland.

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Teresa Madeyska

MŁODOPLEJSTOCEŃSKIE OSADY JASKINIOWE W POLSCE

Streszczenie

Przedstawiono metody i wyniki badań archeologicznych, paleozoologicznych i geologicznych młodoplejstoceńskich osadów jaskiń i schronisk skalnych w Polsce, ze szczególnym uwzględnieniem Wyżyny Krakowsko-Wieluńskiej.

W jaskiniach Wyżyny Krakowsko-Wieluńskiej są zachowane serie osadów odpowiadające czasowo ostatniemu okresowi zimnemu (Vistulian), przy czym z ich charakteru litologicznego można odczytać kolejne wahania klimatyczne drugiego rzędu. Wahania te zapisały się w postaci zróżnicowania stopnia zwietrzenia gruzu wapiennego i zmian w składzie gliny jaskiniowej.

Zasadowe środowisko, jakie stanowią osady jaskiniowe, sprzyja dobremu zachowaniu szczątków zwierząt. Skład fauny kopalnej nie odpowiada ściśle zespołom naturalnym zamieszkującym w danym czasie okolice jaskiń, lecz jest wynikiem selekcji związanej ze sposobami dostawania się szczątków zwierzęcych do osadów jaskini. Mimo to prześledzenie zmian składu fauny pod względem wymagań ekologicznych poszczególnych gatunków jest — obok badań litologicznych — podstawą rekonstrukcji warunków środowiskowo-klimatycznych.

Jaskinie były wykorzystywane przez człowieka pradziejowego jako miejsce schronienia, czego efektem są ślady jego pobytu, głównie w postaci ognisk i narzędzi krzemiennych. Znaleziska te należą do środkowego i górnego paleolitu, a także do neolitu i do kultur młodszych. Dzięki szczegółowym badaniom stratygraficznym stwierdzono, że kultury środkowego paleolitu rozwijały się we wczesnym Vistulianie górnego paleolitu (w tzw. interpleniglacjale), a podczas dwu pleniglacjalnych wahnień arktycznych brak osadnictwa w Polsce południowej.

Teresa Madeyska

SÉDIMENTS CAVERNEUX DU PLÉISTOCÈNE RÉCENT EN POLOGNE

Résumé

L'article présente les méthodes et les résultats des recherches archéologiques, paléozoologiques et géologiques sur les sédiments caverneux du Pléistocène récent et les abris sous roche en Pologne, en considérant particulièrement le Haut-Plateau de Cracovie—Wieluń.

Dans les grottes du Haut-Plateau de Cracovie—Wieluń se sont conservées des séries de sédiments correspondant temporai-

rement à la dernière période froide (Vistulian). Leur caractère lithologique permet de lire les oscillations succesives du deuxième ordre. Elles se sont inscrites en forme de différentiation du dégré d'alteration des débris calcaires et de changements de la composition de la limon de caverne.

Le milieu alcalin, que constituent les sédiments caverneux, favorise une bonne conservation des ossements d'animaux. La composition de la faune fossil ne correspond pas exactement aux associations natureles habitant les environs des grottes dans le temps donné, mais elle résulte de la sélection liée à la façon dont les ossements d'animaux se sont trouvés dans les sédiments caverneux. Malgré cela, l'étude des changements de la composition de la faune du point de vue des exigences écologiques des espèces particulières constitue, à côté des recherches lithologiques, la base de la reconstruction des conditions de l'environnement et du climat.

Les grottes servaient d'abris à l'homme préhistorique. Les foyers et les outils de silex sont effets de sa présence. Ces trouvailles appartiennent également au Paléolithique moyen et supérieur, au Néolithique et aux cultures inférieures. Les études stratigraphiques détaillées ont permis de constater que les cultures du Paléolithique moyen se développaient dans le début du Vistulian celle du Paléolithique supérieur, pendant l'Interpleniglaciaire, et qu'il manquait de colonisation au Sud de la Pologne durant les deux oscillations arctiques pleniglaciaires.

Traduit par Teresa Korba-Fiedorowicz

Marian Pulina*

Karst—related phenomena at the Bertil Glacier, West Spitsbergen

Abstract: The paper deals with karst-related features found at the Bertil Glacier in the central part of West Spitsbergen. Such features are connected with an underground drainage of the glacier. Among the surface features there are oval-shaped depressions with shafts-ponors and pocket valleys, localized in a marginal part of the glacier. Inside the glacier there is a system of channels with a central collector — a large horizontal cave with a system of caves and wells in the marginal part of the glacier. The explorated caves are over 1 km long. The paper comprises also the results of hydrologic and hydrochemical analyses carried out at the Bertil Glacier. Several genetic water types were distinguished, among them, ancient waters flowing inside the central collector. These waters remained unfrozen during polar winters.

The results of investigations have been applied to a glacial water intake project. In autumn and in winter 1979/1980 these waters supplied the Soviet settlement and the mine at Pyramiden.

Introduction

Phenomena of ice karst in West Spitsbergen, similar to the ones noted at the Bertil Glacier, were described by S. Baranowski (1968) and J. Czerwiński (1968) — the members of the Polish expedition acting in the Hornsund region during the IIIrd International Geophysical Year. The glacier caves of the Kongsfjord area were described by G. Gallo (1968), a member of the French expedition.

The author started his studies on glaciers in the southern part of West Spitsbergen at the beginning of the seventies, during the expeditions organized by the Wrocław University. During these works several caves have been discovered in glaciers and in many years' snow as well as features at glacier surfaces, similar to the ones noted in limestone karst areas. Such features noted at Spitsbergen were found at that time to be strictly connected with an underground glacial drainage system (Pulina, 1979).

In 1979—1980 the author** continued these investigations with a particular regard to glacier hydrology and hydrochemistry. New caves were discovered inside Hans, Werenskiold and Torell glaciers of the Hornsund area and inside the Bertil Glacier by Billefjorden. At the Bertil Glacier the most fully developed (among the ones noted at Spitsbergen until that time) phenomena, similar to karst ones, were found. Some information about these investigations was enclosed in several scientific notes (Krawczyk, Pulina, 1980; Różkowski, 1980, 1980a). Full results of these studies, carried out during the whole year, polar night included, will be the subject of a separate paper.

According to the author's knowledge, the ice caves and some glacier features similar to karst ones, were described by L. Clayton (1964), W. R. Holliday and C. H. Anderson (1970), M. Seppälä (1972) and R. A. Watson (1976); literature on

* Laboratory of Karst Geomorphology, University of Silesia, ul. Mielczarskiego 58, PL 41-200 Sosnowiec, Poland

** The investigations were carried on during the national expedition organized by the Institute of Geophysics, Polish Academy of Sciences.

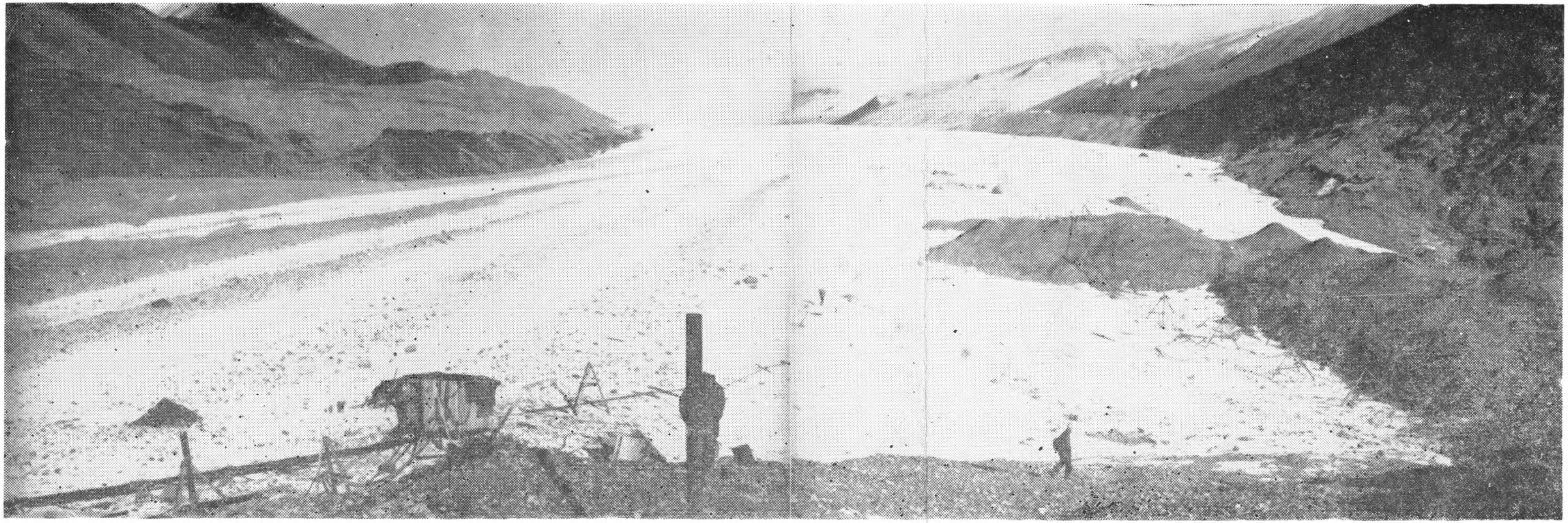
thermokarst features in permafrost was collected by J. Dylik (1968), A. L. Washburn (1973) and A. Jahn (1975).

The investigations at the Bertil Glacier were carried out by the Polish-Soviet expedition in autumn and winter 1979, invited by the manager of a coal mine at Pyramiden. The Polish participants were: A. Różkowski (Geological Institute, Sosnowiec), J. Pereyma (Wrocław University), S. Swerpel (Institute of Meteorology and Water Administration, Gdynia) and J. Karkoszka (member of the Spitsbergen expedition organized by the Silesian University, whereas the Soviet ones: I. S. Postnov, A. D. Kasatkin, E. Lipatova and V.P. Volodskiy, SEVMORGEO — Leningrad). The purpose of these investigations was to find possible application of waters from the inner part of the Bertil Glacier to supply the settlement and the coal mine Pyramiden, as well as to provide an estimation of the water resources and their usefulness for consumption. A description of the glacier hydrology, a definition of water types and their physico-chemical properities were the scientific effect. The chemical analyses of waters were done in the field with use of the field laboratory MP-1 (Markowicz, Pulina, 1979). The complementary analyses were performed in the hydrochemical laboratory of the Silesian University, installed at the Polish polar station in Hornsund. The samples for oxygen and hydrogen isotopes analyses were collected by A. Różkowski. They were examined at the Institute of Nuclear Research, Mining--Metallurgical Academy at Cracow. As the result, two expert appraisals were prepared (Pulina, Postnov, 1979; Pulina, Postnov, Różkowski, Kasatkin, 1979). Geological materials and geodesic maps were supplied by the manager of the Pyramiden mine.

As there are difficulties in the water supply of settlements at Spitsbergen, especially in winter, the investigations of the Bertil Glacier are of great methodical and practical significance. A continuation of these studies is expected with a use of the most modern measuring methods. In summer 1980 the Soviet glaciologic and geologic expeditions collected geophysical data and undertook drilling in the glacier ice. The author attended these works, continuing the hydrologic and hydrochemical observations.

Morphology of the Bertil Glacier

The Bertil Glacier is located in Dickson Land in the central part of West Spitsbergen. It occurs to the north-west of the northern branch of Billefjorden. The valley of the Bertil Glacier enters directly into the buried part of the Miner Bay (Fig. 1). The Bertil Glacier occurs in a deep valley, cutting the southern slopes of a rock massif that rises up to 1000 m above the water level in the Bille, Dickson and Aust fiords. The valley is about 500 m deep and 5.5 km long, and it separates two highest ranges of this massif: Reuterskiolfjellet (1029 m above sea level) with the peak of Little Pyramid and the range of Great Pyramid (935 m above sea level). The valley is of the alpine type and has typical glacial features. In the upper, wider section of the valley there is a two-stage firn field and beneath its threshold — a steep-sided glacial trough. The trough is entered by two side valleys with hangind cirque glaciers, coming from Little Pyramid and Great Pyramid. The glacier is located in the central glacial cirque at 450—550 m above sea level. The firn field passes gently northwards into the glaciers: Ferdinandbreen and Sweenbreen, being a fragment of the central part of the large ice cap that covers the Dickson Massif. Southwards, the field passes into a narrow glacial tongue, about 4 km long. A front of this glacier decends to the altitude of 120 m above sea level (Phot. 1). The ice threshold at the contact of the firn field and the glacial tongue is gentle and inclined at an angle less than 20°. Two glaciers in the side glacial cirques have no connection with the tongue of the Bertil Glacier. The larger of them — a glacier of a cirque type, is located at the slope of Little Pyramid. The Bertil Glacier is surrounded by high lateral moraines, observed down the glacial cirque. At the foot of a flat glacier front there are end moraines, with magnificent adjoining eskers.



Phot. 1. Snout of the Bertil Glacier, seen from the end moraine, September 1979. In the right central part are gravel-sandy ridges — a residuum of melted out sediments of an ice cave. The Elza Cave occurs in the central part of the snout near the hut. The caves of a marginal meander are located at the foot of Great Pyramid, at the contact of the tongue of the Bertil Glacier with a lateral moraine (in the right). The pipe in the foreground is the borehole that found the entrance fragment of the Elza Cave.

All photographs are the author's

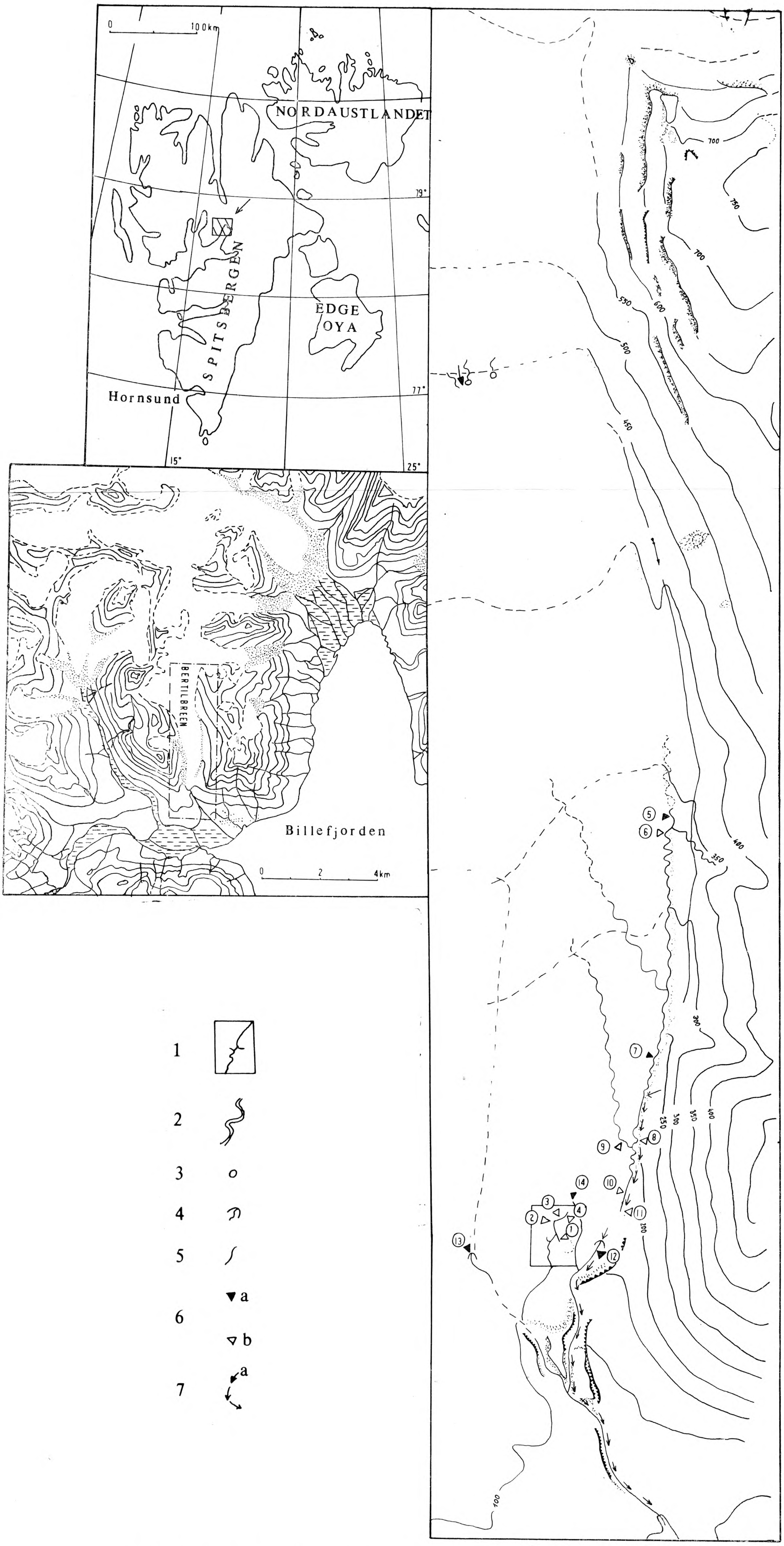


Fig. 1. Creek network and caves inside the Bertil Glacier (West Spitsbergen). September —October 1979. A map in the scale of 1 : 10 000. The topographic map was prepared by the geodesists of the Soviet coal mine at Pyramiden:

1 — a map showing artificial galleries and natural passages of the Elza Cave (Fig. 2), 2 — cave meanders, 3 — ice wells, 4 — springs, 5 — creek, 6 — sampling sites of water for chemical analyses (Table 1): a — surface waters, b — waters of ice caves; 7 — path of a tracer (fluorosceine) transport: a — drop site of the tracer

The lower part of the end moraine is cut by glacial streams that out from a typical fluvioglacial fan, reading the bottom of the buried fragment of Mire Bay. A closer analysis of the frontal part of the Bertil Glacier proves that there is no typical or uniform end moraine but a complex morainic-esker-like feature, created as a result of intensive processes of glacial karst. In winter, an ice cover of an icing is formed at the glacier front as effect of the freezing of waters that flow out from a system of caves of the Bertil Glacier.

Now the Bertil Glacier is intensively retreating. Melting has been pronounsed for the past several years, especially in the depression of the glacier snout. However the snout extent has changed only slightly over the last several years. Lately (1978—1979), the surface of the glacier snout at the end moraine has lowered over 4 m. Hence the average annual ablation is equal about 2 m (personal information of L. Troicky of the glaciological expedition, organized by the Academy of Sciences of the Soviet Union at Moscow). Within the glacier snout the median moraines were melted out (strips of angular blocks) as well as the passages of ice caves gravel-filled (eskers with fluvial gravels). The end moraines, accompanied by eskers and the lateral moraines contain dead glacier ice, many metres thick, in their core.

Karst-related features at the surface of the Bertil Glacier

At the surface of the Bertil Glacier, features similar to karst ones, noted in the areas built of carbonate rocks, were found. They are directly connected with drainage of the glacier surface and with ablation processes.

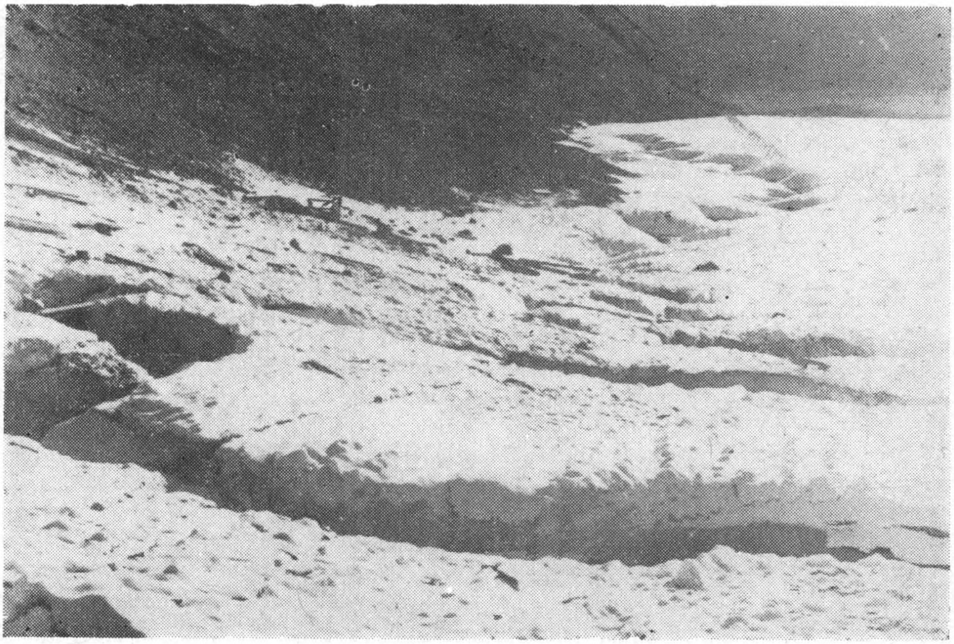
The largest features occur in the firn field of the glacier. They are the oval-shaped depressions with a diameter of over 100 m (Fig. 1). Each depression possesses at least a single well that collects the water — thus serving as a ponor. In the central part of the firn field there are at least two such depressions. At the surface of the firn field there is no superficial drainage.

At the margins of the glacier tongue, mainly in its eastern part, there is a system of marginal surface meanders formed by the action of streams flowing in this part of the glacier (Phot. 2). In the up-glacier section of the tongue, the water flows in superficial meanders but down-glacier it disappears inside the ice (often reaching bedrocks) — in a system of meandering caves. These caves are localized at several levels, at depths to about 20 m. As a result of exploration of these cave systems in September 1979, passages of over 1 km length were discovered. The caves run horizontally and occur at several levels formed during successive phases of underground meander bottom erosion. The passages are the narrow galleries, several metres high. Locally, the passages are open and reach directly to the glacier surface (wells and break-downs to over 20 m deep). At the bottom of the meandering passages there are streams that flow amidst typical cave gravels. In the meandering caves almost all the features noted in limestone caves were found. The features formed in a phreatic phase and channel features are particularly interesting.

The meandering caves contact directly with streams flowing down the slopes of Great Pyramid. Their tunnels cut across dead ice of the lateral moraine. In addition, they are connected with the streams flowing off the central part of the glacier tongue (particularly from under the threshold of the firn field). A connection is realized through a system of increased meanders.

The surface of the glacier and of the lateral moraine within the marginal meanders is intensively deformed. There are numerous depressions, sinkholes and open fissures. It is a typical area of mezoforms of a superficial karst.

In the glacier snout area there are eskers, being the fragments of melted-out gravel-filled cave passages (Phot. 1). In addition there are ponors that contain the waters flowing down this part of the glacier snout. Inside the latter a central cave passage was found that conducted the waters from the inner part of the Bertil Glacier. The collector got out into the surface within the limits of the end moraine. In winter, it supplies with water that forms an



Phot. 2. A fragment of marginal meanders at the foot of Great Pyramid on a tongue of the Bertil Glacier. View down-glacier, September 1979

ice fan. The Elza Cave is a fragment of the central system.

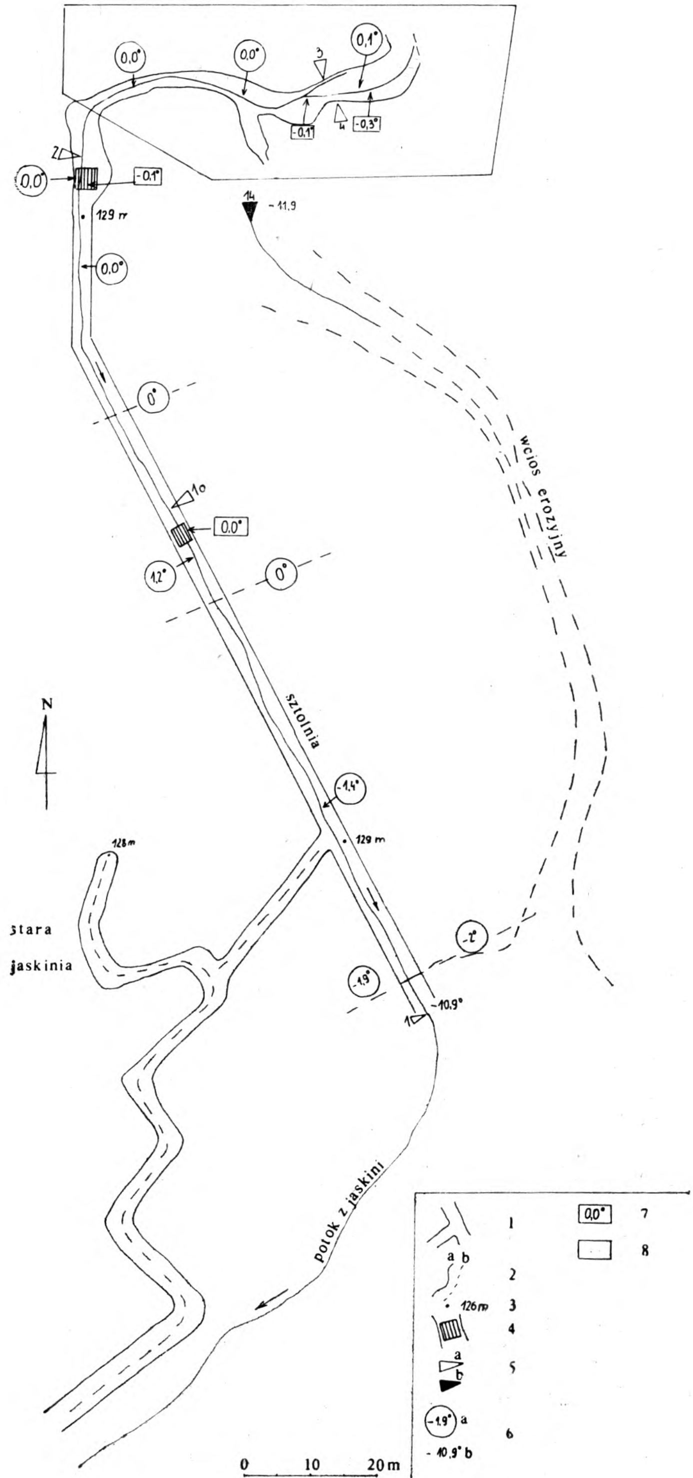
Inside the end moraine of the glacier there are numerous melting-out features as well as depressions and wells, located above the network of the underground central collector.

The Elza Cave inside the Bertil Glacier

Figure 2 presents a localization of the Elza Cave inside the snout of the Bertil Glacier. The cave is a fragment of a large central system that conducts waters from inside the glacier. It is composed of typical „karst" channel, formed at the border of the phreatic and vadose zones (Phot. 3). It has distinct channel features (bottom vadose incision, horizontal channel grooves, typical transversal section, ceiling half-tubes, scallops, potholes), and good examples of features formed under high water pressure, among others oval-shaped passages (Phot. 4). The fluvial gravels in this cave need some attention. They occur at the bottom of a central passage and fill the side channels, some of them — completely. Gravels are the typical cave sediment; they are well-rounded and have a varying petrographic composition that reflects the geologic structure of the glacier valley. During the high water levels in spring 1979, large-size gravels were transported. A fragment of the artificial gallery, running to the Elza Cave,

Fig. 2. Scheme of a network of artificial galleries and natural passages of the Elza Cave (October 1979):

1 — articifial galeries and natural passages of the Elza Cave, 2 — natural underground creek: a — present, b — ancient, 3 — altitude of a passage bottom in metres above sea level, 4 — water pump, 5 — water sampling sites for chemical analysis: a — underground waters, b — waters at the glacier surface, 6 — air temperatures in °C inside the gallery and the cave (a), at the surface (b) on 18th and 19th October 1979, 7 — water temperatures in °C on 18th and 19th October 1979, 8 — area of a natural cave (enlarged at Fig. 3)



0,0°
0,0°
3
0,1°
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-0,3°
2
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14
- 11,9
129 m
0,0°
0°
10
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0°
wcios erozyjny
sztolnia
N
-1,4°
129 m
128 m
stara
jaskinia
-2°
-1,9°
-10,9°
1
potok z jaskini
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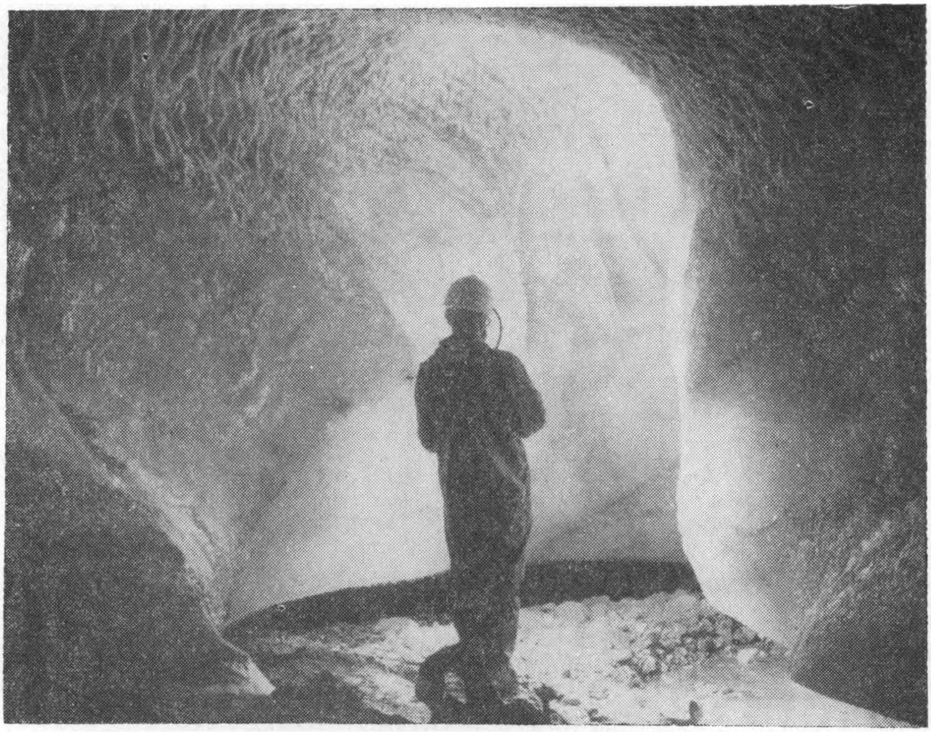
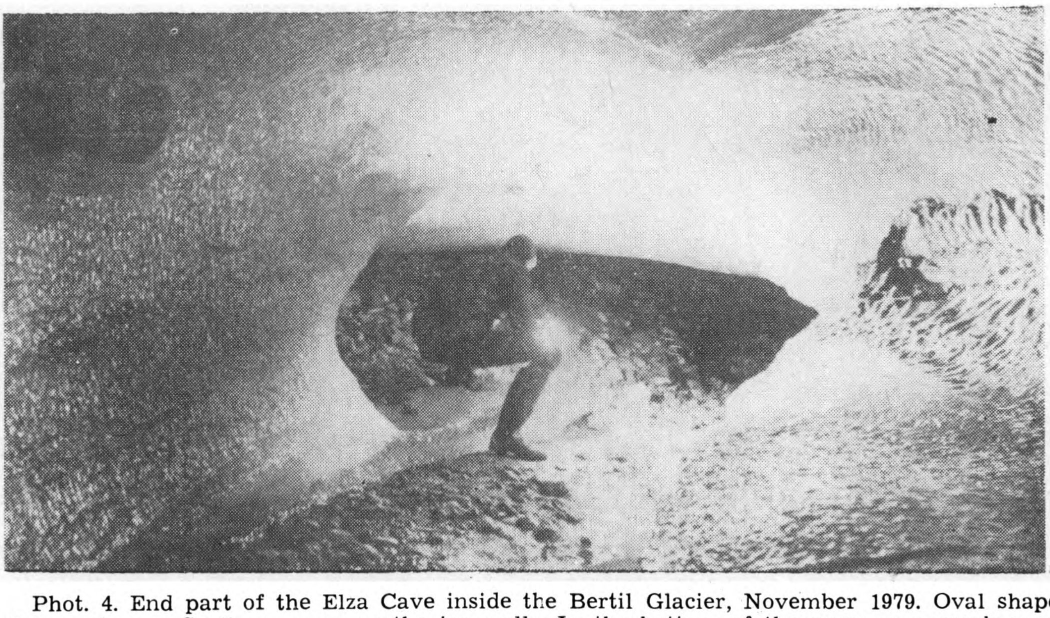


Phot. 3. Central passage of the Elza Cave, the Bertil Glacier, November 1979. Profile of an ice passage is of a figure eight shape. At a wall and at the top of the passage are scallops. In the bottom, a creek flows amidst the gravels lying on the glacial ice.



Phot. 4. End part of the Elza Cave inside the Bertil Glacier, November 1979. Oval shape of the passage. Scallops occur on the ice walls. In the bottom of the passage, a creek runs amidst the gravels.

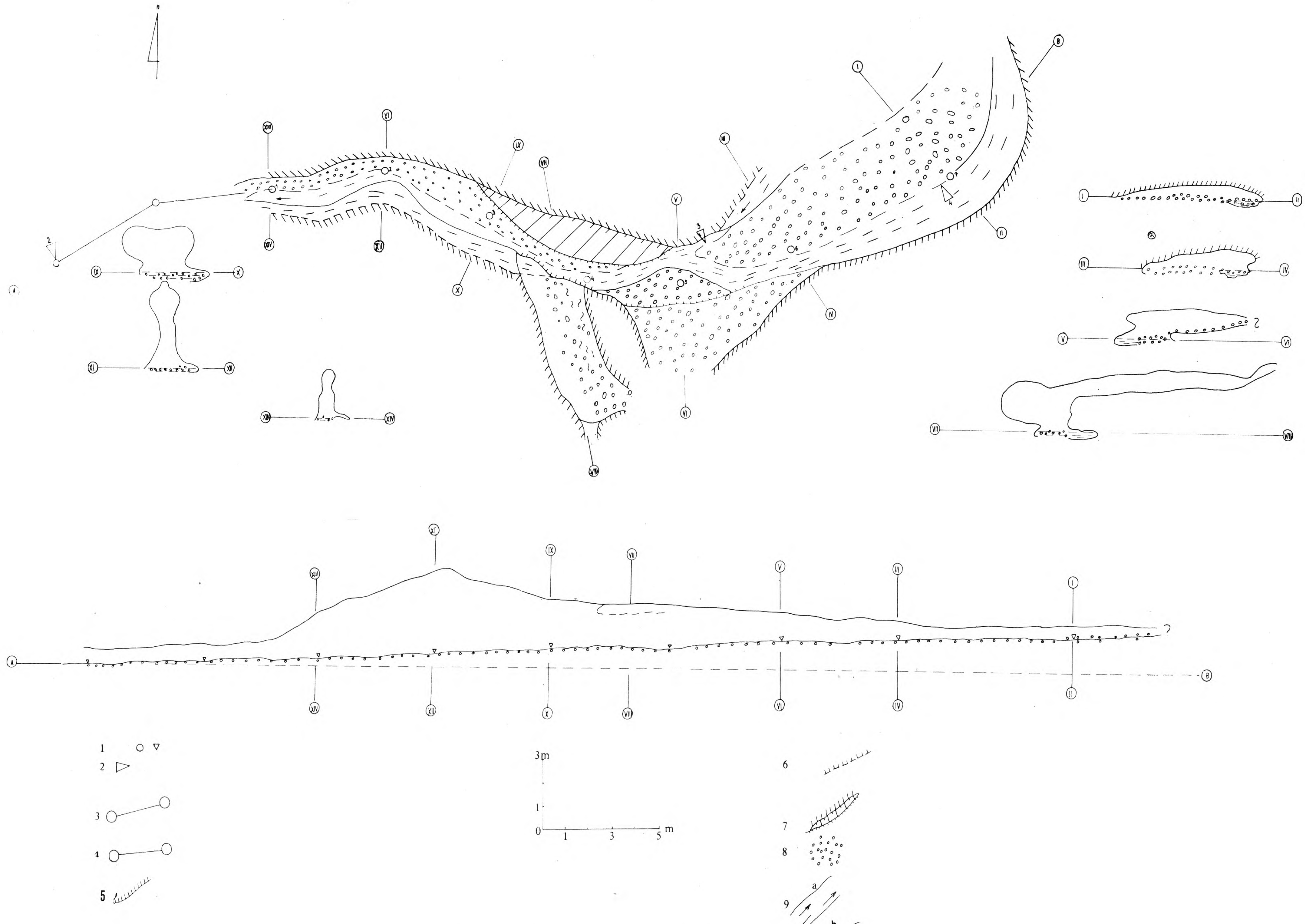


Fig. 3. Plan and sections of the Elza Cave at the Bertil Glacier. September—October 1979:

1 — topographic points, **2** — localization of water samples for chemical analysis, **3** — transversal sections, **4** — longitudinal sections, **5** — ice walls at 2 m above the bottom of a passage, **6** — ice wall at a passage bottom, **7** — ice ledge, **8** — fluvioglacial sediments at a passage bottom, **9** — water stream: a — in a plan, **b** — at sections was at that time almost completely filled by these gravels during several days. Figure 3 presents a detailed plan of the cave and morphologic sections.

The Elza Cave was discovered and explored in autumn 1979 by the Polish-Soviet team, working on the invitation of the coal mine manager at Pyramiden. In this cave, in September and October 1979 a water intake was installed that supplied the settlement and the coal mine at Pyramiden.

Remarks on hydrology of the Bertil Glacier

Based on the hydrological investigations and the effects of exploration of the cave networks, the following water types were distinguished in the Bertil Glacier:

1. Allochthonous waters. They come from outside the glacier, first of all from the slopes of the glacier valley (waters of melting of snow patches and waters of side glaciers).

The allochthonous waters flow at the glacier surface in its marginal part and under the ice, inside the meandering caves. Usually, they come into contact with these caves under the ground surface. No allchthonous water was found to directly feed the central collector. The allochthonous waters are connected in a meander network with autochthonous superficial waters.

These waters leave the glacier at its snout. They flow out at typical springs, usually as open channels or as ascending springs (Fig. 1).

The allochthonous waters and the waters mixed in the marginal caves — meandering caves, flow from June to October. They disappear at the beginning of winter.

2. Autochthonous waters. They come from the melting of glacier ice and snow as well as from atmospheric precipitation that falls on to the glacier surface. The waters of this type flow at the glacier surface and are usually directed into the inner part of the glacier through a network of wells — ponors (in the firn field and in the central part of the glacier tongue) or towards the meandering caves in the marginal part of the glacier where they connect with the allochthonous waters.

Inside the glacier there is a central collector that conducts the waters from the glacier firn field and from the central part of the glacier tongue.

The surface waters flow in spring until the end of summer, usually in May, June--September, October. However, water circulates in the main underground system all the year round, the whole polar winter and night included.

The waters inside the Elza Cave are a good example of the waters circulating inside the central collector (Phot. 3, 4). They get out into the surface as open outflows (in the sixties such an outflow had been observed from the cave located at the foot of an end moraine of the Bertil Glacier) or, most fraquently, as ascending springs. The winter outflows of these waters from an ice fan.

A definition of genetic water types of the Bertil Glacier was done on the basis of chemical analyses (see the next chapter) and of tracing the underground waters by a use of fluorescein (Fig. 1).

Physico-chemical properties of waters of the Bertil Glacier

Two sample series have been collected in several superficial and underground creeks and springs. In addition, the waters that flew out the Elza Cave, have been sampled several times. The samples were collected on 8th and 9th September 1979 and on 19th and 21st October 1979. Some extra samples from the Elza Cave were collected in May and June 1980. In all 24 samples were collected, in which the main ions were determined as well as: pH, free CO_2 and total mineralization (Σ_M). These determinations were done in the field with a use of field laboratory MP-1. Results are presented in the Table 1. In addition, several samples to determination of oxygen and hydrogen isotopes were collected (R ó ż k o w s k i, 1980).

Table 1

Physico-chemical properties of waters of the Bertil Glacier
(September, October 1979; May, June 1980)

Locality no.*	Localization	Date	Time GMT	t_w [°C]	pH	CO_2 [mg/l]	Ca^{2+} [mv/l] [mg/l]	Mg^{2+} [mv/l] [mg/l]	$Na^{+}+K^{+}$ [mv/l] **	HCO_3^{-} [mv/l] [mg/l]	SO_4^{2-} [mv/l] [mg/l]	Cl^{-} [mv/l] [mg/l]	$CaCo_3$ [mv/l] [mg/l]	ϱ_{18} [Ω/cm]	Σ_M [mg/l]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Elza Cave-Bertil Glacier, outlet of an ice tunnel	8th Sept. 1979	5 p.m.	0.3	7.2	—	0.90 18.0	0.46 5.5	1.40	1.30 79.3	0.87 41.7	0.59 20.9	1.36 68.0	5075.3	141.9
1a	Elza Cave-Bertil Glacier isnide an ice tunnel-near a pump	19th Oct. 1979	11 a.m.	—	—	—	0.86 17.2	0.62 7.4	1.71	1.45 88.4	1.11 53.5	0.63 22.4	1.48 74.0	4383.1	164.3
1	Elza Cave-Bertil Glacier outlet of an ice tunnel	21st Oct. 1979	11 a.m. sample for isotopic analyses (tritium)	•	•	•	•	•	•	•	•	•	•	•	•
2	Elza Cave-an ice tunnel below a cave	19th Oct. 1979	1 p.m.	0.1	7.4	2.2	0.92 18.4	0.56 6.7	1.82	1 40 85.4	1.24 59.6	0.66 23.4	1.48 74.0	4275.6	168.4
2	Elza Cave new water intake	1st May 1980	8 p.m.	0.1	7.5	4.4	1.10 22.0	0.80 9.6	2.51	1.75 106.7	1.50 72.0	1.16 41.2	1.90 95.0	3317.1	217.1
2	Elza Cave new water intake	2nd May 1980	10 a.m.	—	7.5	4.4	1.10 22.0	0.70 8.4	2.51	1.75 106.7	1.40 67.2	1.16 41.2	1.80 90.0	3317.1	217.1
2	Elza Cave new water intake	3rd May 1980	3 p.m.	—	7.4	5.5	1.10 22.0	0.76 9.1	2.46	1.90 115.9	1.26 60.5	1.16 41.2	1.86 93.0	3317.1	217.1
2	Elza Cave new water intake	4th May 1980	4.30 p.m.	—	7.4	5.5	1.06 21.2	0.70 8.4	2.41	1.75 106.7	1 26 60.5	1.16 41.2	1.76 88.0	3317.1	217.1
2	Elza Cave new water intake	5th May 1980	8 a.m.	—	7.5	4.4	1.10 22 0	0.70 8.4	2.51	1.75 106.7	1.40 67.2	1.16 41.2	1.80 90.0	3317.1	217.1
2	Elza Cave — an ice tunnel beneath the cave — new intake	1st June 1980		—	7.6	•	•	•	•	•	•	•	•	3225.0	223.3
3	Elza Cave — right orographicly creek	9th Sept. 1980	9.30 p.m.	0.0	7.6	—	0.90 18.0	0.50 6.0	1.34	1.40 85.4	0.76 36 6	0.58 20.6	1.40 70.0	5048.2	142.6
3	Elza Cave — right creek orographicly	19th Oct. 1979	0.30 p.m.	0.1	7.6	2 2	0.88 17.6	0.72 8 6	1.67	1.50 91.5	1.14 54.5	0.63 22.4	1.60 80.0	4275.6	168.4

4	Elza Cave — left creek orographicly	9th Sept. 1980	9.20 p.m.	0.1	7.5	—	0.90 18.0	0.46 5.5	1.40	1.40 85.4	0.78 37.6	0.58 20.6	1.36 63.0	5013.6	143.6
4	Elza Cave — left creek orographicly	19th Oct. 1979	12 a.m.	0.0	7.2	3.3	0.92 18.4	0.60 7.2	1.70	1.50 91.5	1.09 52.1	0.63 22.4	1.52 76.0	4337.8	166.0
5	Bertil Glacier — left meander orographicly — marginal stream of the glacier	9th Sept. 1979	3.15 p.m.	0.1	7.4	—	1.26 25.2	0.38 4.6	—	1.75 106.7	—	0.27 9.6	1.64 82.0	7771.5	92.6
6	Bertil Glacier — left meander orographicly — after a connection of streams	9th Sept. 1979	3 p.m.	0.2	7.4	—	1.56 31.2	0.84 10.1	0.24	1.55 94.5	0.82 39.5	0.27 9.6	2.40 120.0	5014.3	143.6
7	Bertil Glacier — left meander oragraphicly — stream by the „camp"	8th Sept. 1979	12 a.m.	0.0	7.2	—	1.80 36.0	0.88 10.6	0.24	1.50 91.5	1.10 52.7	1.10 11.4	2.63 134.0	4628.6	**155.6**
8	Bertil Glacier — left meander orographicly — inside the cave before a connection	8th Sept. 1979	0.10 p.m.	0.0	7.2	—	1.80 36.0	0.80 9.6	0.25	1.65 100.6	0.91 43.9	0.29 10.3	2.60 130.0	4651.3	154.8
9	Bertil Glacier — tributary from the glacier to a left meander (orographicly)	8th Sept. 1979	12 a.m.	0.1	6.3	—	0.50 10.0	0.20 2.4	—	0.85 51.8	—	0.19 6.7	0.70 35.0	19006.3	37.9
10	Bertil Glacier — left meander orographicly inside the cave by the entrance	8th Sept. 1979	0.30 p.m.	0.1	7.2	—	1.68 33.6	0.82 9.8	0.11	1.55 94.5	0.77 36.8	0.29 10.3	2.40 120.0	5085.2	141.6
11	Bertil Glacier — left meander orographicly inside the cave-deeply	**8th Sept.** 1979	1 p.m.	0.1	7.1	—	1.80 36.0	0.54 6.5	0.21	1.65 100.6	0.58 27.9	0.32 11.4	2.34 117.0	5146.0	139.9
12	**Bertil Glacier — left meander orographicly, a creek at the** surface of the whole meander	8th Sept. 1979	1.30 p.m.	0.0	7.2	—	1.76 35.2	0.82 9.8	0.11	1.65 100.6	0.79 37.8	0.25 8.9	2.58 129.0	4387.3	147.3
13	**Bertil Glacier — right meander orographicly**	9th Sept. 1979	2 p.m.	0.2	7.0	—	1.20 24.0	0.34 4.1	—	1.50 91.5	—	0.17 6.0	1.54 77.0	8909.5	30.8
14	Bertil Glacier — a creek at the ice surface — above the cave	8th Sept. 1979	5 p.m.	**0.2**	**6.8**	**—**	0.64 12.8	0.18 2.2	—	1.05 64.0	—	0.17 6.0	0.82 41.0	16952.4	42.5

* Numbers of sites in agreement with figures 1, 2 and 3.

** ($Na^{+}+K^{+}$) evaluated from a difference of cations and anions.

On the basis of the analyses presented in the diagrams (Figs 4—8) and in the Table 1, three genetic water types can be distinguished:

1. Autochthonous waters. They circulate at the glacier surface and feed the underground water network inside the glacier. These waters are slightly mineralized: Σ_M is smaller than 50 mg/l, a water type $HCO_3^- - Ca^{2+} - (Na^+ + K^+)$. Sample 14 in Table 1 and in Figure 5 is an example of such water.

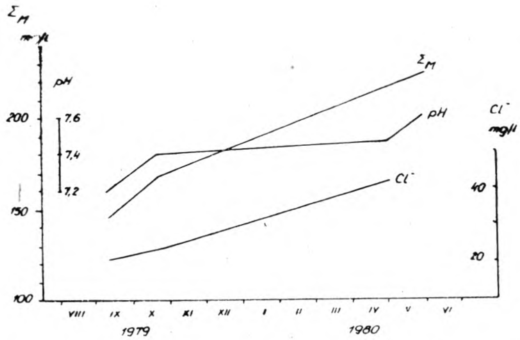


Fig. 4. Increase in mineralization of waters of the Bertil Glacier (the Elza Cave) from the end of autumn 1979 until the end of winter 1980

2. Allochthonous waters. They flow in marginal meanders. They come from the slopes of the glacial valley and possess a mean mineralization of 100—150 mg/l. They are of the type $HCO_3^- - Ca^{2+} - SO^{2-}$ (Mg^{2+}). The ionic composition of these waters reflects the kind of rocks they pass over. These rocks mainly flow inside the meandering caves of the Bertil Glacier.

3. Allochthonous — underground waters. They occur inside the Bertil Glacier. They come from the surface glacial waters and run into glacier wells and ponors. The waters circulate inside the vast basins and networks of ice passages; their exchange lasts for several years as proved by tritium analyses and results of experimental cryochemical works of the same author. The waters possess a mean mineralization of: **142—217 mg/l (n° 1, 2, 3, 4, at Fig. 5 and** in the Table 1). The type of water is similar to the one of feeding — autochthonous waters:

$$HCO_3^- - Ca^{2+} - (Na^+ + K^+)$$

The mineralization of these waters was found to increase considerably in time from spring to summer to winter. The maximum of mineralization occurs at the end of winter whereas its minimum — in spring. The increase in the amount of some ions in these waters is well illustrated by Figs 4 and 8. Such phenomenon is caused, as proved by the author's experiments done at the Polish station in Hornsund, by the so-called cryochemical effect.

Final remarks

The investigations carried out at the Bertil Glacier have noted phenomena similar to karstic ones. Similar phenomena had been found previously at the glaciers of the Hornsund area (Pulina, 1979). Superficial karst-related features are directly connected with underground glacial drainage and with some aspects of ablation. Thanks to a discovery of large cave systems inside the Bertil Glacier and the possibilities to carry out there hydrological and the hydrochemical studies, a well-organized hydrographic system of the glacier was found. Inside the glacier occur basins filled with water and a network of channels connected with a central collector. The Elza Cave is the outlet fragment of this collector. The waters circulate inside the basins and the caves of the central channel for several years whereas their mineralization and some physico-chemical properties are created by the cryochemical effect.

Based on hydrological and hydrochemical investigations as well as on a result of a cryochemical experiment, the following data have been received. The volume of the karstic system of the Bertil Glacier, inside which the waters circulate in winter, is over 100 thousand cubic metres. At the same time the passages of the ice caves occupy only a small part of the volume. Most of it, is occupied by water-bearing basins for-

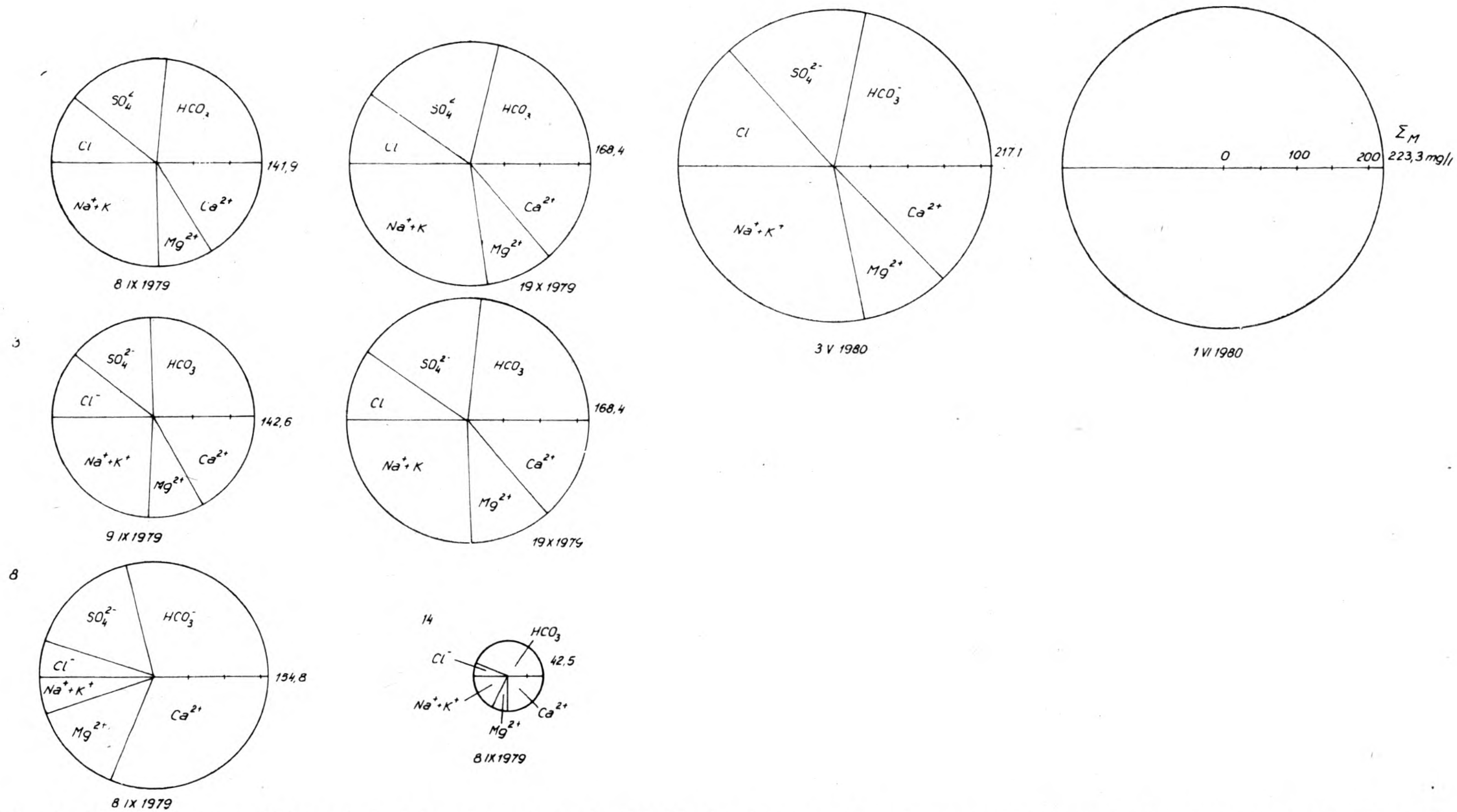


Fig. 5. Chemical composition of glacial waters of the Bertil Glacier in a circular diagram. The sample numbers as in the Table 1

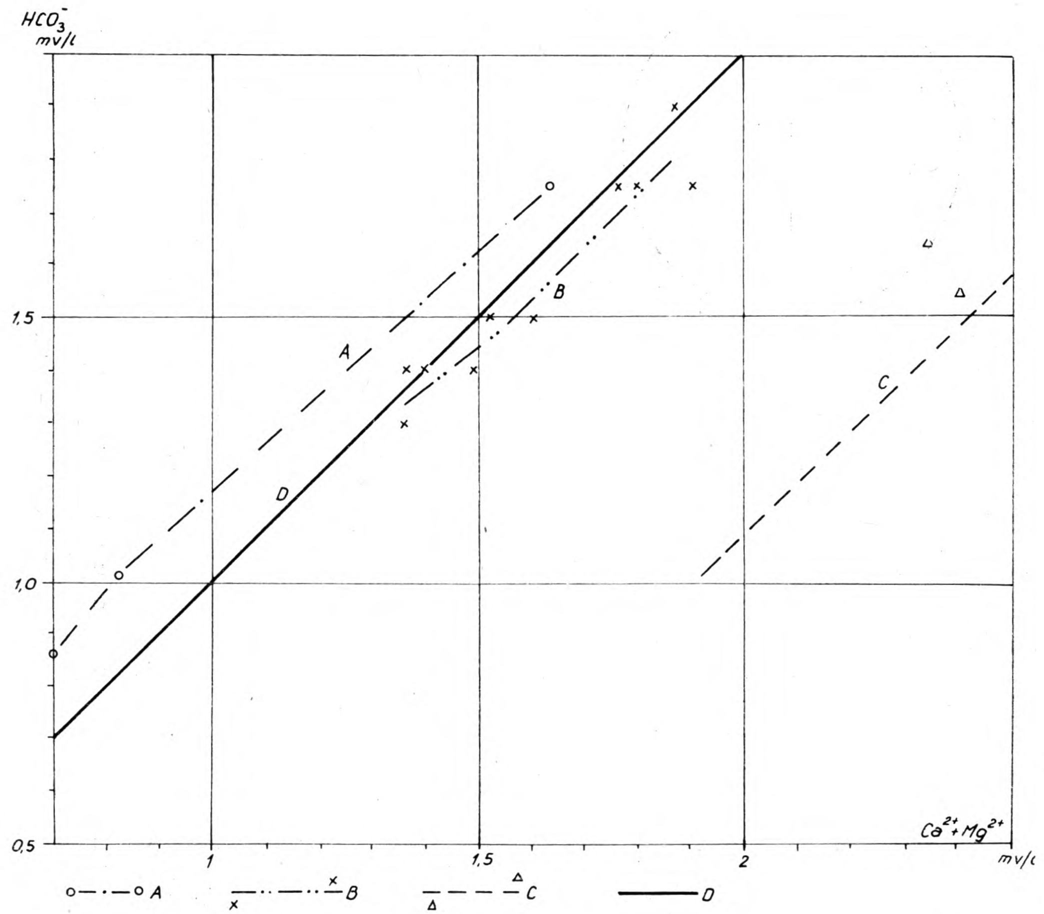


Fig. 6. Dependence of the concentration of HCO_3^- on the concentration of $(Ca^{2+}+Mg^{2+})$ in waters of the Bertil Glacier (September, October — 1979; May, June — 1980):

A — waters at the glacier surface $\frac{HCO_3^-}{Ca^{2+} + Mg^{2+}} = 1.1—1.3$

B — waters inside the Elza Cave $\frac{HCO_3^-}{Ca^{2+} + Mg^{2+}} = 0.9—1.0$

C — waters inside the caves of a left meander $\frac{HCO_3^-}{Ca^{2+} + Mg^{2+}} = 0.6—0.7$

D — equilibrium curve $\frac{HCO_3^-}{Ca^{2+} + Mg^{2+}} = 1$

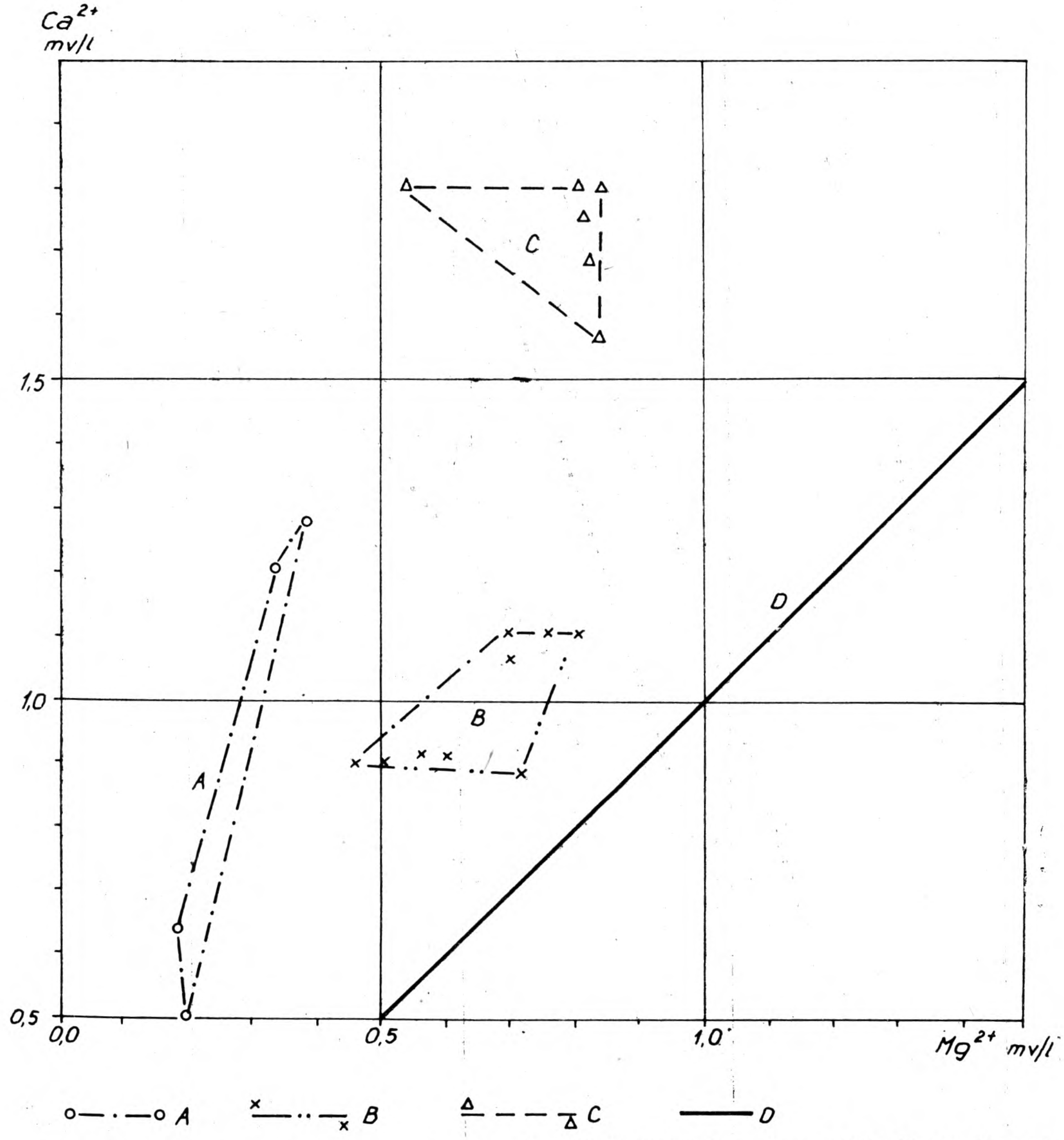


Fig. 7. Dependence of the concentration of Ca^{2+} to Mg^{2+} in waters of the Bertil Glacier (September, October 1979; May, June 1980):
A — waters at the glacier surface, **B** — waters inside the Elza Cave, **C** — waters inside the caves of a left meander, **D** — equilibrium curve

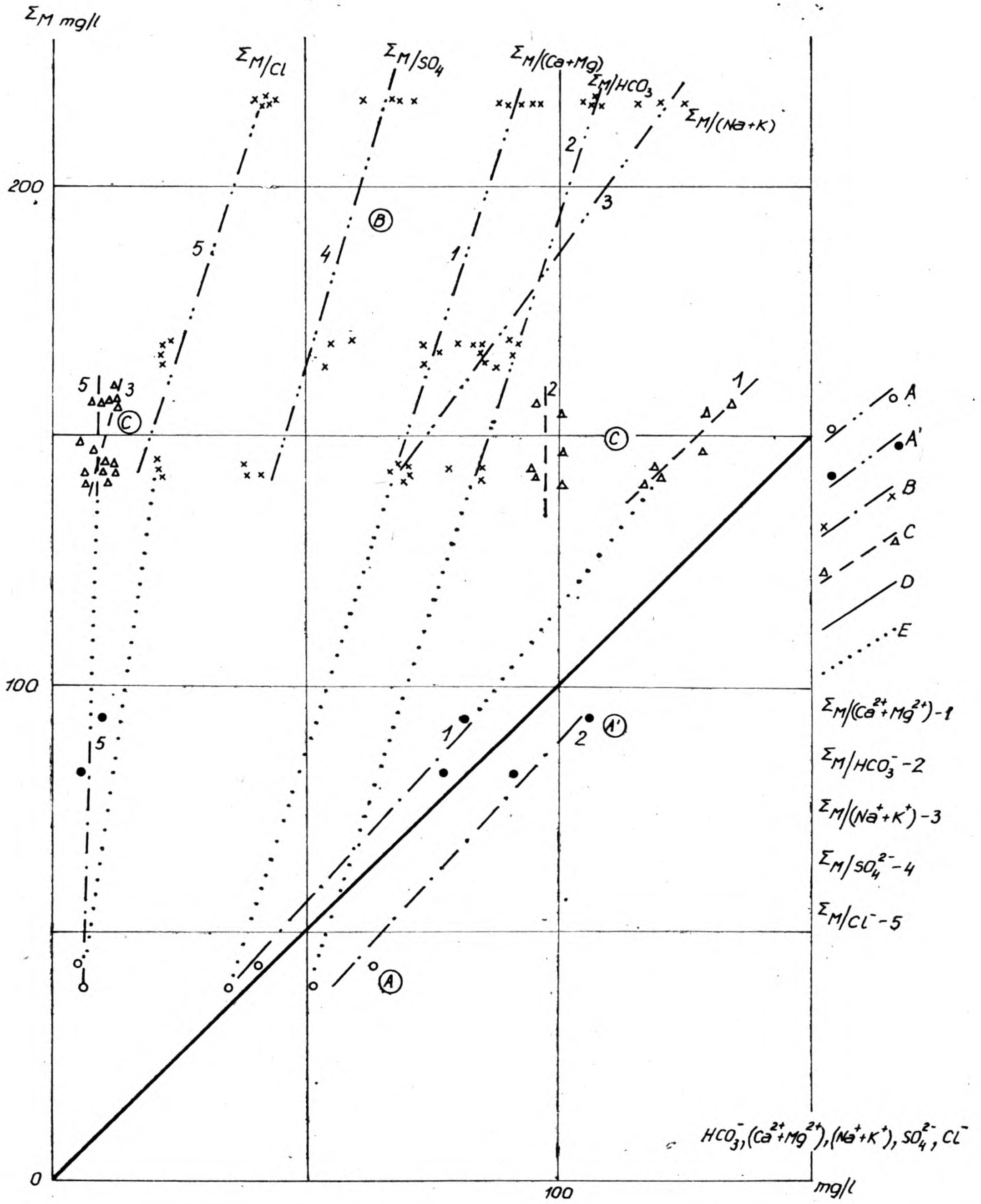


Fig. 8. Dependence of concentrations of ions ($Ca^{2+} + Mg^{2+}$), HCO_3^-, $Na^+ + K^+$, SO_4^{2-} Cl^- on the total mineralization (Σ_M) in waters of the Bertil Glacier (September, October 1979; May, June 1980):

A — waters at the glacier surface in its central part, **A'** — waters at the glacier surface in its marginal part, **B** — waters inside the Elza Cave, **C** — waters inside the caves of the left meander, **D** — equilibrium line, **E** — optimum means of genetic connection of water types of the Bertil Glacier med of micro-channels, as small as 1 cm in diameter. The volume of the karstic system is equal to about 0,05% of the volume of the whole Bertil Glacier. The volume of the network must be accepted to increase by at least twice in summer. Therefore, it may constitute over 0,1% of the volume of the whole glacier.

The volume of waters that flow out the glacier in winter, can be evaluated as over 100 thousand cubic metres. The water carries out about 17 tons of dissolved salts, mainly calcium carbonate and sulphates.

The presented results of studies from the Bertil Glacier, although they are only preliminary, prove that at Spitsbergen there are glaciers which have a well developed karstic hydrography. The waters circulate inside the glaciers all year round, during the polar winter night as well.

The hydrochemical investigations are the principal way to distinguish the genetic types of waters inside glaciers similar to the Bertil Glacier. Results of these investigations are of great practical significance of the settlement and the coal mine at Pyramiden. The cost of getting the water and its exploitation are many times smaller and more certain than the previous hydrological applied at Spitsbergen.

Translated by Leszek Marks

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Marian Pulina

ZJAWISKA ZBLIŻONE DO KRASOWYCH W LODOWCU BERTIL, ZACHODNI SPITSBERGEN

Streszczenie

Tematem artykułu są formy zbliżone do krasowych, odkryte w lodowcu Bertil, położonym w centralnej części Zachodniego Spitsbergenu (rys. 1). Formy te są powiązane z podziemnym odwodnieniem lodowca oraz z systemem jaskiń i studni położonych w części marginalnej lodowca. Długość korytarzy tych jaskiń przekracza 1 km.

Artykuł zawiera również wyniki badań hydrologicznych i hydrochemicznych przeprowadzonych w lodowcu Bertil (tab. 1, rys. 4, 5). Wyróżniono tu kilka genetycznych typów wód, w tym wieloletnie wody płynące w centralnym kolektorze (rys. 6—8). Wody te nie zamarzają w czasie nocy polarnej.

Wyniki badań zostały wykorzystane do projektu ujęcia wód z lodowca Bertil. W sezonach jesiennych i zimowych 1979 i 1980 wody te zasilały radzieckie osiedle i kopalnię Piramiden.

Marian Pulina

PHÉNOMÈNES RESSEMBLANT AUX PHÉNOMÈNES KARSTIQUES DANS LE GLACIER BERTIL, SPITSBERG OCCIDENTAL

Résumé

Dans cet article sont discutées les formes ressemblant à celles karstiques, découvertes dans le glacier Bertil, situé dans la partie centrale du Spitsberg Occidental (fig. 1). Elles sont liées à la déshydratation souterraine du glacier et un système de grottes et de puits situés dans la partie marginale du glacier. La longueur des galeries depasse 1 km.

L'article présente également les résultats des recherches hydrologiques et hydrochimiques effectuées dans le glacier Bertil (tableau 1, fig. 4, 5). Ont y été distingués quelques types d'eaux génétiques, y compris les eaux de longues années coulant dans le collecteur central (fig. 6—8). Ces eaux ne gèlent pas durant la nuit polaire.

Les résultats des recherches ont été effectués pour le projet du captage d'eaux du glacier Bertil. En saison d'automne et d'hiver 1979 et 1980 ces eaux alimentaient une cité soviétique et la mine Piramiden.

Traduit par Teresa Korba-Fiedorowicz

REVIEW PAPERS

Zbigniew Wójcik*

An outline of history of Polish speleology**

Abstract: A short review of more important attainments of Polish speleology is presented, with a particular attention paid to the studies carried out after 1945 (including: geologic, archaeologic, biospeleologic studies). The considerable interest of Polish naturalists in geologic and palaeontologic aspects of palaeokarst is emphasized. Also, a considerable interest was focused on applicative problems of studying caves and on works on the origin of deposits in the karstic areas.

Introduction

Archaeologic studies have been carried through since the XIXth century in the caves of the Polish territory (cf. Kowalski, 1951—1953). They proved that the caves were inhabited by man during the Palaeolithic and Neolithic. Later on, the caves were used for storage. First notes about the karst features can be found already in a literature of the XVIth and XVIIth century (at that time the caves were already described as well as speleothems occurring in them, disappearing streams, large springs, etc.). The first attempts of a scientific interpretation of cave origin can be connected with the studies carried by S. Staszic (1815) in the XVIIIth and at the beginning of the XIXth centuries in the Cracow Upland (Ojców area near Cracow) as well as in the Polish, Slovakian and Hungarian Carpathians. He belived in the considerable role of infiltrating waters in the washing of limestones and speleothem formation. In addition, he described the bone remains of cave bears, known especially from the caves of the Niżnie Tatra Mts.

Back then, many geologists dealt with various aspects of cave origin and afterwards, also of superficial karst. I wish to mention some papers in that field: 1 — S. Płachetko (1876) who described several sinkholes in limestones at Podhorce near Lvov, 2 — S. Syrski (1876) who presented a complex description of the Postojna Cave with an analysis of the living conditions of Proteus anguinus, 3 — A. Rehman (1895) who described the Slovakian Karst when he prepared a geographic description of the Carpathians and introduced the term „karst" into the Polish literature, 4 — W. Łoziński (1907) who studies the karst of the Galician Podole, 5 — L. Sawicki (1909) who used the concept of W. M. Davis for an interpretation of geomorphologic evolution of karstic areas, 6 — K. Kowalski (1951—1953) who published an investory of the Polish caves with a compendium of knowledge of a karst and caves in this country and with an analysis of previous achievement in geology, hydrology, microclimate, biospeleology, nature conservation, etc.

Since the very beginning of karst and cave research, geologic, archaeologic and palaeontologic aspects of cave deposits have been analyzed. At the beginning of the XXth century biospeleologic investigations had been also started and then, works for the purposes of natural conservation (especially

* Museum of the Earth, Polish Academy of Sciences, al. Na Skarpie 20/26, PL 00-488 Warszawa, Poland

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in connection with saving cave fillings from being exploited as fertilizers). Recently, complex investigations of more interesting caves or vaster karst have been carried through.

Polish geologists have been interested in caves of many European countries since the XVIIIth century. In the XIXth century J. Czerski (1876) carried out speleologic investigations in Siberia. After World War II, the Polish cavers have worked in many countries (starting from the tropics of Cuba to the polar area of the Svalbard Archipelago). At first, they were interested in caves within limestones, then within gypsum, loess and sandstones, and lately within glacier ice as well.

In Poland there is now a very active team for cave research (scientific fields, tourist and sport) of palaeokarst and of similar phenomena. In spite of this, there is neither a separate research institute nor a speleological federation in this country. Therefore, a proper application of results of domestic and external research expeditions is not easy.

Era of basic physiographic studies (XIXth and the beginning of XXth centuries)

The quantity of scientific contributions to karst and caves (about 2000***) makes the subdivision of the history of Polish speleology into separate periods a complex task. Generally speaking, one can accept that until the end of the Ist World War there had been a period of so-called basic physiographic studies. But in that time also, many regional syntheses have been prepared, much similar to the ones of the period between the two world wars. Finally, in the last period initiated by the monograph of K. Kowalski (1951—1954), attempts of more general complex studies predominated.

The interest in caves and karst during the period of so-called physiographic studies, reflects the general trends of natural sciences in the XIXth and at the beginning of the XXth century. More intensive works in the caves have been started in the second half of the XIXth century in result of studies of cave fills for archaeological purposes (comp. Zawisza, 1871; Demetrykiewicz, 1914). These works have also initiated palaeontologic (comp. Łomnicki, 1881; Kiernik, 1913), botanic (comp. Żmuda, 1915) and zoologic (Syrski, 1877; Demel, 1918) investigations. Firstly speculation on the origin of a single cave was the problem or an analysis of its specific features (eg. the recent fauna of the Postojna Cave — Syrski, *op. cit.*, the origin of a speleothem cave at Łokutki by Tłumacz, Podole — Łomnicki, 1895) or of a small area with sinkholes and underground streams in Podhorce (Płachetko, *op. cit.*). But already before, the need for cave investigations of certain mountain areas had been appreciated. Owing to that J. G. Pawlikowski (1887) worked out the caves in the Western Tatra Mts.

Period of first regional syntheses (between the two world wars)

The period of so-called physiographic studies as well as the following period of first regional syntheses are not uniform. The palaeontologic and geologic study of J. Czerski (*op. cit.*), dealing with the origin of the Nizhne-Udinskaya Cave and associated investigations in the surroundings of Lake Baikal, was an attempt in interpretation of the geomorphologic evolution of a karstic area, being ahead of the ideas of W. M. Davis. These investigations have been, to some extent, continued by L. Sawicki (1909) who interpreted karst evolution as an effect of changing climatic, tectonic, etc. conditions; which he based on a detailed analysis of the geomorphologic evolution of the Slovakian Karst and of typical karstic areas in Europe (French Central Massif, Dinarides, Jura, etc.). A reference to the idea of the geographic cycle of W. M. Davis by him was therefore quite for-

*** For this reason the author mentions only some papers: he hopes to prepare another paper with a full analysis of the achievements of Polish speleology.

mal. The lasting value of Sawicki's idea (similarly as the one of Czerski) results from a tight connection of karst evolution with conditions of relief formation in the analyzed areas.

The investigations of the period between the two wars, carried out by L. Sawicki (1924) in Thailand or by B. Zaborski (1932) in the Central Massif, also broadly dealt with the geomorphologic evolution of these areas. The same approach was also represented by A. Wrzostek (1933) in his paper dealing with karst in the Tatra Mts., in connection with the idea of A. Grund about a uniform level of karstic waters. To a certain degree, his investigations were continued by S. Zwoliński (1955) although the latter considered the origin of karst as a result of the evolution of many separate units.

In the period between the two world wars the first cave monographs in the Cracow Upland (Ciętak, 1935) had been initiated as well as attempts of interpretation of great units of karst origin dependant on definite tectonic deformations of a karst area of the Dinarides (Malicki, 1938). A study on a gypsum karst in Pokucie (by Malicki, 1938) is also a regional synthesis. Independently, research on fossil mammals, found in a cave at Węże by Działoszyn, had been started for palaeogeographical purposes (Samsonowicz, 1934).

Speleological investigations after 1945

The most recent period of speleological studies in Poland is, at the same time, greatly connected with very intensive investigations. A cave inventory of K. Kowalski (1951—1954) was not only a recapitulation of hitherto knowledge but it also provoked a younger generation of naturalists to further studies.

Geology of karst and caves

Lately many papers have been published in this country and abroad; among them I have chosen only some to be presented here in groups:

1. Experimental studies.

They have been initiated in Poland by J. Rudnicki (1960) with his works on flutes. In a laboratory he has obtained a series of scalops in plaster-of-Paris using water streams of different flow velocity. The created forms not only proved the direction of a flow but also reflected a functional dependency of the depression shape on the flow velocity. This paper should be considered as a preliminary work on the problem.

J. Balwierz and S. Dżułyński (1976) have modelled the conditions in which phreatic karst process deformations has caused rock. In experiments they used a cracked plaster-of-Paris material and a continuous water stream in open tanks and closed containers. These investigations were of practical significance and were applied during analyses of the origin of karst lead and zinc deposits (see below).

2. Morphology of caves and surface karst relief.

Based on the analyses of various features of cave relief, attempts to reconstruct the origin of underground and surface karst have been initiated. The idea connected with concepts of M. Klimaszewski (1958) and S.Z. Różycki (1960), about a karst Palaeogene relief (monadnocks) in the Cracow-Częstochowa Upland, influenced for many years the studies on karst relief. The investigations of the underground karst relief in the Cracow Upland (Gradziński, 1962), studies on surface relief by S. Dżułyński et al. (1966) and on the cave sediments in that area (Madeyska-Niklewska, 1969) proved that the present topography of the Cracow-Częstochowa Upland is younger (Upper Miocene, Pliocene, Quaternary).

Detailed studies on the morphogenesis of caves have been started in Poland by J. Rudnicki (1958, 1967) and R. Gradziński (1962). The former has analyzed on this basis the cave evolution in the Tatra Mts., whereas the latter — in the Cracow Upland. In both cases a reconstruction of the evolution of the underground karst was connected with the morphogenetic environment of the Polish uplands and mountains in the Tertiary and Quaternary.

Morphologic aspects of karst evolution, particularly in the tropics, were studied by R. Gradziński and A. Radomski (1963) in Cuba and by J. Głazek (1966, 1970) in North Viet-Nam. Main emphasis was placed on the formation of monadnocks and poljes, considering the climatic conditions of karst evolution as well as the geology of the investigated area.

Such studies also included, among others, a monograph of a gypsum karst in the Carpathian Foredeep (Flis, 1954) and also, the study of A. Malicki (1946), dealing with karst-like features of loess. Within this sphere many other smaller papers have been published, describing the caves within flysch sandstones in the Carpatians (comp. Kowalski, 1954).

Among the most recent research results the most significant ones include a paper about the formation of so-called proglacial caves (Głazek et al., 1977) and the study of J. Rudnicki (1979) about the influence of convection currents on karst evolution in the phreatic zone.

3. Tectonic cave problems.

Among others two aspects have been studied. J. Grodzicki (1970) noted the significant part played by tectonic predispositions in the formation of cave passages. Comparing the cave sections in sandstones of the Beskides and in limestones of the Tatra Mts., he found that in many caves corrosion played only a secondary role in the formation of underground passages.

Some other problems were investigated by Z. Wójcik and S. Zwoliński (1959). They described the discontinuous deformations of cave passages in the Tatra Mts. and associated their formation with neotectonic movements.

4. Hydrochemical investigations.

The studies in this field tended among other things, to find the rate of karst denudation. They were carried out in the Cracow—Częstochowa Upland by M. Markowicz-Łohinowicz (1972), in the Holy Gross Mts. by J. Głazek and M. Markowicz-Łohinowicz (1973), in the Sudetes by M. Pulina (1974, 1977) and in the Tatra Mts. by A. Kotarba (1972). Generally speaking, a considerable loss of limy mass was noted for the holocene. Similar investigations were carried out by M. Pulina (1968, 1971, 1972, 1977, 1978) in other countries, including East Siberia and Spitsbergen, and by M. Markowicz, W. Popow and M. Pulina (1972) in Bułgaria. Studies on large underground overflows were also done (comp. Głazek et al., 1972).

5. Speleothems studies.

Speleothems studies on the origin of moonmilk in the caves of the Tatra Mts. have defined the conditions in which they existed (Gradziński, Radomski, 1957). Detailed geochemical studies of B. Lis et al. (1967) have suggested a probable participation of organic matter in moonmilk formation.

Much attention was paid to various problems connected with the origin of several types of calcite speleothems. I suggest to distinguish two paper groups only: ones dealing with cave pearls (ooids) and mushroom-shaped sinters. The former inludes the paper about pearls from caves in Cuba. R. Gradziński and A. Radomski (1967) were interested in problems of pearl shape and surface, depending on a sedimentary environment but also, in further calcite recrystallization inside them. In another paper the same authors (Gradziński, Radomski, 1976) analyzed the recrystallization rate of Tertiary ooids found near Cracow. A considerable metamorphosis of the ooid structure was not, however, connected by them with deformation within the sediment (which seemed to be obvious) but with changes in the sedimentary environment (humidity changes). In addition R. Gospodarič and Z. Wójcik (1965) described pearls from the Postojna Cave that have been formed after 1912. Many similar problems were described in a paper about onkoliths from streams in North Viet-Nam and in the Polish Tatra Mts.

(Głazek, 1965); the paper also contained some information on the participation of flora in the sedimentation of calcium carbonate in streams of limy areas.

Mushroom-shaped sinters are especially common in the caves of the Tatra Mts. and of the Cracow—Częstochowa Upland. Their origin was associated by R. Gradziński and R. Unrung (1960) either with an infiltration of solution inside a porous rock or with a splashing of water drops. Other authors (Kasiński, Krajewski, 1978) connected the growth of these sinters with a cyclic sedimentation, dependant on climatic variation near the cave.

6. Cave sediments.

Quite a lot of attention has been paid to studies of allochthonous sediments in the caves of the Tatra Mts. by Z. Wójcik (1966, 1968). The sediments have been transported into the caves by superficial streams and occur at various altitudes above the valleys. They create a specific geologic sequence which reflects the changing weathering conditions in alimentary areas. Attempts of detailed chronologic interpretation of these sediments (unquestionably of Pliocene and Pleistocene age) have been unsuccessful due to unsatisfactory palaentologic documentation.

In the Cracow—Częstochowa Upland an analysis of Late Pleistocene clastic sediments in caves has been accomplished (Madeyska-Niklewska, 1969: Madeyska, 1977), Usually, the autochthonous sediments occuring there reflect climatic variations.

One should add that in the sediments of several caves in the Tatra Mts. various cryogenic features have been noted, among them, structural soils as well. M. Z. Pulinowa and M. Pulina (1972) explained the very beginning of these soils by deformations caused by the freezing of clastic covers at cave bottoms. I consider the problem to be much more complicated: the soils were formed as a result of sediment deformation in seasonally changing humidity conditions. The problems however need further investigations. But a description of weathering and sedimentary features, especially found in the entrance parts of the Tatra caves, is undoubtedly of great cognitive significance.

7. Hydrogeologic investigations.

These have been carried out on a larger scale in the Tatra Mts. (Dąbrowski, 1967a, 1967b; Dąbrowski, Głazek, 1968). By dyeing methods (uranin) of waters, the main hydrogeologic units have been distinguished, with deep overflows usually independent of surface topography.

8. Problems of a palaeokarst.

These have been undertaken many a time and some attempts of the recapitulation of analytic data were presented by S. Gilewska (1964, 1971) as well as by R. Gradziński and Z. Wójcik (1966), J. Głazek, T. Dąbrowski and R. Gradziński (1972). Another view on the problem was presented by J. Głazek (1973) who stressed the significance of palaeokarst for an understanding of the palaeogeographic evolution of the Polish territory. The latter author has initiated a broader action on a comprehensive analysis of palaeokarst features, among others in the Cracow—Częstochowa Upland (comp. Bosák et al., 1979) and in the Holy Cross Mts. (Głazek et al., 1976).

9. Karst deposits.

This problem has been investigated many a time, especially in reference to origin of copper deposits in the Holy Cross Mts. (Rubinowski, 1958) and later on of zinc and lead deposits in the Cracow-Silesian area (o.g. Bogacz et al., 1970, 1975; Sass-Gustkiewicz, 1975a, 1975b, 1974; Dżułyński, 1976; Dżułyński, Kubicz, 1971). The investigations of these authors proved that dissolution of Middle Triassic limestones followed by a deposition of ores in karst voids were caused by warm waters.

For many years the studies over a karst origin of many depressions, then filled with peats (cf. Szczepanek, 1971) or with brown coal (cf. Gradziński, Wójcik, 1966), have been carried through. Some of these deposits occur in karstified gypsum caps of salt diapirs.

The investigations of moulding sands of the Cracow—Częstochowa Upland shoud be also mentioned. Among many papers there is a documentary monograph of the central part of this area by M. Błaszak (1970), a study on the sedimentation of Tertiary sinkhole deposits found in Jurassic limestones (Gradziński, 1977) as well as considerations on the origin age of such sediments in Central Europe (Bosák et al., 1977).

10. Other problems.

Attempts to apply absolute dating methods have been undertaken to define the age of bone remains found in karstic features and caves (Wysoczański-Minkowicz, 1969). These methods enabled a documentation of Pliocene and Pleistocene sediments.

Quite a lot of attention has been paid to problems of conservation of significant palaeokarst objects. I would just like to mention a paper of A. Szynkiewicz (1976) about the reserve „Węże" near Działoszyn as it has been the starting point for the preparation of a landscape park in that area. A list of palaeokarstic features, conserved and worth conserving, was published by Z. Wójcik (1976).

Problems of cave archaeology

An up-to-date synthesis of dating of cave sediments by archaeologic methods was presented by S. Krukowski (1939). After the last World War the studies in this field have been generally of a complex type. The monographs of the Koziarnia Cave near Ojców (Chmielewski et al., 1967), the Raj Cave in the Holy Cross Mts. (Kowalski et al., 1972) are the good examples. The most ancient sediments in these caves come from the Last Interglacial whereas the cultural remains are connected with the Würm and Holocene.

Palaeontologic investigations

These have a long tradition in this country. After the last World War they have been carried out at first, among others, by K. Kowalski (1961, 1964b, 1974, 1977). Initially, they concerned the bats and then, small mammals of the Cracow—Częstochowa Upland and the Holy Cross Mts. The greater mammals were investigated by Z. Ryziewicz (1957) who described, among others, a nearly complete skeleton of a cave bear from the Tatra Mts. Such studies have been lately continued by T. Wiszniowska (1976, 1978) who presented a monograph on the remains of cave bears and cave panthers of the Niedźwiedzia Cave in the Sudetes.

In the last few years comprehensive studies on the Miocene beetles of Przeworno in the Lower Silesia have been presented (Galewski, Głazek, 1973, 1978) as well as on small mammals from the Cracow—Wieluń Upland (Sulimski, 1964; Sulimski et al., 1979).

Intensive investigation of subfossil remains of bats in the Tatra caves have been carried out by B. W. Wołoszyn (1970) they supplied many data on the evolution of these animal assemblages during the Holocene.

Biospeleologic investigation

In spite of considerable tradition in this field (cf. Łomnicki, 1881; Kiernik, 1913; Żmuda, 1915) investigations have greatly increased after the Second World War. Quite a lot of attention has been paid to invertebrates of the caves in various parts of Poland and surrounding areas. From the caves of the Tatra Mts. a relic fauna has been among others described (Chodorowska, Chodorowski, 1960) whereas from the caves of the Polish uplands numerous species of aquatic invertebrates (Skalski, 1970, 1973, 1976). The fauna of the Sudetic caves was described among others by Z. Hajduk and A. Ogorzałek (1970).

Studies on recent mammals have been also carried out particularly on the bats (Kowalski, 1953, 1955, 1964b; Wołoszyn, 1964). Such works have been also done for the caves of other countries as e.g. of Cuba.

Microclimatic investigations

The need for such investigations has been realized quite recently. These analyses have been, after all, done on occasion of geographic-physical studies (Pulina, 1968b), ecologic studies (Starzecki, 1959) or for purposes of a general description of the environment (Kwiatkowski et al., 1979).

The present works in this field are more and more of strictly practical significance. On their basis the rate of destruction of speleothems in the caves commonly visited by tourists is evaluated (Rubinowski, 1977). Owing to these works e.g. the Raj Cave is from time to time closed for tourists.

Other investigations

The exploration of the Niedźwiedzia Cave in the Sudetes resulted in many specific papers. Among others, geophysic resistivity methods were applied to find passages previously unknown (Bieroński, 1978). In the same cave a laser was used to fix the transversal sections in the chambers (studies of S. Cacoń and company, prepared to press).

Broader literature on the subject is also included by a medical discipline, called speleotherapy. This branch of science utilizes, among others, previous mining excavations of the Wieliczka salt mine for the treatment of deseases of the respiratory system.

Complex investigations

The efforts of the Cracow Cavers' Club resulted in an inventory of Polish caves by K. Kowalski (1951—1954). The members of this club have done mainly the cartographic surveys. Later in other centres the idea of complex studies has been taken up. In *Prace Muzeum Ziemi* of 1968 a collection of works on the scientific exploration of the Szczelina Chochołowska Cave in the Tatra Mts. has been published. Among them were geologic, geochemic (moonmilk), hydrogeologic and biospeleologic (subfossil bats, recent water fauna) analyses.

The exploration of the Niedźwiedzia Cave in the Sudetes in 1966 resulted not only in efforts to the legal conservation of this object and its surroundings but first of all, in the beginning of detailed multidisciplinar studies. In 1970—1978 three volumes have been published by the Wrocław University (A. Jahn — editor) on this cave; they included the results of geologic and geomorphologic, palaeontologic and biospeleologic, geophysic and hydrographic studies. All these works have been managed from the very beginning by M. Pulina, who published, since 1977, new papers on the Niedźwiedzia Cave in the periodical of the University of Silesia *Kras i speleologia*.

A collection of papers on the Raj Cave in the Holy Cross Mts. has been also published. In 1972 „Folia Quaternaria" vol. 41 included several papers on cave sediments documented by archaeologic and palaeontologic methods. In 1974 the Kielce Scientific Society published a volume entitled ***Investigations and accession of the Raj Cave*** (editor Z. Rubinowski). This volume enclosed, among others, geologic, geomorphologic, hydrogeologic descriptions. In 1976 a popular monograph by Z. Rubinowski and T. Wróblewski (in collaboration with K. Kowalski and J. K. Kozłowski) was dedicated to this cave.

Final remarks

All the works presented above are also continued at present. Among them, the studies of J. Głazek, A. Szynkiewicz and A. Sulimski on the palaeokarst of the Cracow—Wieluń Upland and of neighbouring areas seem to be most interesting. They contribute towards the more precise description of palaeogeography as well as of the geomorphologic evolution of the Polish territory, especially outside the Carpathians.

The problem, lately undertaken by J. Rudnicki on the basis of his studies in Italy and Cuba, seems to be also of particular significance. He helps define the corrosive role played by mixing of saline and fresh waters. The consequences of these analyses are obvious, especially for the more precise fixing of the extent of the seas in various geologic epochs.

Within the field of biospeleology works on the evolution of aquatic fauna in caves and karstic fissures in the Late Tertiary and Quaternary are carried on. The historical expression of this purely zoologic subject seems to be important for geologic investigations.

The foreseeable future should bring a synthesis of the origin of deposits connected with karst evolution. The need of such a synthesis is emphasized by the present works.

Translated by Leszek Marks

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Zbigniew Wójcik

ZARYS DZIEJÓW SPELEOLOGII POLSKIEJ

Streszczenie

Dokonano krótkiego przeglądu ważniejszych osiągnięć speleologii polskiej, zwracając szczególną uwagę na badania prowadzone po 1945 roku (m.in. studia geologiczne, archeologiczne, biospeleologiczne). Podkreślono znaczne zainteresowanie polskich przyrodników geologicznymi i paleontologicznymi aspektami krasu kopalnego. Zwrócono także uwagę na znaczne zainteresowanie praktycznymi zagadnieniami badań jaskiń oraz studiami nad genezą złóż obszarów krasowych.

Zbigniew Wójcik

PRÉCIS D'HISTOIRE DE LA SPÉLÉOLOGIE POLONAISE

Résumé

A été faite une brève révision de plus importantes réalisations dans le domaine de la spéléologie polonaise, en tenant particulièrement compte aux études effectuées après 1945 (entre autres études géologiques, archéologiques et biospéléologiques). A été soulignée l'attention des naturalistes polonais aux aspects géologiques et paléonthologiques du karst fossil. A été également remarqué l'intérêt aux questions pratiques concernant les recherches des grottes et les études sur la génèse des gisements des régions karstiques.

Traduit par Teresa Korba-Fiedorowicz

Jerzy Grodzicki
Rafał M. Kardaś*

Inventory of Polish Caves

Abstract: Works on the inventorying of about 1250 caves discovered in Poland are presented with a description of their progress in every site region. A scope of fundamental cave documentation is presented.

Studies on karst phenomena, enormously important for cognitive as well as for economic purposes, must start with inventory and preliminary works on the features of surface karst and pseudo-karst and first of all, of underground karst. A recapitulation of the present state of cave exploration and basic data on caves should be found in the documentation collection of each region i.e. in the cave inventory.

Traditions in the preparation of Polish cave documentations go back to the second half of the XIX[th] century (Kowalski, 1951, 1953); interesting data have been collected especially in the thirties of this century (excellent cave maps prepared by Stefan and Tadeusz Zwoliński) but it wasn't until the last thirty years that the modern cave inventory has been prepared. The monograph of K. Kowalski (1951, 1953, 1954) should be considered as the first and principal one, dealing with the whole country and including a documentation of 658 caves. Since it was published, our knowledge about the Polish caves has considerably advanced. K. Kowalski's monograph covers about half of the caves known today and many of those catalogued at that time, have been explored with good results, leading sometimes to a discovery of vast caves sections. Also since that time, many research works have been carried through (zoological, geological, hydrogeological, archaeological, climatological and other ones). New ideas of cave origin and evolution were created, new problems dealing with karst and caves — being an effect of human action — arose or became significant.

In 1954—1975 only some explorers of various centres have continued more or less irregularly the studies of K. Kowalski. One should mention the Warsaw centre and editorial board of *Speleologia* derived from it, which published, as new information is obtained *Supplements to the inventory of Polish caves* (continued now by *Kras i speleologia*). There was also the Cracow centre that published, in its club biulletins, much documentation on newly discovered caves. The Częstochowa centre kept exploring the caves of the Cracow-Wieluń Upland whereas the Wrocław centre — particularly the karstic areas of the Sudetes. From the beginning of the seventies the Silesian centre started action.

In the seventies an increased interest in documentation works was noted. In 1975 the Warsaw Branch of the Polish Society of Fellows of the Earth Sciences, in consultation with the Tatra National Park, started the works leading the inventorying of the Tatra caves. All existing detailed data on every cave was hoped to be gathered, completed with a field collection of

* Jerzy Grodzicki, Institute of Geological Sciences, Polish Academy of Sciences; ul. Żwirki i Wigury 93, PL 02-089 Warsaw, Poland

Rafał M. Kardaś, Warsaw Branch of the Polish Fellows Society of Earth Sciences, ul. Wspólna 27 m. 22, PL 00-519, Warsaw, Poland

necessary information — particularly for the caves (or its parts) discovered after the inventory of K. Kowalski (1953) was published. Starting the works in the Tatra Mts. stimulated a more common interest on inventorying and documentation of caves. An attempt to develop this action in all karst areas of Poland, to co-ordinate efforts and to standardize methods and conventions, resulted in the idea of organization of annual all — Polish meetings under the name of *Problems of Inventorying and Documentation of Caves.* The organization of three conferences up to date was undertaken by the Warsaw Branch of the Polish Society of Fellows of the Earth Sciences — individually or together with other institutions.

Besides an exchange of experience and views as well as a report session, these conferences resulted in many definite decisions in organizing and methodic fields. There were discussed, among others: the content of cave documentation, applied conventional symbols, the use of a computer program to prepare plans and sections, the accuracy attained of surveying works, documentation problems of exploration expeditions. Based on a broad discussion a final set of instructions or guide lines for cave documentation was prepared (Grodzicki, Kardaś, 1978). It was accepted as obligatory during a meeting at Szczyrk (1978). These instructions comprise a collection of principles for the preparation of cave documentation, considered to be of universal type — used as the starting point for research studies as well as for exploration or sport caving. The methodology and content of each part of documentation were also defined. Fifty nine conventional symbols, adapted to Polish karst areas were given in an annex to the instructions.

The conference in 1977 also resulted in some organizational solutions. Polish Society of Fellows of the Earth Sciences was postulated to patronize the all-Polish inventorying action. This postulate, although it has not yet been fully introduced, effected in the formation of the Committee for Karst Research, Polish Society of Fellows of the Earth Sciences; the committee possesses a sub-committee for cave inventorying. For an effective preparation of documentation and to avoid a doubling, also a regional subdivision of cave areas into individual centres and teams was done; at the same time, co-ordinators and scientific consultants of works in every region were appointed.

Therefore, a cave documentation prepared in agreement with the accepted instructions (Grodzicki, Kardaś, 1978) includes:

— in graphic part: plan, transversal and longitudinal sections; blockdiagrams and localization sketches if need be;
— in the text: principal geographic and morphometric information, entrance localization and topographic description of the cave, actual information on the cave (general description, basal scientific observations and results of studies, history of exploration and studies), references;
— in the photographic part: photos with a localization of the entrance, possible photos of typical and interesting inner fragments, dripstones, erosive and corrasional features, etc.

The works in individual regions are differently advanced; among these cave regions the following ones used to be distinguished: Tatra Mts., Pieniny Klippen Belt, Beskidy Mts. with Sub-Carpatians, Sudetes, Cracow-Wieluń Upland, Nida Trough, Holy Cross Mts.

The Tatra Mts. are the most important cave area: in a small area they comprise the deepest (Wielka Śnieżna Cave — 768 m deep) and the longest (Miętusia Cave — 9040 m long) caves in Poland (13 caves deeper than 100 m and 15 longer than 1 km). Almost all the caves have been formed in carbonate rocks but about a dozen — in crystalline rocks of the High Tatra Mts. (caves of tectonic origin). This area is explored by clubs from the whole of Poland and the number of explored caves has increased from about 70 in 1954 (Kowalski, 1953, 1954) to about 480 at present and from — 213 m in depth and 1900 m in length to the dimensions cited above. In previous years some works have been prepared but systematic studies on a monograph of the Tatra Mts. have been started in 1975 by the inventorying team of the Warsaw Branch of the Polish Society of Fellows of the Earth Sciences that has located, until October 1980, almost 380 caves, and collected 374 full documentations of caves of their own and other authors and 45 fragmentary documentations. The end of this principal phase of works is planned for the last months of 1981. The team collaborates with Warsaw speleologic clubs: Caving Section of High-mountain Club, Warsaw Speleoclub of the Polish Touring Society, WAKS and also with other centres, including the Katowice Speleologic Club, Caving Section of the High-mountain Club in Cracow and Cracow Branch of the Polish Society of Fellows of the Earth Sciences should be mentioned first of all.

The Pieniny Klippen Belt possesses weakly developed caves. Among 15 caves known in this area the greatest dimensions are presented by the Cave in Ociemne (170 m long and 60 m deep). All catalogued caves (K o w a l s k i, 1954 — 10 caves; the others by Cracow cavers are published in mimeographed biulletins).

The Beskidy Mts. and the Sub-Carpathians are the most important region where the caves in non-karstic rocks occur within flysch sandstones. About 40 caves have been discovered there (K o w a l s k i, 1954 — 23) up to 400 m long (the Cave in Trzy Kopce) and 45 m deep (the Diabla Dziura Cave in Bukowiec). Systematic works in this area are carried out by the Speleoclub from Bielsko-Biała that successively duplicates the information and also, some works are published in an annual „Wierchy".

In the Sudetes the caves occur in small lenses and intercalations of carbonate rocks, arranged in islands amidst insoluble rocks (total area of 15 km^2 — P u l i n a, 1977). Up to now about 43 caves have been explored (among them 7 caves were destroyed during exploitation in quarries). This number includes also 5 non-karstic caves. The longest cave in the Sudetes (the Niedźwiedzia Cave) is 2 km long, the others are shorter than 300 m whereas the deepest cave (the Jasna Cave in Wojcieszów) has an relative relief of about 95 m (−80, +15). After the work of K. K o w a l s k i (1954), who described 19 caves; the studies in this area were continued by the Lower Silesian groups, mainly from Wrocław until the beginning of the seventies, lately a systematic inventory was started by a team from the Speleoclub at Żagań. Many supplements have been published (partly mimeographed information).

The Cracow-Wieluń Upland is the greatest karstic area in Poland with about 600 explored caves (the longest one — the Szachownica Cave is about 1000 m long whereas the deepest — the Januszkowa Szczelina Cave is 56,5 m deep). Since the studies of K. K o w a l s k i (1951, 1954), who described 513 caves, significant progress in exploration has been noted. Work on the supplements have been carried out by various centres — mainly by Częstochowa and Cracow, partly by Warsaw; lately, the most systematic inventorying activity is carried on by the Katowice Speleoclub and AKSiA of the Silesian Medical Academy. But some documentation is not fully agreeable with inventory demands.

The Nida Trough is the area where small caves in gypsum occur (the longest one — 280 m long Skorocicka Cave composed of several fragments separated by a collapsed roof). K. Kowalski described 14 caves and since that time no exploration has been done in this area.

In the Holy Cross Mts. over 50 caves have been identified. The longest — the Raj Cave — is 240 m long whereas the deepest is only 21 m deep. Only 11 caves have been described in detail up to now (but a list of a review cataloque was published — W o ł o s z y n, W ó j c i k, 1965). Now the inventory works have been discontinued.

On the seaside, close to Puck, K. K o w a l s k i (1954) described two small caves in sandstones. More caves of this type have not been discovered.

Translated by Leszek Marks

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Jerzy Grodzicki, Rafał M. Kardaś

INWENTARYZACJA JASKIŃ POLSKI

Streszczenie

W latach 1951, 1953 i 1954 wydane zostały 3 tomy opracowanej przez K. Kowalskiego monografii jaskiń Polski. Dzieło to zawiera dokumentacje 658 jaskiń. Obecnie poznano w Polsce ok. 1250 jaskiń. Różne ośrodki i kluby speleologiczne podjęły prace zmierzające do wykonania aktualnych inwentarzy dla poszczególnych obszarów występowania jaskiń. Przyjęte zostały jednolite zasady ich opracowywania i ustalono zawartość podstawowych dokumentacji.

W poszczególnych rejonach poznano dotychczas następujące jaskinie: Tatry — około 480 (obszar na którym występują największe jaskinie Polski), Pieniny — 15, Beskidy i Podkarpacie — około 40 (jaskinie w piaskowcach fliszowych), Sudety — 43, Wyżyna Krakowsko-Wieluńska — około 600, Niecka Nidziańska — 14 (kras gipsowy), Góry Świętokrzyskie — ponad 50 i Wybrzeże — 2 (jaskinie w spojonych piaskach plejstoceńskich).

Jerzy Grodzicki, Rafał M. Kardaś

INVENTAIRE DES GROTTES DE POLOGNE

Résumé

Dans les années 1951, 1953 et 1954 ont été édités trois volumes de monographies des grottes de Pologne élaborées par K. Kowalski. Cette oeuvre contient les documentations sur 658 grottes. Actuellement en Pologne on a découvert 1250 grottes environ. Les différents centres et clubs spéléologiques ont entrepris des travaux ayant pour but l'execution des inventaires actuels pour les régions respectives. Ont été admis les mêmes principes de leur élaboration et a été établit le contenu des documentations élémentaires.

Dans les régions respectives ont été reconnues les grottes suivantes Tatras — 480 environ (la région où apparaissent les plus grandes grottes de Pologne), Pieniny — 15, Beskides et Podkarpacie — 40 environ (grottes dans le grès de flysch), Sudetes — 43, le Haut-Plateau de Cracovie-Wieluń — 600 environ, Niecka Niedziańska — 14 (karst gypseux), Montagne de St^{e} Croix — plus de 50 et la Côte — 2 (grottes dans les sables cimentés du Pléistocène).

Traduit par Teresa Korba-Fiedorowicz

Rafał M. Kardaś*

Greatest Caves of Poland

Abstract: A review of the greatest caves in Poland was done; they were presented in two lists i.e. of caves over 100 m deep (or high) and of caves over 1 km long (after the data on February 1981). For each cave, principal information, needed by Commission of Great Caves of the International Union of Speleology (UIS), was collected.

Introduction

Lists of greatest caves in Poland have been prepared several times. First, only the lists of the deepest caves were presented (Rajwa, 1968; Rajwa, Parma, 1970; Grodzicki, 1971a) but then, a list of the longest caves was added (Grodzicki, 1975a, 1976). All these lists were limited to figures known at that time. More information about these caves was included in the materials for the VII[th] International Congress of Speleology at Sheffield (Chabert, 1977).

The present list (according to data of February 1981) includes full information needed by the UIS Commission of Great Caves: the name of the cave, its length or depth (height), topographic location (mountain chain or upland, mountain group, nearest valley or mountain), administrative location (provincial administrative centre — a district, borough or municipality), entrance height in metres above sea level, geologic data, history of explorations and the most important references. The list includes all the caves over 100 m deep (high) and over 1 km long. As the exploration of some caves has not been finished yet, further changes in the above figures are still possible. There are differences, relating to the previous lists and some cited papers which result from continued exploration as well as from a verification of calculations and measurements.

In this paper, references were used as well as many other published notes and paragraphs, information in duplicated bulletins of speleologic clubs (papers, notes, maps), original unpublished information of the Warsaw Branch of the Polish Society of Fellows of the Earth Sciences (abbreviation: OW PTPNoZ) that keeps collecting the data on the Tatra caves, also used was information of other authors, personal ones as well. The preparation of this list was made easier due to the help of dr J. Grodzicki (who deals with inventorying works in the Tatra Mts.). I am genuinly indebted for this help.

A. Caves over 100 m deep (high)

1 — Wielka Śnieżna Cave (a connection of Nad Kotlinami, Jasny Awen and Śnieżna caves) (Fig. 1) . . . . —768 m

The Carpathians, Western Tatra Mts., Mała Łąka Valley; Nowy Sącz, Zakopane. Entrances: 1876 m (Nad Kotlinami), 1851 m (Jasny Awen), 1703 m (Śnieżna). Limestones, dolomites with shale intercalations — Triassic. Spring: Lodowe Spring in the Kościeliska Valley (971 m a.s.l.).

* Warsaw Branch of the Polish Fellows Society of Earth Sciences (abbreviation: OW PTPNoZ), ul. Wspólna 22 m. 27, PL 00-519 Warsaw, Poland

Śnieżna Cave: discovered in 1959 and explored to a depth of about — 370 m (the Zakopane speleologists), in 1960 — to about — 565 m (the Zakopane — Warsaw expeditions), in 1961 — a sump at — 568 m (an international expedition).

Nad Kotlinami Cave: discovered in 1966, connection with the Śnieżna Cave in 1968 — depth −741 m (speleologists from Gliwice, Cracow, Warsaw, Zakopane). In 1972 passing through a final sump, in 1978 — depth −750 m — next sump, and in February 1981 behind following sump — depth −768 m (the Warsaw speleologists).

Altitudes of entrances and depths after new measurements of the cave (OW PTPNoZ). Previously, a depth of −783 m (the Wielka Śnieżna Cave) was published and −755 m for the first sump (−623 m from the Śnieżna Cave entrance).

References: Speleologia (1967); K o i s a r, 1969a; G r o d z i c k i, 1975b. Maps: Speleologia (1967 the Śnieżna Cave); K o i s a r, 1969a (the Wielka Śnieżna Cave); G r o d z i c k i, 1974b, 1975 (final sumps); C o u r b o n, 1972, 1978.

2 — Bandzioch Kominiarski Cave . . . 570 m (−550, +20)

The Carpathians, Western Tatra Mts., Massif of Kominiarski Wierch; Nowy Sącz, Zakopane. Entrances: 1682,7 m and 1456,3 m. Jurassic limestones (a fragment in carbonaceous sandstone).

Discovered in 1968, in 1968—1969 an exploration to about 330 m (−250, +80) — the Poznań speleologists (the explorers presented the overestimated figures). The speleologists from Cracow reached in 1973 a height of + 100 m and then: in 1974 — 410 m (−280, + 130), in 1976 — a depth of −505 m (discovery of the upper entrance), in 1977 — 570 m (−550, +20).

References: W i ś n i e w s k i, 1977a, b, 1978a; G r o d z i c k i, 1978a. Map: not published in full.

3 — Wielka Litworowa Cave . . . . . 347 m (−344, +3)

The Carpathians, Western Tatra Mts., Miętusia Valley; Nowy Sącz, Zakopane. Entrance: 1870 m. Triassic limestones and dolomites.

Discovered and explored to a depth of about −160 m (after new measurements) in 1962 (the Zakopane cavers). In 1967 — a depth of −212 m (cavers from Zakopane and other centres). In 1974 a depth of −236 m (Warsaw expedition). In 1977—1979 the Warsaw and Zakopane expeditions reached a difference of cave altitudes of 242 m (−239, +3). In 1981 the Warsaw Speleoclub expedition reached the present depth −344 m. The published depths of −260 m and −225 m are false.

References: W ó j c i k, 1964; K a r d a ś, 1977. The map of whole system has not been published.

4 — Ptasia Studnia — Lodowa Litworowa Cave . . . . −295 m (−255?)

The Carpathians, Western Tatra Mts., Miętusia Valley; Nowy Sącz, Zakopane. Entrances: 1620 m (Ptasia Studnia Cave), 1560 m (Lodowa Litworowa Cave). Triassic limestones and dolomites, Jurassic limestones.

Both caves were discovered in 1960 by the Zakopane speleologists who reached in 1962 the bottom of the Ptasia Studnia Cave (−295). A further verification of the measurements system is still needed (last measurements of the Ptasia Studnia Cave resulted in −255 m).

References and map: G r o d z i c k i, 1971b, c.

5 — Czarna Cave . . . . . 284 m (−137, +147)

The Carpathians, Western Tatra Mts., Kościeliska Valley; Nowy Sącz, Zakopane. Entrances: 1326 m (main one), about 1300 m (second southern one), 1408 m (northern one). Triassic, Jurassic and Cretaceous limestones. Springs: in the Kościeliska Valley — Lodowe Spring (971 m a.s.l.) and saesonal spring in Organy (1110 m a.s.l.).

Discovered in 1961 by the speleologists from Wrocław who had explored, up to 1964, most of the passages. Until 1977, the altitude difference was known to be 202 m (−137, +65). In 1978 the cavers from Cracow enlarged it to 284 m (−137, +147).

References: R a b e k, 1963; D ą b r o w s k i, R u d n i c k i, 1967; G r o d z i c k i, 1971a; W i ś n i e w s k i, 1977c; C i s z e w s k i, 1979. The map is not published in full.

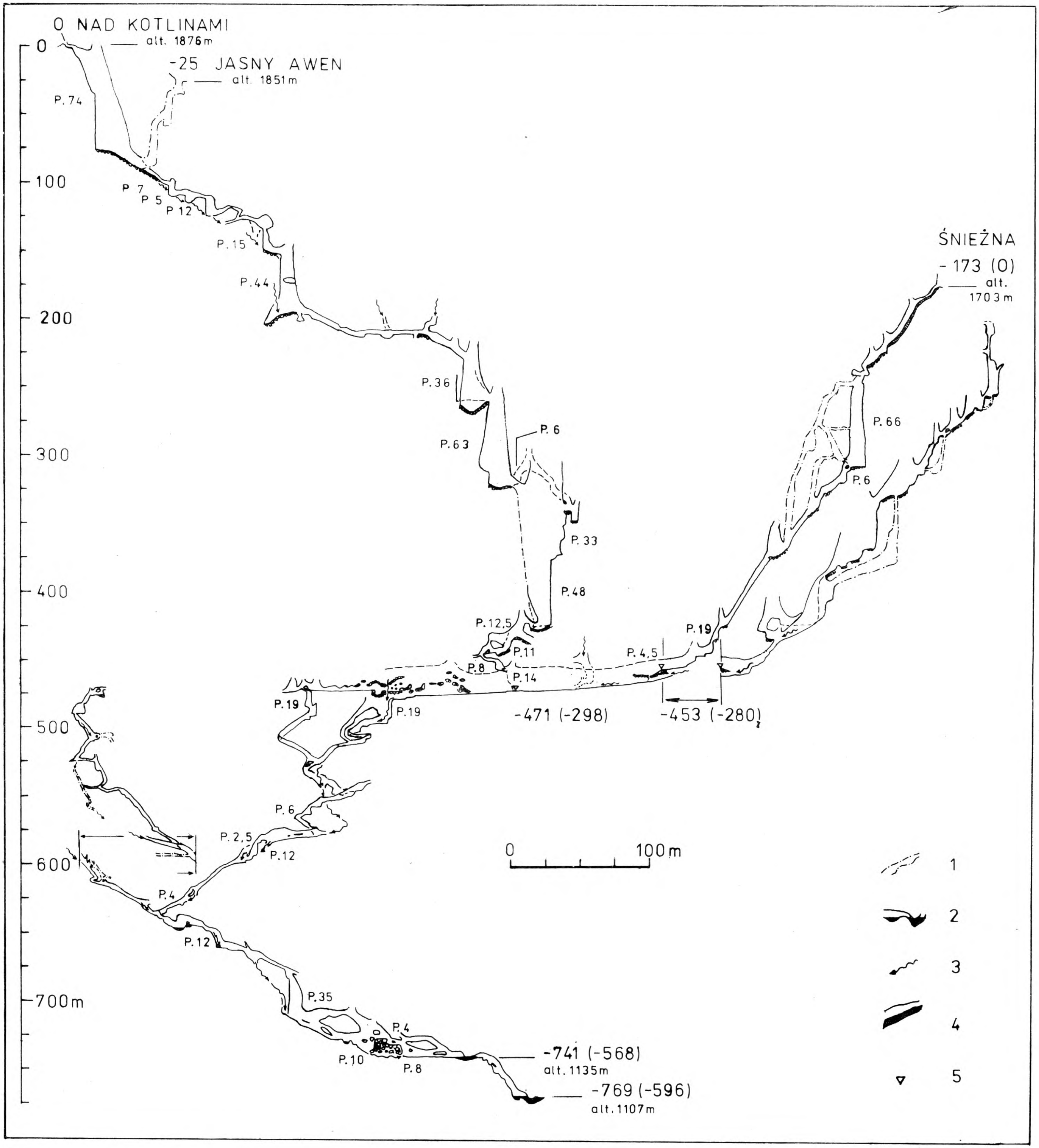

Fig. 1. Longitudinal section of the Wielka Śnieżna Cave:
1 — non-mapped fragments (sketch), 2 — sumps, lakes, 3 — water flow, 4 — ice, snow, 5 — altitude points, depths referred to the entrance of the Nad Kotlinami and the Śnieżna caves (in brackets)

Prepared by R. M. Kardaś on the basis of measurements done by SW PTTK — Warsaw, STJ KW Cracow and SG Wrocław till October 1980, Further investigations and corrections of sump part are not marked

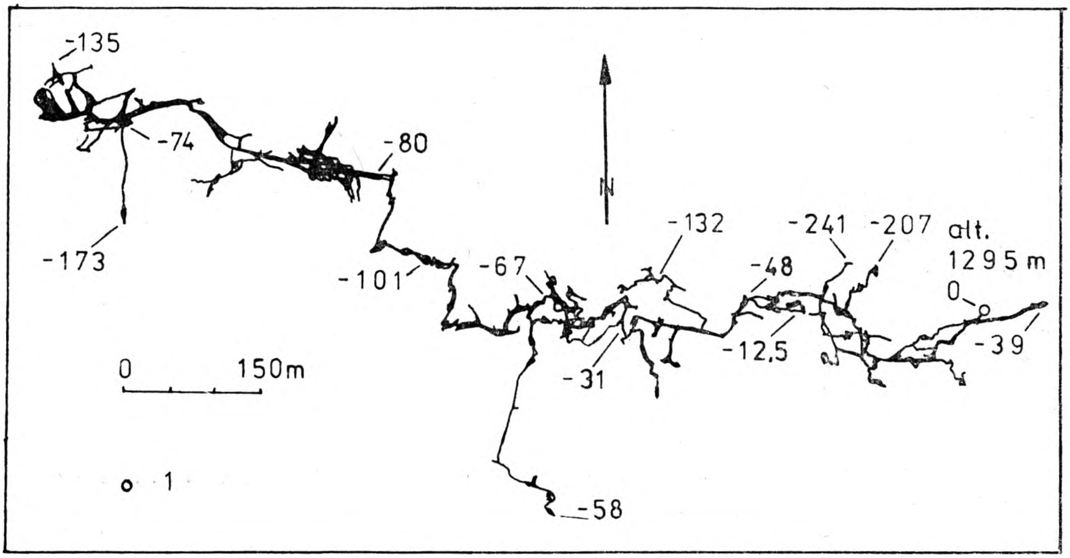

Fig. 2. Map of the Miętusia Cave (1 — entrance). Prepared by R. M. Kardaś on the basis of OW PTPNoZ documentation

6 — Miętusia Cave (comp. Fig. 2) . . −241 m

The Carpathians, Western Tatra Mts., Miętusia Valley; Nowy Sącz, Zakopane. Entrance: 1295 m. Triassic, Jurassic and Cretaceous limestones. Springs: probably the Lodowe Spring in the Kościeliska Valley (971 m a.s.l.).

Discovered in 1936 by the Zakopane cavers who reached in 1937 a depth of −128 m. In 1952 a depth of −213 m (after new measurements) was attained by the Cracow speleologists. In 1972 a Warsaw expedition got down to −241 m (diving to a depth of 28 m). Published depths: −250 m and −278 m are false.

References: Rudnicki, 1967; Grodzicki, 1969, 1978b; Kardaś, 1979. Map: Grodzicki, 1969 (fragments only); Kardaś, 1979 (schema of the whole system — after verification of measurements).

7 — Za Siedmioma Progami Cave . . 220 m (−203,+17)

The Carpathians, Western Tatra Mts., Cracow Gorge; Nowy Sącz, Zakopane. Entrances: 1482 and 1469 m. Jurassic limestones.

Discovered before 1950; until 1952 only fragments of its entrance have been explored, of small relief, about 20 m. The Silesian cavers reached in 1973 the altitude difference 115 m (+13,−102) and then, in 1979 the altitude difference 189 m (+17, −172) and lately, in 1980 −220 m (+17,−203).

References: Kowalski, 1953; Czepiel, 1973. Map: Kowalski, 1953 (entrance fragments); Czepiel, 1973 (fragments discovered in 1972—1973), an actual map is not published.

8 — Wysoka Cave . . . . . . 218 m (−123,+95)

The Carpathians, Western Tatra Mts., Cracow Gorge; Nowy Sącz, Zakopane. Entrances: 1499 m (main one), 1514 m. Jurassic and Cretaceous limestones.

Discovered in 1955 and explored mainly by the Zakopane centre. In 1956 an altitude difference of 199 m (−123,+76) was explored whereas in 1978 — of 218 m (−123,+95) by the Katowice cavers.

References: Zwoliński, 1955a, Wysoka Cave (1959). Actual map is not published; there is only the 1959 map without fragments of passages already known at that time (Wysoka Cave).

9 — Małołącka Cave . . . . −164 m

The Carpathians, Western Tatra Mts., Mała Łąka Valley; Nowy Sącz, Zakopane. Entrance: 1873 m. Triassic limestones and dolomites.

Discovered in 1959 by the speleologists from Zakopane (entrance parts). Further exploration — by cavers from Cracow and Zakopane (−164 m in 1960).

References: H a b i l, 1961. Map is not published.

10 — Wyżnia Miętusia Cave . . . . . . 155 m (−105,+50)

The Carpathians, Western Tatra Mts., Miętusia Valley; Nowy Sącz, Zakopane. Entrance: 1410 m. Triassic and Jurassic limestones.

Discovered in 1949 and explored in 1950 by the Cracow cavers, then until 1969 by teams from various centres. A relative relief of 155 m (−105,+50) was reached.

References: K o w a l s k i, 1953; G r o d z i c k i, 1971a, 1978b. Map: K o w a l s k i, 1953 (fragments), actual map is not published.

11 — Pod Wantą (Litworowy Dzwon) Cave . . . . −151 m

The Carpathians, Western Tatra Mts., Miętusia Valley; Nowy Sącz, Zakopane. Entrance: 1790 m. Triassic limestones and dolomites.

Discovered in 1961 and explored to −28 m (Cracow cavers). In 1964 an exploration to −144 m (Warsaw cavers) and in 1978 — to −151 m (Katowice cavers).

References: G r o d z i c k i, 1968: Map: to −144 m — G r o d z i c k i, 1968, actual map is not published.

12 — Zimna Cave . . . . . . 122 m (−9,+113)

The Carpathians, Western Tatra Mts., Kościeliska Valley; Nowy Sącz, Zakopane. Entrance: 1120 m. Triassic and Jurassic limestones. Spring at the valley bottom beneath the entrance (1000 m a.s.l.).

Known before 1882. At first its lower fragment of small relief was explored. Basic exploration in the upper fragment in 1952—1957 resulted in an altitude change of 122 m (−9, +113) — in Cracow, Zakopane and Wrocław cavers.

References: Z w o l i ń s k i, 1960; D ą b r o w s k i, R u d n i c k i, 1967; K o i s a r, 1968. Map: K o i s a r, 1968 (verified and completed at present).

13 — Naciekowa Cave . . 103 m (−63, +40?)

The Carpathians, Western Tatra Mts., Kościeliska Valley; Nowy Sącz, Zakopane. Entrances: 1197 m and 1186 m. Jurassic limestones.

Discovered in 1959 (Warsaw cavers), depth −25 m. In 1978—1979 the Zakopane cavers explored to a relative relief of 103 m (−63,+40).

References and map: R u d n i c k i, 1959 (Fragments discovered in 1959), actual map is not published.

B. Caves over 1000 m long

1 — Miętusia Cave (Fig. 2) . . . . . . 9040 m see p. 105.

A preliminary exploration by the Zakopane cavers (1936—1937) and the Cracow cavers (1948—1956) resulted in the discovery of passages over 1200 m long. Since 1956, exploration has been started by the Warsaw cavers who discovered passages over 7 km long thus extending the cave to 9040 m.

References: G r o d z i c k i, 1969; K a r d a ś, 1979.

2 — Bańdzioch Kominiarski Cave . . . . over 8700 m see p. 104.

The Poznań cavers discovered passages over 2,5 km long (1968—1969). In 1969—1975 passages about 1 km long were explored by various centres (mainly Cracow). During further exploration (Cracow cavers) the following fragments have been discovered: in 1976 — over 5000 m long, in 1978 — over 8500 m long and in 1979 — over 8700 m long. These data are not unquestionable — detailed measurements were done in the passages about 6,5 km long.

References: W i ś n i e w s k i, 1976, 1977b, 1978b.

3 — Czarna Cave . . about 6000 m see p. 104.

Most discoveries in 1961—1964 (the Wrocław cavers) resulting in a length of about 5450 m (also values of 5500, 6000 and 11 000 m are noted — they are overestimated). In 1975 — exploration of the northern entrance (Cracow cavers and Silesian cavers). In 1978 the length was increased to about

6000 m (discoveries of the Cracow cavers). Length evaluations need verification.

References: R a b e k, 1963; C h a b e r t, 1977; C i s z e w s k i, 1979.

4 — Wielka Śnieżna Cave (comp. Fig. 1) . . . over 5100 m see p. 103.

In 1959—1965 passages over 2000 m long were discovered (Zakopane and Warsaw cavers, international expedition). During further exploration and particularly, in result of connection with the Nad Kotlinami Cave (1968) the system gained about 4700 m (a value of about 2700 m — much to low — was also noted). In 1978 the Wrocław cavers added to the system the Jasny Awen Cave and in 1979—1980 the Cracow cavers kept exploring the side chimneys that made the cave over 5000 m long. The mapping is not finished.

References: Speleologia (1967); G r o d z i c k i, 1976; A u g u s t y n, 1979.

5 — Zimna Cave . . about 3300 m see p. 106.

In 1885 a section 122 m long was known. The next discoveries by the Zakopane cavers made the cave 140 m long in 1913, 609 m — in 1936, 680 m — in 1938. In 1952—1957 a major exploration of Cracow, Zakopane and Wrocław centres was carried out and then completed with small discoveries. The cave length was about 2990 m at the end of 1967 (overestimated figures were also published — to 4000 m). In 1980 the Warsaw expedition reached the length about 3180 m, and in 1981 the Cracow cavers reached about 3300 m of total passage length. The records are now verified and completed.

References: Z w o l i ń s k i, 1960; K o i s a r, 1968.

6 — Wielka Litworowa Cave . . . . about 2800 m see p. 104.

Until 1974 about 1150 m worth of passages had been explored (Zakopane and other centres). In 1976—1979 a length of about 2100 m was attained (mainly Warsaw but also Zakopane cavers), in 1981 — about 2800 m (Warsaw cavers).

7 — Kasprowa Niżnia Cave . . about 2320 m

The Carpathians, Western Tatra Mts., Kasprowa Valley; Nowy Sącz, Zakopane. Entrance: 1228 m. Jurassic and Cretaceous limestones.

The entrance known before 1849. Until 1951 passages about 1150 m long have been discovered (mainly the Zakopane cavers). In 1952—1953 the Cracow cavers made the cave about 1500 m long. A further exploration was carried out by various centres — especially by Cracow and Warsaw (mainly diving); a lenght of about 2015 m was gained in 1971 and up to the end of 1978 — about 2320 m.

References: K o w a l s k i, 1953; K o i s a r, 1971; P ł a c h c i ń s k i, P r z y b y s z e w s k i, 1975; K l e s z c z y ń s k i, 1978. Map: K o i s a r, 1971; P ł a c h c i ń s k i, P r z y b y s z e w s k i, 1975 (sumps).

8 — Chochołowska Szczelina Cave . . . . . . about 2300 m

The Carpathians, Western Tatra Mts., Chochołowska Valley; Nowy Sącz, Zakopane. Entrances: 1051 m, 1072 m, 1083 m. Jurassic limestones.

Fragments of the entrance were discovered in 1938 by the Zakopane cavers (100—120 m). In 1951—1952 explored to 1650 m (mainly Cracow but also Zakopane cavers). Small discoveries in 1962 and exploration of the passages ended with a third entrance and resulted in a final lenght of about 2300 m (Warsaw expedition).

References: K o w a l s k i, 1953; W ó j c i k Z., 1967a, b; K o i s a r, 1969b. Map: W ó j c i k Z., 1967a, b; K o i s a r, 1969b.

9 — Wysoka Cave . . . . 2017 m see p. 105.

In 1955—1956 passages about 970 m long were discovered (mainly the Zakopane cavers). Successive exploration — by the Cracow cavers in 1958—1959 (about 450 m) and the Silesian cavers (since 1976). Until 1980, 2017 m worth of passages have been explored.

References: Z w o l i ń s k i, 1955a.

10 — Niedźwiedzia Cave . . . . 2000 m

The Sudetes, Śnieżnik Kłodzki Massif, Kleśnica Valley; Wałbrzych, Stronie Śląskie. Entrance: 800 m. Proterozoic (?) marbles.

Discovered in 1966 in a quarry. Explored by the Wrocław cavers; in 1966 a length of 218 m was explored, in 1967—1971 — over 800 m, in 1972 — 2000 m (sometimes overestimated length of 2200 m is noted).

References and map: P u l i n a, 1977.

11 — Za Siedmioma Progami Cave . . . . about 1600 m see p. 105.

Until 1952 only 123 m of passages were explored. Since 1972, cavers from Katowice carried further exploration and in 1979 they reached 502 m of total passage length and in 1981 — about 1600 m.

12 — Ptasia Studnia — Lodowa Litworowa Cave . about 1540 m (1500?) see p. 104.

A connection of both caves was found in 1962 and finally passed in 1963. Until 1967 the cavers of many centres have explored about 1170 m (or 1130 m taking the lower values measured in 1980). In 1976—1979 a length of about 1540 m (about 1500?) was explored — discoveries of various teams. A verification of the records is needed for a final fixing of the system size.

References: G r o d z i c k i, 1971b, c.

13 — Naciekowa Cave . . . . . about 1500 m see p. 106.

In 1959 the Warsaw cavers explored about 400 m of passages. In 1978—1979 the Zakopane speleologists explored the passages about 1500 m in length.

References: R u d n i c k i, 1959.

14 — Mylna Cave . . . . about 1300 m

The Carpathians, Western Tatra Mts., Kościeliska Valley: Nowy Sącz, Zakopane. Entrances: 1098 m, 1098 m, 1098 m, 1098 m (southern entrances), 1095 m (northern entrance). Jurassic limestones.

Entrances known before 1860, first visit in 1885. Up untill 1934 passages totaling 644 m long have been explored. In 1934 the Zakopane cavers explored the cave to 1120 m in length. Further exploration resulted in a length of about 1300 m.

References: K o w a l s k i, 1953; G r o d z i c k i, 1975a, 1976.

15 — Bystrej Cave . . . . about 1200 m

The Carpathians, Western Tatra Mts., Bystrej Valley; Nowy Sącz, Zakopane. Entrance: 1178 m. Triassic and Jurassic (?) limestones.

The entrance was dug up in 1033 by the Zakopane cavers who have explored about 600 m of passages until 1949. In 1956 the successive discovers of the Zakopane cavers reached a length of about 1200 m.

References: K o w a l s k i, 1953; G r o d z i c k i, 1974a, 1976. Map: K o w a l s k i, 1953 (actual for 1949); Z w o l i ń s k i, 1961 (actual for 1956), actual for the present has not been published.

16 — Magurska Cave . . . . 1200 m

The Carpathians, Western Tatra Mts., Jaworzynka Valley; Nowy Sącz, Zakopane. Entrance: 1465 m. Triassic, Jurassic and Cretaceous limestones.

Known before 1860. Until 1938 its length of about 220 m has been known. After a small exploration in 1938 the Zakopane cavers fulfilled the principal discoveries in 1948—1950 in the passages 1200 m long (a value of 1070 m is also noted — with no regard to a passage cut off by a sump, silted up after the exploration).

References: K o w a l s k i, 1953; Z w o l i ń s k i, 1955b, 1961; W ó j c i k Z., 1966. Map: K o w a l s k i, 1953 (without a passage behind the siphone); Z w o l i ń s k i, 1955b, 1961 (complete set).

17 — Szachownica Cave . . . about 1000 m

Cracow—Wieluń Upland; Krzemienna Mt, Częstochowa, Lipie. 14 entrances: 220—225 m a.s.l. Jurassic limestones. The entrances were exposed until 1962 during exploitation of limestones. In 1972—1975 studies over by the Warsaw geologists and cavers. A noted length of about 1000 m composes, however, 6 separate fragments of the system (the longest ones — about 600 m and over 200 m), divided by the quarry and partly transformed due to underground limestone exploitation. An overestimated length 1100 m was also published.

References and map: G ł a z e k et al., 1978.

Translated by Leszek Marks

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Rafał M. Kardaś

NAJWIĘKSZE JASKINIE POLSKI

Streszczenie

Artykuł zawiera przegląd największych jaskiń Polski (według stanu na październik 1980 r.). Zestawiono dwie listy jaskiń: o głębokości przekraczającej 100 m (A) i o długości przekraczającej 1000 m (B). W stosunku do publikowanego poprzednio zestawienia (Chabert, 1977) wprowadzono zmiany uwzględniające postępy eksploracji, prac dokumentacyjnych oraz weryfikację obliczeń.

W przypadku każdej jaskini podano podstawowe dane wymagane przez Komisję Wielkich Jaskiń Międzynarodowej Unii Speleologicznej (UIS): nazwa, głębokość (lista A) lub długość (lista B), lokalizacja, wysokość n.p.m. otworu (otworów), litologia i wiek skał, w których jest rozwinięta, nazwa, lokalizacja i wysokość n.p.m. wywierzyska wód z jaskini (lista A, w miarę ujawniania informacji o stwierdzeniu połączeń), historia eksploracji (data odkrycia i kolejne postępy), najważniejsze pozycje literatury (z informacją o publikowanych planach lub przekrojach).

W opracowaniu wykorzystano zarówno cytowane pozycje literatury, jak i wiele innych publikowanych notatek i wzmianek, materiały zamieszczane w powielanych biuletynach klubów speleologicznych (artykuły, notatki, plany), nie publikowane, oryginalne materiały opracowującego inwentarz jaskiń tatrzańskich zespołu Oddziału Warszawskiego Polskiego Towarzystwa Przyjaciół Nauk o Ziemi oraz innych autorów, a także informacje ustne.

Artykuł ilustrują: przekrój najgłębszej jaskini Polski — Wielkiej Śnieżnej (—769 m) — ryc. 1 i plan najdłuższej jaskini Polski — Jaskini Miętusiej (9015 m) — ryc. 2.

Rafał M. Kardaś

LES PLUS GRANDES GROTTES DE POLOGNE

Résumé

L'article présente la revue de plus grandes grottes de Pologne d'après l'état de 1980. Ont été faites deux listes: gouffres à la profondeur dépassant 100 m (A) et grottes à la longueur dépassant 1 km (B). Par rapport à la spécification publiée antérieurement (Chabert, 1977), la présente envisage le progrès de l'exploration, des études documentaires et de la vérification des mesures.

Pour chacune des grottes ont été présentées les données élémentaires exigées par la Commission de Grandes Grottes de l'Union International Spéléologique (UIS): nom, profondeur (liste A), ou longueur (liste B), localisation, attitude de l'orifice, lithologie et âge des roches dans lesquelles la grotte s'est développée; nom, localisation et altitude de la source vauclusienne des eaux de la grotte (liste A, s'il y a des informations constatant des articulations), histoire de l'exploration (date de la découverte et ses étapes succesives), la plus importante bibliographie (avec l'information sur les projets et les revue publiés).

Dans l'élaboration présente ont été également utilisés: la bibliographie citée ci-dessus, les différentes notes et notices, les matériaux insérés dans les bulletins des clubs spéléologiques (articles, notes, projets), les matériaux non publiés de la section varsovienne de la Société des Amis de la Science de la Terre élaborant l'inventaire des grottes de Tatras, les informations orales.

L'article est illustré par le profil du plus profond gouffre de Pologne — Wielka Śnieżna (769 m) — fig. 1 et le plan de la plus longue grotte — Grotte Miętusia (9015 m) — fig. 2.

Traduit par Teresa Korba-Fiedorowicz

Jerzy Mikuszewski*

Polish speleological literature

A b s t r a c t: Polish speleological literature has a long history and a substantial output. The intensive development of speleologic activity in this country after the Second World War and expeditions into external cave areas have been reflected in numerous publications. Their number has grown more quickly than of papers in this field published during the precending period until 1939.

Speleological literature of this earlier period, nowadays rather applied to study the very beginning of Polish explorative and scientific speleology, is scattered in various periodicals as no specialistic speleological publication existed at that time in Poland. Information on literature of that period, as there is no specialistic bibliography, is quite difficult to obtain. The reader interested in the problem can avail himself of bibliographic lists in: *Jaskinie Polski* of K. K o w a l s k i and *Retrospektywna Bibliografia Geologii Polski* of R. F l e s z a r o w a (see bibliographies).

Review of Polish speleological literature after 1945

Speleological literature of Poland of the period after the Second World War was supplemented, almost at the beginning of this period, in a three-volume monograph of Kazimierz K o w a l s k i: *Jaskinie Polski* that, as an inventory of Polish caves known at that time, attained a higher standard than similar monographs published in countries where a speleology was more developed. Nowadays, the significance of this monograph as an inventory, is considerably amaller due to discoveries of many new caves but it is still the only inventory of caves that has been published in Poland until now.

But still *Jaskinie Polski* is the most comprehensive bibliographic source of Polish speleologic literature since that time, as no specialistic monograph of that type has been published.

The following review of speleological literature is presented in a system of various types of publications.

* Committee of Karst Investigations, Polish Fellows Society of Earth Sciences, ul. Mickiewicza 16 m. 23, PL 01-517 Warszawa, Poland

Bibliographies

Speleologic bibliographies

K o w a l s k i, Kazimierz — *Jaskinie Polski,* PWN Warsaw **1951: 1 bibliography p.** 47—71; 1953: 2 bibliography p. 28—41; 1954: 3 bibliography p. 13, 28—31, 80—86, 127, 144—145, 159—160, 167—169, 180—181 — in total 884 bibliographic positions.

K [o w a l s k i], K[azimierz] — *Bibliografia speleologii polskiej,* Grotołaz **1955 : 1 p. 55—57, 1956 : 2 p. 51—52; 1956 : 3/4 p. 39—41** — bibliography spans the period from January 1955 to October 1956.

M i k u s z e w s k i, Jerzy 1976: *Caving literature in Poland,* The Windy City Speleonews, **16**, 1 : 10—12, Chicago, USA — bibliography of close prints and monographs published after 1945, a total of 44 titles.

Various bibliographies with permanent sections on speleology

Bibliografia geologiczna Polski, publ. by Geological Institute, Warsaw PL ISSN 0373-

-1987 since 1957 : 27 (for the year 1954) it comprises the entries: *speleology* and *karst* in the factual index.

F l e s z a r o w a, Regina — *Retrospektywna bibliografia geologiczna Polski*, publ. by Geological Institute, Warsaw 1963: part I (1900—1950) vol. II (sectional system) — bibliography to the entry *speleology* p. 1111—1116; 1966: part II (1750—1900) no. 1 — in the factual index: *speleology* p. 536—537.

C z a r n e c k i, Stanisław and M a r t i n i, Zofia 1972: *Retrospektywna bibliografia Polski 1750—1950 (supplement)*, publi. by Geological Institute, Warsaw — in the factual index: *karst phenomena* p. 273, *speleology* p. 287.

Bibliografia górska, Wierchy, publ. by PTTK Cracow—Warsaw — annual bibliography with a section: *speleology*.

International speleologic bibliographies

Internationale Bibliographie für Speläologie (Karst- und Höhlenkunde), publ. by Landesverein für Höhlenkunde in Wien und Niederösterreich 1954—1971 Wien — eleven bibliographic annuals for the years 1950—1960 comprise 354 titles of Polish speleologic literature.

Speleological Abstracts UIS, publ. by Société Helvetique des Sciences Naturelles, Neuchâtel — 18 annuals of bibliography for the years 1969—1979 comprise 334 titles of Polish speleologic literature.

Current Titles in Speleology (international), publ. by Anne Oldham, Rhychydwr, United Kingdom — 7 annuals of bibliography for the years 1973—1979 comprise 308 titles of Polish speleologic literature. See K a v k a, J. (1976).

Periodicals

Speleologic periodicals

Speleologia — a bulletin edited by the Warsaw Speleoclub PTTK and Subcommission of Speleology, Main Board PTTK until 1959 1:3, then by Commission of Speleology, Main Board PTTK, Warsaw PL ISSN 0561-6018, edited: 1959 1:1/2, 3, 4; 1960 2:1, 2—4; 1967 3:1, 2; 1969 4:1, 2; 1970 5:1—2; 1971 6:1—2; 1972 7:1—2; 1974 8:1; 1975 8: 2; 1976 9 : 1—2, now the periodical is continued by *Kras i speleologia*.

Kras i speleologia — a separate series of Prace Naukowe, University of Silesia, an annual, publ. by University of Silesia, Katowice PL ISSN 0137-5482, edited: 1977:1 (X); 1978:2 (XI); 1979:3 (XII); the periodical is a continuation of the bulletin Speleologia.

Taternik — an organ of the Polish Association of Alpine Clubs, sacrificed to mountaineering and speleology, a quaterly, publ. by RSW Prasa-Książka-Ruch, Warsaw PL ISSN 0137-8155.

Speleo' — a register published by the Caving Commission, Polish Association of Alpine Clubs and the Commission of Speleology, Main Board of PTTK, Cracow, edited: 1980:1—2 (in 1979 a special interclub edition of Speleo' was published).

List of more significant bulletins of Polish speleologic clubs

Aven — a bulletin edited periodically (1966:1), published by speleologic clubs of Częstochowa and of Upper Silesian Coal Basin, continued.

Gacek — a bulletin of the Caving Section, Circle of the Mountaineering Club at Cracow (for a period 1963—1967 — 8 fascicles), revived (1977) as the information bulletin of the Caving Section, the Mountaineering Club at Cracow, edited since 1977:9 (30) until 1981 (winter-spring): 17 (38) — 9 fascicles.

Grotołaz — a chronicle of the Cracow Cavers' Club, Cracow 1950:1 to 1952:16, then as a bulletin of the Cracow District Caving Section of PTTK, Cracow 1955:1 (17) until 1957:5 (21), continued as Gacek.

Jamnik — a bulletin of the Cracow Caving Club, the Cracow Circle of PTTK, Cracow 1979:1 until 1979:9, discontinued.

Meander — a bulletin of the Speleoclub of PTTK „Górnik" — Katowice, now of the Katowice Speleologic Club at the Society for the Propagation of Physical Culture „*Spartakus*" Katowice 1976:1, 2 and special editions: „Hagengebirge '78" (1978) and „Jubileuszowe" edition (1980).

Wiercica — a bulletin of the Warsaw Speleoclub of PTTK, Warsaw 1955:1 until 1980 (winter): 41 (53), continued.

Alpiniste Complet — a bulletin of the

Students' Club of Speleology and Mountaineering, at the Silesian Medical Academy, Katowice—Zabrze 1978:1, continued.

List of more important Polish scientific periodicals that publish the speleologic papers

Acta Archaeologica Carpathica, Academia Scientiarum Polonia, Collegium Cracoviense, Cracovia PL ISSN 0001-5229 (one-two every year).

Acta Geologica Polonica, Polish Academy of Sciences — Committee of Geological Sciences, Warsaw PL ISSN 0001-5709 (a quaterly).

Acta Zoologica Cracoviensia, Polish Academy of Sciences, Laboratory of Systematic and Experimental Zoology, Cracow PL ISSN 0065-1710 (15—25 every year).

Biuletyn Peryglacjalny, Societas Scientiarum Lodziensis, Sectio 3, Łódź PL ISSN 0067-9038 (one every year).

Chrońmy przyrodę ojczystą, Polish Academy of Sciences, Laboratory of Conservation of Nature and Natural Resources; an organ of the State Council for Nature Conservation, Cracow PL ISSN 0009-6172 (a bimonthly).

Dokumentacja Geograficzna, Polish Academy of Sciences, Institute of Geography and Spatial Administration, Warsaw PL ISSN 0012-5032 (a bimonthly).

Folia Quaternaria, Polish Academy of Sciences, Section at Cracow, Biologic Committee, Cracow PL ISSN 0015-573x (one-two every year).

Kwartalnik Geologiczny, Geological Institute, Warsaw PL ISSN 0023-5873 (a quaterly).

Ochrona Przyrody, Polish Academy of Sciences, Laboratory of Conservation of Nature and Natural Resources, Cracow PL ISSN 0078-3250 (one every year).

Prace Geograficzne, Polish Academy of Sciences, Institute of Geography and Spatial Administration, Warsaw PL ISSN 0373-6547 (in series).

Prace Muzeum Ziemi, Polish Academy of Sciences, Muzeum of the Earth, Warsaw PL ISSN 0032-6275 (one-two every year).

Przegląd Geologiczny, State Geologic Survey, Warsaw PL ISSN 0033-2151 (a monthly).

Rocznik Polskiego Towarzystwa Geologicznego, Polish Geological Society, Cracow PL ISSN 0079-3663.

Studia Geomorphologica Carpatho-Balcanica, Polish Academy of Sciences, Committee of Geographical Sciences, Cracow PL ISSN 0081-6434 (a yearly).

Wierchy, Commission of Mountain Tourism, Main Board of PTTK, Warsaw PL ISSN 0137-6829 (a yearly).

Wszechświat, Copernicus Society of Polish Naturalists, Cracow PL ISSN 0043-9592 (a monthly).

Selection of more important close prints of Polish speleology published after 1945

Scientific monographs

A l e x a n d r o w i c z, Zofia; D r z a ł, Maria; K o z ł o w s k i, Stefan 1975: *Katalog rezerwatów i pomników przyrody nieożywionej (A Catalogue of inanimate nature reserves and monuments in Poland)*, Studia Naturae series B 26:1—298 Cracow — description and documentation of 26 speleologic--karstic objects protected legally.

Badania i udostępnianie Jaskini Raj (The Studies and accessibility of the Raj Cave), Ed. Z. R u b i n o w s k i, Materials of the Xth Jubilee Speleologic Symposium in the Holy Cross Mts. on 9—11th June 1972, p. 1—223, Wydawnictwa Geologiczne, Warsaw 1974.

B o c h e ń s k i, Zygmunt 1974: *Ptaki młodszego czwartorzędu Polski (The birds of the Late Quaternary of Poland)*, p. 1—212, PWN, Cracow.

C h m i e l e w s k i, Waldemar 1961: *Civilisation de Jerzmanowice*, p. 1—93, Ossolineum, Wrocław (in French).

Jaskinia Niedźwiedzia w Kletnie (The Bear Cave in Kletno), vol. I and II. Acta Universitatis Wratislaviensis, 1970, I:1—119 (no. 127 — Studia Geogr. XIV); 1978, II:1——159 (no. 311 — Studia Geogr. XXIV) Wrocław (vol. III see T. W i s z n i o w s k a, 1976).

G ł a z e k, Jerzy; D ą b r o w s k i, Tadeusz; G r a d z i ń s k i, Ryszard 1972: *Karst in Poland*, [in:] *Karst — Important karst regions of the northern hemisphere*, Ed. M. Herak, V. T. Stringfield, p. 327—340, Elsevier Publish. Company, Amsterdam.

K a v k a, Josef 1976: *Geologia literaturo en esperanto*. Geologio Internacia — ISAE

3:137—146 Wydawnictwa Geologiczne, Warsaw (in Esperanto) — international bibliography that comprises, among others, 24 titles of speleologic publications.

K o t a r b a, Adam 1972: *Powierzchniowa denudacja chemiczna w wapienno-dolomitowych Tatrach Zachodnich (Superficial chemical denudation in the calcareous-dolomite Western Tatra Mts.)*, Prace Geograficzne, Polish Academy of Sciences, 96:1—116, Wrocław.

Materiały z III i IV Sympozjum Speleologicznego (Papers from the IIIrd and IVth Speleological Symposium), Ed. A. Skalski, p. 1—163. District Museum at Częstochowa, Częstochowa 1971 (printed in 1972).

Niphargus — Materiały II Jurajskiego Seminarium Speleologicznego (Niphargus — Papers from IInd Speleological Seminar), Ed. K. Kościelecki, p. 1—103, Speleoclub of the PTTK Section at Częstochowa, Częstochowa 1967.

P u l i n a, Marian 1968: *Zjawiska krasowe we Wschodniej Syberii (Karst phenomena in Eastern Siberia)*, Prace Geograficzne, Polish Academy of Sciences 70:1—91, Warsaw.

P u l i n a, Marian 1974: *Denudacja chemiczna na obszarach krasu węglanowego (Chemical denudation in the carbonate karst areas)*, Prace Geograficzne, Polish Academy of Sciences 105:1—155, Wrocław.

P u l i n a, Marian 1977: *Zjawiska krasowe w Sudetach Polskich (Karst phenomena in the Polish Sudetes)*, Dokumentacja Geograficzna, Polish Academy of Sciences 2—3:1——118, Wrocław.

Seminarium Speleologiczne I Ogólnopolskiego Zjazdu Badaczy Krasu 29 maja — 1 czerwca 1963 w Św. Katarzynie (Speleologic Seminar of the Ist All-Polish Symposium of Karst Scientists at St. Katarzyna) on 29th May — 1st June 1963), Kielce Scientific Society, Kielce 1964.

S t r z e l e c k i, Zbigniew; K l e c z k o w s k i, Antoni and others 1975: *Kompleksowe badania górotworu na przykładzie akcji ratunkowej w Smoczej Jamie na Zamku Królewskim na Wawelu (Complex investigations of the rocks on the basis of the rescue work in the Dragon's Cave at Wawel, the Royal Castle of Cracow)*, Górnictwo 14:1—63, Prace Komisji Górniczo-Geodezyjnej, Polish Academy of Sciences, Cracow.

Studies on Raj Cave near Kielce (Poland) and its deposits, Folia Quaternaria 41:1—148, Cracow 1972 (in English).

Symposium on Evolution of Karstic Relief in Southern Poland — Cracow 1969 (Papers), Studia Geomorphologica Carpatho-Balcanica 5:1—138, Cracow 1971 (in English, French, Russian).

W i s z n i o w s k a, Teresa 1976: *Niedźwiedź jaskiniowy z Kletna i innych jaskiń Polski (Ursus spelaeus from Kletno and other Polish caves)*, [in:] *Jaskinia Niedźwiedzia w Kletnie (The Bear Cave in Kletno)*, vol. III, p. 1—75, Acta Universitatis Wratislaviensis n°. 329, Studia Geogr. XXV, Wrocław.

W o ł o s z y n, Bronisław 1970: *Holoceńska fauna nietoperzy (Chiroptera) z jaskiń tatrzańskich (The Holocene Chiropteran fauna from the Tatra caves)*, Folia Quaternaria 35 : 1—52, Cracow.

W ó j c i k, Zbigniew 1968: *Rozwój geomorfologiczny wapiennych obszarów Tatr i innych masywów krasowych Karpat Zachodnich (Geomorphological development of the limestone areas of the Tatra Mts. and other karst massifs in the Western Carpathians)*, Prace Muzeum Ziemi 13 : 3—169, Warsaw.

Wybrane zagadnienia krasu (Selected problems of the karst), Przegląd Zagranicznej Literatury Geograficznej, Institute of Geography, Polish Academy of Sciences 3 : 1—164, Warsaw 1964 (translations of foreign literature).

Popularized scientific papers

F l o r c z a k, Zbigniew 1970: *Sztuka łamie milczenie — z prahistorii plastyki*, ed. 1, p. 1—240, Wyd. Literackie, Cracow; ed. 2 supplemented, p. 1—320, Wyd. Literackie, Cracow 1974.

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K a h l k e, Hans-Dietrich 1972: *Wykopaliska z czterech kontynentów* (original title: *Ausgrabungen auf vier Kontinenten)*, ed. 1, p. 1—264, Wiedza Powszechna, Warsaw.

K o w a l s k i, Kazimierz 1965: *Jaskinie polskie*, ed. 1, p. 1—144, Wiedza Powszechna, Warsaw.

K u n s k ý, Josef 1956: *Zjawiska krasowe* (original title: *Kras a Jeskyně*), ed. 1, p. 1—207, PWN, Warsaw.

L a m i n g, Annette 1968: *Skarby w grocie Lascaux* (original title: *Lascaux, peintures et gravures)*, ed. 1, p. 1—177, Omega PWN, Warsaw.

P a r m a, Christian 1980: *Jaskinie — wszystko o*, ed. 1, 122 p., Krajowa Agencja Wydawnicza, Warsaw.

P a r m a, Christian; Rojek, Tadeusz (in press): *500 zagadek o jaskiniach*, Wiedza Powszechna, Warsaw.

Z w o l i ń s k i, Stefan 1961: *W podziemiach tatrzańskich*, ed. 1, p. 1—253, Wydawnictwa Geologiczne, Warsaw.

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Guide-books

P a r m a, Christian; R a j w a, Apoloniusz 1978: *Turystyczne jaskinie Tatr — przewodnik*, ed. 1, p. 1—128, Sport i Turystyka, Warsaw.

R u b i n o w s k i, Zbigniew; W r ó b l e w s k i, Tymoteusz 1968: *Jaskinie Ziemi Kieleckiej*, ed. 1, p. 1—12, Wyd. Artystyczno-Graficzne, Cracow.

R u b i n o w s k i, Zbigniew; W r ó b l e w s k i, Tymoteusz 1973: *Jaskinia Raj w Górach Swiętokrzyskich*, ed. 1, p. 1—20. Wyd. Artystyczno-Graficzne, Cracow; ed. 2, p. 1—20, Krajowa Agencja Wydawnicza, Section at Cracow, Cracow 1976.

Z w o l i ń s k i, Stefan 1973: *Jaskinia Mroźna w Dolinie Kościeliskiej w Tatrach*, ed. 1, p. 1—16, Zakopane Section of PTTK, Zakopane.

Z y z a ń s k a, Halina; Z y z a ń s k i, Henryk; K ę s e k, Edward 1979: *Turcja (Polacy w jaskiniach świata)*, ed. 1, p. 1—41, maps and plans of caves enclosed, Speleoclub „Bobry" PTTK, Żagań.

Maps

Ojcowski Park Narodowy — mapa turystyczna 1 : 25 000, ed. 1, format 57 cm×61 cm, Państwowe Przedsiębiorstwo Wydawnictw Kartograficznych, Warsaw (with a localization of caves).

Karstic-speleologic maps of the Tatra National Park (sheet 14: *Mapa lokalizacji jaskiń w obszarach krasowych* TPN, 1:50 000; sheet 15: *Plany i przekroje wybranych jaskiń)*, [in:] *Atlas Tatrzańskiego Parku Narodowego* (in press). Edited by the headquarters of the Tatra National Park and the Polish Fellows Society of Earth Sciences, Cracow Section.

Albums

R u b i n o w s k i, Zbigniew; W r ó b l e w s k i, Tymoteusz 1976: *Jaskinia Raj*, ed. 1, p. 1—59, illustrations — 82 plates, Wydawnictwa Geologiczne, Warsaw.

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The presented review of Polish speleological literature is assumed to be a bibliographic sketch that only slightly enlarges and makes more up-to-date the knowledge of the problem, based mainly on a compilation of the literature by K. K o w a l s k i, done at the beginning of the fifties, and of the monograph *Jaskinie Polski.* The considerable shortage in this field in the future by the results of actions undertaken by the Committee of Karst Investigations, Polish Fellows Society of Earth Sciences, tending to prepare the Polish Speleological Bibliography.

Translated by Leszek Marks

Jerzy Mikuszewski

POLSKIE PIŚMIENNICTWO SPELEOLOGICZNE

Streszczenie

W artykule zamieszczono informacje o polskim piśmiennictwie speleologicznym po 1945 roku, które ujęto w kilka podstawowych grup wydawniczych: bibliografie, czasopisma, listę ważniejszych biuletynów polskich klubów speleologicznych, ważniejsze czasopisma naukowe publikujące materiały speleologiczne oraz wybór ważniejszych druków zwartych dotyczących polskiej speleologii, w którym wydzielono: monografie naukowe, wydawnictwa popularnonaukowe, podręczniki, przewodniki, mapy i albumy.

Jerzy Mikuszewski

LITTÉRATURE SPÉLÉOLOGIQUE POLONAISE

Résumé

Dans l'article ont été présentées les informations sur la littérature spéléologique polonaise après 1945. Elles on été concues en quelques groupes éditoraux: bibliographies, périodiques, liste de plus importants bulletins des clubs spéléologiques polonais, périodiques scientifiques publiant les matériaux spéléologiques, choisies d'imprimés sur la spéléologie polonaise dans lesquelles ont été distingués des monographies scientifiques, des oeuvres de vulgarisation scientifique, des manuels, des guides, des cartes et des albums.

Traduit par Teresa Korba-Fiedorowicz

Jerzy Mikuszewski*

Organization of speleology in Poland

Abstract: The present structure of speleology in Poland is greatly disintegrated as there is no central institution constituting a speleological society or federation. Speleologic activity comprises: touring — explorative, sportive-explorative, sportive and research disciplines; the latter mainly in geologic and biospeleologic fields, and in paleontologic and archaeologic to a smaller degree. The cave tourist trade and speleotherapy are of minute significance in this country.

Three former disciplines have been organized since the beginning of the fifties.

Evolution of speleologic organizing structures in Poland

Before 1939

From a historic point of view exploration and archaeologic research of the caves near Ojców should be considered as the first speleologic activity in the Polish territory; these investigations have been undertaken by the Anthropological Committee, Polish Academy of Knowledge at Cracow after 1870.

The establishment of the Speleologic Club at the Naturalistic Section, Polish Tatra Society at Zakopane in 1923 — has been the only attempt to a willful creation of the organization for speleologic activity in Poland.

From 1945 to 1974

After the last world war a reactivation of cave exploration has been noted in this country, particularly in two centres — at Zakopane where the pre-war activity is continued by Stefan Zwoliński and in Cracow — where speleologic activity was initiated by Kazimierz Kowalski.

In 1950 the Cavers' Club was established in Cracow — the first speleologic organization in Poland after the war and the first speleologic organization in general in Poland of a sportive-explorative type. It is considered to be the ideological and organizational archetype for Polish caving.

Following this example, sections of caving have been established at regional branches of the Polish Tourist-Touring Society at Warsaw, Zakopane and Toruń. The activity of all the speleologic clubs of that time was administered by the Subcommittee of Caving, Alpinism Committee of the Main Board, Polish Tourist-Touring Society. In this way an organizational pattern for Polish cavers' clubs was initiated.

The reactivation of the Alpine Club in 1956 — an organization of great alpine traditions — resulted in a reorganization of the organizational structure of speleology existing up to that time. The devotees of sportive achievements in cave exploration passed into the Alpine Club and formed the sections of caving of the Club pranches at Cracow, Toruń, Warsaw, Wrocław and Zakopane. At the same time the Caving Commission was established at the Main Board of the Alpine Club. The devotees of tourism in cave exploration remained in Polish Tourist-Touring Society and formed the Speleologic Clubs of this organization — at first of the branches at War-

* Committee of Karst Investigations, Polish Fellows Society of Earth Sciences, ul. Mickiewicza 16 m. 23, PL 01-517 Warszawa, Poland

saw and Zakopane. At the Main Board of the Polish Tourist-Touring Society the Subcommittee of Speleology was etablished, then renamed (in 1960) the Committee of Speleology. Since the accession of Poland to the International Union of Speleology (UIS) in 1973 at the VIth International Speleologic Congress at Olomunec, this Committee has been playing the part of the national organization, representing of Poland at UIS.

Since 1960, both above mentioned organizational sections of speleology have been under the juristicion of the Main Committee for Physical Culture and Tourism (GKKFiT**).

In 1958, when the Cavers' Section was established at Wrocław in the Students' Tourist Club, a new organizational section of speleology in Poland has originated. It was comprised of students. After the next sections were formed at other universities, a federation of these sections was created in 1972 — at first named the Federation of Students' Cavers Clubs and now, the Federation of Students' Speleological Clubs. It is dominated by the main boards of students' organizations in this country.

This system of three independent speleologic organizational sections had existed until 1974; that year the Main Committee for Physical Culture and Tourism defined new principles for alpinism in this country, cave alpinism included.

Present organization of speleology in Poland

Organization of sportive-explorative activity in caves

The Polish Association of Alpine Clubs (PZA), created in 1974 and being an organization of a sportive type, united all the speleologic organizations of the previous three independent organizational branches. Administration of internal and external activity of Polish cavers' clubs was entrusted to the Caving Commission of the Polish Association of Alpine Clubs (KTJ PZA), composing of a president, three deputies for training, cave expeditions, popularization and external contacts, and a secretary.

The quantitative data of Polish speleology are illustrated by the following information of the end of 1979: 19 clubs of Polish Association of Alpine Clubs, 1300 members of the clubs-among them 350 ones of higher degrees i.e. of a self-dependent and an ordinary caver. Warsaw, Cracow and Katowice with the Silesian Coal Basin region are the main organizational centres whereas Zakopane, Bielsko-Biała, Wrocław, Żagań, Gdynia and Poznań are smaller ones.

Preliminary training and trainings to lower caver degrees are carried on in clubs. Trainings to hihger caver degrees and to caving instructors are realized with the cooperation of the Training Committee of the Polish Association of Alpine Clubs. Studies at the Academy of Physical Education in Cracow at the Postgraduate Study of Alpinism Instructors enable one as well to quality as an instructor of caving.

In 1979 the Caving Commission, Polish Association of Alpine Clubs initiated the formation of two subcommissions: of Cave Security and Rescue as well as of Cave Diving. The former subcommission controls the action of two non-professional groups of cave rescuers. One of these groups — the Intervention Group of Cave Rescue has existed since 1979 at Cracow; it collects the cavers of this centre. The other group — the Intervention Group of Cave Divers — was created in 1979 at the Warsaw Speleoclub, Polish Tourist-Touring Society of Warsaw. Both these life-saving groups form the specialistic basis for a professional mountain rescue service in Poland, particularly of the Tatra Group, Volunteer Mountain Rescue Service.

Polish speleologic activity is presented abroad now by the Polish Association of Alpine Clubs trough its Commission of Cave Alpinism and its representatives as, since 1977, it has taken over the rights and responsibilities of a representative of Polish speleology at the International Union of Speleology from the Committee of Speleo-

** In 1974 GKKFiT was replaced by: Main Committee of Physical Culture and Sport (GKKFiS) — PZA included, and Main Tourist Committee (GKT) — PTTK included.

logy, Main Board of the Polish Tourist-Touring Society.

Besides the presented organizational pattern of the sportive-explorative activity of speleology, there are also the organizational forms within the scientific research field of speleologic activity in Poland.

Institutions and speleologic-scientific organizations

The Speleologic Section, of the Polish Naturalists' Society named after Copernicus, exists since 1964 and assembles the members being workers and students of various scientific disciplines who connect their professional activity with various scientific aspects of speleology. The section enables scientific discussion by the organization of symposia on speleology (thirteen symposia in 1964—1980). Other activity of the section includes: the awarding of a scientific prize named after Maria Markowicz-Łohinowicz — for scientific achievements in speleology and the organization of a national competition of speleologic photography.

Karst sections of Students Scientific Circles are common mainly in geologic and geographic departments. The karst sections of Students' Scientific Circles of Geographers carry through scientific investigations for various karst problems; besides, the Coordinative Committee of these circle has organized three all-Polish Speleologic Seminars — in 1960 and 1970 in the Western Tatra Mts. and in 1980 — in the Sudetes. The Karst Section of the Young Geologists' Circle, Geological Department of the Warsaw University, has organized (aside from carrying out geological investigations on karst) two scientific expeditions abroad — into the karst areas of Turkey (1976) and Afghanistan (1977).

Laboratory of Karst Geomorphology, Institute of Geography-University of Silesia at Sosnowiec: since the 1st of October 1976 it has been the first research-didactic institution in Poland on karst problems. The laboratory, aside from teaching and its own research, is the organizer of the all-Polish scientific meetings named „the Speleological School", to which also the experts on karst research from abroad are invited. The meetings have been organized at Lądek-Zdrój (Sudety Mts.) every year since 1975, during the students' winter break. During the Vth Speleological School (in 1979) the International Symposium of the Committee of Karst Physicochemistry and Hydrogeology of UIS was held. The Laboratory deals also with the publication of a library edition of the University of Silesia — *Kras i speleologia*.

The Committee for Karst Research, Polish Fellows Society of Earth Sciences (PTPNoZ) at Warsaw — was established in 1979 to form the organizational limits to realize, by the Society, its own speleologic studies and to coordinate multidisciplinary and interdisciplinary scientific investigations within the field of speleology, carried on up to that time in Poland by various institutions and organizations in an isolated and dispersed way. The present activity of the Committee continues previous speleologic work realized by the Polish Fellows Society of Earth Sciences in two branches: 1) information-popularizing — through the organization of lectures, exhibitions, scientific conferences in a series entitled „Problems of inventorying and documentation of caves", participation in the organization of the „Speleological Schools", 2) the scientific-research branch — by sponsoring the speleologic investigations in Niedźwiedzia Cave at Kletno, the inventorying works and studies in the Polish caves — up to now in the caves of the Polish Tatra Mts. and of a part of the Cracow-Wieluń Upland, and participation in the preparation of speleologic maps for the Atlas of the Tatra National Park.

A presented list of specialistic activity of organized speleologic activity in Poland is not complete as speleologic problems are also reflected in works, investigations and activity of many institutions — research, technical and industrial ones — in extent and sphere dependent on their merits.

A list of more significant institutions acting in Poland in various fields of speleology

Geology, hydrogeology, mining

Institute of Geological Sciences, Polish Academy of Sciences at Warsaw (in: speleogenesis, karst geochronology, sedimentology of karst sediments)

Institute of Geography, Jagiellonian University at Cracow (in: karst geomorphology)

Institute of Earth Sciences, the Maria Curie-Skłodowska University at Lublin (in: karst geomorphology, karst-like phenomena within loesses)

Laboratory of Karst Geomorphology, University of Silesia at Sosnowiec (in: karst geomorphology, chemical denudation, glacial speleology, cave climatology)

Geographical Institute, Wrocław University at Wrocław (in: karst geomorphology, pseudokarst)

Institute of Geology, Warsaw University at Warsaw (in: palaeokarst, geochronology of karst in Poland)

Institute of Geology and Mineral Raw Materials, Mining-Metalurgical Academy at Cracow (in: karst in zinc-lead and salt deposits)

Institute of Hydrogeology and Engineering Geology, Mining — Metallurgical Academy at Cracow (in: hydrogeology of karstic waters in areas of zinc-lead deposits, dewatering of mines in karstic areas)

Institute of Projects and of Mine construction, Mining-Metallurgical Academy at Cracow (in: mining methods of protection and conservation of a karst formation)

Geological Institute at Warsaw (in: karst of sedimentary sulphur deposits, karst of non-ferrous metal deposits — realized by the Holy Cross Section of the Geological Institute at Kielce, hydrogeology of karstic waters of hard coal deposits as well as of zinc and lead deposits in the Upper Silesian area — realized by the Upper Silesian Section of the Geological Institute at Sosnowiec)

Palaeontospeleology and biospeleology

Laboratory of Systematic and Experimental Zoology, Polish Academy of Sciences at Cracow (in: palaeontology of Cainozoic vertebrates, biospeleology)

Zoological Institute, Wrocław University at Wrocław (in: palaeontology of the carnivores and the hoofed mammals, biospeleology)

Institute of Palaeobiology, Polish Academy of Sciences at Warsaw (in: palaeontology of small mammals)

District Museum at Częstochowa (in biospeleology)

Anthropospeleology

Institute of Archaeology, Warsaw University at Warsaw (in: Palaeolithic and Mesolithic of cave sites)

Institute of Archaeology, Jagiellonian University at Cracow (in: Palaeolithic of cave sites in Poland)

Archaeologic Museum at Cracow (in: Palaeolithic and Neolithic of cave sites in the Cracow Upland)

Conservation of Nature and Natural Environment

State Board of Nature Conservation, Committee of Inanimate Nature Conservation (in: legislation of conservation of caves and karstic areas in Poland, practical realization of conservation in cooperation with District Conservators of Nature and Headquarters of National Parks — of Tatra Mts. and of Ojców)

Laboratory of Conservation of Nature and Natural Resources, Polish Academy of Sciences at Cracow (in: interdisciplinar investigations of karstic areas for purposes of conservation of the natural environment and its resources).

Museology and archivistics

Museum of the Earth, Polish Academy of Sciences at Warsaw (in: organization of exhibitions, lectures, collecting of speleologic collections in geology, palaeontology, archives and iconographic materials for the history of Polish speleology since the most ancient times, collecting of speleologic books)

Archaeologic Museum at Cracow (collections of Palaeolithic relics from caves at Ojców)

District Museum at Częstochowa (collections of cave palaeofauna from caves of Poland and from external caves)

Tatra Museum named after Tytus Chałubiński at Zakopane (collections: geological and palaeontological ones from the Tatra caves, archives to study a history of caves in the Polish Tatra Mts.)

Museum of the Tatra National Park at Zakopane (collections: a geological one from caves of the Polish Tatra Mts., archives to history of caving in the Tatra Mts.)

Museum named after Professor Szafer in the Ojców National park (collections: geological, palaeontological and archaeological from the caves of the Ojców National Park)

Geological Museum at the Mining-Metallurgical Academy at Cracow (stationary exhibition dedicated to karst problems)

Museum of Cracow salt-mines at Wieliczka near Cracow (exhibition of the only in the world existing collection of salt minerals created due to a salt karst — salt monocrystals of the Grota Kryształowa, stalactites, stalagmites and other salt sinters)

Museum of Sport and Tourism at Warsaw (archives and iconographic materials to the history of recent Polish caving)

Editorial office of *Kras i speleologia* at Sosnowiec (speleologic library, exchange of the bulletin *Kras i speleologia* for foreign speleologic periodicals)

Caves accessible for tourists

Mroźna Cave, Western Tatra Mts. — the cave accessible for tourists since 1958, electric lights, guides, administered by the Zakopane Section of the Polish Tourist-Touring Society at Zakopane

Raj Cave near Kielce, Holy Cross Mts. — the cave accessible since June 1972, electric lights, guides, speleologic exhibition, snack-bar, open all the year round — every day but Monday, administered by the District Tourism Office „Łysogóry" at Kielce

Niedźwiedzia Cave at Kletno by Kłodzko, Eastern Sudeten Mts. — the cave accessible for tourists since 1982, electric lights, guide, administered by the District Tourist Office „Śnieżnik" at Kłodzko

Speleotherapy

Allergologic sanatorium „Kinga" at Wieliczka near Cracow (speleotherapy realized since 1964). The sanatorium is open all year round and is located in underground excavations and natural caverns of an ancient salt mine; in the accompanying centre of clinical inquiries a new theory of pathology of dyspnoea and its therapy (subterraneotherapy) has been prepared

Radon Inhalatorium, Complex of Jelenia Góra Health Resorts at Kowary-Podgórze, Sudeten Mts. (speleotherapy in underground excavations of an ancient uranium mine)

Adresses of more important speleologic organizations and institutions in Poland

Komisja Taternictwa Jaskiniowego
Polski Związek Alpinizmu
ul. Sienkiewicza 12/439
PL 00-010 Warszawa

Komitet Badań Krasu
Polskie Towarzystwo Przyjaciół Nauk o Ziemi
ul. Mickiewicza 16 m. 23
PL 01-517 Warszawa

Sekcja Speleologiczna
Polskie Towarzystwo Przyrodników im. Kopernika
ul. Podwale 1
PL 31-118 Kraków

Katedra Geomorfologii Krasu
Uniwersytet Śląski
ul. Mielczarskiego 58
PL 41-200 Sosnowiec

Redakcja „Kras i Speleologia"
c/o Katedra Geomorfologii Krasu
Uniwersytet Śląski
ul. Mielczarskiego 58
PL 41-200 Sosnowiec

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of names of more significat organizations **and institutions mentioned** in the text, **their French equivalents and original names in Polish, together with their official abbreviations**

English	French	Polish	Abbreviation
Caving Commission	Commission de l'Alpinisme Souterraine	Komisja Taternictwa Jaskiniowego	KTJ
Commission of Speleology	Commission de la Spéléologie	Komisja Speleologii	
Committee of Karst Investigations	Comité des Recherches du Karst	Komitet Badań Krasu	KBK
Copernicus Society of Polish Naturalists	Société Polonaise de Naturalistes-Copernic	Polskie Towarzystwo Przyrodników im. Kopernika	
Federation of Students' Cavers Clubs	Fédération des Clubs d'Etudiants des Spéléologues	Federacja Akademickich Klubów Grotołazów	FAKG
Federation of Students' Speleological Clubs	Fédération des Clubs d'Etudiants de Spéléologie	Federacja Akademickich Klubów Speleologicznych	FAKS
General Committe for Physical Culture and Sports	Comité Général d'Education Physique et du Sport	Główny Komitet Kultury Fizycznej i Sportu	GKKFiS
General Committee for Physical Culture and Tourism	Comité Général d'Education Physique et du Tourisme	Główny Komitet Kultury Fizycznej i Turystyki	GKKFiT
General Committee for Tourism	Comité Général du Tourisme	Główny Komitet Turystyki	GKT
Geological Institute	Institut de Géologie	Instytut Geologiczny	IG
Mountaineering Club	Club de Haute Montagne	Klub Wysokogórski	KW
Polish Academy of Sciences	Académie Polonaise des Sciences	Polska Akademia Nauk	PAN
Polish Association of Alpine Clubs	Association Polonaise d'Alpinisme	Polski Związek Alpinizmu	PZA
Polish Fellows Society of Earth Sciences	Société Polonaise des Amis des Sciences sur la Terre	Polskie Towarzystwo Przyjaciół Nauk o Ziemi	PTPNoZ
Polish Tourist Society	Société Polonaise de Tourisme	Polskie Towarzystwo Turystyczno-Krajoznawcze	PTTK

Jerzy Mikuszewski

ORGANIZACJA SPELEOLOGII W POLSCE

Streszczenie

Autor przedstawia szkic rozwoju organizacji speleologicznych w Polsce począwszy od końca XIX wieku oraz aktualny stan organizacji polskiej speleologii — tak w zakresie sportowo-eksploracyjnym, jak i naukowo-badawczym — poprzez wymienienie i krótkie scharakteryzowanie poszczególnych jednostek organizacyjnych: sportowych — Komisja Taternictwa Jaskiniowego Polskiego Związku Alpinizmu, organizacja reprezentująca Polskę w Międzynarodowej Unii Speleologicznej — UIS; naukowych — Sekcja Speleologiczna Polskiego Towarzystwa Przyrodników im. Kopernika, Sekcje Krasowe Studenckich Kół Naukowych, Katedra Geomorfologii Krasu w Uniwersytecie Śląskim, Komitet Badań Krasu Polskiego Towarzystwa Przyjaciół Nauk o Ziemi. Wymieniono także instytucje naukowe podejmujące badania speleologiczne w różnych dziedzinach nauki, takich jak: geologia, hydrogeologia, górnictwo, paleontologia, biospeleologia, archeologia, speleoterapia, a także w zakresie ochrony przyrody i środowiska naturalnego, muzealnictwa i archiwistyki oraz zagospodarowania turystycznego jaskiń.

Artykuł zawiera adresy ważniejszych organizacji i instytucji związanych ze speleologią w Polsce, ich indeks wraz z oryginalnymi odpowiednikami w języku polskim i ich oficjalnymi skrótami.

Jerzy Mikuszewski

ORGANISATION DE LA SPÉLÉOLOGIE EN POLOGNE

Résumé

L'auteur présente le développement des organisations spéléologiques en Pologne de la fin du XIXième siècle à leur état actuel — dans le domaine du sport, de l'exploration, de la science et des recherches — en citant et en caractérisant d'une facon brève leurs unités d'organisation sportives et scientifiques entreprenat les recherches spéléologiques dans les différents domaines de la science, comme — géologie, archèologie, hydrologie, science minière, paléonthologie, biospéléologie, spéléothérapie; aussi dans le domaine de la protection de la nature et de l'environnement, de l'archivistique, et de l'amémagement touristique des grottes.

L'article publie les adresses des organisations et des institutions liées à la spélèologie en Pologne et aussi l'index avec des èquivalants originaux polonais et leurs abréviations.

Traduit par Teresa Korba-Fiedorowicz

REPORTS

Jerzy Mikuszewski*

Vth International Conference of Cave Rescue

In 1st — 6th October 1979 the Vth International Conference of Cave Rescue was organized in the Tatra Mts. at Kalatówki hostel by the Commission of Caving, Polish Association of Alpinisme. Poland was charged with an organization of the Conference by the Commission of Cave Rescue of the International Union of Speleology.

The opening ceremony was done on 2nd October at presence of: president of Polish Association of Alpinisme — Dr. Andrzej Paczkowski, representative of UIS Office — professor Adolfo Eraso (Spain) and invited guests — representatives of the town Zakopane authorities and of the professional mountain rescue organization, acting in the Tatra Mts.

The Conference was attended by 120 persons, among them 80 were from abroad; Austria was represented by 4 persons, Belgium — 16, Bulgaria — 4, Czechoslovakia — 7, France — 3, Spain — 4, Yugoslavia — 3, German Demokratic Republik — 10, Portugal — 1, Federal Republik of Germany — 1, United States — 1, Hungary — 3, Great Britain — 7, Italy — 12, Soviet Union — 4. Among the members of the Commission of Cave Rescue the Conference was attended by: president Alexis de Martynoff (Belgium), secretary Eric Catherine (Great Britain) and head of Equipment Subcommission Hermann Kirchmayr (Austria).

The program of the Conference — as proposed by the organizers — included „an activity of non-professional teams of cave rescue" and composed of reports (21) and practical demonstrations of rescue technics. The demonstrations in the field — at the slope of the Nosal Mt. — were presented by Polish, Italian and Bulgarian teams. A technic of climbing with a use of a steel rope was demonstarated by the representative of the Soviet Union. A demonstration of a use of a floating stretchers, English made, was presented at a swimming pool by Antałówka. A life-saving equipment was also presented during a session of the Subcommission of Equipment. The greatest interests was aroused by the stretchers used in a cave rescue, especially the stretchers constructed by Dr. Pierre Castin from France (model of 1978).

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*Commission of Caving, Polish Association of Alpinisme, ul. Sienkiewicza 12/439, PL 00-010 Warszawa, Poland

During two evening projection programs the members of the conference saw the slide sets and two films — the latter of H. Kirchmayr and P. Castin. Besides, many speleologic publications were presented — especially the ones dealing with rescue.

During the Conference there was a session of the UIS Commission of Cave Rescue in result of which many organizational changes were introduced to increase the activity of most member countries of UIS in this field, important for cavers. And so, the commission changed its previous name into „the Commission for Cave Prophylaxis, Security and Rescue", some personal changes in the commission office occurred and the latter was extended from 4 to 9 persons. So, the office composes now of: president — Alexis de Martynoff (Belgium), three vice-presidents for separate regions: America — Daniel Smith (United States), Western Europe — Giuseppe Guidi (Italy), Eastern Europe — A. P. Yefremov (Soviet Union), general secretary — György Denes (Hungary), heads of subcommissions: of Prophylaxis — Petko Nedkov (Bulgaria), of Security and Medicine — vacat, of Equipment — Hermann Kirchmayr (Austria), of Technics and Rescue — Mike Meredith (Great Britain). Agenda of future meetings were fixed: in July 1981 — International Camp of Cave Rescue at Bowling Green, Kentucky (United States), whereas in 1983 the next — VIth International Conference of Cave Rescue in Hungary.

The Conference enabled also a meeting of the members of the UIS Office; among the ones who arrived at Poland there were: professor Dr. Arrigo A. Cigna (Italy) — president of the UIS, docent Dr. Hubert Trimmel (Austria) — general secretary, professor Dr. Adolfo Eraso (Spain) — secretary of the UIS and head of its Scientific Department. A rich program of the Office session comprised, among others, two most important problems for the Union: present as well as future status of the UIS in an organizational structure of UNESCO and the preparation of the Ist UIS European Regional Conference of Speleology, organized in 1980 by Bulgarian Federation of Speleology.

Recapitulating the results of the Conference one should admit that it was the next successful step in an improvement of the organizational structure of the international speleological activity.

Translated by Leszek Marks

Adolfo Eraso
Marian Pulina*

IIIrd Meeting of the UIS Commission of Karst Physicochemistry and Hydrogeology at Lądek-Zdrój (Poland) on 12th February 1979

During the work of the Vth Scientific School of Speleology, organized by the University of Silesia at Lądek-Zdrój (5th—12th February 1979), a meeting of the Commission of Karst Physicochemistry and Hydrogeology of the UIS was held, dealing with the following problems:

1. Research accomplished by various countries in order to promote international cooperation in the karst studies.
2. Purposes of the Commission change of the UIS status in relation to UNESCO, theoretical basis of karstology, practical problems and their economic and social consequences.
3. Commission working program: internal organization, chosen themes (basic and applicative research), operation methods.

The meeting was attended by the following committee members and invited guests: from Bulgaria — Konstantin Spassov, from Cuba — Julio Valdes, from Czechoslovakia — Pavel Bosak, Vladimir Lysenko, Josef Slačik, from France — Michel Bakalowicz, Alain Mangin, from Hungary — Ferenc Cser, from Italy — Carlo Balbiano (took part in the work of the Vth School and in first sessions of the Committee), from Poland — Jerzy Głazek, Jerzy Mikuszewski, Marian Pulina, Andrzej Różkowski, from Romania — Liviu Valeńas, from Spain — Adolfo Eraso (president of the Commission), Rafael Fernandez Rubio.

Research accomplished by various countries in order to promote international cooperation in the karst studies.

Bulgaria. Organizations: Bulgarian Federation of Speleology (Karst Research Coordination Centre, organization for scientific conferences grouping 42 clubs and 800 speleologists). Research organizations: Institute of Meteorology and Hydrology, Academy of Sciences (dealing with a relationship between karst and hydrogeology, resource expectations, planning, water che-

* Adolfo Eraso, Catedra de Geodinamica externa, Facultad de Ciencias Geologicas, Ciudad Universitaria, Madrid — 3, Spain
Marian Pulina, Laboratory of Karst Geomorphology, University of Silesia, ul. Mielczarskiego 58, PL 41-200 Sosnowiec, Poland

mistry, experimental drainage basin of the Rhodope Mts.). Geographical Institute, Academy of Sciences (karst palaeohydrogeology). Zoological Institute, Academy of Sciences and National Museum of Nature (biospeleology and palaeontology). University of Sofia — departments of Mineralogy, Hydrogeology, Climatology, Tourists Geography. Stated problems: karst occupies about 25% of the country's area (30 000 km^2). Research studies in an experimental drainage basin. Karst waters protection. Dams in karst areas.

Cuba. Organizations: there is a special institution for karst research — Department of Speleology of the Geographical Institute, Cuban Academy of Sciences. Many other nonprofessional groups of the Cuban Society of Speleology also deal with some research problems. There is a team working on karst geodynamics. The work done by this team conforms well with the aims the UIS Commision of Physicochemistry an Hydrogeology; it is mainly focused on geology, geophysics, geochemistry and geomathematics. The Department of Applied Geophysics, High Technical Institute „Jose A. Echevarria", acts generally in geophysical problems in karst areas. Various institutions such as the Institute of Hydroeconomics, deal with karst phenomena.

Karst occupies 65 000 km^2 of Cuba i.e. about 60% of the country's area.

The studies deal with research and applicative aspects of karst, depending on its significance. Principal applicative problems concern hydrogeology, geology, engineering and public engineering connected with industrial hydraulic works as well as with exploitation and mastering of water resources.

Spain. Considering the undertaken works as probably guaranteed to be continued, karst research is done at various universities: external geodynamics at Madrid, biospeleology at Barcelona and hydrogeology at Granada. There is a working group on Scientific Speleology, Royal Society of Natural History at Madrid. At Madrid there is also a project to form an underground laboratory of the Natural Sciences Museum run by the High Council of Scientific Research. At Barcelona there are studies on biospeleology at the Museum of Zoology. A branch of hydrogeology, being administered by the Scientific Research High Council, is in Granada: the Documental International Centre dealing with hydrogeological problems arising during mining.

The National Committee of Speleology groups the sportsmen and so, it has neither a scientific intention nor a relation with research institutions dealing with karst problems.

Karst occupies about 150 000 km^2 in Spain i.e. 28% of the area in the country; there are mainly karst problems in mining, in connection with hydrogeology, engineering works and exploitation of water resources.

Presently, the works are carried through to solve these problems; in addition, the karstification of dolomitic rocks and the relation of karstification to cleavage are of main interest. A hydrogeologic collaboration with Portugal, France and Switzerland has been established, concerning studies of karst areas in the Mediterranean countries.

Now the only publication on karst are: *Speleon* — printed in Barcelona by Centre Excursionista de Catalunya, *Kobie* — printed by Excma, Diputation Provincial de Bilbao, *Cuadernos de Espoleologia* — printed by the Museo de Prehistoria y Arqueologia de Santander.

France. Research works are carried out at several universities: Montpellier — dealing with karst hydrogeology, Besançon, Bordeaux, Aix-en-Provence — with biospeleology, but also at the laboratory of the National Centre of Scientific Research at Moulis — dealing with hydrogeology and biospeleology as well as at several other institutions concerned with applicative problems as the Mining and Geological Research Bureau, Electricity of France.

However, no coordination among these institutions is noted.

The National Speleologic Federation which groups the French sporting speleologists, comprises the Scientific Commission which does no research work on karst. However, the Federation collects all the topographic documentation of caves.

Karst occupies 170 000 km^2 in France i.e. 28% of the country, different problems result from its distribution: exploitation of karst water resources, mines, etc.

Some experimental drainage basins are analyzed; such work has long traditions and is of a high standard not only in geomorphology but also in hydrogeology. In addition, karst research is supplied with means and analyses.

Some collaboration in studies of Mediterranean karst areas have been established with Spain and Switzerland.

The only publication dealing with karst — *Spelunca* — collects the activities of the French Federation of Speleology.

Hungary. Organizations: research works are carried out in karst areas by different institutions concerned with mining and water resources. The Institute of Speleology submitted to the Nature Protection Service, has been just established to control and coordinate the research works as well as drilling and exploitation and sporting activity of non-professional clubs grouped in the Hungarian Society of Speleology. Publications: *Karst es Barlang.*

Stated problems: recent karst occupies 1.45% of the territory i.e. about 1350 km^2 whereas palaeokarst — recent karst altogether — over 50% (about 48 000 km^2). Mining in palaeokarst areas below the piezometric level. The relationship of thermal conditions and karst, particularly — of hydrothermal karst.

Poland. Organizations: research institutes — University of Silesia, Laboratory of Karst Geomorphology (geomorphology and hydrohemistry of calcareous areas); Warsaw University, Institute of Geology (fossil karst, its palaeogeographical and practical significance); Geological Institute of the Central State Geological Office (CUG) — Silesian Branch at Sosnowiec (laboratory of hydrogeology and hydrodynamics, application of karst aquifers, organization of permanent observation in experimental drainage basins); Institute of Geological Sciences, Polish Academy of Sciences (coastal karst, karst fillings, sedimentation and chronology, history of speleology).

Scientific societies: Polish Society of Natural Sciences, speleologic section — annual scientific symposiums, scientific prizes; Polish Fellows Society of Earth Sciences — on-professional works, documentation, inventory.

Tourist and sporting organizations: Polish Alpine Association, Committee of Underground Alpinism — speleologic clubs; the union is the Polish representative at the UIS.

Publications: *Kras i speleologia,* edited since 1958 as *Speleologia.*

Stated problems: recent karst occupies about 1.5% of the territory (5000 km^2) while palaeokarst-recent karst altogether 35% (100 000 km^2). Mining in karst areas below the piezometric level. Mineralization connected with sediments of hydrothermal karst and palaeokarst; cooperation with the United States.

Rumania. Organizations: research institutes — E. Racovic'a Institute of Speleology at Bucharest and at Cluj; Geographical Institute, Museum at Oradea; Applied Research Institute — geology, hydrogeology, geophysics and special drillings; University of Bucharest.

Sporting clubs: forty five clubs grouping 1000 cavers, coordinated by the Central Committee of Sport Speleology. The committee acts as a connection between explorers and research institutions.

Publications: five reviews.

Stated problems: burried karst, palaeokarst, thermal conditions connected with karst.

Czechoslovakia. Organizations: research institutes — there are no particular institutes dealing with karst but only separate researches within some institutions — Academy of Sciences, universities, regional institutes.

A speleologic organization is being formed e.g. the group Tarcus with a special commission; but no coordination exists.

Defining of Commission purposes

The Commission expects that future works will result in effective cooperation of all members in karst knowledge — in its water and mineral resources. Keeping this in mind, it has been found obligatory to clearly define the karstology concepts, to define the basis for philosophy of karst research. Therefore, it will be possible to propose the UIS as a category B candidate to UNESCO.

The Commission finds it necessary to define karst as a physical entity in a simple and precise way; this entity should be the basis for every activity. It seems convenient to complete a morphological approach to karst with a quantitative approach. Taking this into account, karst has been defined by its physical pecularities as a medium in which springs connect with one another creating drainage systems which conduct water to some distributaries. Such a system of springs corresponds with an arrangement of the distributaries; it proves that karst should be defined both morphologicialy and hydrologicialy. This point of view enables us to introduce some quantitative parameters of karst as well as thermodynamic approach. A „karstic system" that constitutes a drainage system after this definition, seems to be an interesting entity as the basis for different studies: hydrogeological, geomorphological, physico-chemical ones, etc.

Karstification is the complete process that results in a karst formation. Various mechanisms take part in this process: chemical mechanisms, rock dissolution, clevage of rock, etc. Such an approach allows to localize various processes that take part in karst formation, to reflect their interrelationship, to distinguish a process — karstification — from its effect — karst, and to quantify different parameters. Besides, such an approach presents some fundamental points such as:

1) studies of karst must be accomplished in multidisciplinary teams,

2) a great number of observation and data should be collected as they are very important in the case of a reductive logic,

3) the representativeness of these observation and data can be easily determined.

This definition seems to be, by all means, extremely important. In fact, it must be not only at the basis of fundamental research but also, it may be considered if looking for a solution during exploitation works in a karst area.

This is the reason why the Commission found it necessary to make a general account of present practical problems that are represented by karst. These are:
— problems of mining beneath the piezometric level,
— problems connected with engineering activities, dams, etc.,
— water resources,
— the application of submarine waters,
— problems of expert training and information,
— connections between theoretical and practical works,
— authorities consciousness of the problems which the karst represents.

Work program of the Commission

The need of facilitating communications between different countries was found to be a problem of the first order. For this purpose, M. Pulina (Poland) was designated as a representative and coordinator of the following countries: Bulgaria, Hungary, Poland, Rumania, Czechoslovakia, Soviet Union and Yugoslavia. He is to assure the connections between these countries and the Commission Centre at Madrid.

J. Mikuszewski was nominated the secretary of this linking organism which would uphold direct communication between the Commission members.

The activity of the Commission was based on working groups and themes. The Commission has appointed a chairman and a collaborator in each group. There are the following groups or themes:

Study of Infiltration
Chairman: A. Mangin (France)
Collaborator: L. Maucha (Hungary)
Geochemistry of karstic waters
Chairman: M. Bakalowicz (France)
Collaborator: F. Cser (Hungary)
Geochemistry of the caves
Chairman: J. Slačik (Czechoslovakia)
Subterranean Climatology
Chairman: D. Dimitrov (Bulgaria)
Collaborator: P. Andrieux (France)
Geophysis in Karst
Chairman: J. Valdes (Cuba)
Problems of exploitation of Karstic Aquifers
Chairman: T. Böcher (Hungary)
Karst Incidence on barrage and engineering problems
Chairman: A. Eraso (Spain)
Karstic waters incidence on mines
Chairman: R. Fernández Rubio (Spain)
Collaborator: A. Różkowski (Poland)
Coordination in the field of expert training
Chairman: M. Pulina (Poland)

Each working group is supposed to cover one or two very representative examples of the practical problems of karst. In the first stage each group is to send a one page summary each month to the Committee. These documents are to be presented to the UIS responsibles every year. At the same time, an annual was proposed to be issued for the experts dealing with karst hydrogeology and physicochemistry. All members are kindly requested to cooperate fully in this field.

The next Committee meeting is to be organized in Bulgaria in September 1980, during the international pre-congress of the UIS. For this reason, the first contact with the Bulgarian organizers has been established. The Bulgarian representative has informed the Committee about the organization of the congress.

The Polish representative offered the possibility of the Committee members meeting in February 1980, on the occasion of the VIth School of Speleology, in order to exchange views on the progress of the Committee works. A report of this meeting is to be published in a special volume of *Kras i speleologia*.

The Polish representative proposed as well to publish the future result of work of the Committee in the same review.

Every country was asked to furnish documentation on a representative drainage basin of a karstic environment. If such basins do not exist their possible creation is advised to be taken into account. All the documents on features of these basins (dimensions, geologic structure, climatology etc.) should be sent in 1979 to:

Alain Mangin
Laboratoire Souterrain du C.N.R.S.
MOULIS, F-09200 SAINT GIRONS (France)

These data are to be published in the International Journal of Speleology.

Consequently, annual data should be sent to the same address before June of next year, in order to be published in an annual.

This report has been prepared by all the assistant members of the Committee and has been unamimously approved.

Translated by Leszek Marks

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