GENETIC PROBLEMS OF THE HUGE GYPSUM CAVES OF THE UKRAINE

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Not even in the geomorphological and geological literature of the Soviet Union has it been sufficiently demonstrated that the Podolian plateau in the Ukraine is one of the most extensive, interconnected gypsum karsts on the Earth (1, 7), while the international literature in general makes no mention at all of this fact (4). In fact, however, to the north of the River Dnyester, in the region of the towns Lvov, Ternopol and Chernovtsi, and indeed extending as far as the area of the Pripyach

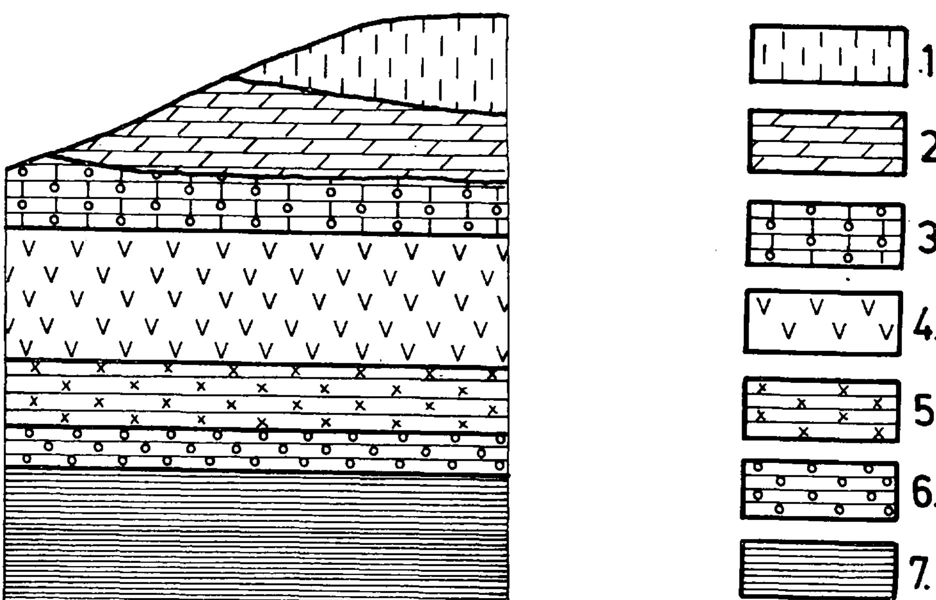

Fig. 1. Geological type-profile of the gypsum karst of the Podolian plateau.
1 = Pleistocone loess,
2 = Lower Sarmata sandy, calciferous clay,
3 = Upper Torton limestone,
4 = Middle Torton gypsum,
5 = Lower Torton Lithothamnium limestone,
6 = Lower Torton sandstone,
7 = Silurian clay slate.

marshes and to Poland, an extensive gypsum karst has developed which is undoubtedly the largest in Europe, its surface area far exceeding those of the gypsum karsts of Asia Minor, the Urals or Germany (Harz Mountains, Kyffhäuser Mountains). The central region of the Podolian gypsum karst covers at least 50.000 km², but further research will certainly reveal at present unknown karst processes of the gypsum layers in more distant areas.

The reason why the gypsum karst nature of the Podolian plateau was discovered only relatively recently is that the karstified gypsum layers generally lie under the surface, covered by various thicknesses (5—25 m) of younger layers of non-karstifying rocks, and by soils formed in part by the corrosion of these and in part of Pleistocene loesses (Fig. 1.). Because of this, the karstic corrosion of the covered horizontal gypsum strata has given rise only to few karst forms which can be seen free from the layers covering the gypsum; it may even be that they appear as extralithomorphological forms in the karstic form varieties of these non-karstic deposits (Fig. 2.) In effect, it is only the considerable Podolian cave discoveries of the past few years which have provedc onclusively that the gypsum deposits of the Podolian ridge have undergone a very intensive subcutaneous karstification (in the course of their subsurface hydrographic development). Today, however, mainly as a result

Fig. 2. Extralithomorphological karst doline formed on a sandy clay terrain in the region of Korolivka. The non-draining depression projects onto the surface the corrosional destruction of the gypsum layer in the depths.

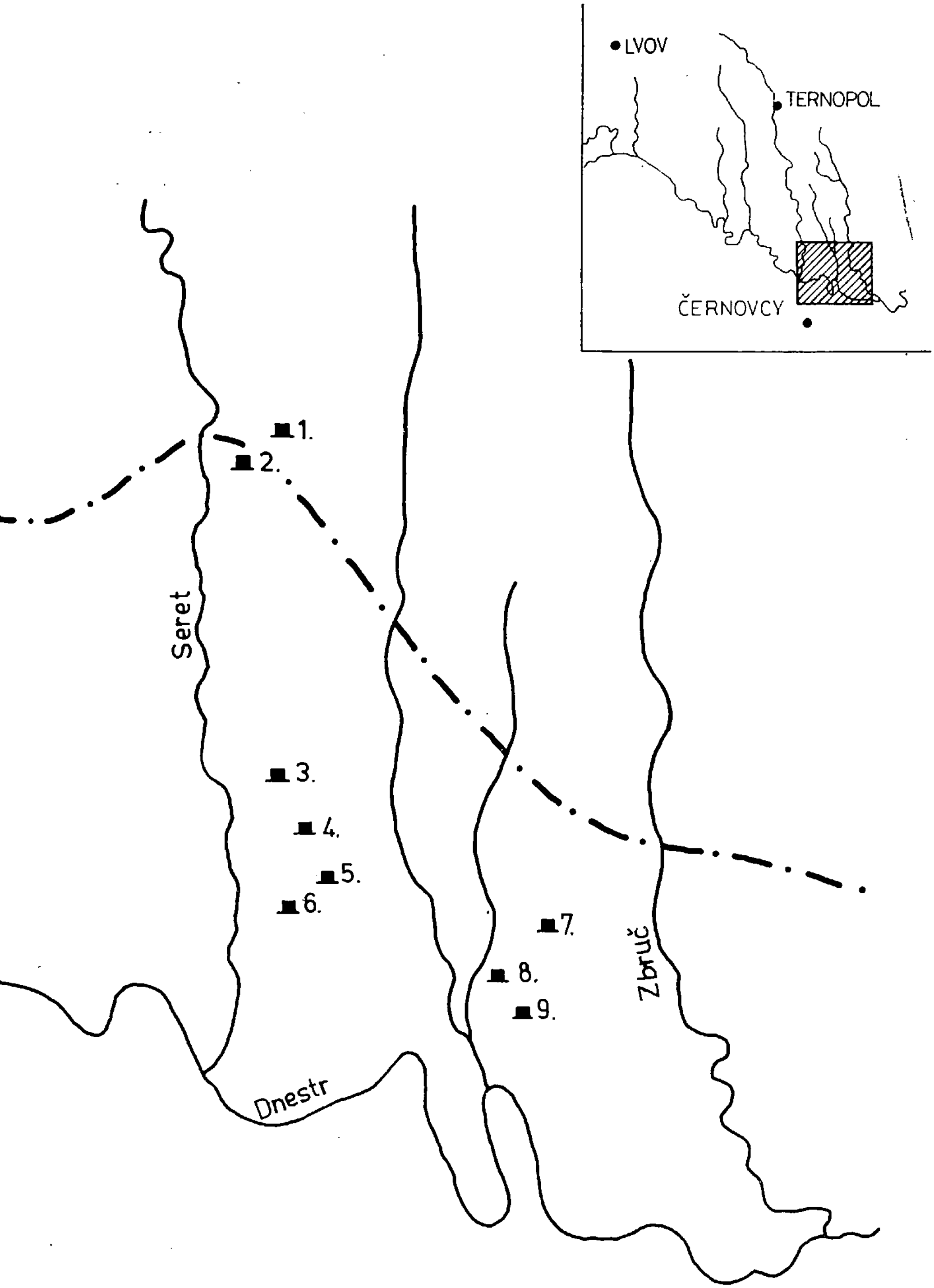

Fig. 3. District of occurrence of the already partially explored gypsum caves on the Podolian plateau.
1=Ugriny Cave 2=Mlinka Cave 3=Verteba Cave 4=Ozernaya (Lake) Cave 5=Vetrovaya (Windy) Cave 6=Optimist Cave 7=Lyubittyelnaya Cave 8=Kristalnaya (Crystal) Cave 9=Nahomah Cave
The dashed line indicates the northern limit of the gypsum karst.

of the successful exploratory investigations of the Lvov, Ternopol, Minsk and Odessa speleological groups, it is known that the central Dnyester region of the Podolian ridge conceals a whole series of gigantic gypsum caves (2, 3, 8, 9) (Fig. 3.) Our own studies in this region led us to observations on the basis of which we believe that the subsequent speleological work here will shortly reveal the longest cave networks on Earth (6). The Podolian gypsum plateau has thus now been demonstrated to be a covered karst abounding in erosional karst phenomena.

The plateau-like ridge, which slopes gently towards the south, has a high relief energy, for the various rivers (the Stripa, Druzhin, Zbruch, etc.), at times cutting out deep canyon valleys have cut up the surface to the Silurian clay slate and formed

Fig. 4. Typical scene of the Podolian gypsum plateau, with erosion river valleys cut into the plateau.

small blocks (some tens of kilometres in size) from it (Fig. 4). These blocks enclose the enormous Optimist (109 km), Lake (103 km), Crystal (19 km), etc. cave complexes. Numerous gypsum and anhydrite areas are known on the various continents, but it is only on the Podolian ridge that cave labyrinths several tens of kilometres in length have formed in block details even smaller than 1 km² (Figs. 5—7).

Fig. 5. Ground-plan map of the Optimist Cave, reflecting the situation in January 1975 (109 km).

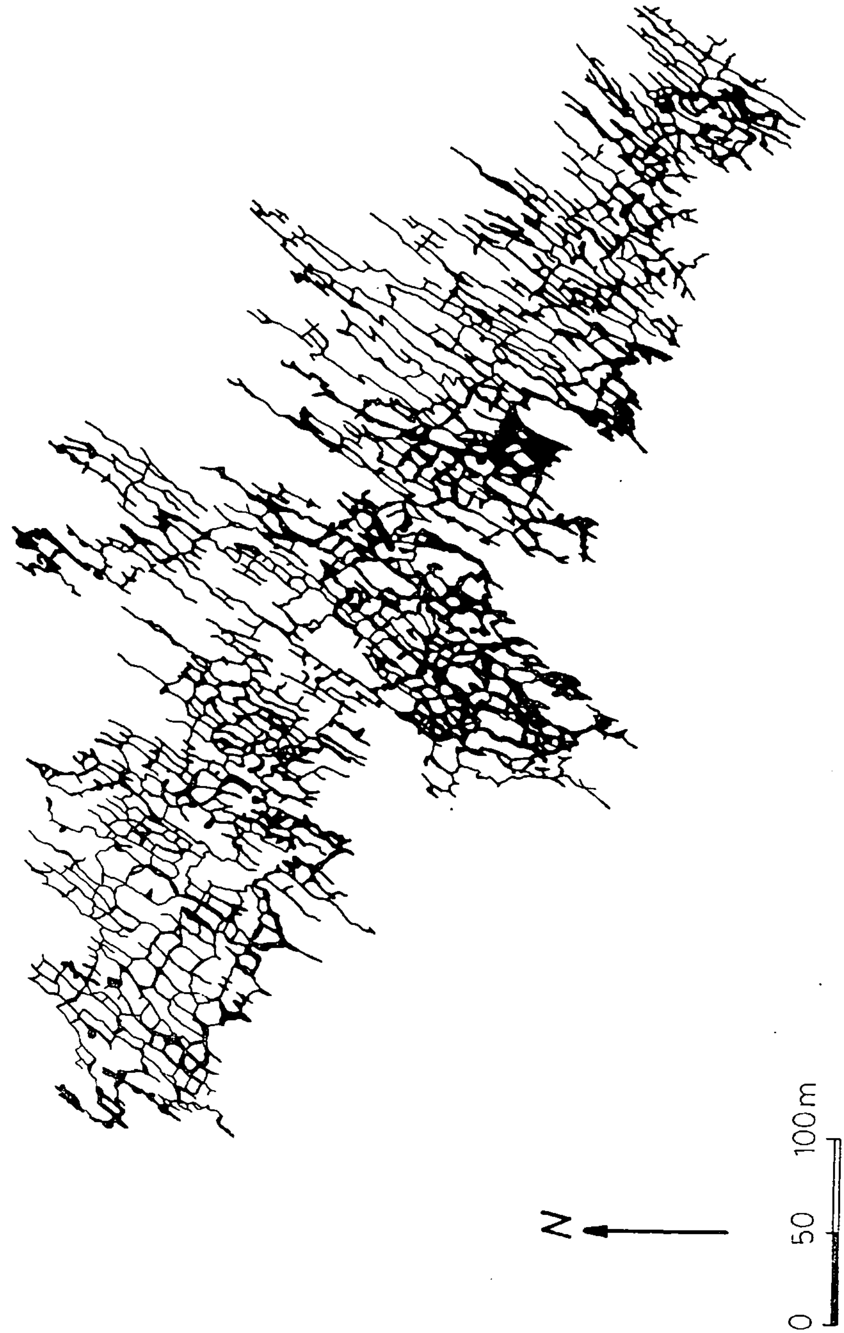

Fig. 6. Ground-plan map of the Crystal Cave (18,785 m) according to Dublyansky.

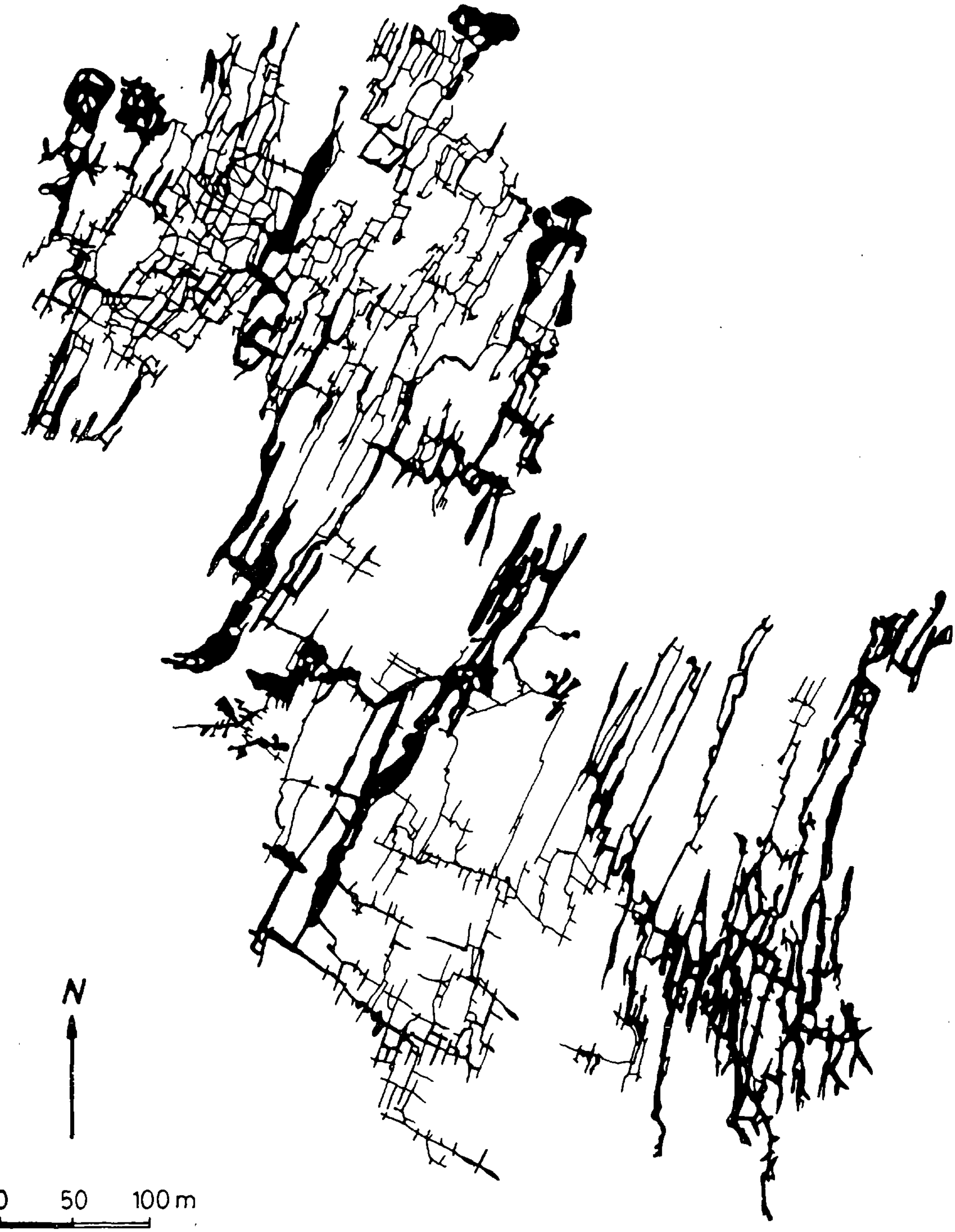

Fig. 7. Ground-plan map of the first 26 km section of the Lake Cave, already explored over a length of 103 km in 1975.

That part of the ridge between the Zbruch and Seret rivers, with an average altitude of 200—350 m, was also studied by us: this area stretches north from the Dnyester, right up to the height of Ternopol. The climate of this region is temperate and mildly wet. The annual amount of precipitation is 700 mm. The average annual mean temperature is 6.8—7.0 °C; the mean temperature for January is -5.5 °C, and that for July is 18.5 °C.

The Palaeozoic and Cainozoic deposits lie almost horizontally between the valleys of the Seret and the Zbruch. The caves have developed in gypsum from the Torton, with an average thickness of 30 m. The gypsum lies on a 10—25 m thick Lower Torton sandstone, or more rarely Lithothamnium limestone, which is deposited on Silurian clay slate. The gypsum is covered by Upper Torton sandstones, clays and in places Ratinski limestone, which is covered in turn by Lower Sarmata marl. The sequence of deposits is concluded by loess. This gypsum stratum extends for a length of about 300 km between Lvov and the Dnyester.

In November 1974, at the invitation of the Lvov "Cyclops" Speleological Group, we took part in the 31st Optimist Cave expedition. The aims of this expedition were the continuation of the mapping and scientific research of this huge gypsum cave, and a comparative morphogenetic study of further caves and other surface and subsurface karst formations.

The Optimist Cave, which was discovered by the Lvov speleologists in 1965, is situated in the vicinity of the village of Korolivka. We carried out the mapping of the northern, previously unknown part of the cave, which, to commemorate this successful research collaboration, was named the "Szegedskaya-peshchera" (Szeged section of the cave) (see Fig. 24).

In the central and western sectors of the cave the thickness of the gypsum is 60—70 m, whereas elsewhere it is generally 25—30 m. The temperature of the cave in the eastern sector is 7.9—8.2 °C, while in the central and western sectors it is 9—10° C (10).

The differences in temperature between the eastern and western cave sectors can only partially be attributed to the different possibilities of exchange of the air with the external atmosphere. The temperature of the eastern sector corresponds to the annual mean temperature of the region; in this sector the entrance opening has been exposed. In winter the direction of the draught transports air from outside into the cave, whereas in summer this transport direction is reversed. On the above basis, the temperature of the eastern sector must be regarded as normal. However, the fact that the temperature of the cave in the western sector is higher than expected from the annual mean temperature can be ascribed not to a geothermic heat flow, but, in our view, to exothermic physico-chemical processes taking place in the cave (e. g. the absorption of water by anhydrite and its conversion to gypsum; crystallization heat production, etc.)

Three morphologically well separated levels can be distinguished in the cave (the Podolian caves in general have 2—3 levels) (Fig. 8).

However, the Optimist Cave, together with the Lake Cave (which genetically and paleohydrographically probably forms one system with it) and the Windy Cave (so far explored over a distance of 4 km), lie in one orographic block; after the discovery of the still unknown connecting sections, therefore, this will be the longest cave system in the world.

The Crystal Cave (19 km), which is the only Podolian gypsum cave open to the public, was discovered in 1963. In contrast with the swallow-hole entrance to the Optimist Cave, its entrance is a one-time spring branch, opening 60—65 m above

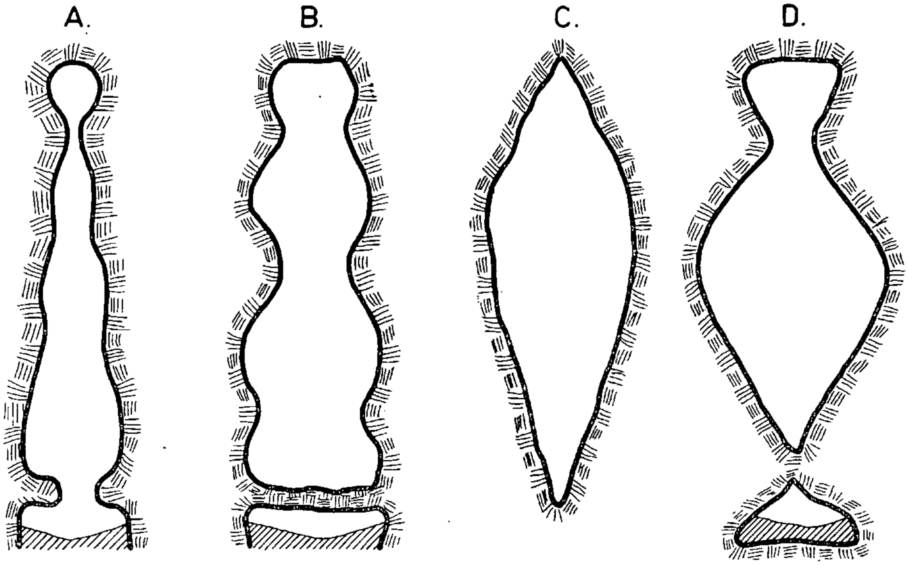

Fig. 8. Profile-types attributable to water throughput changes in the passages of the Optimist Cave.

the level of the Tsiganka stream. It is a two-level cave, with a temperature of 10—12 °C (Fig. 9).

Compared to these above-mentioned caves, the Windy Cave possesses narrower and lower (at most 2.0—2.5 m) passages (Fig. 10). We took part here in excavation work too, the aim of which was to interconnect the Windy and Optimist Caves. It has not yet succeeded in establishing this interconnection, but we were able to increase the mapped length of tha cave by a further 2 km.

The small brooks forming on the plateau surfaces sooner or later flow into swallow-holes. Excavation of such a swallow-hole led, among others, to the discovery of the Optimist Cave (Figs. 11—12). In places one can observe shallow, non-draining, round dolines, which indicate the location of the gypsum close to the surface. The area can in general be regarded as typical covered karst. Only in the valley-sides, where the gypsum has been exposed, has its carrification also begun. Water-dyeing investigations of the swallow-hole valleys have shown that the waters flow away primarily not linearly, but in the boundary plane of the gypsum and its overlying layer, by areality. Because of this, not discrete springs, but entire "spring-lines" develop in the valleys. Just this is one of the sings that the reticular cave formation also took place of necessity where cave passages have not yet been revealed and made accessible (Fig. 13).

All these many types of genetic factors are well documented by the ground-plans of the caves. It is mainly due the to development of a pseudotectonic fracture system as a result of the roof pressure, and to the strong preformational effect of

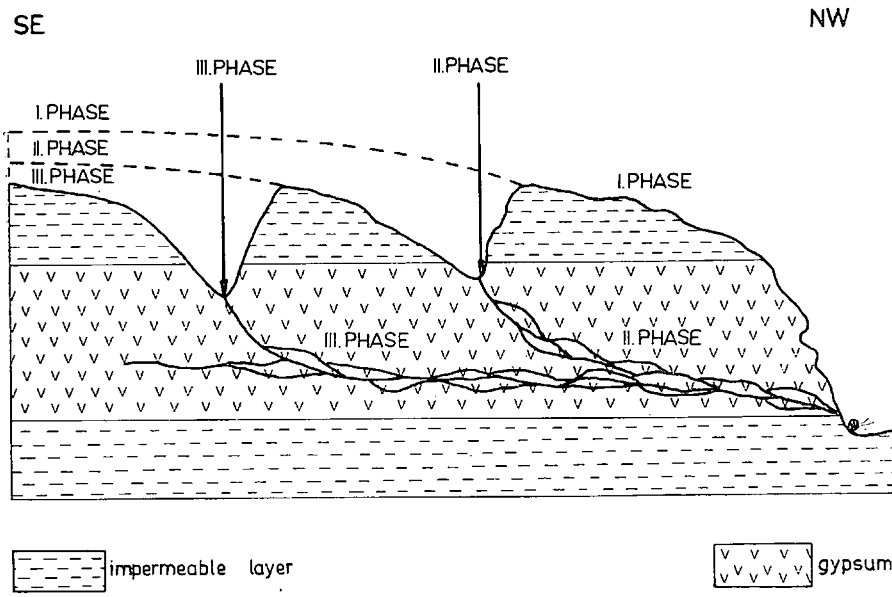

Fig. 11. Hydrographic and genetic correlation between the river valleys, springs, swallow-holes and cave passages on the Podolian plateau. In phase I of the hydrologic development the side-streams still had a surface course. In phase II the gypsum stratum tapped the stream by depression from below (bathycapture) and the upper level of the caves developed; later, the swallow-hole was shifted back to the upper section of the stream valleys, and the lower (active) level of the caves was produced (phase III). The type of this genetic correlation is materialized in the connection of the Optimist Cave (phase III) and the Windy Cave (phase II.)

this, that the ground-plan of such a cave differs considerably from that of a stream limestone cave, which is reminiscent of a surface river system. A significant role was played in this, however, by the fact that the crevice waters flowing predominantly in the NW—SE direction at the end of the Pliocene took part in the formation of the Podolian gypsum caves (the Pliocene fractures were NW—SE [Carpathian] in direction), and that these were subsequently replaced by waters moving in the NE—SW direction in the Pleistocene (Fig. 19).

It has also proved possible to find a parallel between the levels of the individual cave systems and the terraces of the Dnyester.

A few words must be mentioned about the very characteristic crystal formations to be found in the caves. Basically, we observed 5 crystallization types. These are as fallows;

Fig. 12. Active swallow-hole entrance of the Optimist Cave.

Fig. 15. Fissure-preformation cave passage, but strongly widened by stream erosion; it exhibits the strongest lateral erosion at the mid-height of the profile.

Fig. 16. Erosional cave rock terraces in the gypsum walls of the passages of the Crystal Cave.

Fig. 17. Erosional rock terraces in the Optimist Cave, indicating the changes in water throughput of the stream washing out the cave.

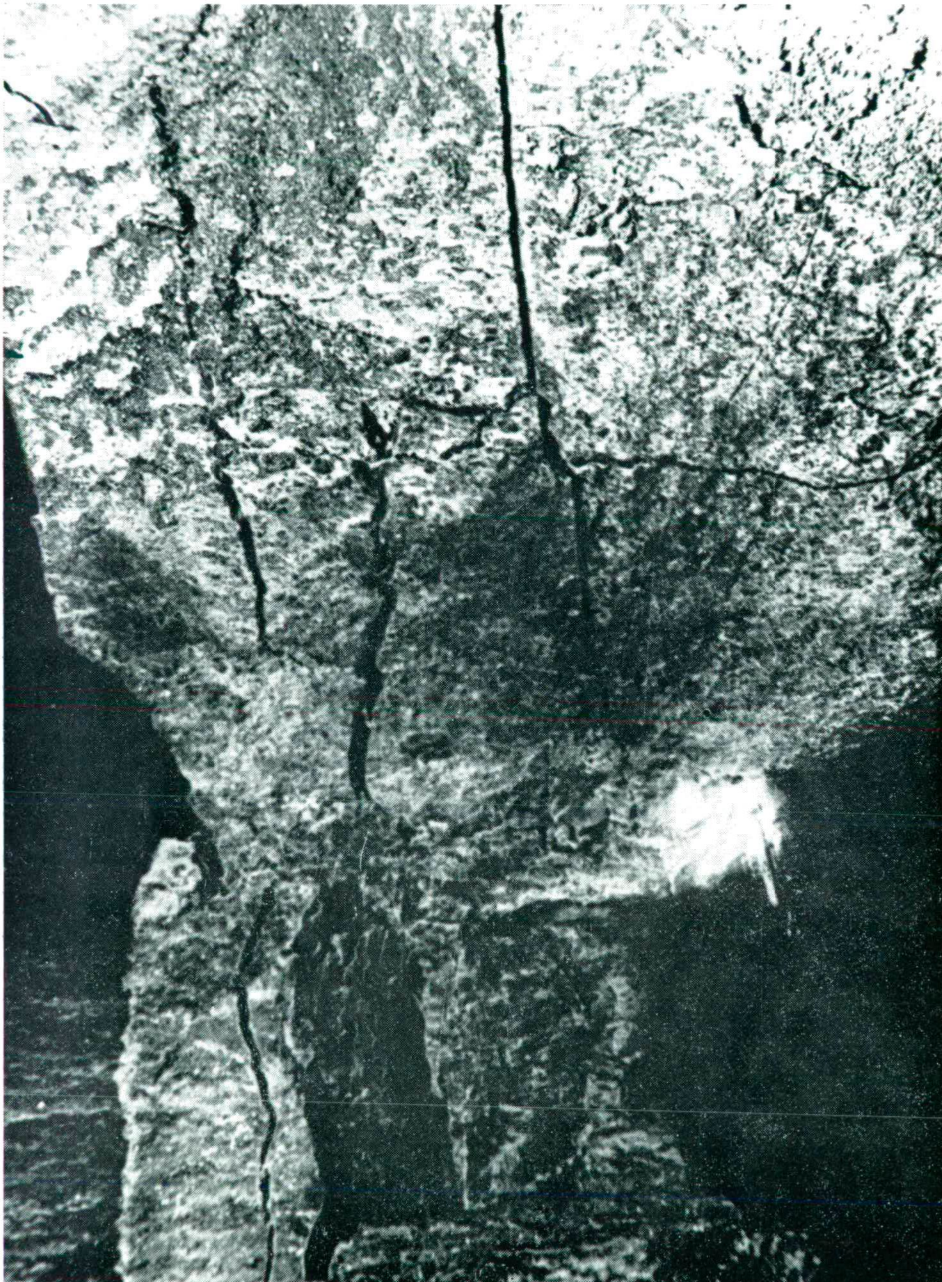

Fig. 18. Pseudotectonic fissures are being formed at present too in the rock material of the gypsum stratum, as a consequence of the pressure of the rock layers covering the cave.

wooden sticks in the game of Morocco, tipped out on to the face of a table. Their genesis has not yet been clarified. If it is assumed that they are syngenetic with the formation of the mother-rock, then the crystal bundles visible on the walls of the passages were exposed by the corrosion of the flowing water syngenetically with the dissolution of the cavity. This assumption appears to be supported by the fact that similar "wheat-ear crystals" are also formed on the surface, where the gypsum is exposed to the corrosion of the rainwater. According to another viewpoint, however, their formation is analogous to that of the monocrystals, or that of the arago-

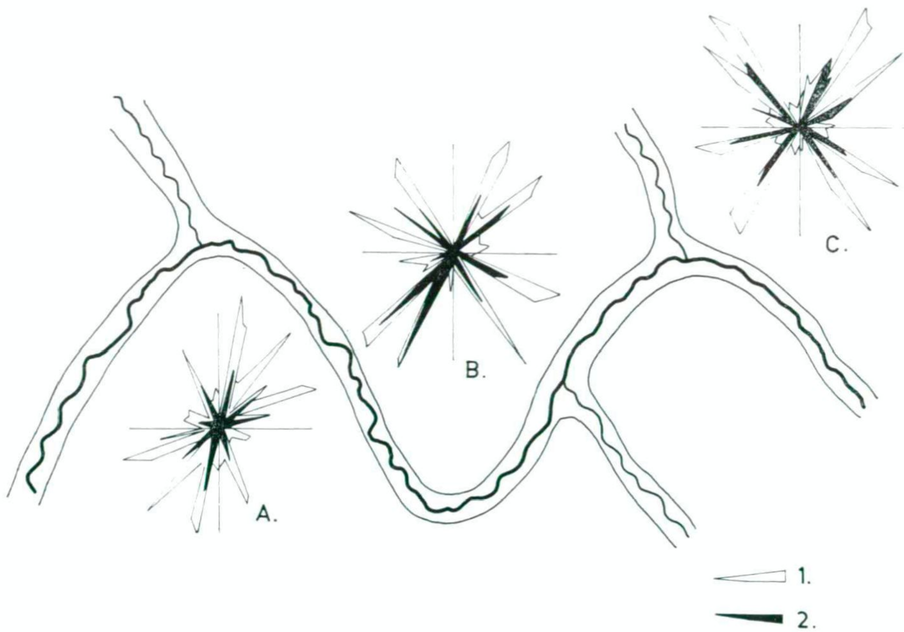

Fig. 19. Correlation of the axial directions of the surface valleys, the cave passages and the rose-diagram of the rock fissures on the example of the Optimist Cave.
1 = direction, length and width of the cave passages,
2 = direction and density of the lithoclases of the rock.

nite "iron flowers", and they grow only on the walls of the cave or at a depth of a few cm in the wall of the gypsum cavity.

(d) A further group of crystals consists of "condensed crystals", which were deposited on the walls of the passages by the mediation of the atmospheric moisture in the period when the cave was filled with water of high concentration. The water deposited from cavern air of high humidity dissolves the surface of the crystal particles of the rock, recrystallizes them, and gives rise to new needle crystals (Fig. 22).

(e) Crystal bundle arrangements reminiscent of arched, plicated folds can be observed on certain sections of the cave wall. These tumefaction forms, produced on the later transformation of the locally originally anhydrite-based deposits into gypsum, prove that $CaSO_4$ was not deposited in the form of gypsum everywhere in the Torton lagoons (Fig. 23).

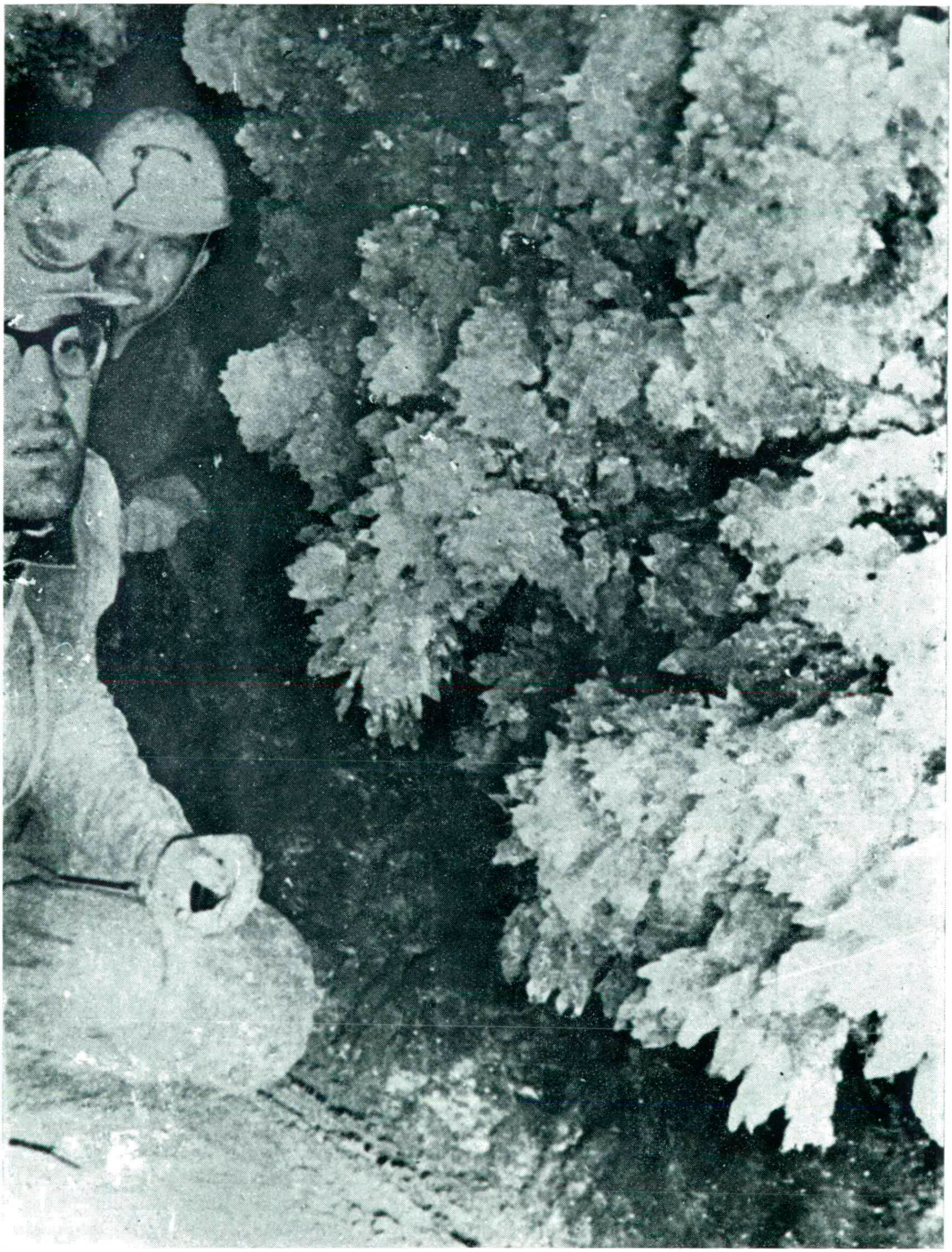

Fig. 20. Rock face-adherent gypsum crystal druses on the walls of the Optimist Cave.

Fig. 21. "Wheat-ear crystals" on the ceiling of the Optimist Cave.
The longitudinal axes of the crystals fit into the depressions in the meandering ceiling bed, incised at the beginning of the erosional cave formation phase.

Fig. 22. "Condensed crystal" coating on the ceiling of the Optimist Cave, deposited from the moisture content of the air of the underground cavity system, and recrystallized by the mediation of the condensed water.

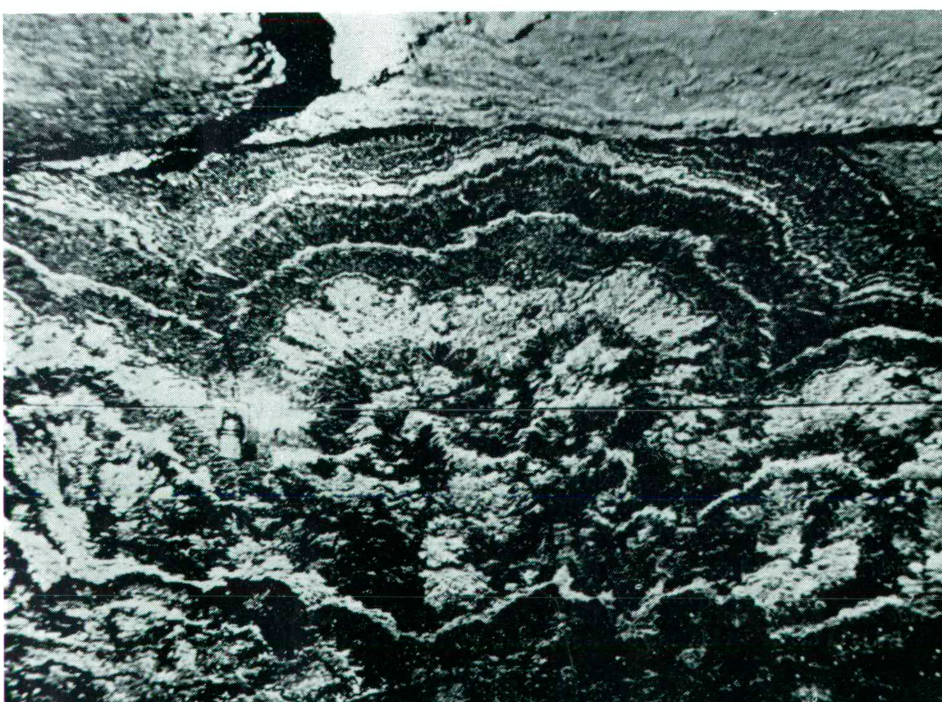

Fig. 23. Crystal formations of tumescent (anhydrite — gypsum) origin in the Optimist Cave, comprising pseudotectonic folds.

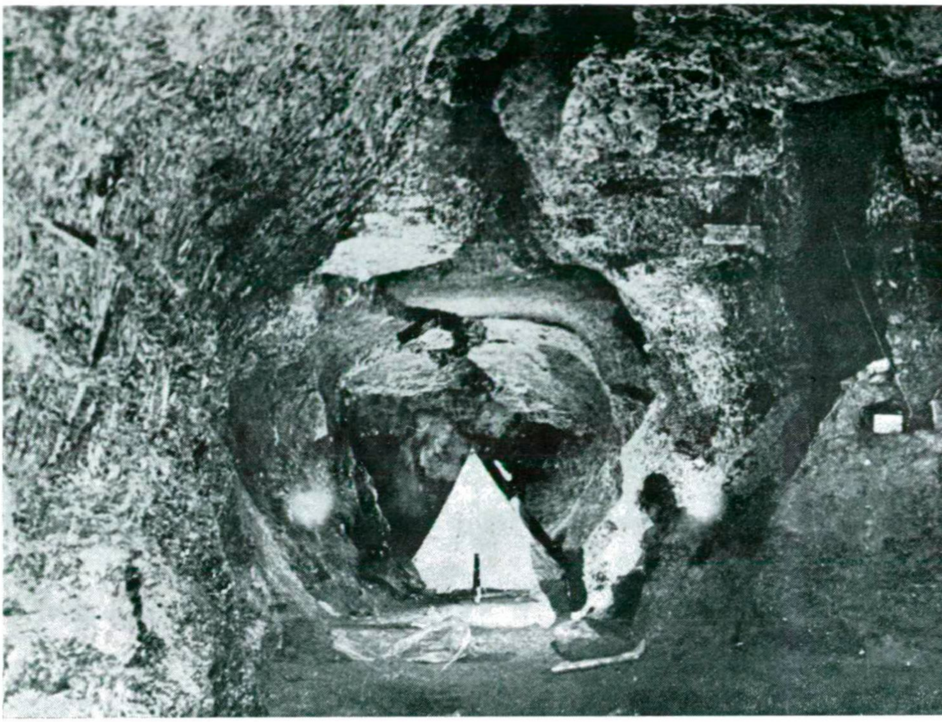

Fig. 24. Underground research base in the Cyclops Chamber of the Optimist Cave.

Limestone stalactites and stalagmites characteristic of karst caves are encountered only rarely in the Podolian gypsum caves, primarily where the chemical compositions of the limestone covering the gypsum stratum and of the soilwaters permeating through it corresponded to the chemical and physical conditions of carbonate accumulation.

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