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AGE AND DEVELOPMENT OF COLLAPSE DOLINES ABOVE THE CAVE SYSTEMS THE EXAMPLES FROM CLASSICAL KARST OF SLOVENIA (NW YUGOSLAVIA)

by

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(3 figures and 1 table)

RESUME. - Age et genèse des dolines d'effondrement des systèmes de grottes. L'exemple du karst classique de Slovénie (N-W de la Yougoslavie).
Les exemples de la région de la Grotte de Postojna et de Skocjanske jame prouvent que les dolines d'effondrement sont le résultat morphologique de la karstification accentuée dans des conditions géologiques et spéléohydrologiques favorables. Elles se sont formées et se sont développées en même temps que les galeries souterraines, en périodes froides de crue du Pléistocène et de l'Holocène. Les dolines d'effondrement ne sont pas un phénomène mécanique soudain, mais un phénomène progressif de spéléogenèse karstique.

ABSTRACT. - Different hypotheses about collapse dolines development have been suggested. The most current one advances as a cause sudden roof collapse above karst caves. The investigations on classical Karst of NW Yugoslavia (Škocjanske Jame, Postojna Cave System, etc.) show that the collapse dolines were formed as a result of the development of water channels under them. The vast collapse forms gradually developed from former dolines, in several phases. They got their significant shapes mostly during huge climatic changes in Upper Würm and Holocene.

On the classical Karst of Slovenia the collapse dolines are very remarkable phenomena of the karst relief. They are distributed singly, in groups or in series, the most frequently in ponor or spring regions of the underground rivers and on the border of karst poljes. They have more than 9 millions m^3 of volume, reaching a depth of up to 160 m and a width of more than 200 m.

Several researchers have written about the topography, the morphology and the origin of these collapse dolines; among them A. Schmidl (1854), E.A. Martel (1894) and in recent times P. Habič (1963) and I. Gams (1974). These studies treated them as the result of roof breakdown above the caves, partly considering erosion and corrosion processes. Namely F. Šušteršič (1973, 1974) showed by morphometric and geomechanical analyses, that the majority of collapse dolines could not develop only by simple breakdowns of the halls. Their volumes are namely too small for all the breakdown material coming from incomparably bigger collapse dolines regarding their volume. To obtain the collapse dolines, more than 90 °/o of the material are to be removed in a way or another.

We thus have to ascertain where, how and when the missing breakdown material was removed. These questions were in general little studied and not explained in previous studies. From the examples of the regions of Postojnska and Škocjanske cave systems we shall see that such data can be gathered and usefully included into collapse dolines speleogenesis.

1. **Postojnska jama** extends on 19 km of dry and water passages in the levels 525 and 510 m, which can be reached through five entrances. Among these entrances only the one at the contact of Eocene flysch and Cretaceous limestone is comfortable, while the other four (Otoška jama, Črna jama, Magdalena jama, Pivka jama) are secundary collapse dolines. Several other collapse dolines do not have any direct contact with the underground channels, although they developed together with them. From this point of view the most characteristic one is the collapse doline named Stara apnenca (fig. 1). The speleogenetic study of the cave system proved (R. Gospodarič, 1976) that this collapse doline could develop because the underground river transported the boulders from the roof and from the pothole-like access on the surface; this process was the most expressive in Lower and Upper Würm. As the water course in Postglacial and Holocene deviated and lowered into new channels, the transportation of gravel and rockfalls was interrupted. The result is the actual closed collapse doline, as there are many similar above Postojnska jama. In nearby open collapse dolines, as are Črna jama and Pivka jama the direct connection with water channels is preserved, perhaps re-established as the underground Pivka permanently removed the breakdown material even in Postglacial and Holocene.

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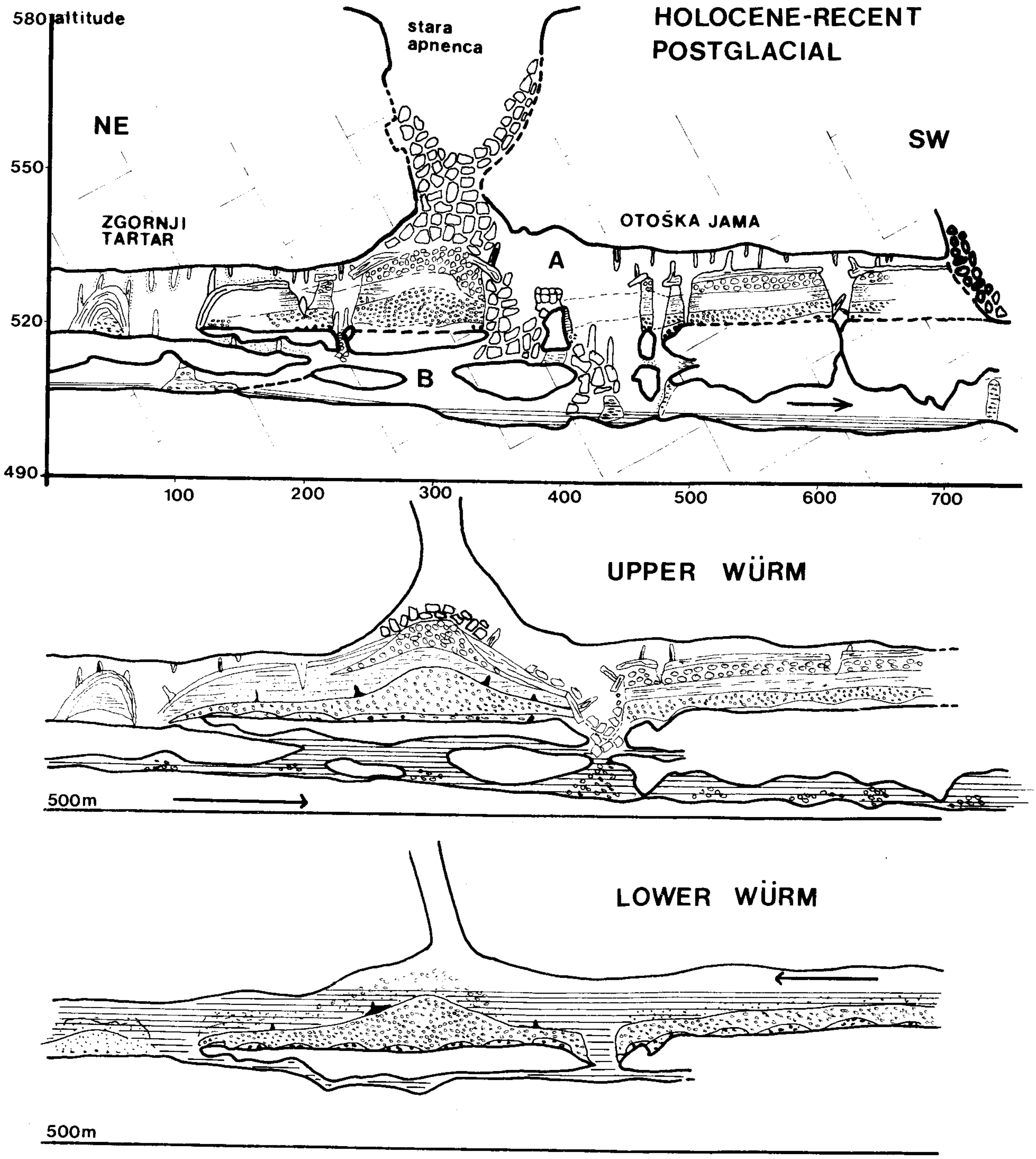

Figure 1. – Part of Postojnska jama, three evolution phases of collapse doline and channels. A. older channel Otoška jama–Zgornji Tartar with sediments; B. younger channels with Underground Pivka river flow.

2. Planinska jama is built of 6,000 m of accessible channels, the most important being the Rak Branch, draining the water from Cerknica polje and Pivka Branch, where a part of autochthonous underground Pivka flows. In the 1,565 m long and 30 m high Pivka Branch recent and fossil water levels are connected. The fossil one is proved by sediments, composed by layers of allochthonous sand and loam and autochthonous flowstones. The most interesting among the sediments is parautochtonous gravel, deposited along the channel in the form of an alluvial fan between 80,000 years (U/Th analyses, R. Harmon) and about 40,000 years (^{14}C analyses, M.A. Geyh, H.W. Franke) old flowstone (R. Gospodarič, 1976). The gravel is composed exclusively by pieces of Cenomanian limestone, which is building also the end of Pivka Branch and the Planina collapse doline above it (R. Gospodarič, R. Pavlovec, 1974). The gravel from the collapse doline region was thus transported and deposited in the underground channel in Lower Würm (fig. 2).

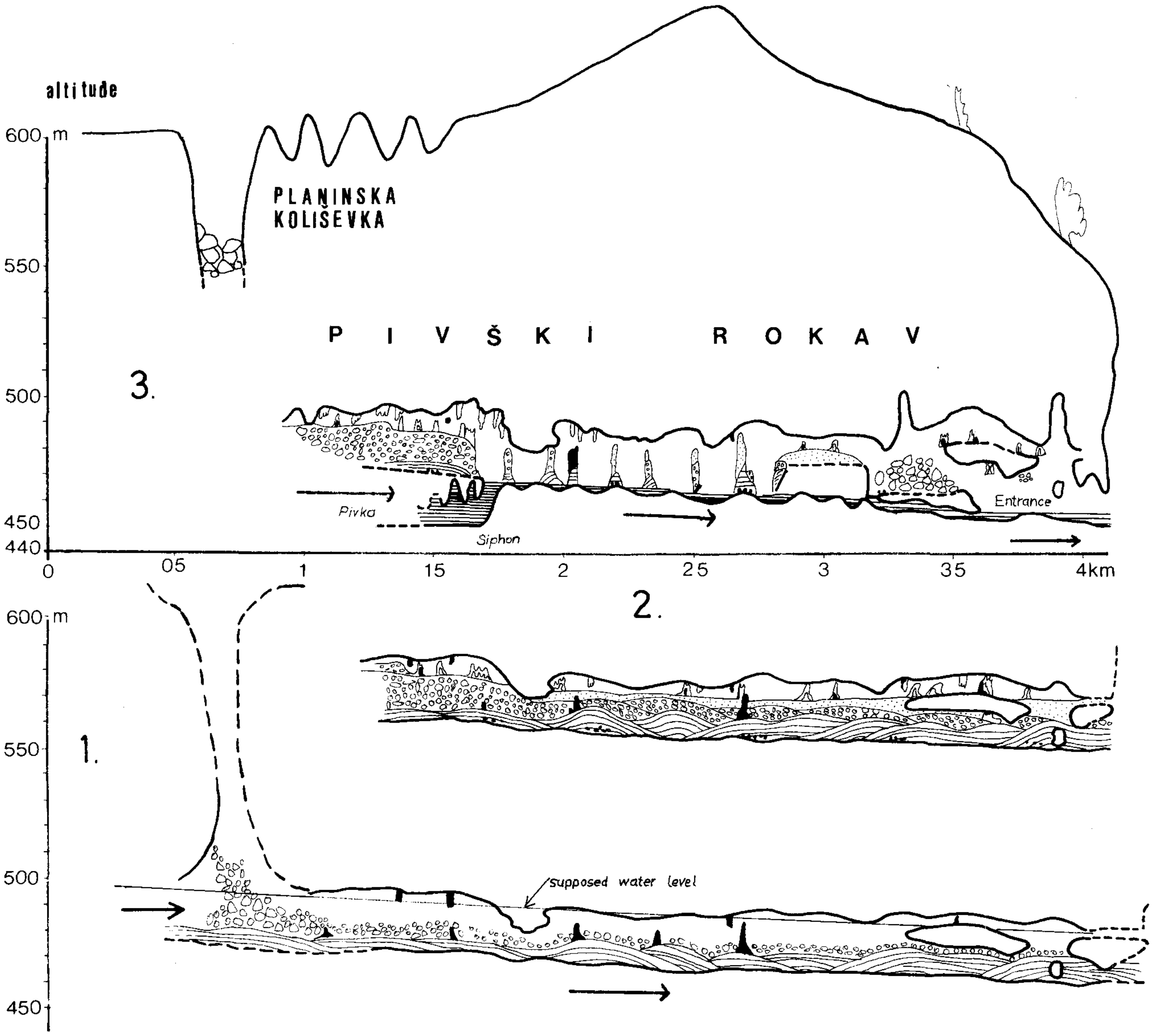

Figure 2. - Part of Planinska jama, three evolution phases of Pivški rokav channel and Planinska koliševka collapse doline. 1. rubble fan sedimentation; 2. filled up channel; 3. today situation.

Consequently the material from the collapse doline was not "lost", but preserved in the underground in the quantity of about half a million of m^3. Its regular grains prove the origin during mechanical surface weathering while its stratigraphic position between the cave sediments proves the gravitation and erosion deposition along the water channel in cool and wet conditions of Lower Würm. This sedimentation was interrupted after Middle Würm because of decreasing transportation power of the underground river as it deviated from the former channel under the collapse doline towards new, siphon channel. Therefore the rest of cryoturbation gravel from Würm 3 remained on the surface and filled up the former pothole. In Postglacial and Holocene the collapse doline and the underground channel developed separately.

There are a lot of similar collapse dolines and underground rivers under them in the karst of Ljubljanica, f.e. in Rakov Škocjan, on the northern side of Planina polje, where Najdena jama lies (R. Gospodarič, 1982). Everywhere the accordance to underground channels development is seen.

3. Škocjanske jame are known because of big water channels and extensive collapse dolines. Till now known channels, 5,300 m long all together, developed in connected water level on 280 m and in dry levels on 330 m and 300 m above the sea level; the last mentioned are interrupted by collapse dolines. Among the ten most expressive collapse dolines, the biggest have up to 9,103 m^3 of volume. Velika and Mala dolina are speleogenetically the most interesting as they

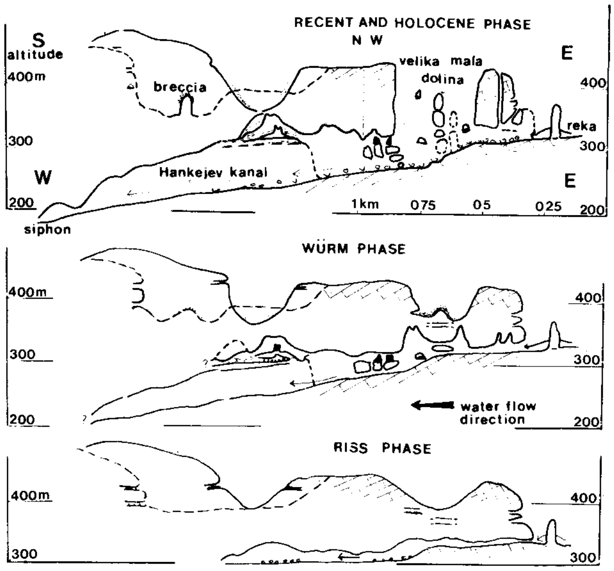

Figure 3
Škocjanske jame, evolution of channels and collapse dolines, Mala dolina and Velika dolina particularly.

directly connect the surface and all three mentioned levels (fig. 3). Speleologenetical study of the whole system showed the following development of Velika and Mala dolina :

Table 1

Surface	Cave level 330 m	300 m	280 m	Time
4. walls weathering	non-active	flood	active	Holocene
3. final collapse	beakdowns	flood	active	Postglacial
2. dolina deepening	breakdowns floods	active	–	Würm
1. wide dolina	active	–	–	Riss ?

A similar development can be supposed for other depressions and collapse dolines on this karst surface and underground. Actual forms of the depressions show different development phases. Wide, dish-shaped dolines preserved older, kidney-shaped double collapse doline younger and cylindrical collapse doline the youngest phase. They are tightly connected to the activity of the underground river in Postglacial and Holocene. On classical Karst of Slovenia the collapse dolines present an important karst phenomenon as they point out the regions of accentuated superficial and underground karstification and specially the erosion activity of the underground rivers. The cited examples prove that the collapse dolines developed gradually together with underground channels in Younger Pleistocene and Holocene.

This development was dependent on geological setting and speleological predispositions and was controlled by changing climatic and hydrologic conditions. The speleogenetical collapse dolines explanation is based on the finding that their breakdown material is partly or in whole preserved in the underground channels where it was deposited by the underground river in the cool, humid Würm period. In that time the potholes and dolines on the surface mostly changed to collapse dolines. These processes occur even in Postglacial and Holocene. But, because of changed underground hydrologic conditions the transportation of the breakdown material was in some places obstructed and in other places accelerated. In the first case the collapse dolines became wider filled up, and developed separately from the underground channels, while in the second case they mostly deepened at the same time as the underground channels.

The suggested hypothesis on the collapse dolines speleogenesis on classical Karst in the period of Younger Pleistocene and Holocene seems more acceptable than the previous "catastrophical" hypothesis which mostly did not consider the geochronological factor. We think that this hypothesis can be of some help in one study of collapse dolines in other regions of Dinaric karst as well as everywhere they are known.

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