# CLASTIC SEDIMENTS FROM DOLINES AND CAVES FOUND DURING THE CONSTRUCTION OF THE MOTORWAY NEAR DIVAČA, ON THE CLASSICAL KARST

# KLASTIČNI SEDIMENTI IZ VRTAČ IN JAM NA TRASI AVTOCESTE PRI DIVAČI, KLASIČNI KRAS

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**Andrej Mihevc & Nadja Zupan Hajna: Klastični sedimenti iz vrtač in jam na trasi avtoceste pri Divači, klasični Kras**

Vrtače se ločijo po obliki, velikosti in po vsebini oziroma sedimentih. V številnih vrtačah so bili najdeni alohtoni nekarbonatni prodi, peski ter ilovnati sedimenti. Pri gradnji avtoceste na Krasu je bilo pri gradbenih delih odprtih večje število vrtač in z mehanskimi sedimenti zapolnjenih jam. Analiza sedimentov je pokazala, da so nekatere depresije stare jame zapolnjene s fluvialnimi alohtonimi sedimenti, kasneje odprte na površje zaradi zniževanja površja in spremenjene v površinske depresije.

**Ključne besede**: jame, vrtače, jamski alohtoni klastični sedimenti, mineralna sestava, zniževanje površja, speleogeneza, Kras, Divača, Slovenija

**Abstract** UDC 551.435.83(497.4)
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**Andrej Mihevc & Nadja Zupan Hajna: Clastic sediments from dolines and caves found during the construction of the motorway near Divača, on the classical Karst**

Dolines differ in form and size and also by the sediments in them. In numerous dolines allochthonous non-carbonate pebbles, sands and loam sediments were found. During the construction of the motorway across the Karst the works uncovered a vast number of dolines, and crossed several caves filled up by mechanical sediments. Sediment analyses showed that some depressions were actually fossil caves filled up by fluvial allochthonous sediments and later opened to the surface due to its lowering and so changed into superficial depressions.

**Key words**: caves, dolines, cave allochthonous clastic sediments, mineral composition, lowering of the surface, speleogenesis, Karst, Divača, Slovenia

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## INTRODUCTION

The classical Karst is a vast carbonate plateau gently sloping towards the north-west. At its upper border the Reka river sinks into Škocjanske jame and its underground flow may be traced in some other caves. In the upper part of the Karst, around Divača, the underground Reka flows about 250 m below the surface. Thus one may presume that an equally thick karst vadose zone exists there. Dolines are the most common relief forms. They developed on places where larger amount of rock had been dissolved and transported through the karst giving rise to circular depressions. They vary in shape, size, depth and density; genetically they may form by dissolution, collapse or a combination of these. Solution dolines, their density up to 70 per square kilometer, are usually small. In general they are up to 10 m in depth and 50 m across. Larger dolines are usually attributed to collapse origin. During the motorway construction over the Karst the works uncovered a large number of dolines or similar depression forms and also fossil, unactive cave passages (Knez & Šebela 1994; Mihevc & Šebela 1995) that are filled by allochthonous fluvial sediments. Helped by these sediments we succeeded in distinguishing some dolines from eroded cave passages near Divača. Cave sediments found on the surface of the Karst differ from other superficial sediments and may provide an important diagnostic trace to distinguish between solution dolines and underground caverns similar to dolines. Similar sediments that we found during the laying-out of the motorway had been already perceived and described in the Karst. They were usually attributed to superficial deposits, to the remains of a once much wider dam of the former Reka when it, supposedly, had still flowed over the Karst (D'Ambrosi 1965; Melik 1961; Radinja 1964). These sediments would be preserved in resedimented form at the lowest parts of the Karst surface, in the bottoms of dolines. Less frequently and in particular in a narrow area some authors attributed them to cave sedimentation (Pleničar 1954; Habič 1992). A distinctive character of described sediments can undoubtedly be attributed to cave sedimentation environment, with large distribution and voluminous quantity of these sedi-

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*The cave explorations, in particular the analyses of the sediments, were made feasible by the financial support of DARS within the project of speleological control over the motorway construction.*

ments. It offers a possibility explain the origin of numerous sediments, now found at the surface, as being the remains of the cave sediments which had appeared due to the surface lowering. Not only the possibility of genetically defining single forms, but also their quantity and the location of fluvial sediments indicate that probably most of the allochthonous sediments up to now found on the surface of the Karst have a cave origin and that they are not a deposit from superficially flowing streams, the Reka for instance.

## THE FINDING SITES AND DESCRIPTION OF ALLOCHTHONOUS CLASTIC SEDIMENTS IN THE SURFACE DEPRESSIONS

During the motorway construction over the Karst the works revealed a large number of dolines and caves, filled up by mechanical sediments. The clastic sediments from some of them were studied more in detail (Fig. 1).

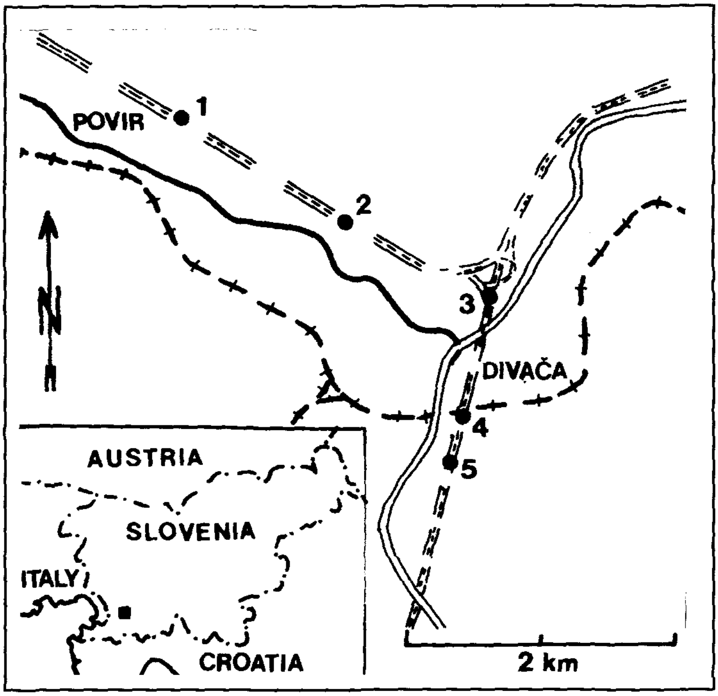



*Fig. 1: Location of described sediments*
*Legend: 1. The Cave without Roof, 2. Profile 650+10, 3. Divaški Hrib, 4. Bojni Dol, 5. Grintavca*

*Sl. 1: Lokacija opisanih sedimentov*
*Legenda: 1. Brezstropa jama, 2. Profil 650+10, 3. Divaški hrib, 4. Bojni dol, 5. Grintavca*

The samples of loam, sand and gravel were analysed by x-ray diffraction technique and some by thin sections. Within the loam the single particles are silt- and clay-sized.

Samples were analysed by x-ray diffraction method in such a way that less represented minerals were more visible. The quantity of the minerals is given in respect to the height of the main reflection of a single mineral in the x-ray record. Thin sections of some samples were made also. Plagioclases are not defined in the samples; their main peaks were not clear enough due to too low level. All the minerals that are defined in traces were not expressed very well because a lot of different minerals occur in one sample and some of them are even not crystallised well, so the background was very high.

**BREZSTROPA JAMA - THE CAVE WITHOUT ROOF**

North of Divača in the axis of the motorway under construction there was an elongated place displaying poor geomechanical properties. The bore-holes (Dular 1993) recorded a depression filled up by mechanically unstable sediments. When the workers had removed the sod and upper layer of soil, red loam and other sediments, it became clear that below was a fossil cave passage intersected in the midle by a shallow doline. Flowstone, speleothems, flutes and scallops are preserved within this passage. Before the motorway construction started the passage was barely visible in the surface relief. On aerial photographs of infrared spectrum in white and black technique (cyclic filming of SRS 1980) it is well seen as a belt of lighter, hence warmer soil. Nearby, away from the laying-out of the road, we saw traces of other similar caves. The whole passage, included 320 m in length and 5 m in depth, or 6900 cubic metres in all, was filled up by allochthonous fluvial cave sediments. In the passage were found yellow brown loams, quartz sand and gravel, up to 25 cm in size. The depth of the excavation mostly did not exceed 3 to 4 m and nowhere touched bedrock (Fig. 2). Cave features are preserved in several places on the walls. In the northern part of the cave the scallops had been covered by a layer of flowstone and thus their features are perfectly preserved. The average size of the scallops is from 2 to 3 cm. In some places in the passage the rock is covered by flowstone and thus it is perfectly preserved, yet elsewhere, close by, corrosion has worn away a more or less thick layer of a rock. At such places we might assess the extent of subcutaneous corrosion since the cave was filled up by sediments. Subcutaneous dissolution removed at the utmost from 5 to 20 mm of the superficial veneer of the rock. At several places in the passage there are points of more intensive vertical percolation and associated transport-controlled reactions indicated by a break-through of brown superficial soil into the cave sediment. Vertical, shallow flutes occurred on the rock. In the sediment filling the passage there are no traces of breakdown. Among the excavated sediments there were a few rocks floating on the sediment but it was impossible to establish whether these are

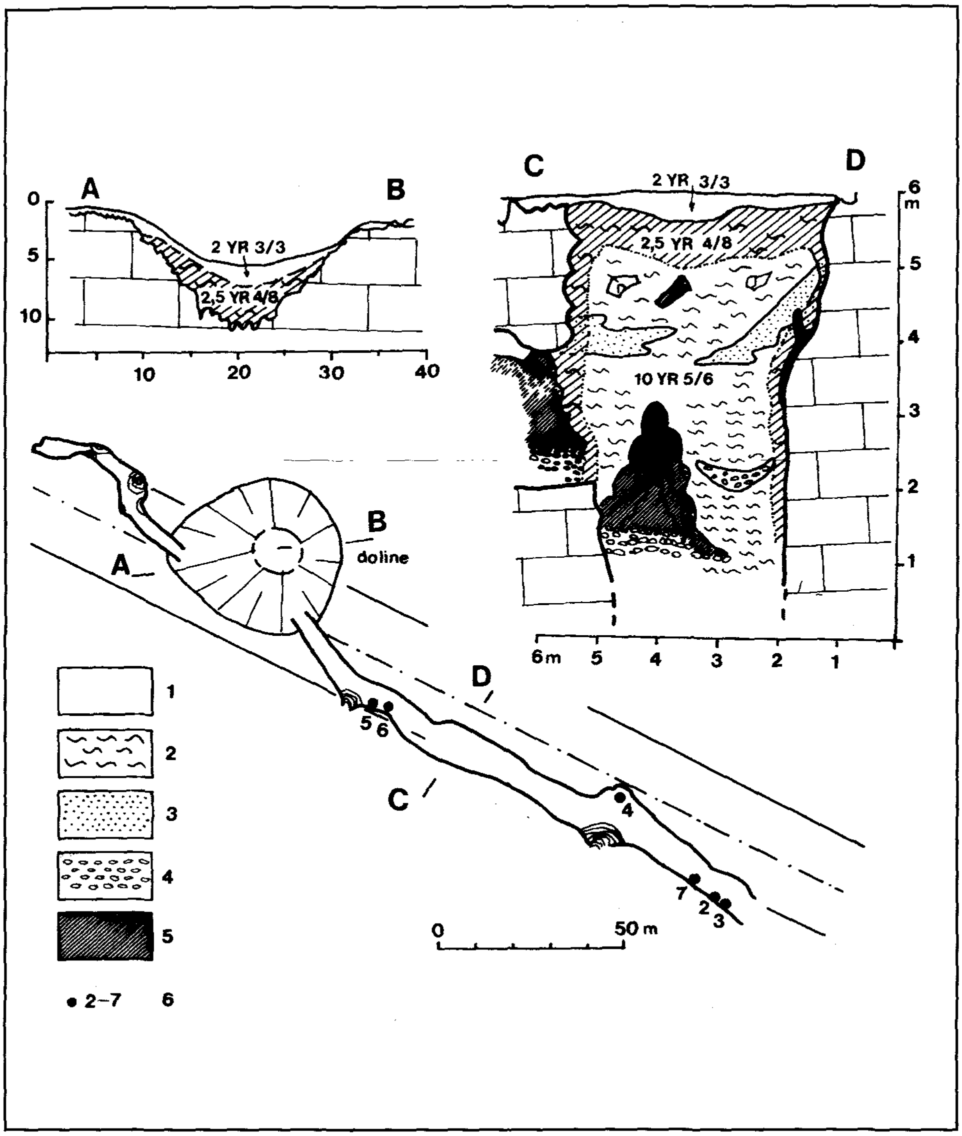



*Fig. 2: The Cave without Roof near Gorenje, ground plan of the cave and location of samples*
*Legend: 1. soil, 2. loam, 3. sand, 4. pebbles, 5. flowstone, 6. samples A-B and C-D, schematic cross section of the cave's sediments*

*Sl. 2: Brezstropa jama pri Gorenju, tloris jame in lega vzorcev*
*Legenda: 1. prst, 2. ilovica, 3. pesek, 4. prodniki, 5. siga, 6. vzorci A-B in C-D, shematska prereza zapolnitve Brezstrope jame*

parts of the cave roof or rocks that had fallen off the upper parts of the walls. Within the sediment some stalactites, up to half a metre long, were found. On the surface there was a layer about 10 cm thick of dark reddish brown soil (2YR 3/3) followed downwards by a 0,5 to 1 m thick layer of terra rossa (2,5YR 4/8) which passed to clastic sediments, loam, sand, and gravel mostly of yellow brown colour.

Most sediments are fom the non-carbonate vicinity. In the passage the sedimentation conditions changed within short distances. The lenses of sand and gravel disappeared and passed over to thinner fractions. In some places the gravel was cemented in a base of massive flowstone. The deposit layers were rotated, indicating that the sediment moved after it had been deposited in the cave. Characteristic types of sediments were sampled. Fig. 2 shows the ground plan of the cave and locations of single analysed samples. We were mostly interested in the origin of clastic sediments and in the possibility comparing them with sediments from elsewhere on the route of the motorway. Due to rapid changes in granulometry and because the excavation was performed by machines we could not reconstruct the sedimentation conditions.

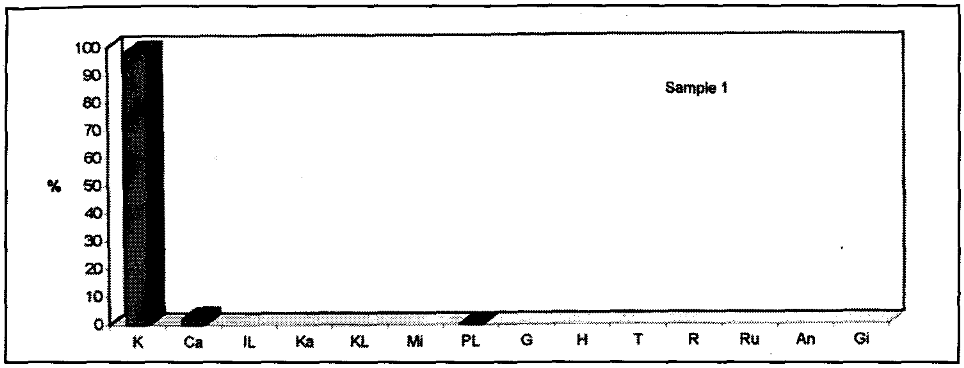
**a. Gravel**

Well rounded non-carbonate pebbles of flysch sandstone, about 5 cm in size, prevailed in the caves. The largest pebble among them was 25 cm on the longer axis. Some of them dried, cracked and disintegrated into smaller pieces. There were also some patinated carbonate pebbles. Even the largest pebbles were lying in quartz sand. The conglomerate that occurred where the flowstone-depositing water flowed through a gravel bar indicates gravel deposition and flowstone accretion at the same time. The conglomerate consists of up to 15 cm large pebbles of flysch sandstone together with some limestone pebbles. The rate of limestone pebbles was higher than in unconsolidated gravel evidencing the corrosion within it.

Chert nodules are very weathered, porous forms, up to 20 cm in size and specially among the gravels. They are angular, with rounded edges and with numerous smoothed semi-circular recesses excluding the possibility that they were rounded during the fluvial transport. Their surface is smooth with a shiny black coating. They were found all over the passage, among the gravels but also among the quartz sand in the south-eastern part of the cave.

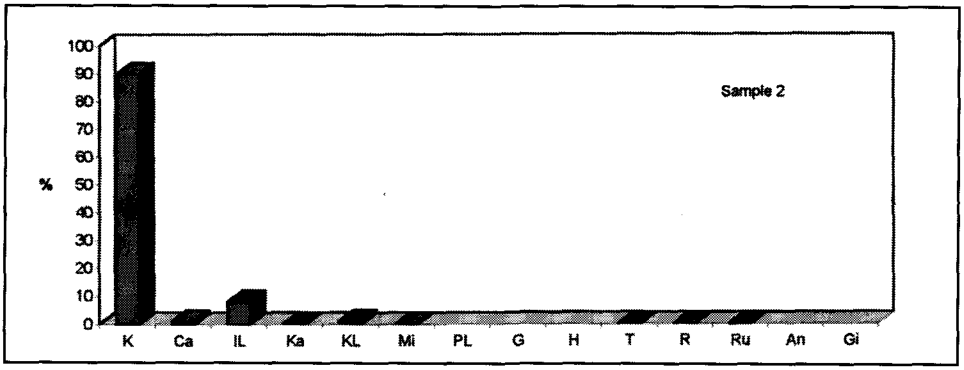
Sample 1

presents a chert pebble of the NW part of the cave. Quartz predominates by 98%, there are only 2% of calcite and plagioclase in traces. A thin section was made. The silification of biomicritic limestone is obvious.




*Sample 1: Quartz pebble from the NW part of Brezstropa Jama*
*X-ray: K - quartz 98%, Ca - calcite 2%, in traces is PL - plagioclase; IL - illite, Ka - kaolinite, KL - chlorite, Mi - microcline, G - goethite, H - hematite, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite*

*Vzorec 1: Kremenov prodnik iz NW dela of Brezstrope jame*
*Rentgen: K - kremen 98%, Ca - kalcit 2%, v sledovih je PL - plagioklaz; IL - illit, Ka - kaolinit, KL - klorit, Mi - mikroklin, G - goethit, H - hematit, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit*




*Sample 2: Yellow brown loam from Brezstropa Jama*
*X-ray: K - quartz 90%, IL - illite 8%, Ca - calcite 1%, KL - chlorite 1%, in traces are T - turmaline, Ka - kaolinite, Mi - microcline, R - hornblende and Ru - rutile; PL - plagioclase, G - goethite, H - hematite, An - anatase, Gi - gibbsite*

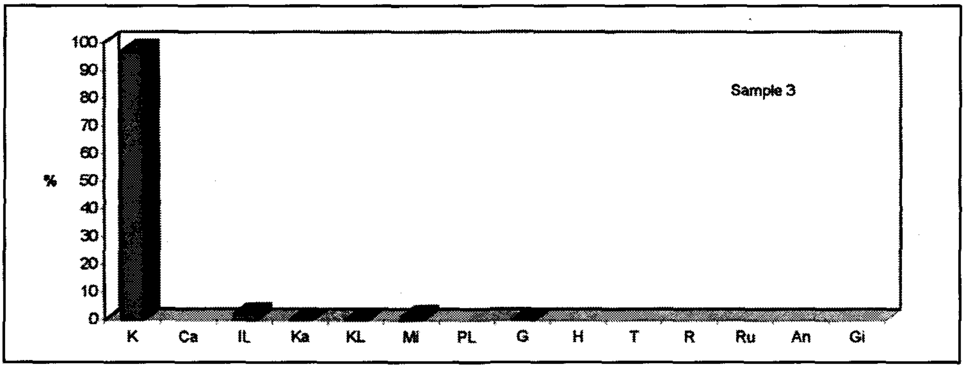
*Vzorec 2: Rumenorjava ilovica iz Brezstrope jame*
*Rentgen: K - kremen 90%, IL - illit 8%, Ca - kalcit 1%, KL - klorit 1%, v sledovih so T - turmalin, Ka - kaolinit, Mi - mikroklin, R - rogovača and Ru - rutil; PL - plagioklaz, G - goethit, H - hematit, An - anataz, Gi - gibbsit*

**b. Sands and loams**

Sands appeared in the form of lense bodies or lamellas within loam, or gravel or independently. The prevailing colour of the sand is yellow-brown in the upper part; at the contact with terra rossa it passes to red. The same happened to pure sands of yellowish brown colour (10YR 5/6) that change into red (2,5YR 4/8) although it is undoubtedly the sediment of the same layer. In the sand there are in places the remains of non-disintegrated pebbles of flysch sandstone. The cave loam is mixed with layers or lenses of sand, and also gravel. A speciality of the loam is a very rotated varve-like sedimentation structure evidencing strong moulding of plastic sediments after they were deposited. The prevailing colour of the loam in the lower part of the profile is yellowish brown (10YR 5/8), sharply passing in the upper part to red (2,5YR 4/8). The same change in colour occurred at the walls of the passage where yellowish brown loam passes into a belt of a red loam.

Sample 2

Yellow brown loam is located in the SE part of the cave. This is a yellow brown loam with sand lenses that passes on the top into red loam. Yellow brown loam consists of 90% of quartz, 8% of illite, 1% of calcite, 1% of chlorite and in traces tormaline, kaolinite, microcline, hornblend and rutile. This sample is a cave yellow flood loam deriving from flysch sediments. The rate of clayey minerals is higher than in Sample 3.

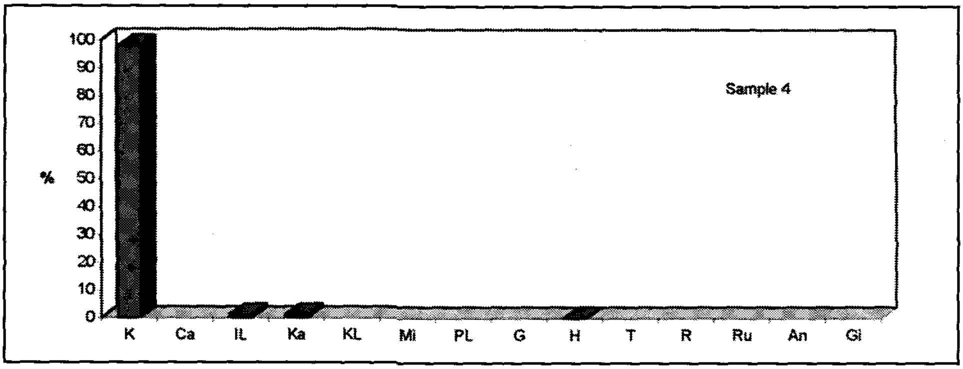



*Sample 3: Sandy lamina out of yellow brown loam No. 2 from Brezstropa Jama X-ray: K - quartz 97%, IL - illite 2%, Mi - microcline 1%, in traces are Ka - kaolinite, KL - chlorite and G - goethite; Ca - calcite, PL - plagioclase, H - hematite, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite.*

*Vzorec 3: Peščena lamina iz rumenorjave ilovice št. 2 iz Brezstrope jame Rentgen: K - kremen 97%, IL - illit 2%, Mi - mikroklin 1%, v sledovih so Ka - kaolinit, KL - klorit and G - goethit; Ca - kalcit, PL - plagioklaz, H - hematit, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit.*

Sample 3
belongs to sandy lamina in yellow brown loam. The mineral composition is 97% of quartz, 2% of illite, 1% of microcline and traces kaolinite, chlorite and goethite. Sand from yellow loam is well washed thus almost only quartz grains are seen. The mineral composition of this sediment corresponds to flysch sediment.

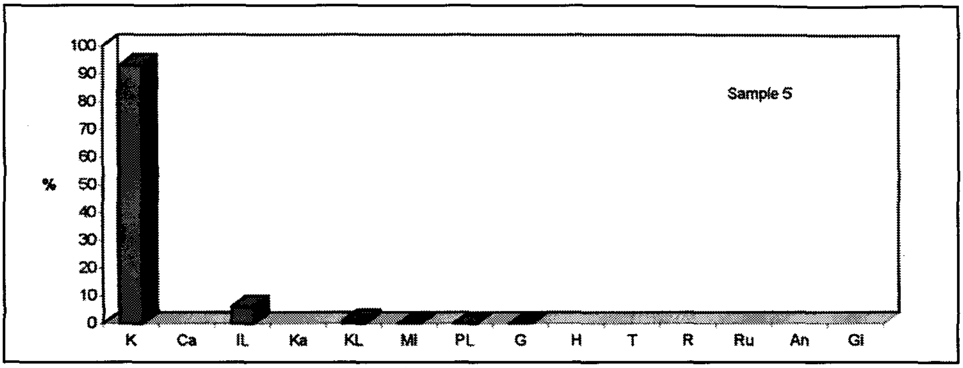
Sample 4
A sample of red sand was taken from the right side of the cave near the contact with wall. It consists of 98% quartz, 1% illite, 1% kaolinite and hematite in traces. It seems that the hematite dyed the other minerals. Also this sand may have its origin in flysch; its red colour, however is due to dehydration of goethite to hematite. It probably happened at the wall where the sand was exposed to weathering.




*Sample 4: Red sand at the contact with the cave wall in Brezstropa Jama*
*X-ray: K - quartz 98%, IL - illite 1%, Ka - kaolinite 1%, in traces is H - hematite; Ca - calcite, KL - chlorite, Mi - microcline, PL - plagioclase, G - goethite, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite*

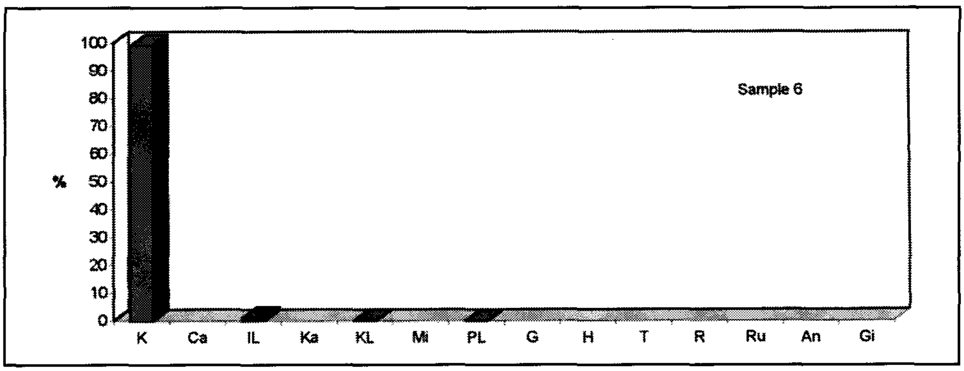
*Vzorec 4: Rdeč pesek s stika z steno jame v Brezstropi jami*
*Rentgen: K - kremen 98%, IL - illit 1%, Ka - kaolinit 1%, v sledovih je H - hematit; Ca - kalcit, KL - klorit, Mi - mikroklin, PL - plagioklaz, G - goethit, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit*

Sample 5
Yellow loamy sand from below the flowstone consists of 93% quartz, 6% illite, 1% chlorite and goethite, microcline, plagioclase in traces. The sample represents cave sediment and may have its origin in flysch sediments.




*Sample 5: Yellow loamy sand from bellow the flowstone in Brezstropa Jama*
*X-ray: K - quartz 93%, IL - illite 6%, KL - chlorite 1%, in traces are G - goethite, Mi - microcline and PL - plagioclase; Ca - calcite, Ka - kaolinite, H - hematite, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite*

*Vzorec 5: Rumen ilovnat pesek izpod sigove kope v Brezstropi jami*
*Rentgen: K - kremen 93%, IL - illit 6%, KL - klorit 1%, v sledovih so G - goethit, Mi - mikroklin and PL - plagioklaz; Ca - kalcit, Ka - kaolinit, H - hematit, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit*




*Sample 6: Yellow washed sand vis-a-vis the flowstone in Brezstropa Jama*
*X-ray: K - quartz 99%, IL - illite 1%, in traces are KL - chlorite and PL - plagioclase; Ca - calcite, Ka - kaolinite, Mi - microcline, G - goethite, H - hematite, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite*

*Vzorec 6: Rumenizpran pesek nasproti sigovi kopi v Brezstropi jami*
*Rentgen: K - kremen 99%, IL - illit 1%, v sledovih so KL - klorit and PL - plagioklaz; Ca - kalcit, Ka - kaolinit, Mi - mikroklin, G - goethit, H - hematit, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit*

Sample 6

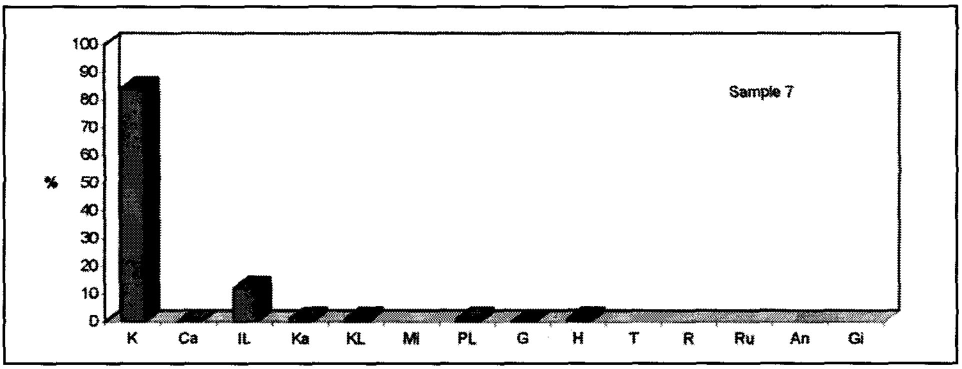
Yellow washed sand opposite to the flowstone in the cave. The X-ray method recorded 99% of quartz, 1% of illite and chlorite and plagioclase in traces. A thin section was made of this sample. Quartz predominates by 99%, there are also some grains of tormaline, muscovite and zircon. A thin film of goethite coats other minerals. This sample is a cave sediment and as it was well washed it does contain almost only quartz.

Sand and loam mostly derive from flysch sandstone that disintegrated during the weathering in situ, during fluvial transport or in the cave from sandstone pebbles. Various colouring of sands is controlled by the recent sedimentation environment where they had been deposited. In respect of mineralogical composition there are no essential differences between both types of loam, red and yellowish brown. In both, quartz (more than 90%) and illite prevail. Eolian origin of the grains is not probable as neither gravel nor loam and flowstone indicate a dry climate; they were deposited at the time when a river flowed through the cave.

**c. Deposits from the surface**

Sample 7

Red loam (2,5YR 4/8) infiltrated from the surface lies near to yellow sand and loam. It consists of 84% quartz, 12% illite, 1% chlorite, 1% kaolinite, 1%




*Sample 7: Red fill from the surface in Brezstropa Jama*
*X-ray: K - quartz 84%, IL - illite 12%, KL - chlorite 1%, Ka - kaolinite 1%, PL - plagioclase 1%, H - hematite 1%, in traces are G - goethite and Ca - calcite; Mi - microcline, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite*

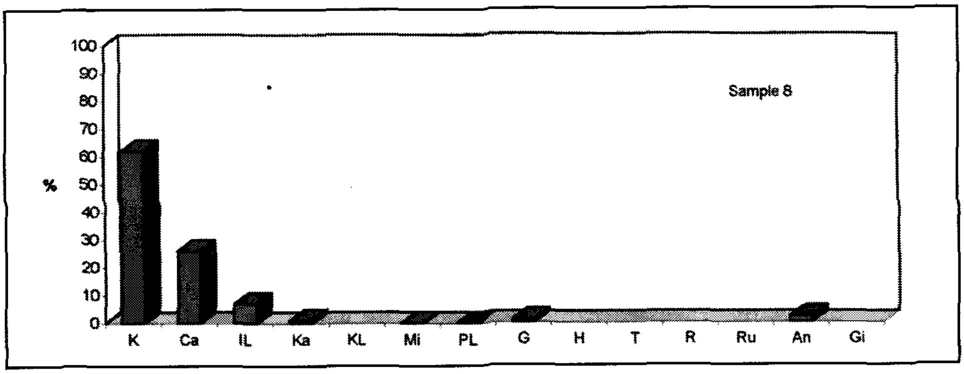
*Vzorec 7: Rdeča zapolnitev s površja v Brezstropi jami*
*Rentgen: K - kremen 84%, IL - illit 12%, KL - klorit 1%, Ka - kaolinit 1%, PL - plagioklaz 1%, H - hematit 1%, v sledovih so G - goethit and Ca - kalcit; Mi - mikroklin, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit*

plagioclase, 1% hematite and goethite and calcite in traces. The location of this material and the ratio of clay minerals are slightly higher than in a previous sample and their association indicates the origin of the infill from the karst surface.

A doline (profile A-B in Fig. 2) that intersected the cave in its middle part was destroyed by earth works first and thus the relationship between the cave and doline was not assessed. We assume that it was filled up by up to 2 m thick red loam without the yellow layers that are typical of cave sediments. Although the passage was opened towards the doline the sediment from the passage did not move into it. The centre the of doline was slightly out of the axis of the passage itself. Obviously the doline and the passage came into existence and developed independently controlled by various initial structures and various conditions. The effect of the doline on the cave was very small.

## SEDIMENTS IN PROFILE 650 + 10

In the profile that lies at 408 m a.s.l. about 1 km SE from the Cave without Roof, two caves filled up by sediment were intersected. One was filled up by rubble and the other by loamy and sandy allochthonous sediments. Due to similarity of these sediments with to from the Cave without Roof only a few samples were analysed.




*Sample 8: Grey yellow loam from the cave on the highway layout at the profile 650 + 10*
*X-ray: K - quartz 62%, Ca - calcite 26%, IL - illite 7%, An - anatase 2%, Ka - kaolinite 1%, G - goethite 1%, in traces are Mi - microcline and PL - plagioclase; KL - chlorite, H - hematite, T - turmaline, R - hornblende, Ru - rutile, Gi - gibbsite*

*Vzorec 8: Sivorumena ilovica iz jame na avtocesti na profilu 650 + 10*
*Rentgen: K - kremen 62%, Ca - kalcit 26%, IL - illit 7%, An - anataz 2%, Ka - kaolinit 1%, G - goethit 1%, v sledovih so Mi - mikroklin and PL - plagioklaz; KL - klorit, H - hematit, T - turmalin, R - rogovača, Ru - rutil, Gi - gibbsit*

**a. Loams**

The profile of the first passage was filled up by laminated loam sediment with strongly rotated layers. In the lower part of the profile the yellowish brown (10YR 5/8) loam with thin grey layers prevailed. The upper part of the infill was of the same colour as the subsurface red loam (2,5YR 4/8) in the Cave without Roof.

Sample 8

Grey-yellow loam from the cave in the motorway's route consists of 62% quartz, 26% calcite, 7% illite, 2% anatase, 1% kaolinite, 1% goethite and microcline and plagioclase in traces.

This yellow loam is a cave sediment; it probably originated at the time when the cave walls were mechanically eroded, thus explaining high ratio of calcite.

**b. Rubble**

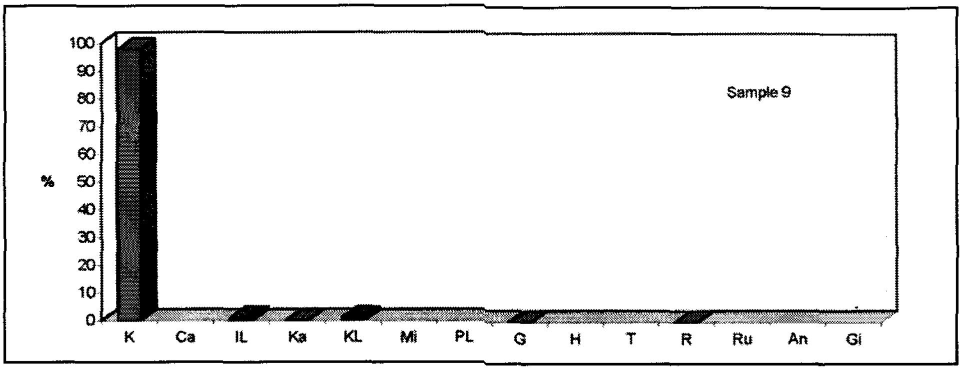
Some meters distant in the same road cutting there was a karst cave filled by angular rubble; the pieces were about 10 cm in size. Unconsolidated rubble was mixed with red loam. There were also a few pieces of stalactite, about 10 cm across. Obviously this was an older, void cave later filled up by Pleistocene climatic rubble.

**LOAM FROM DIVAŠKI HRIB**

A road cutting in Divaški Hrib at 450 m a.s.l. intersected a large cavern. Within the cutting it was seen as a 4 m high and 10 m wide infill of red and yellow brown loam. On the top the roof of this cavern is preserved, about 2 m thick. The cave was filled up by laminated, strongly moulded yellow loam with lenses and layers of sand and macroscopically similar loam of red colour. Layers, lenses and laminas were moulded and rotated. Some rubble intensively dyed by red loam was deposited above. Due to the fact that the road cutting only intersected the cave we could not assess its geometry. It is obvious that the sediments had undergone considerable internal movements (displacements). In one part the cave sediment was controlled by vertical percolation and transport controlled actions of rubble into fossil deposits and became red. Two samples of the infill were analysed.

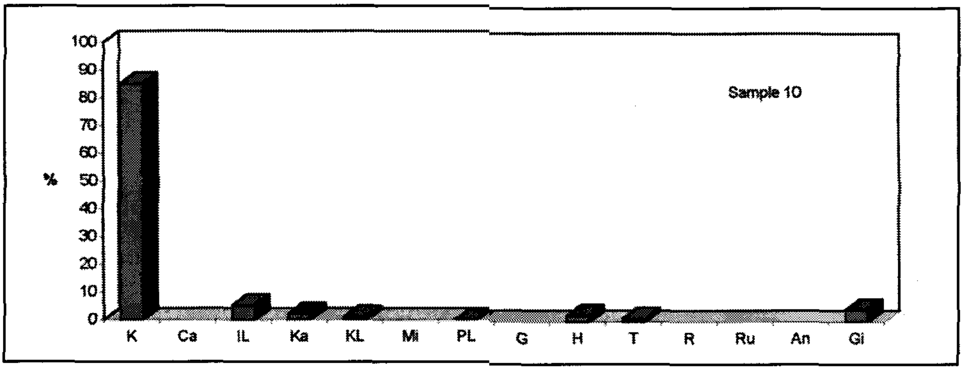
Sample 9

Yellow loam with lamine of fine sand (10YR 6/6), the size of poorly rounded grains varies from 0,1 to 0,025 mm. The sample consists of 98% quartz, 1% illite, 1% chlorite and kaolinite, goethite, and hornblende in traces. It is a cave sediment




*Sample 9: Yellow sand and loam from the cave below Divaški Hrib*
*X-ray: K - quartz 98%, IL - illite 1%, KL - chlorite 1%, in traces are Ka - kaolinite, G - goethite and R - hornblende; Ca - calcite, Mi - microcline, PL - plagioclase, H - hematite, T - turmaline, Ru - rutile, An - anatase, Gi - gibbsite*

*Vzorec 9: Rumen pesek in ilovica iz jame pod Divaškim hribom*
*Rentgen: K - kremen 98%, IL - illit 1%, KL - klorit 1%, v sledovih so Ka - kaolinit, G - goethit and R - rogovača; Ca - kalcit, Mi - mikroklin, PL - plagioklaz, H - hematit, T - turmalin, Ru - rutil, An - anataz, Gi - gibbsit*




*Sample 10: Red loam, deposit from the surface into the cave below Divaški Hrib*
*X-ray: K - quartz 85%, IL - illite 5%, Gi - gibbsite 4%, Ka - kaolinite 2%, H - hematite 2%, KL - chlorite 1%, T - turmaline 1%, in traces is PL - plagioclase; Ca - calcite, Mi - microcline, G - goethite, R - hornblende, Ru - rutile, An - anatase*

*Vzorec 10: Rdeča ilovica infiltrirana s površja, v jami pod Divaškim hribom*
*Rentgen: K - kremen 85%, IL - illit 5%, Gi - gibbsit 4%, Ka - kaolinit 2%, H - hematit 2%, KL- klorit 1%, T - turmalin 1%, v sledovih je PL - plagioklaz; Ca - kalcit, Mi - mikroklin, G - goethit, R - rogovača, Ru - rutil, An - anataz*

Sample 10

Mineral composition of the red loam overlying the yellow sand is 85% quartz, 5% illite, 4% gibbsite, 2% kaolinite, 2% hematite, 1% chlorite, 1% turmaline and plagioclase in traces.

From its mineral composition one may conclude that this material infiltrated into the cave from the surface.

**OPEN CAVE ON GRINTAVCA SW OF DIVAČA**

Between two larger dolines, Dol Češnjevec to the west and Dol Rebidnik, the motorway passes a series of connected shallow dolines. Its altitude is about 449 m a.s.l. and the bottom of the dolines at 446 m. The larger dolines display wide flat bottoms at 433 and 431 m a.s.l. The aerial infrared photographs in white and black technique (cyclic filming of SRS 1980) show a series of dolines as a belt of lighter, thus warmer soil. The bottoms of both dolines have the same shape. On removing the soil it was proved that dolines, shallow relief depressions in fact, developed above an old cave passage, up to 6 m wide, without a roof. Due to the relatively small part excavated we were not able to study this cave in more detail. By digging, both walls were cleared without reaching the bedrock of the passage although the excavation was about 5 m in depth (441 a.s.l.). At two places affected by digging the passage was interrupted as the roof there was still preserved at 448 m a.s.l. Most of the passage was filled up by allochthonous fluvial sediments.

**a. Gravel**

In the lowest part a gravel of coloured cherts mixed with quartz sand was deposited. The size of pebbles varied from 1 to 3 cm. There were no pebbles of flysch sandstone. In the lower part sedimentary sequences were not prominent.

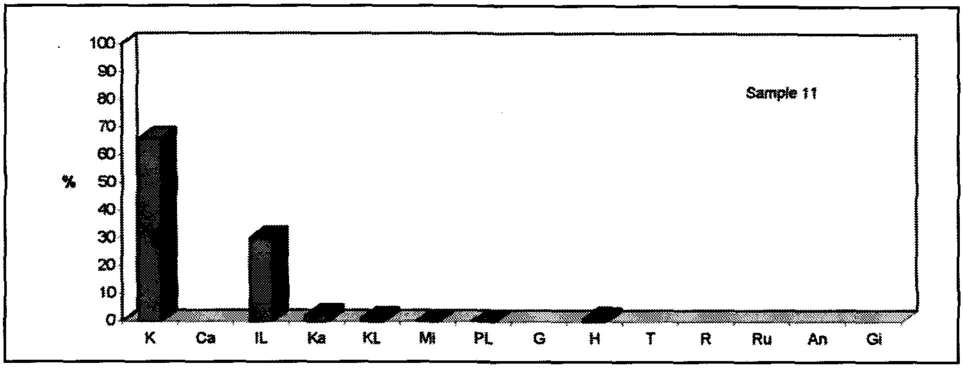
**b. Sand and loam**

Upwards, the gravel dam passes without a sharp boundary to yellow sand (2,5Y 6/6) mixed with thin layers of loam of the same colour. The thickness of this dam was about 3 m. In its upper part and sometimes at the walls the sediment colour passed to red (5YR 4/4). At one place this sedimentation sequence was covered by flowstone, up to 1 m thick, several aquare meters wide.

Above the flowstone another layer of red loam, up to 0,5 m in thickness, was deposited. In the loam that could possibly be a cave sediment or maybe a later superficial sediment, there were single smaller rocks of Cretaceous limestone. Above it was a humus horizon, up to only 10 cm thick.

Sample 11

Only the red loam from upper part of the profile was analysed. It consists of 66% quartz, 30% illite, 2% kaolinite, 1% hematite, 1% chlorite and




*Sample 11: Red loam from the open cave on Grintavca*
*X-ray: K - quartz 66%, IL - illite 30%, Ka - kaolinite 2%, H - hematite 1%, KL - chlorite 1%, in traces are Mi - microcline and PL - plagioclase; Ca - calcite, G - goethite, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite*

*Vzorec 11: Rdeča ilovica iz odprte jame na Grintavci*
*Rentgen: K - kremen 66%, IL - illit 30%, Ka - kaolinit 2%, H - hematit 1%, KL - klorit 1%, v sledovih so Mi - mikroklin and PL - plagioklaz; Ca - kalcit, G - goethit, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit*

microcline and plagioclase in traces. In terms of the mineral composition and the high ratio of clay minerals, the red loam had originated at the surface.

Similar mineral composition of fluvial sediments from a fossil cave only 450 m southwards in Lipove doline was described by Pleničar (1954). The cave became evident by digging the quartz sand and thus massive flowstones and speleothems were revealed. The excavated cave may be followed at the surface in both directions corresponding to a series of elongated depressions/dolines where flowstone periodically appears.

**BOJNI DOL**

Bojni Dol is a large shallow depression. Its bottom lies at 423 m a.s.l. and in its southern part a large doline filled by sediments has been cleared. Autochthonous rubble mixed with larger rocks and red loam predominated; in this lower part of this doline were yellowish brown sand and loam and some fragments of conglomerate.

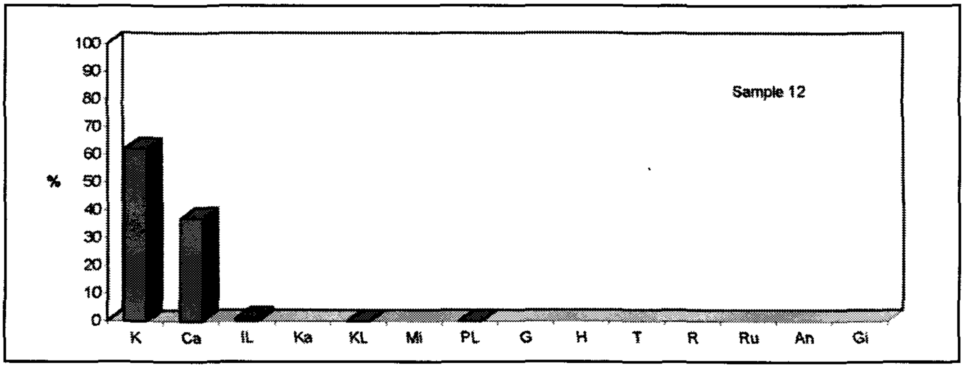
**a. Conglomerate**

The conglomerate consists of coloured chert pebbles, up to 2 cm across, and single limestone pebbles. It was deposited in layers and well sorted. The shape of the sedimentary body could not be established but obviously it is an old cave sediment cut by a doline.

**b. Sand with slope rubble**

Sample 12

The sample of yellow sand from the bottom of the doline near Bojni Dol is mixed with slope rubble. The following minerals are represented: 62% of quartz, 37% of calcite, 1% of illite and chlorite and plagioclase in traces. In terms of mineral composition this is a cave sediment mixed with slope ruble.




*Sample 12: Yellow sand mixed by slope rubble at the bottom of doline near Bojni dol*
*X-ray: K - quartz 62%, Ca - calcite 37%, IL - illite 1%, in traces are KL - chlorite and PL - plagioclase; Ka - kaolinite, Mi - microcline, G - goethite, H - hematite, T - turmaline, R - hornblende, Ru - rutile, An - anatase, Gi - gibbsite*

*Vzorec 12: Rumen pesek pomešan s pobočnim gruščem v vrtači pri Bojnem dolu*
*Rentgen: K - kremen 62%, Ca - kalcit 37%, IL - illit 1%, v sledovih so KL - klorit and PL - plagioklaz; Ka - kaolinit, Mi - mikroklin, G - goethit, H - hematit, T - turmalin, R - rogovača, Ru - rutil, An - anataz, Gi - gibbsit*

## CONCLUSION

The samples of gravel, sand and loam from the Cave without Roof, from the profile 650+10, from the lower part of the cave on Divaški Hrib, from the open cave Grintavca and from the Bojni Dol derive, according to their mineral composition, from weathered remains of flysch rocks.

The infiltration of the material from the surface is obvious in the last sample from the Cave without Roof, from the upper part of the cave on Divaški Hrib, and from the Grintavca cave. But the mineral composition of the red infill is different from sample to sample, as red soils and loams in karst are different in mineral composition and age (Urushibara-Yoshino 1988).

In Bojni Dol the cave sediment is mixed with slope rubble according to its mineral composition.

There is a difference between the minerals identified by x-ray diffraction method and those by thin sections; the fact is due to difficulty in detecting the lesser represented minerals especially when a lot of different minerals are mixed. Another problem arises in detecting hematite and goethite when they exist in thin coating over other minerals.

In the given examples the sediments have without doubt a cave origin but they were deposited in various periods or maybe they differ due to different speleogenesis.

When caves are opened by erosion proceses or intersected by dolines, flood loam and sand appearing in them may be attributed to surface. A yellow brown colour is typical; however, sometimes if the flood sediments are near the surface their colour may change to red. Due to diagenesis brown goethite is transformed to red hematite, but the association of minerals slightly differs from that in surface red soils. The mineral composition of red soils on karst can be totally different and is controlled by their origin.

Similar sediments to those found in the Cave without Roof were discovered at several other places during the construction of the motorway. All these sediments were cave sediments and they displayed some typical common characteristics but also some differences which are due to the individual development of each cave. The most marked differences are occurrence of flowstone, breakdown blocks or sharp rubble underlain to allochthonous sediments indicating the way how a particular cave had been opening towards the surface. In some places the sediments of loam, silt, sand or gravel size were assessed and elsewhere one of the fractions only. These are either caves developed at different levels, belonging to different water flows, or they developed in various time sequences.

In several cases we found cave sediments that filled up dolines and other depressions on the motorway route, for instance around Grintavca between Češnjevec and Rebidnik Dol, in a doline in Bojni Dol, and in several dolines between Povirje and Žirje, and thus we got an impression how the fluvial cave sediments were distributed on the karst surface.

Fluvial cave sediments found in caves that are already affected by corrosional surface lowering are an important source of superficial soils in karst. Their location is either original or they may be partly or entirely resedimented.

Helped by sediments and cave passages one may partly reconstruct the time when these caves had developed. The Cave without Roof is a relic of a larger cave system that had drained the water from the flysch. The external effects did not affect the quantity of deposited flowstone thus indicating at least some ten metres thick roof. The growth of speleothems was at least once interrupted by erosion. The water that flowed through the cave transported large pebbles. From their size and to the great ratio of pebbles from a flysch sandstone which is very loose and does not endure longer fluvial transport (Kranjc 1986, 1989), one may conclude that the swallow holes had not been far away. Today similar pebbles can only be found in the caves of Brkini sinking flows, up to 1 km distant from the limestone-flysch contact. The water discharge varied from some ten l/s to several cubic metres. One may suppose that the cave was entirely filled up by fluvial sediments when the surface above it was still at an altitude of about 450 m and the swallow-holes at the contact of flysch and limestone were at the same level at least but not more than one to two kilometers away. Today the nearest flysch to the cave lies in the Raša valley, some 5 km away and the flysch-limestone contact is found at about 500 m a.s.l. The flysch of Brkini lies still further away, about 7 km. As both flysch areas are too far one may suppose that an area of flysch sandstone must had existed somewhere nearer. A possible origin of gravel might be around Divaški Gabrk, 1 km north-east of the cave, yet there is no flysch there today. As Gabrk consists of younger Paleocene and Eocene alveoline and nummulitic limestones and, according to stratigraphic column, there are only about 120 m missing up to the Eocene flysch layers, this region seems to be the most appropriate origin of the sediments. If this region is truly the original site of these pebbles then the Reka must have already had to disappear into underground at that time, but in separated swallow-holes. Similar conditions controlled other caves discovered but it is more difficult to reconstruct all other circumstances that were in control, as they are smaller or less preserved. Probably they were developed by various sinking streams and the modern speleohydrological conditions are very different. The most important sinking stream is the Reka river that disappears at Škocjanske Jame at 317 m a.s.l. and flows into a siphon at 214 m a.s.l. Close to the described sites of cave sediments there is a free water surface found in Kačna Jama at altitudes between 156 to 180 m fluctuating by about 100 m (Mihevc 1984). Near the Cave without Roof one may expect vadose zone about 220 m deep; this is a zone where the vertical percolation predominates giving rise to shafts and washing the soil downwards. Temporarily this area may be defined as a space where the caves are preserved while free water surface and the water level of karst aquifer was lowered from 400 to 180 m and the surface has suffered some 50 m lowering. According to some calculations the surface has lowered approximately 60 m in the last million years (Gams 1962). If we suppose that the thickness of the roof was 50 m then the Cave without Roof was filled up by sediments about 800.000 years ago.

In such a period the dolines on the surface could have been formed as all the conditions were fulfilled, that is vertical gradient and sufficient water drainage through karst. In spite of an existing vertical gradient the passages remained filled up by sediments. A large amount of sediments had been removed by erosion and resedimented, and these are found today on the surface, sometimes in dolines, and there the former cave sediments have been partly altered.

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## KLASTIČNI SEDIMENTI IZ VRTAČ IN JAM NA TRASI AVTOCESTE PRI DIVAČI, KLASIČNI KRAS

### Povzetek

Vzorci proda, peska in ilovice iz Brezstrope jame, jame v profilu 650+10, spodnjega dela jame v Divaškem hribu, odprte jame v Grintavci in Bojnega dola, glede na mineralno sestavo izvirajo iz preperelih ostankov flišnih kamnin.

V vseh v članku navedenih primerih je šlo za nedvomno jamske sedimente, ki pa so nastali v različnih časovnih obdobjih ali pa so različni zaradi različnega razvoja jam.

Infiltracija materiala s površja je očitna v zadnjem vzorcu iz Brezstrope jame, zgornjega dela jame v Divaškem hribu in jame v Grintavci. Toda njegova mineralna sestava je različna po posameznih vzorcih, ker so rdeče prsti in ilovice na krasu različne glede na mineralno sestavo, starost ter izvor. (Urushibara-Yoshino, 1988).V Bojnem dolu je glede na mineralno sestavo vzorca, jamski sediment pomešan s pobočnim gruščem.

Razlika med mineralno sestavo določeno z metodo rentgenske difrakcije in v zbruskih obstaja, ker je s prvo metodo težko zaslediti količinsko manj zastopane minerale, posebno kadar je v istem vzorcu veliko število različnih mineralov. Težava obstajala pri določitvi hematita in goethita v primerih, kadar prekrivta ostale minerale v obliki tanke prevleke.

Kadar so jame odprte proti površju s procesi erozije ali presekane z vrtačami, se poplavne ilovice in peske, ki izvirajo iz njih, lahko najde na površju. Zanje je značilna rumena barva, v primeru kadar pa so v bližini površja, se pa obarvajo rdeče. Ta prehod rumene barve v rdečo je povezan s procesi oksidacije med potekom diageneze. Pri teh procesih se rjavi goethit pretvori v rdeči hematit. Mineralna združba teh rdečih klastičnih sedimentov je pa malo drugačna kot mineralna združba rdečih prsti, ki so nastale pri površinskih procesih pedogeneze. Tako, da je lahko mineralna sestava rdečih prsti na krasu popolnoma različna in vedno zavisi od njihovega izvora in načina nastanka.

Podobni sedimenti, kakršni so bili najdeni v Brezstropi jami so bili ob gradnji avtoceste najdeni še na več drugih mestih. Pri sedimentih, v vseh primerih je šlo za jamske sedimente, se je pokazalo nekaj izrazitih skupnih potez, pa tudi nekaj razlik, ki so posledica individualnega razvoja vsake jame. Izrazite razlike so pojav sige, podornih skal ali ostrorobega grušča na alohtonih sedimentih, kar kaže način, kako so se posamezne jame odprle proti površju. Ponekod so bili najdeni sedimenti velikosti od gline, melja, peska, do proda, drugod pa le ena od frakcij. Gre bodisi za jame, ki so nastale v različnih višinah, pripadale različnim vodnim tokovom ali nastale v različnih časovnih obdobjih. V več primerih smo našli jamske sedimente, ki so zapolnjevali vrtače ali druge depresije na trasi, na primer na ledini Grintavca med Češnjevcem in Dolom Rebidnik, v vrtači v Bojnem dolu, v več vrtačah med Povirjem in Žirjami, kar nam da dimenzijo razširjenosti fluvialnih jamskih sedimentov na površju krasa.

Fluvialni sedimenti najdeni v jamah, ki jih je že dohitelo korozijsko zniževanja površja so pomemben vir površinskih prsti na krasu. Njihova lega je lahko prvotna, ali pa so delno ali povsem presedimentirani.

S pomočjo sedimentov, ter jamskih rovov lahko tudi delno rekonstruiramo čas v katerem so te jame nastale. Brezstropa jama je ostanek večjega jamskega sistema, ki je prevajal vode ponikalnic s fliša. Zunanji vplivi se v času nastanka niso odrazili na oblikovanje kapnikov in sigovih kop, količina odložene sige kaže na vsaj nekaj deset m debel strop. Rast kapnikov je bila vsaj enkrat prekinjena z erozijo. Skozi jamo je tekla ponikalnica, ki je nosila velike prodnike. Po njihovi velikosti in po velikem deležu prodnikov iz flišnega peščenjaka, ki je zelo krhek ter ne prenese daljšega rečnega transporta (Kranjc 1986, 1989), lahko sklepamo, da ponori niso bili daleč stran. Podobne prodnike danes najdemo le v jamah Brkinskih ponikalnic, do 1 km stran od stika fliš-apnenec. Pretok vode je varial od nekaj deset l/s do več $m^3$. Lahko predpostavimo, da je bila jama popolnoma zapolnjena s fluvialnimi sedimenti, ko je bilo površje nad njo še v višini okrog 450 m, ponori na stiku fliša in apnenca pa vsaj v enaki višini, a ne več kot 1 - 2 km stran. Danes je najbliže jami fliš nad dolino Raše, oddaljen okrog 5 km, stik fliša in apnenca pa je v višini okrog 500 m. Brkinski fliš, ki leži SE je še dlje, 7 km stran.

Ker sta obe flišni področji predaleč, lahko predpostavimo, da je moralo obstajati bližje izvorno področje flišnega peščenjaka. Možen izvor proda bi bil na območju Divaškega Gabrka 1 km NE od jame, kjer fliša danes ni več. Ker Gabrk grade mlajši paleocenski in eocenski alveolinski in numulitni apnenci, nad katerimi manjka po stratigrafskem stolpcu do eocenskih flišnih plasti le okrog 120 m, se zdi to področje najverjetnejši vir sedimentov. V podobnih razmerah so se oblikovale tudi druge odkrite jame, vendar je zanje teže rekonstruirati ostale okoliščine nastanka, saj so manjše ali slabše ohranjene.

Sedanje speleohidrološke razmere so precej drugačne. Najpomembnejša ponikalnica je Reka, ki ponika v Škocjanskih jamah v nadmorski višini 317 m ter teče v sifon, ki je v višini 214 m. V bližini opisanih nahajališč jamskih sedimentov pa je prosta gladina vode v Kačni jami višinah med 156 in 180 m in niha za okrog 100 m (Mihevc, 1984). V okolici Brezstrope jame lahko torej računamo na 220 m globoko vadozno cono, to je cono kjer prevladuje vertikalno prenikanje, rast brezen ter spiranje sedimentov in prsti navzdol. Časovno lahko ta prostor opredelimo kot prostor v katerem so se ohranile jame, medtem ko se je gladina prostotekočih rek in gladina kraške vode v jamah spustila od 400 m na 180 m, površje znižalo za najmanj 50 m. Po nekaterih izračunih naj bi se površje v zadnjih milijon letih znižalo za približno 60 m (Gams, 1962). Ob predpostavljeni debelini stropa 50 m je bila Brezstropa jama zapolnjena s sedimenti pred okrog 800 000 leti.

V tem času so se na površju lahko oblikovale tudi vrtače, saj so bili izpolnjeni vsi pogoji, to je vertikalni gradient ter zadovoljivo odvajanje vode skozi kras. Klub obstoječem vertikalnem gradientu pa so rovi ostali zapolnjeni s sedimenti. Velik del sedimentov je bil iz jam, ki jih je erozija že popolnoma odstranila, presedimentiran in jih najdemo danes na površju, ponekod tudi v vrtačah, kjer so se nekdanji jamski sedimenti lahko tudi delno spremenili.