

# Ground Penetrating Radar Exploration of Recently Discovered “Mushkarova Yama” Gypsum Cave (Western Ukraine)

Vitalii Prokhorenko, Volodymyr Ivashchuk, Igor Stefanyshyn, Sergiy Musiyachenko, Sergiy Korsun, Olga Dykovska  
Transient Technologies LLC  
P.O.Box 28, Kyiv 02147, Ukraine  
pvp@viy.com.ua

**Abstract**— The paper presents ground penetrating radar (GPR) exploration of recently discovered gypsum cave called as “Mushkarova Yama”. Entrance of the cave is on the sinkhole bottom. It was excavated on August 24, 2008. Current mapped length of the cave exceeds 5 000 meters. The VIY 2-300 and VIY 2-125 GPRs were used to find unknown cavities outside of the cave perimeter. The VIY 2-125 GPR sounds the cave from the surface, whereas VIY 2-300 GPR surveys walls from within the cave. Some known galleries lied up to 12 meters depth were located from the surface. Discontinuities in rock and sediment including cavities and cracked regions were determined behind the wall up to 7 meters distance. The investigations are still continuing.

**Keywords**—Ground Penetrating Radar; GPR; VIY-2 GPR; Gypsum Caves

## I. INTRODUCTION

Authors of the paper have been cooperating for a lot of time with Ukrainian cavers in area of ground penetrating radar (GPR) application for caves exploration. Main goals of the cooperation are known caves investigation and search of new caves. Primarily we utilized VIY 2-125 GPR with sounding capabilities up to 15 meters depth for subsurface location of karst appearance [1]. Then we applied VIY 2-300 GPR that can find discontinuities up to 8 meters depth for underground search of discontinuities inside the caves. The VIY-2 series GPR have strong and compact monoblock design and very short deployment time. They can operate in difficult environments.

At first we utilized VIY-2 series GPR for exploration of well-known gypsum caves in Western Ukraine and limestone caves in Crimea. We examined the GPR inside the caves and confirmed its very promising abilities [2]. Therefore it was naturally to apply the GPR for research of recently discovered cave that could enter to list of longest gypsum caves of Western Ukraine.

## II. MUSHKAROVA YAMA CAVE

On April 2008 Igor Stefanyshyn inspecting karst relief at interfluvium of left tributary Dnister/Seret and Nichlava rivers to east of Oleksynty village discovered a small sinkhole that has perspectives for future exploration. Members of “Karst” caver

club and caver group of Arsenal tourist club from Kyiv spent some days for excavation the sinkhole. On August 24, 2008 as a result of two expeditions the entrance into the underground cavity was opened. This cave was called as “Mushkarova Yama” owing to situated not far from the cave entrance Mushkariv hill.

Entrance into the cave is about 12 meters from the surface (Fig. 1). The cave has three levels and 13 meters amplitude from first level floor to the third level roof. Passages height range from 20 cm to 8 meters. There are some lakes and siphons marked by blue color on the map.



Figure 1. Entrance into the Mushkarova Yama cave

In geomorphology sense this area is lofty, small hilly plateau of 260-310 meter absolute height levels slotted by canyon like valleys. Karst rocks are presented by upper neogene gypsum and gypsum anhydrite of Tiras formation. Gypsum thickness is about 20 meters. Gypsum lies down cloak-shapely between 260-280 meters absolute height level and covered by low-powered cover of above gypsum sandy-clay neogene-quadernary deposits. Power of recovering cover in the area reaches up to 27 meters however most often it is about 15 meters. Higher of gypsum section there are from below to up: 20-30 cm layer of chemogenic limestone, 2-3 meters of poorly cemented fine-grained battleship gray or drab

sandstone, up to 25 meters of light-brown loess-like loam and up to 1 meter topsoil of black earth (Fig. 2).

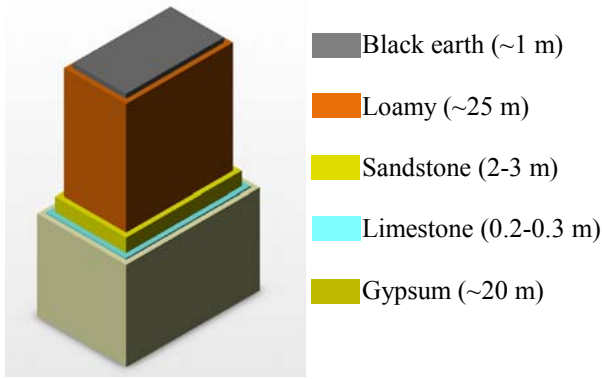


Figure 2. Geological section

Over the time of 2008-2009 we realized 15 expeditions, fulfilled topographical, magnetic and radioactivity mapping of the cave. More than 1360 man-days have been spent for the cave exploration. By the end of 2009 known length of the cave labyrinth exceeded five thousand meters (Fig. 3). Survey of the cave is still continuing.

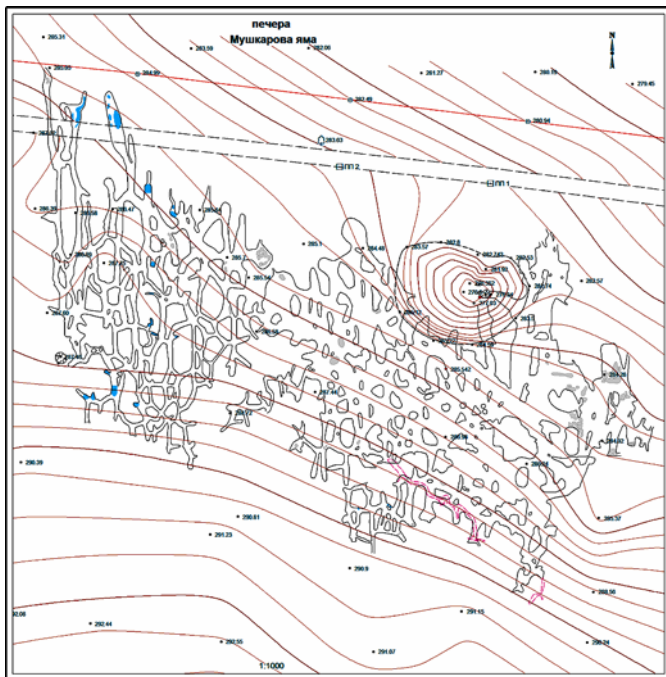


Figure 3. Map of Mushkarova Yama cave

### III. SURFACE GPR SOUNDING

The VIY 2-125 GPR (made by Transient Technologies LLC, Ukraine) was used for subsurface sounding during the twelfth expedition (October 22-26, 2009). The main goal was to examine GPR abilities to locate known caverns lied down lower than 12 meters depth. The GPR movement route (red arrow) crossed some known galleries with 2-3 meters width and height that are located on 10-13 meters depth (Fig. 4).

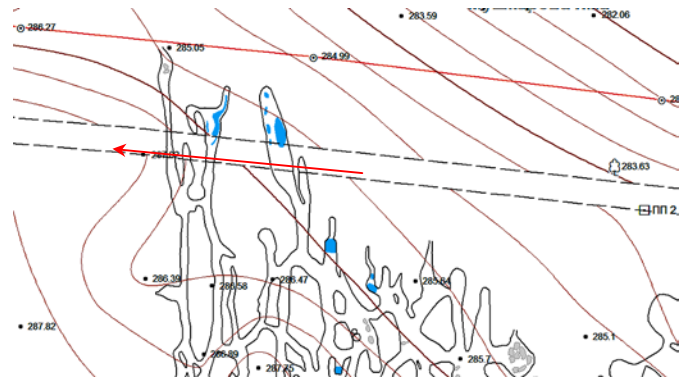


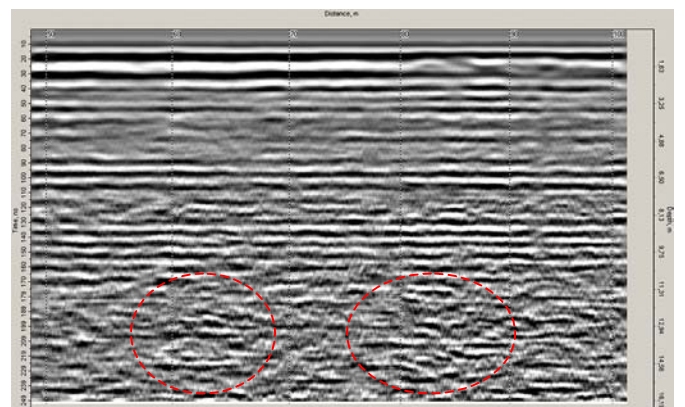
Figure 4. Survey map

Since wet grass and soil due to fall weather the GPR was moved along asphalt road edge (Fig. 5).

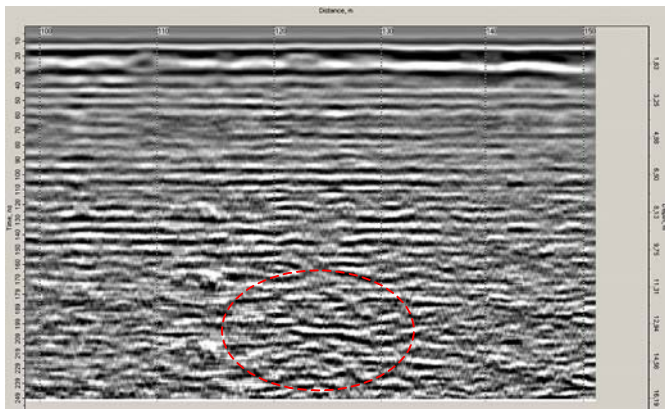


Figure 5. Subsurface data acquisition by VIY 2-125 GPR

Three 50-meters profiles were obtained here. The first profile (Fig. 6a) crossed known galleries. It can be seen layer interruptions and ground softening above the galleries (marked be red dotted line).



a)



b)

Figure 6. GPR profile: 50-100 meters (a) and 100-150 meters (b) distance

The second profile (Fig. 6b) shows the same behavior (red dotted line). Perhaps this trace crossed unknown cavity over the cave border. Distance between western known gallery and located cavity is about 30-35 meters.

#### IV. UNDERGROUND GPR SURVEY

The VIY 2-300 GPR was utilized for explorations within the cave during the twelfth (October 22-26, 2009) and the fourteenth (November 26-29, 2009) expeditions. The main aim was a search of new cavities behind the cave border.

Currently Mushkarova Yama cave consists of two big parts named as “Entrance hall” and “Lake region” that have different morphology. Entrance hall and Lake region are connected by narrow crawlway.

Entrance hall contains three layers and occupies eastern part of the cave. Middle layer has plain roof supported by small columns. There are some white cones consisted admittedly with lime sand (Fig. 7). Upper layer is labyrinth type. Lower layer is mainly filled by clay or water. Middle and upper layers of the Entrance hall are jointed in southwestern direction.



Figure 7. White cone in Mushkarova Yama cave

Lake region contains two layers and represents labyrinth bounded by clay avalanches. Lower layer is filled by water and is presented by several lakes with siphons. Lake region occupies western part of the cave.

In the northern direction Entrance hall floor is rising up to closing with the roof one. Eastern side of the hall proceeds to blocks heaps. Southern side of the hall presents several galleries closed by clay-stone heaps. This direction was recognized as the most probable for search of the cave continuing.

We explored western wall of two galleries in southern side of Entrance hall (# 1 and #2) and eastern wall of a gallery (# 3) in Lake region (Fig. 8).

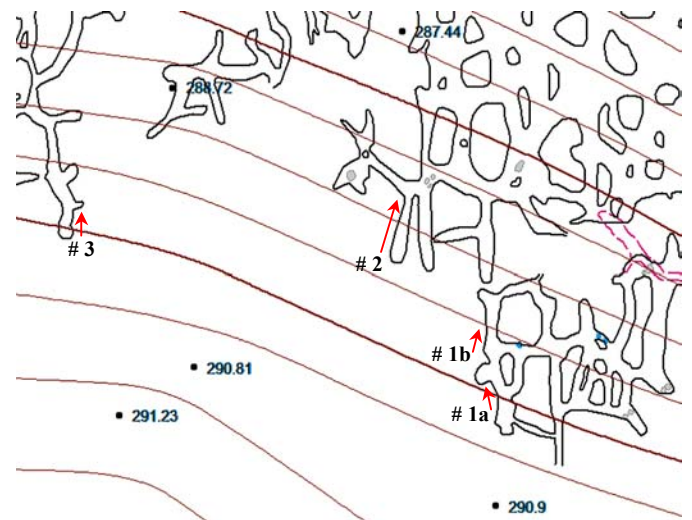


Figure 8. Survey scene

During location of western wall of the gallery # 1 we moved GPR horizontally along the surface with a meter height from the floor (Fig. 9).



Figure 9. Data acquisition in the gallery # 1 (western wall)

Since the wall contained a roomy niche therefore GPR profile consists of two parts. It can be seen some discontinuities

on about 2-2.5 and 5.5-6.0 meters distances behind the wall (Fig. 10).

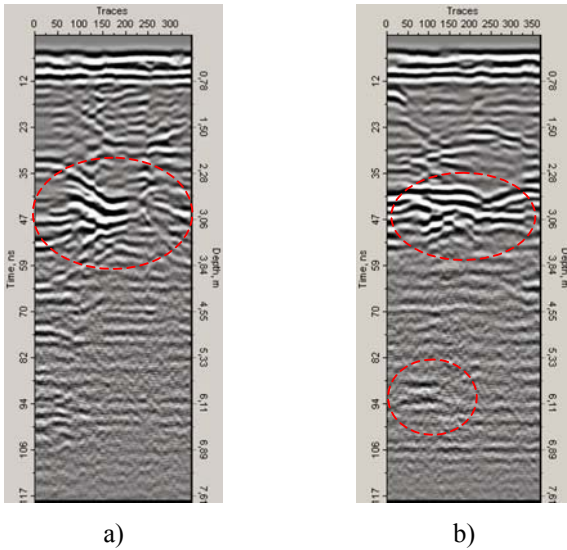


Figure 10. GPR profile of the gallery # 1 (western wall)

The gallery # 2 has only a half a meter height therefore we moved GPR along the western wall touching the floor (Fig. 11).



Figure 11. Data acquisition in the gallery # 2 (western wall)

The GPR profile presents several discontinuities on different distances from 1 to 6 meters (Fig. 12). It can be interpreted as presence of complex geological situation (breaking rock, for example) or unknown cavity at 3-3.5 meters over the wall.

Between western wall of gallery #2 and eastern wall of gallery #3 is labyrinth in lower layer named as “Diamond fund”. It was necessary to find out availability of the labyrinth continuation. In addition it was necessary to get clear in morphology distinction of two parts of the cave. Whereas Entrance hall has three levels, Lake region has only two ones. To make sure in upper level presence we explored also roof of the gallery # 3.

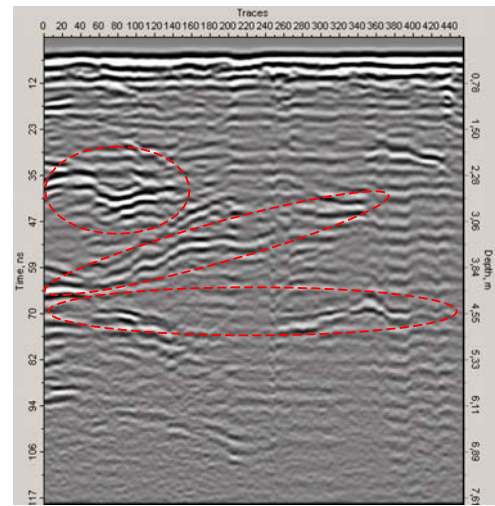


Figure 12. GPR profile of the gallery # 2 (western wall)

The GPR profile of the eastern wall demonstrates discontinuity at the 2 meters distance and unknown gallery at 3-3.5 meters over the wall (Fig. 13a). Probably this is a continuation of the Diamond fund labyrinth.

The GPR profile of the roof shows flaky structure of the deposit and possibly upper level of Lake region at about 4 meters higher the gallery roof (Fig. 13b). It demonstrates geological similarity Entrance hall and Lake region in spite of their morphological differences. And it suggests presence of unknown labyrinths over the cave perimeter.

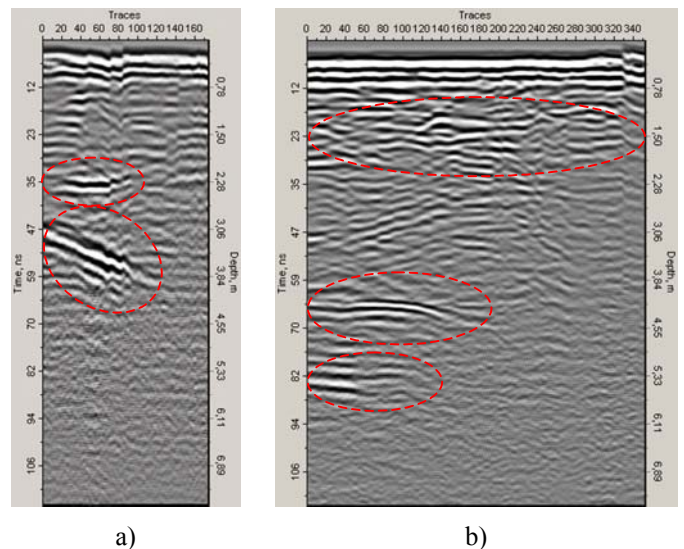


Figure 13. GPR profile of the gallery # 3 (a - eastern wall, b - roof)

## V. CONCLUSIONS

The examinations confirmed that subsurface GPR sounding could be used for location of associated karst processes (softening of ground above the cavities, for example); underground GPR probing is effective for rock surfaces. Faults, cavities (empty or filled), inclusions can be located up to 7 meters distance; roof sounding finds in homogeneities

(stratifications, exfoliations, cavities etc.) up to 4 meters distance.

The GPR exploration of Mushkarova Yama cave revealed some presumable unknown cavities marked by dotted lines (Fig. 14). It can lead to discovery of new labyrinth.

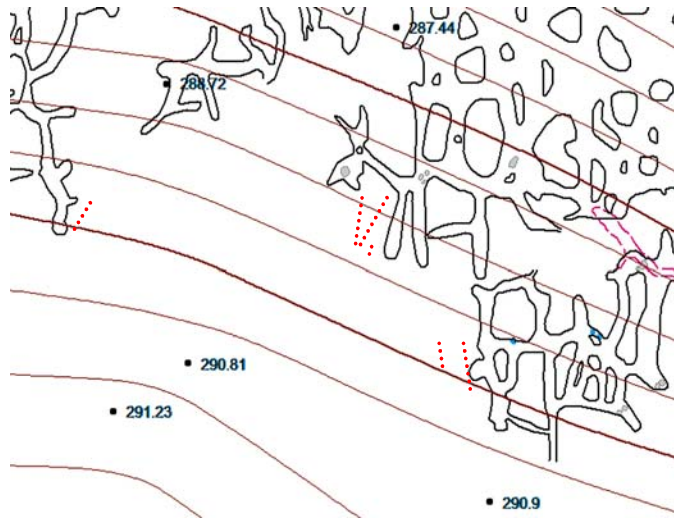


Figure 14. Discontinuities marked by red dots

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