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Karst Cavity Forms and Their Radio Images Revealed by Comparative Physical Modelling

Davit T. Odilavadze, Tamaz L. Chelidze

Ivane Javakhishvili Tbilisi State University, Mikheil Nodia Institute of Geophysics

ABSTRACT

GPR surveys were conducted to select a safe location for the construction site in a limestone region. Using the theory of similarity of electromagnetic fields, the results of laboratory physical modelling were extended to field data. The survey data were interpreted with high accuracy for decoding underground objects.
The tasks set by the builders were solved on the basis of the geo-radar works: the less and most karst-damaged areas were identified.

Key words: *GPR, similarity of electromagnetic fields, comparative physical modelling.*

Introduction

The paper considers the issue of a certain building area in order to develop a capital construction on the mountainous territory of borough Khoni in West Georgia. The selected geological medium is presented as the lower and upper Cretaceous limestones, Neogene sandstones and clay, Quaternary boulder and clay. It is characterized with karst phenomena (Maruashvili, 1971). Therefore, geophysical /geo-radiolocation studies were required in order to verify the safe probable area for the building territory. The geo-radiolocation studies were conducted by GEORADAR Zond 12 with its set 75 MHz dipole antenna and the data were obtained and processed by means of software Prism 2.5.

Georadiolocation prospecting

Georadiolocation is a geophysical method that is based on the use of electromagnetic waves in the radio range to study the structure of the subsurface environment in areas such as geology, construction, agriculture, archeology, forensics, security, etc.Passing through the studied environment, waves are partially reflected from the interfaces between materials with different electrophysical properties (from the boundaries between layers of different soils, layers with different moisture content, from the levels of groundwater, voids, metal or concrete objects, boulders, etc.) and in a weakened form, they return to the surface, where they are captured by the receiving antenna, converted into digital form, processed and stored. When a georadar equipped with a displacement sensor and a path meter moves along the surface (or above the surface) of the investigated medium, an aggregate record of the received signals is formed - a GPR profile, or a georadarogram.

Materials and Methods

The investigations were carried out with GPR ZOND 12e equipped with 75 GHz transmissive/receiving antenna. The obtained results were processed using the software PRISM 2.5. Interpretations of the radiograms were conducted using the method of similarity of electromagnetic fields by comparative physical modelling for solution of direct and inverse problems developed by the authors. A direct problem is solved by laboratory modelling: the radio image of an object is determined by high or super-high frequencies and the result, due to the similarity of the radio images, is used to solve an inverse problem for the interpretation of the field material [1-10].

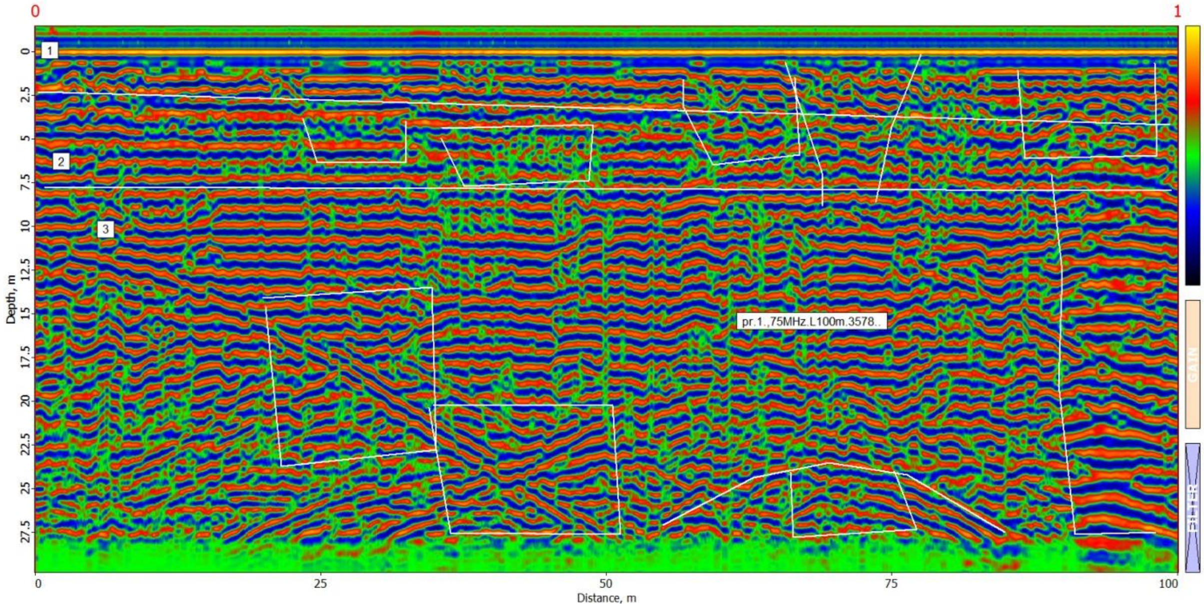

Fig. 1 shows Profile 1 conducted by means of geo-radar Zond 12 with 75 MHz dipole antenna. The length of the profile is 100 m.

According to the syn-phase axis texture we distinguished three geo-radiolocation layers in Profile 1: the first layer with 2.5 m thickness, the second layer from 2.5 m to 7.5 m, the third layer - below 7.5 m.

We distinguished the radio images of certain geological formations on the radiogram. Their locations are marked with white lines. The radio images corresponding to the cavity located at the boundary of the first and second layers at 50-75 m distances at 7.5-8 m depth are clearly seen; a cavity at 100 m distance at the end of the profile is also marked.

The radio image obtained as a result of laboratory physical modelling is shown in *Figure 2* for rectangular prism form (hole, box) cavity.

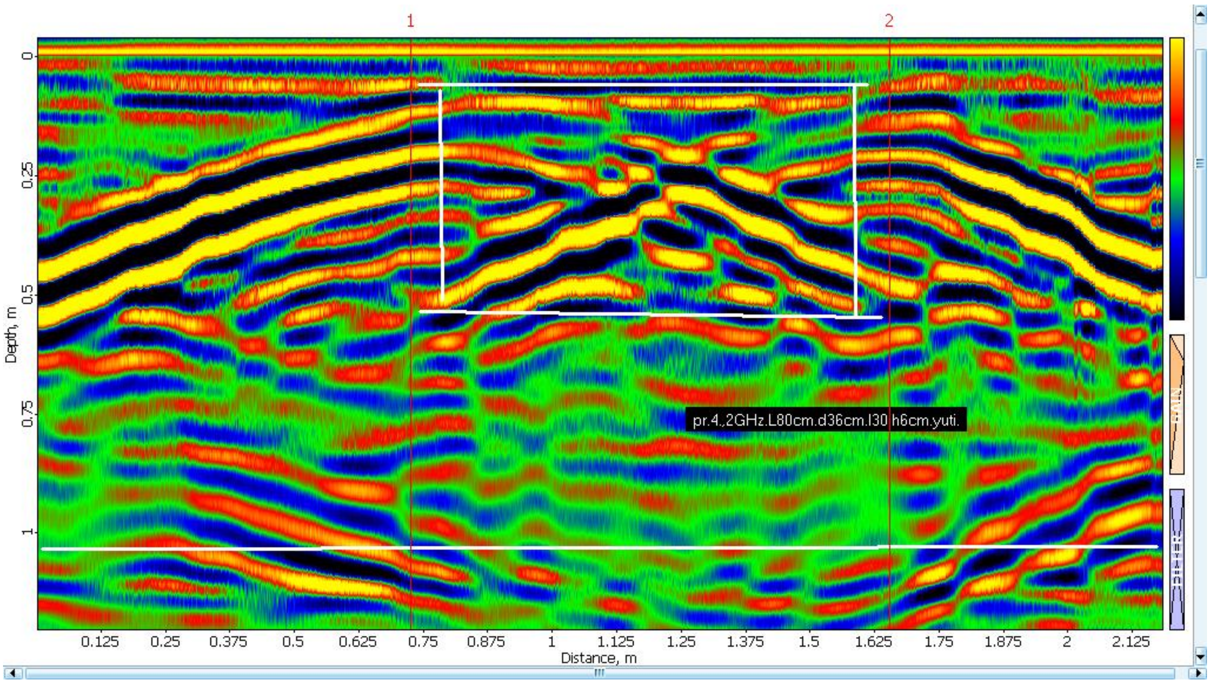

Fig. 2 shows the radio image of the laboratory model of the so-called "box" at the frequency 2 GHz.

The real sizes of the box are marked with white linear and vertical markers. The special form of the radio image (bow-tie) obtained as a result of overlapping the internal reflection and external refraction EM waves is marked within the white rectangle.

The electromagnetic waves radiated and received from the radar contain the information about the radio image formed by the overlapping of refracted and reflected from the hidden object waves. In the radiogram it is presented as a geometric form and texture of the syn-phase axes of the resulting overlapped electromagnetic waves, which are connected with the box form buried object. Namely, a part of the radio image formed by reflected waves has a parabola form and a part of the bow-tie type radio image is formed by the refracted waves. According to the principles of the electromagnetic field superposition they give an aggregate radio image characteristic of the existent cavity.

Let us go back to *Figure 1*. At 2.5-7.7 m depths in the second layer, we marked the forms of the disintegrated (crushed, destroyed) medium at 25-50 m distances.

In the third layer also at 25 and 50 m distances a bow-tie type special form is marked, which must correspond to the relevant size cavities with centres at 17 and 25 m depths.

At 25 m depth at 75 m distance a probable arch roof cavity was distinguished. At 100 m distance a medium containing cavities was distinguished by the texture and was marked by the vertical line.

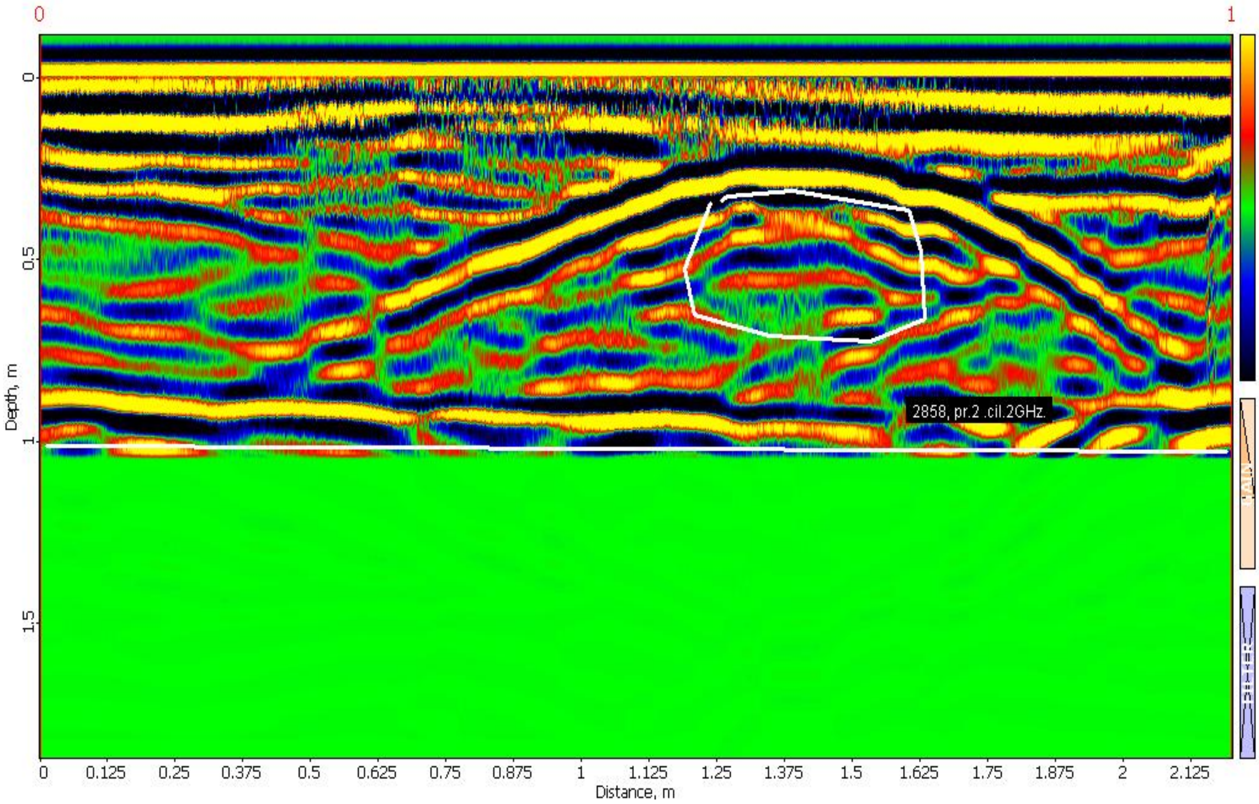

Fig. 2 shows a laboratory radio image of a cylindrical cavity (plastic tube) with an intensification option. The bow-tie was distinguished, which means a clearly reflected form under the parabola, i.e. the radio image proves the existence of the cavity for the "tube".

The "box" model, in regard with the tube, can be understood as a transformation of the tube into an extremely clear bow-tie.

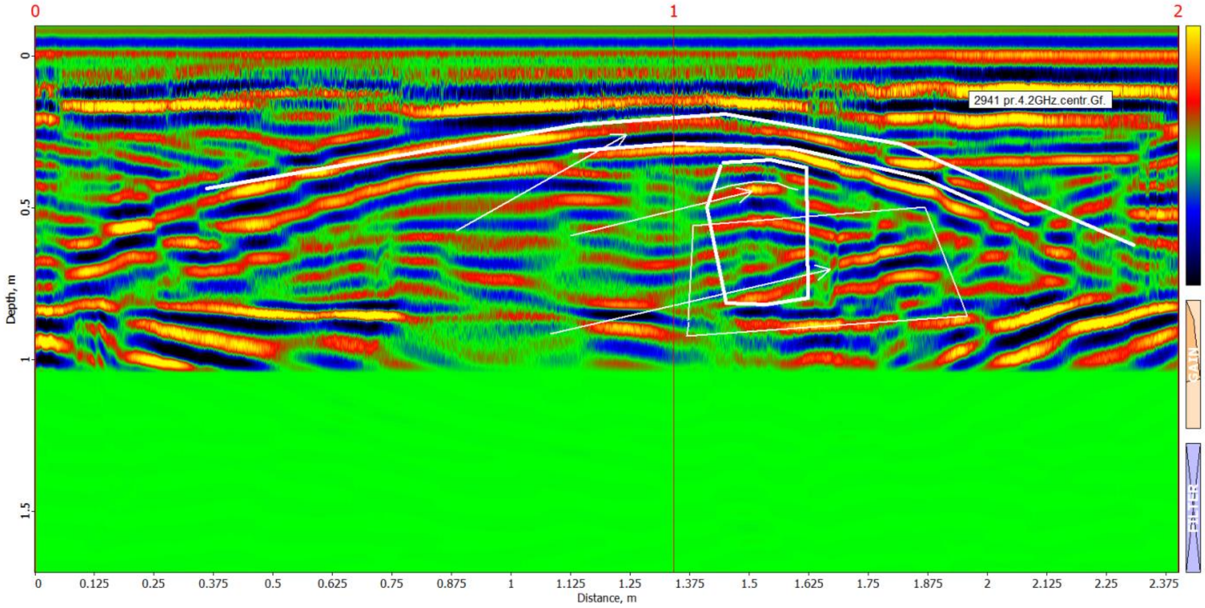

Fig. 3 shows a complex model for the large (0.5 m) and small diameter (0.15 m) tubes.

The main tube (0.5 m) filled with activated coal from below. It contains a small diameter empty tube (0.15 m) which is intersecting the model's central profile.

We marked the parabola formed by reflected waves with expansion to the right at 1.5 m distance and the centre of the small tube and the imperfect bow-tie below it at 0.5 m depth. We also marked the bow-tie between the right wall of the small tube and the internal side of the right wall of the large tube with 1.7 m centre and 0.6 m depth at the coordinates.

The model enables us to determine the object forming the parabola type radio image seen in *Figure 4* of the field radiogram, namely, we suppose it also must be formed by a complex structure (tube-in-tube type object).

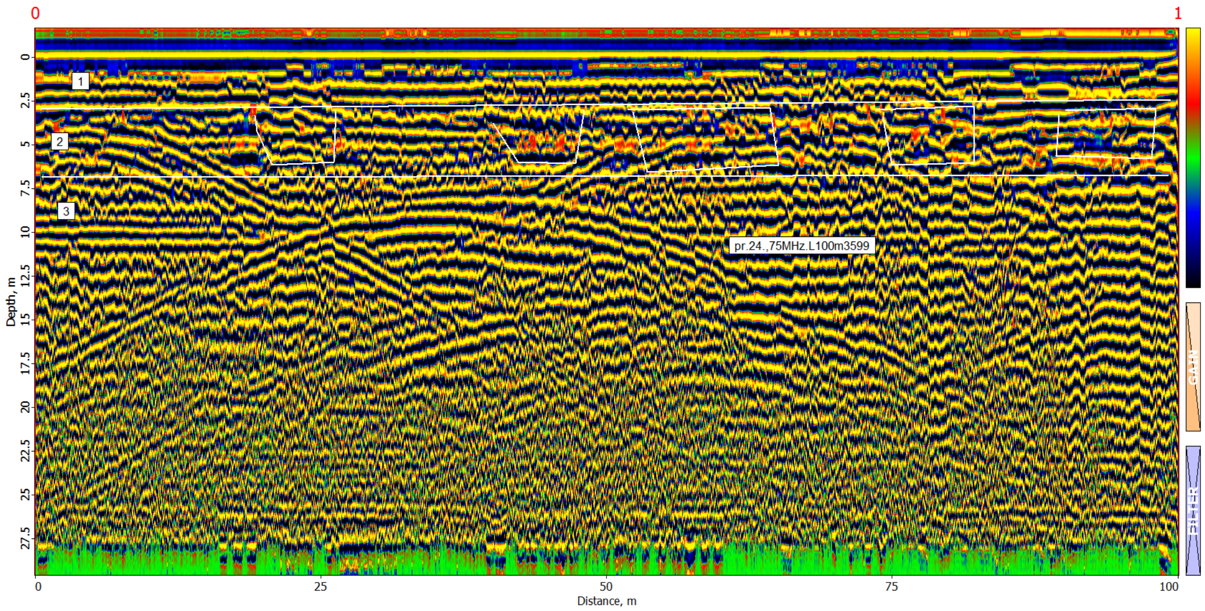

Fig. 4. The radiogram of Profile 24 received by means of the 75 MHz sensor antenna of the geo-radar. The length of the profile is 100 m.

We distinguished three main geo-radiolocation layers in Profile 24 according to the syn-phase axes texture. The thickness of the first layer is 2.5 m, the thickness of the second layer is 7.5 m and the third layer is located below 7.5 m depth.

The first layer is more or less homogeneous and partly disintegrated. The second layer contains the radio images of cavity type watered inhomogeneity. The third layer of the geo-radar section contains numerous reflection intersections, which might have be formed due to external electromagnetic field or a transformed arch type large tube cavity, which contains the radio image of a small tube cavity as in the laboratory model in *Figure 3*.

Any external electric filed source (transmission lines) is not observed on the study territory. It means that the radio image at 25-70 m distance and 7.5-20 m depth must be formed by a complex, large arch type underground object.

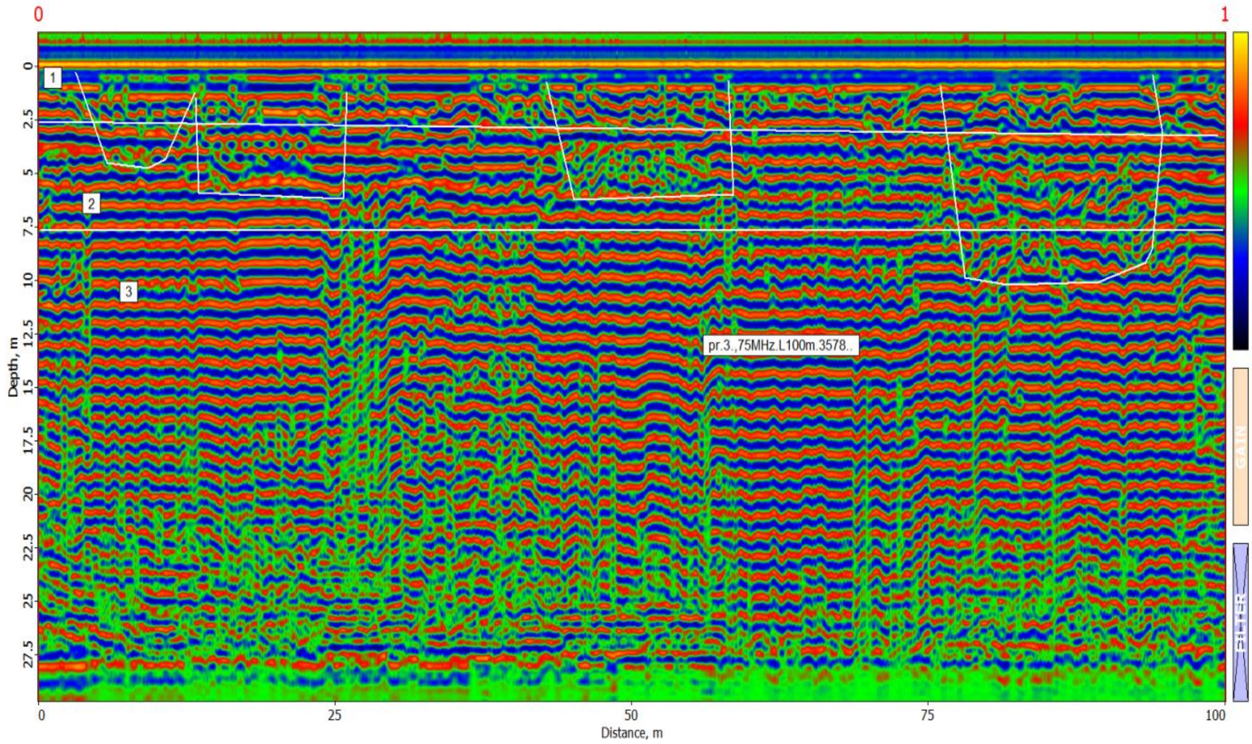

Fig. 5. The radiogram shows Profile 3 received by means of the 75 MHz sensor antenna of the geo-radar. The length of the profile is 100 m.

We distinguished three main geo-radiolocation layers in Profile 3 according to the syn-phase axes texture. The thickness of the first layer is 2.5 m, the thickness of the second layer is 2.5-7.5 m and the third layer is located below 7.5 m depth.

The radiogram shows the radio images of certain geological formations, which are marked by white lines. The radio images of the cavities located at the boundary of the first and second layers at 0-25 m and the anomalies distributed on the surfaces of the first, second and third layers at 75-100 m distance with depth 5-7-10 m depth are obviously seen.

The first layer at the distance 50 m at 0-2.5 m depth includes the syn-phase axes of relatively homogenous rocks with a cavity, below which there is a significantly disintegrated (eroded by water) medium distributed to 7.5 m.

The watered sites are located in the disintegrated areas of the marked cavities.

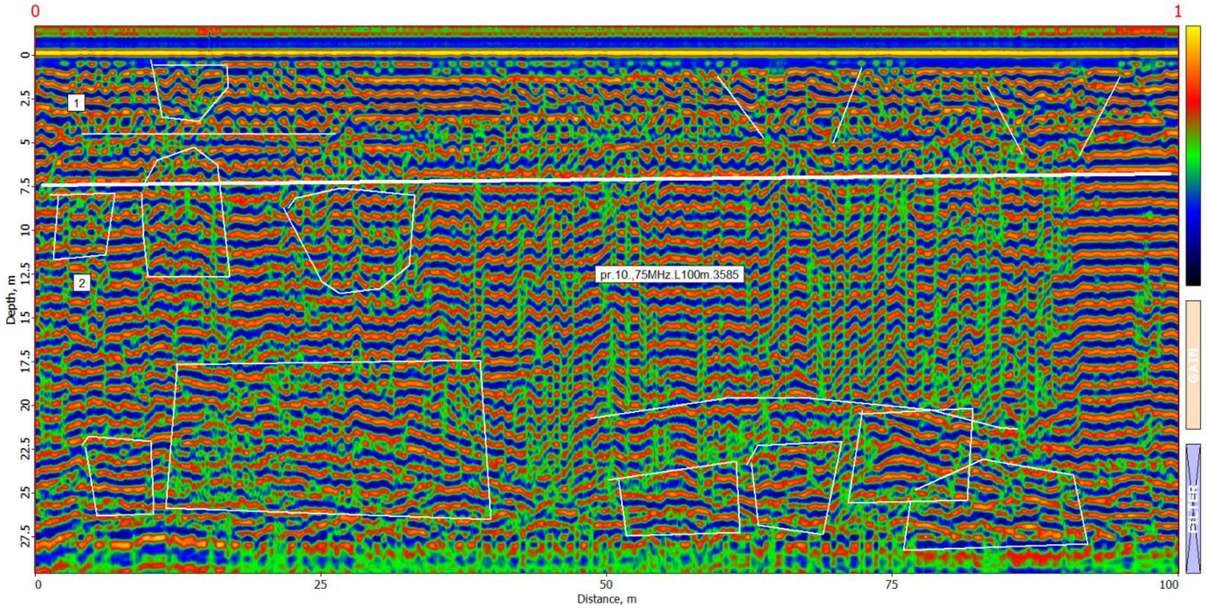

Fig. 6. The radiogram of Profile 10 received by means of the 75 MHz sensor antenna of the geo-radar. The length of the profile is 100 m.

We distinguished two geo-radiolocation layers in the Profile 10 according to the syn-phase axes texture. The thickness of the first layer is 5 m, the second layer is located at 7.5 m depth and below. The boundary between the layers is watery and disintegrated.

The first layer includes inhomogeneities, among them the radio images of funnel type objects at 60 and 80 m distances. The second layer contains the cavities with centres at 10-23-25 m depths. The radio images belong to different-size objects characteristic of cavities.

Conclusion

According to the Electromagnetic Fields Similarity Theory for geo-radiolocation frequency fields worked out by the authors the results of the laboratory physical modelling were applied to the radio images of the field data and were interpreted with high reliability to decode underground objects.
On the basis of the conducted works we distinguished the less and most karst-damaged areas number and informed the client about their location.
As is of the geo-radar works: the less and most karst-damaged areas were identified.

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კარსტული სიღრუის ფორმები და მათი რადიო სახეები, რომლებიც გამოვლენილია შედარებითი ფიზიკური მოდელირებით

დ.ოდილავაძე, თ.ჭელიძე

რეზიუმე

კარსტულ რაიონში ჩატარდა გეორადიოლოკაცოური კვლევები უსაფრთხო სამშენებლო მოედნის გამოსავლენად. ელექტრომაგნიტური ველების მსგავსობის თეორიის გამოყენებით ფიზიკური მოდელირების ლაბორატორიული კვლევის შედეგები გავრცელებულ იქნენ საველე მონაცემებზე. საველე მონაცემები ინტერპრეტირებულ იქნენ მაღალი სიზუსტით მიწისქვეშა ობიექტების გაშიფვრისათვის. მშენებელთა მიერ დასახული ამოცანა გადაწყვეტილ იქნა გეორადიოლოკაციურ სამუშაოებზე დაყრდნობით: გამოვლენილ იქნა კარსტით მეტად დაზიანებული და დაუზიანებელი მონაკვეთები.

Формы карстовых полостей и их радиоизображения, выявленные с помощью сравнительного физического моделирования

Д.Т. Одилавадзе, Т.Л. Челидзе

Резюме

Георадиолокационные исследования были проведены для выбора безопасного места для строительной площадки в известняковом районе. Используя теорию подобия электромагнитных полей, результаты лабораторного физического моделирования были распространены на полевые данные. Данные съемки были интерпретированы с высокой точностью для расшифровки подземных объектов.
Задачи, поставленные строителями, были решены на основе георадиолокационных работ: выявлены наименее и наиболее поврежденные карстом участки.