

# Киевский национальный университет имени Тараса Шевченко Борщевский областной краеведческий музей



Ксения Бондарь

Михаил Сохацкий

Мария Барышникова

Анатолий Чернов

Ярослав Попко

Олег Петрокушин

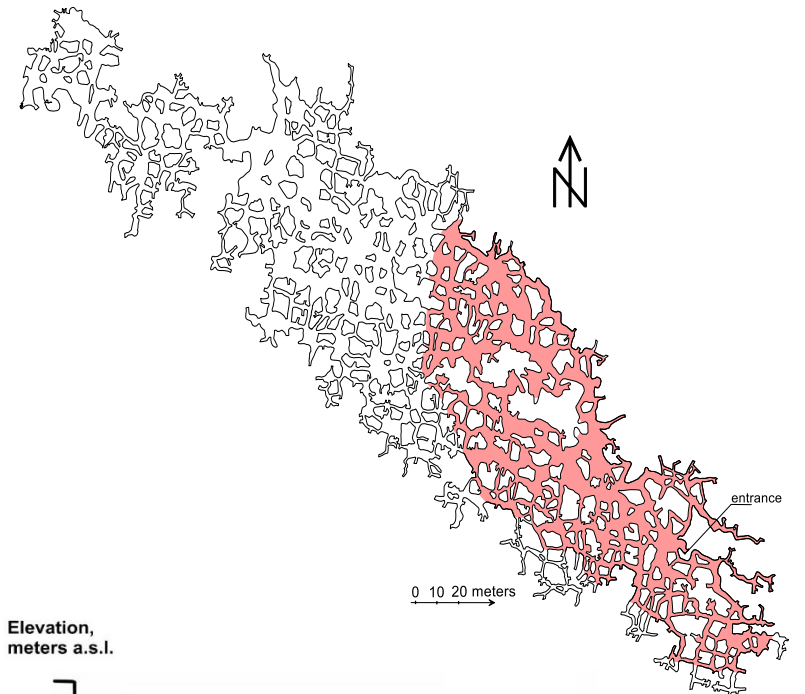
Мирослав Бойко



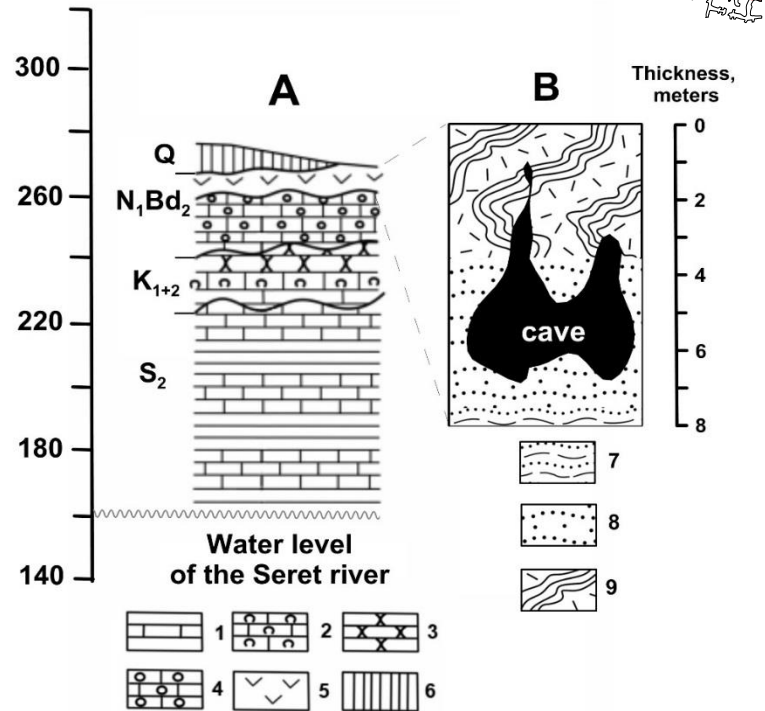
**Геоархеологические исследования памятника  
трипольской культуры пещера Вертеба (Украина)  
геофизическими методами**

**Geoarchaeological study in Verteba Cave – a Trypillian  
Culture Site (Ukraine) - using geophysical methods**



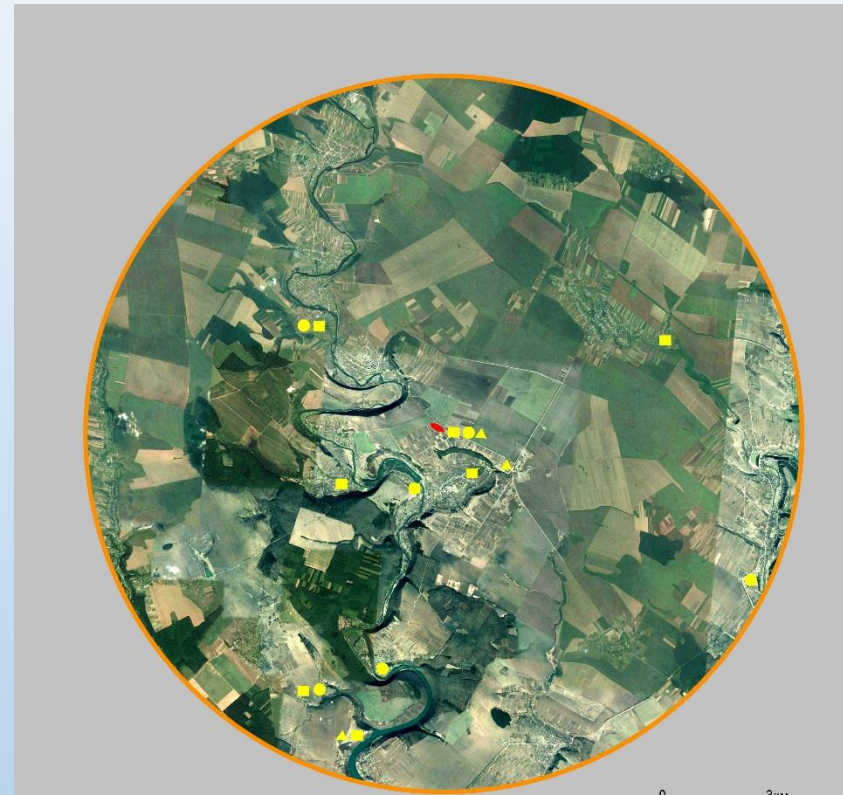


Elevation, meters a.s.l.





The remains of sixteen Trypillian settlements of stages **CI (3700-3200 BC)** and **CII (3200-2750 BC)** were found within a radius of 10 km to the cave, which are synchronous to Verteba cultural horizons, according to radiocarbon dating of selected materials **(3700-2700 BC)**

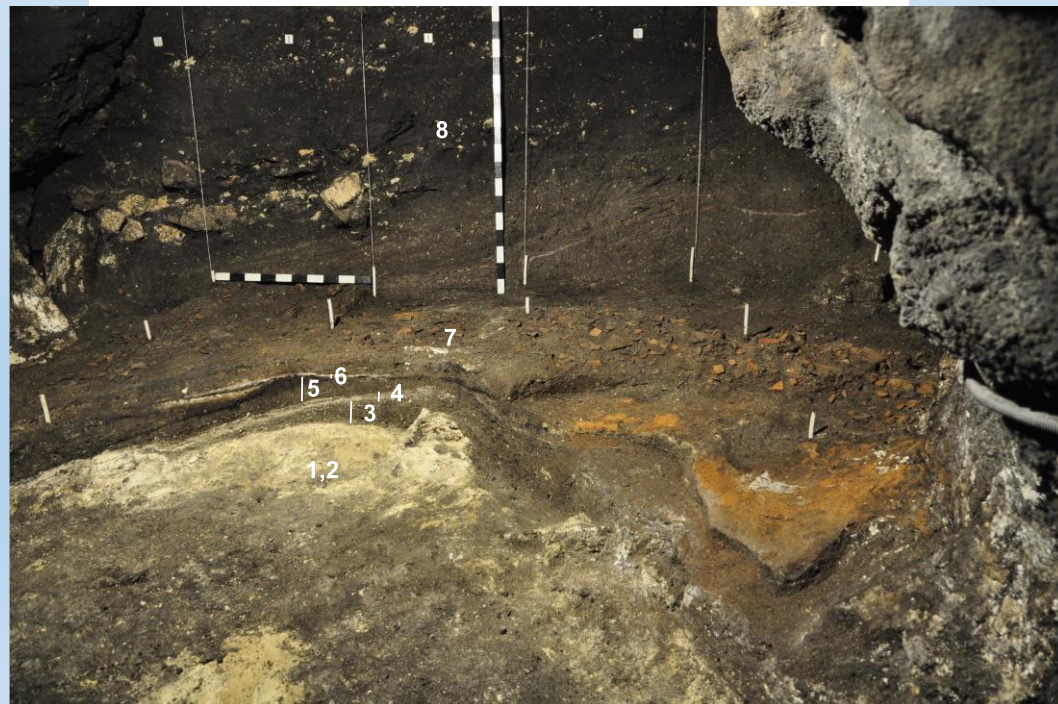
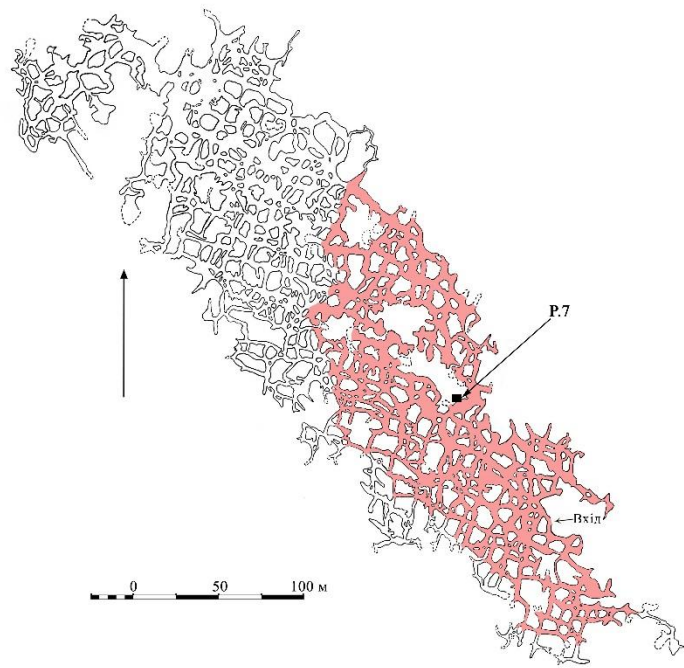


Карта-схема розташування пам'яток трипільської культури етапів С I, СII в радіусі 10 км від печери Вертеба

- - шипинецька група (III фаза)
- - кошиловецька група
- ▲ - касперівська група
- - печера Вертеба



Lithologically the deposits are mainly loamy layers with the inclusions of gypsum fragments. Three chronological horizons of Trypillian culture, which are clearly separated by the 'sterile' layers, are present in the excavation 7. These horizons belong to the chronological periods of CI, CII and represent three local groups of Trypillian culture.

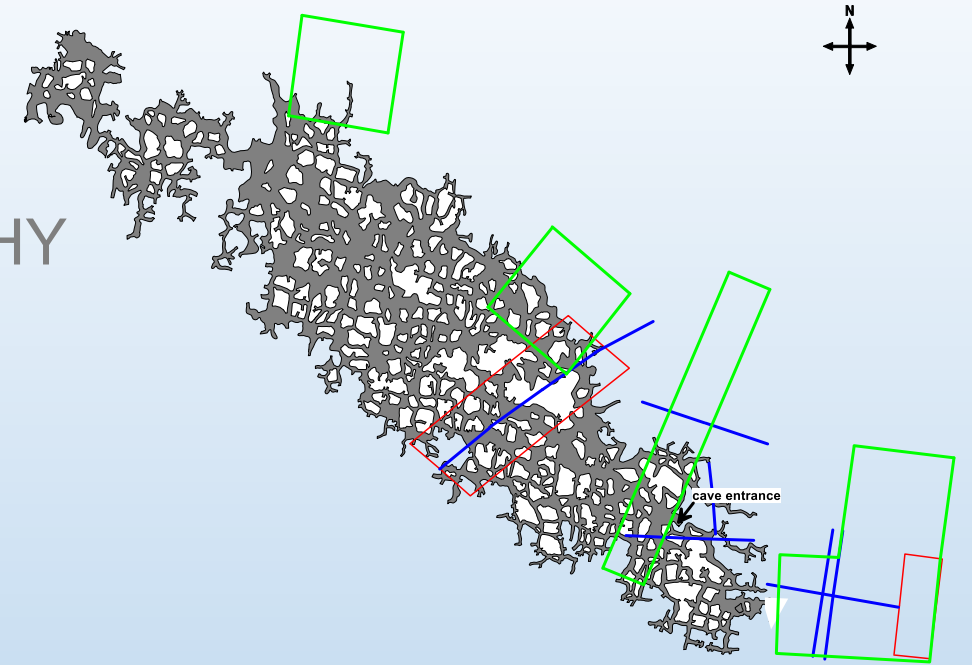


Unit	Thickness, m	Description
1	0,15	Layer of grey-yellowish loam with rough gypsum and limestone debris overlaying gypsum rocky bottom
2	0,15-0,2 m	Coarse-grained lamellated grey loam with gypsum and limestone debris. This is an artificial dip for levelling holes on a rocky bottom.
3	0,4-0,6 m	<b>Dark-grey, carbonate loam. Significant concentrations of coals, ashes and reburned gypsum. Contains ceramic shards, flint and bone products, as well as scattered human and animal bones. The oldest cultural horizon, dated to the late CI phase of Trypillian culture.</b>
4	0,1 m	Pale-yellow loam, carbonate, archaeologically 'sterile', homogeneous
5	0,35-0,4 m	<b>Mixed layer of dark grey loam containing reburned gypsum, coal (small remains of burnt wood). Dense saturation with sherds of painted ceramics. Terracotta figurines of humans and animals, bone products (daggers, trowels, amulets) were found. Whole and fragmented mealing stones and animal bones are present. Anthropological materials are in disturbed condition. Dated to the early CII phase of Trypillian culture.</b>
6	0,1-0,2 m	Pale-yellow loam, carbonate, archaeologically 'sterile', homogeneous
7	0,6 m	<b>Dark-grey loam of cloddy-nut texture with manganese inclusions, small stones, reburned lime and coals. Contains a lot of ceramic sherds. Whole small vessels (cups) were found. Gray pottery with cord impressions prevails. There are models of sledges, ovens and spindlewhorls among finds. Dated to the late CII phase of Trypillian culture.</b>
8	0,8-1 m	Chernozem soil material, dark-grey, loose, carbonate, with fragments of gypsum and limestone deposited through the karstic sinkhole. Does not contain archaeological finds.

## Geophysical techniques

- a) MAGNETOMETRY
- b) ELECTRICAL RESISTIVITY TOMOGRAPHY
- c) GROUND PENETRATING RADAR

Total station, GPS, UAV-photography



## SEG Geoscience Field Camp in Ukraine 2018



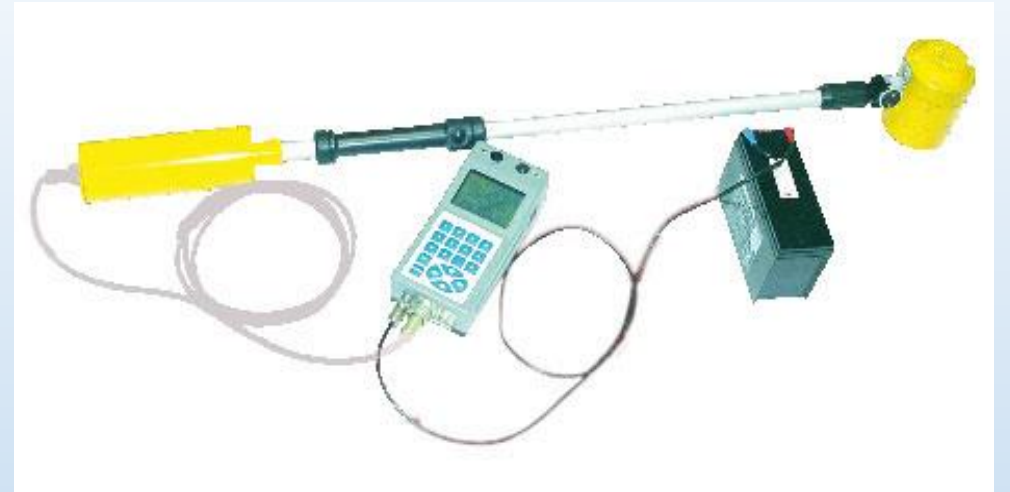
-23 participants;  
-9 countries;

# Magnetic survey

For the survey on the ground surface, we used the cesium magnetometer PKM-1M (Geologorazvedka, Russia). This consists of one magnetometer probe with an automatic data log on a handled controller.

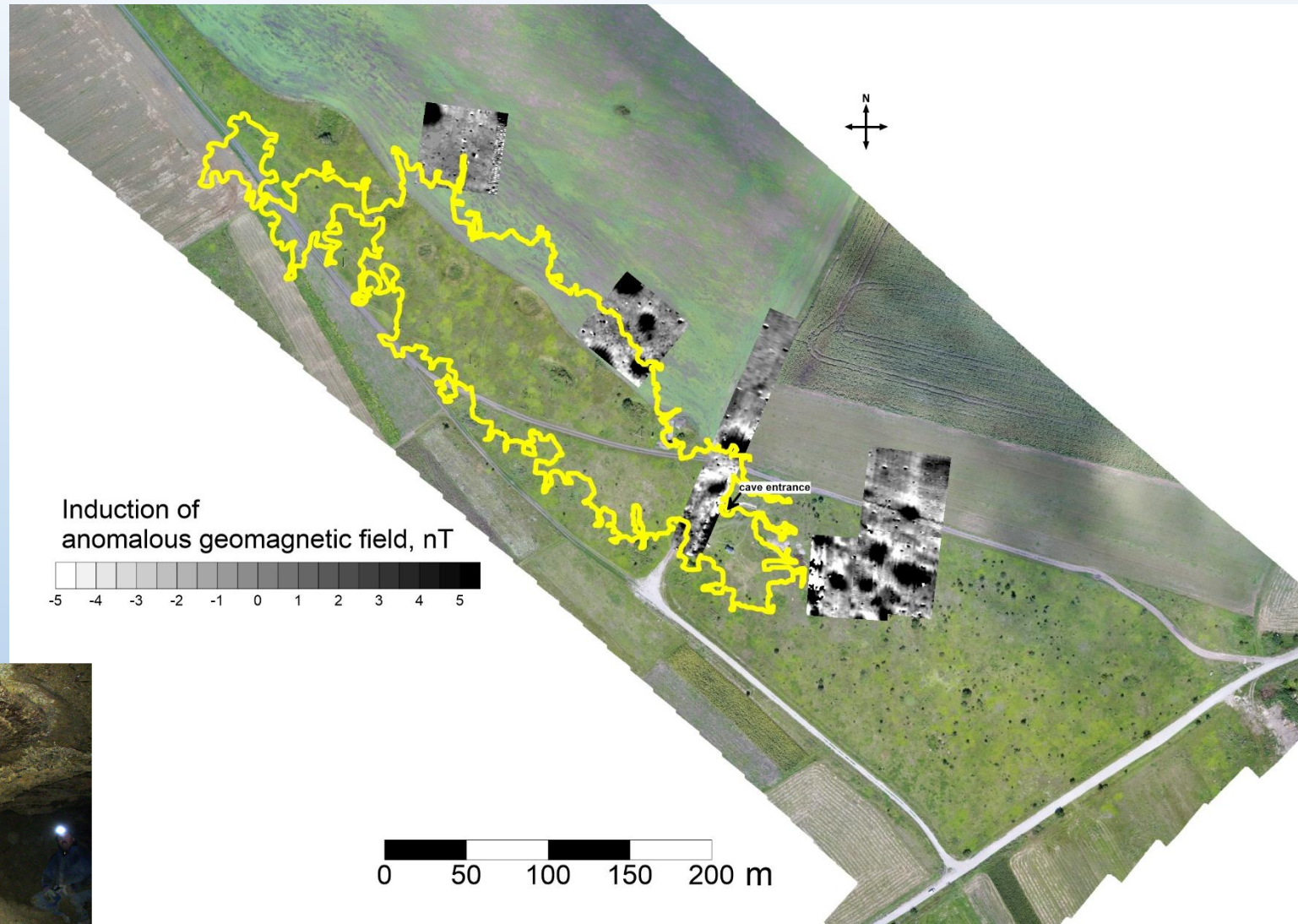
On the surface:

- 10 measurements per second;
- sensitivity of  $\pm 0.01\text{nT}$ ;
- traverse interval was chosen with 1 m;
- measurements were taken in manual mode.



# Results of magnetic survey on the surface

The total 1,5 ha survey area includes series of round and oval-shaped magnetic anomalies with dimensions of 10-25 m and maximal intensity of 15-20 nT. These anomalies are supposed to correspond to old sinkholes infilled with top-soil material and not expressed in the relief. The terrain where the anomalies are located makes potential Verteba cave continuation area. No anomalies have been recorded within the measured plots, which can correspond to Trypillian culture houses or other remnants of habitations from Eneolithic Age.



*Verteba karstic field. Magnetogram in greyscale, raster 1.0x0.1 m interpolated to 0.5x0.5 m, dynamics of the anomalous magnetic field +/-5nT*



# Electrical Resistivity Tomography



During fieldworks on the cave field of Verteba, the one-channel device furnished with 64 brass electrodes was used (Khomenko et al., 2013).

ERT measurements were made using a Shlumberger array protocol.

In the surface survey the electrodes were placed at every 1 m. Such distribution allowed recognizing electrical resistivity to a depth of about 11 m.

In the cave the distance between electrodes was 0.25 m with the maximum depth of 2,5 m achieved.



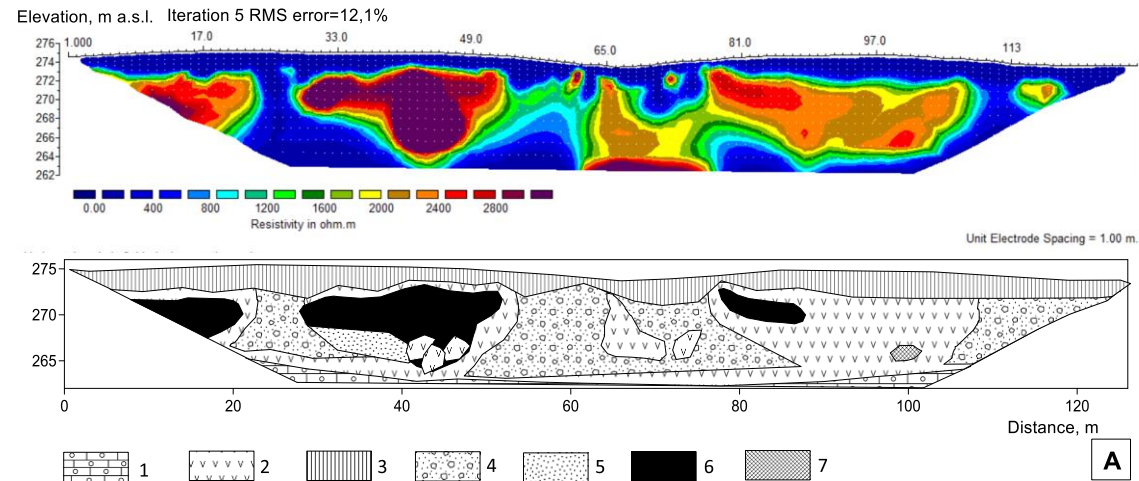
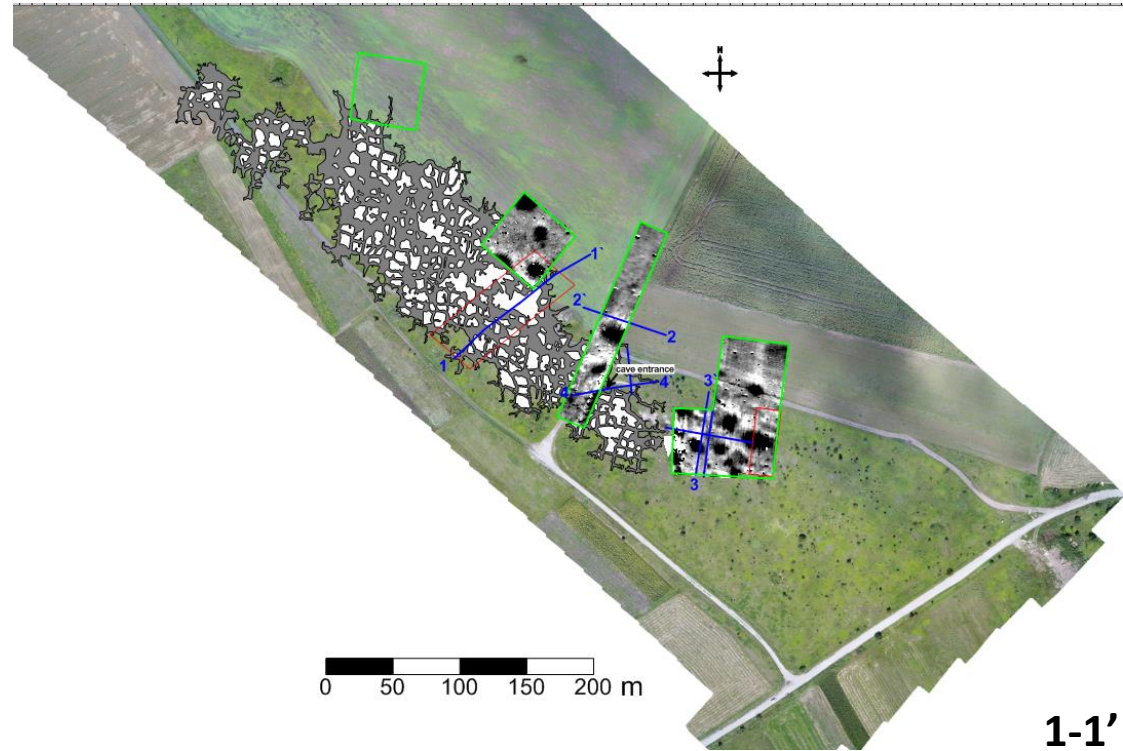
Measured electrical data were inverted using the interpretation software Res2DINV, implying the smoothness-constrained least-squares optimization technique (deGroot-Hedlin and Constable 1990; Sasaki 1992; Loke and Baker 1996) to obtain inversion of a measured resistivity.



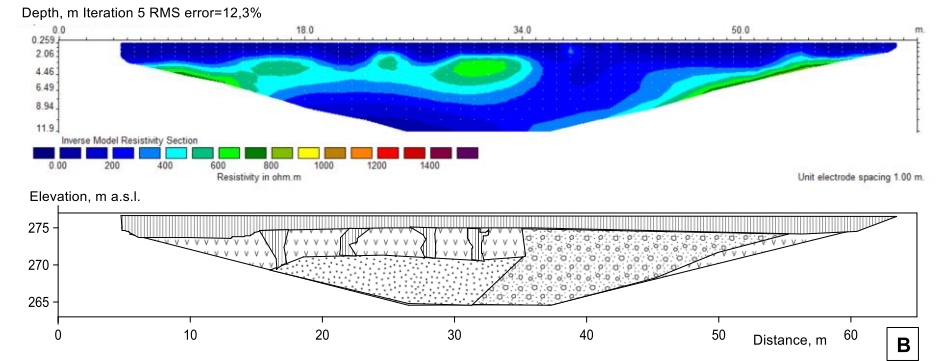
Sulphate rock, containing 75 to 100% of gypsum shows electrical resistivity values in a range of 700–1,000  $\Omega\text{m}$  (Guinea et al, 2010). According to (Dublianskij & Smolnikov, 1968), Miocene gypsum unit contain over 99% of gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ).

Geological units, recognized from inverted ERT profiles are characterized by resistivity values varying in the range 10–3100  $\Omega\text{m}$ . The presence of cavities filled with air leads to high resistivity values ( $>1000 \Omega\text{m}$ ). Low resistivity values ( $<500 \Omega\text{m}$ ) can be associated with loamy sediments and soils.

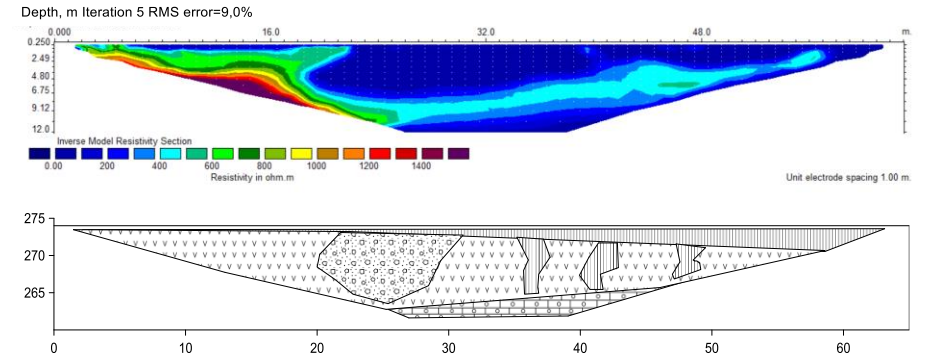
# ERT results on the surface



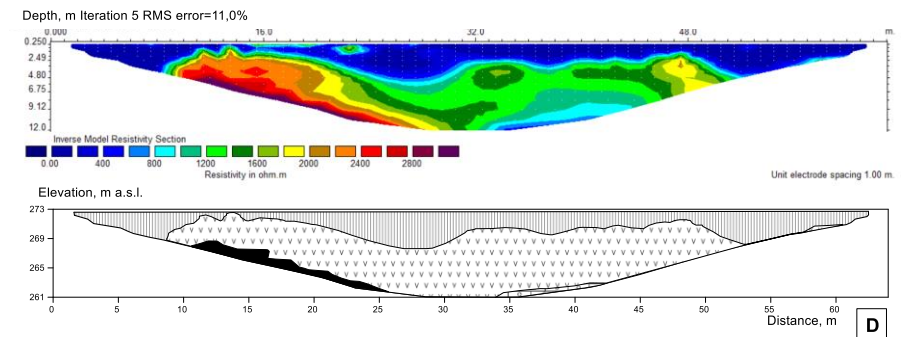
**2-2'**



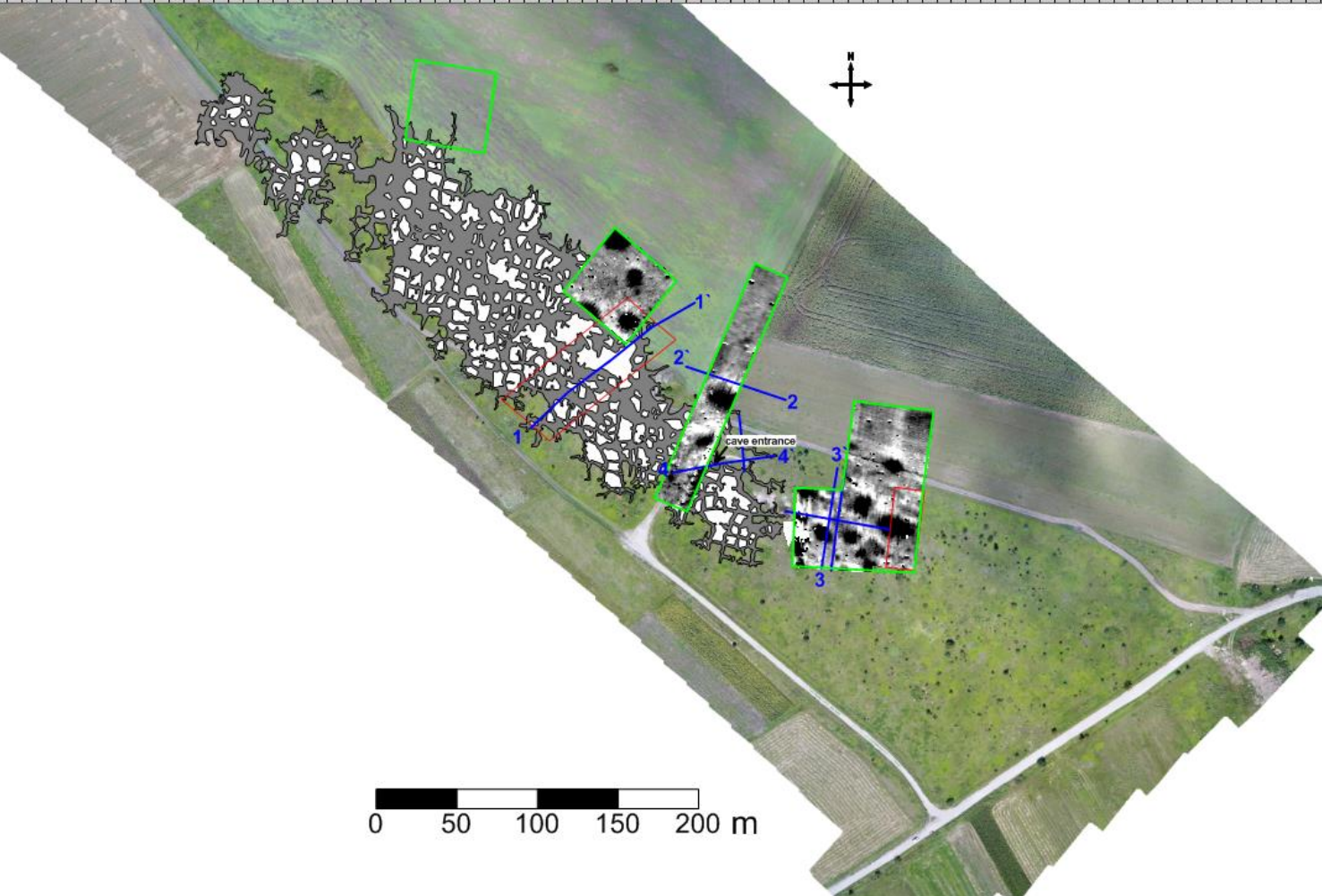
**3-3'**



**4-4'**



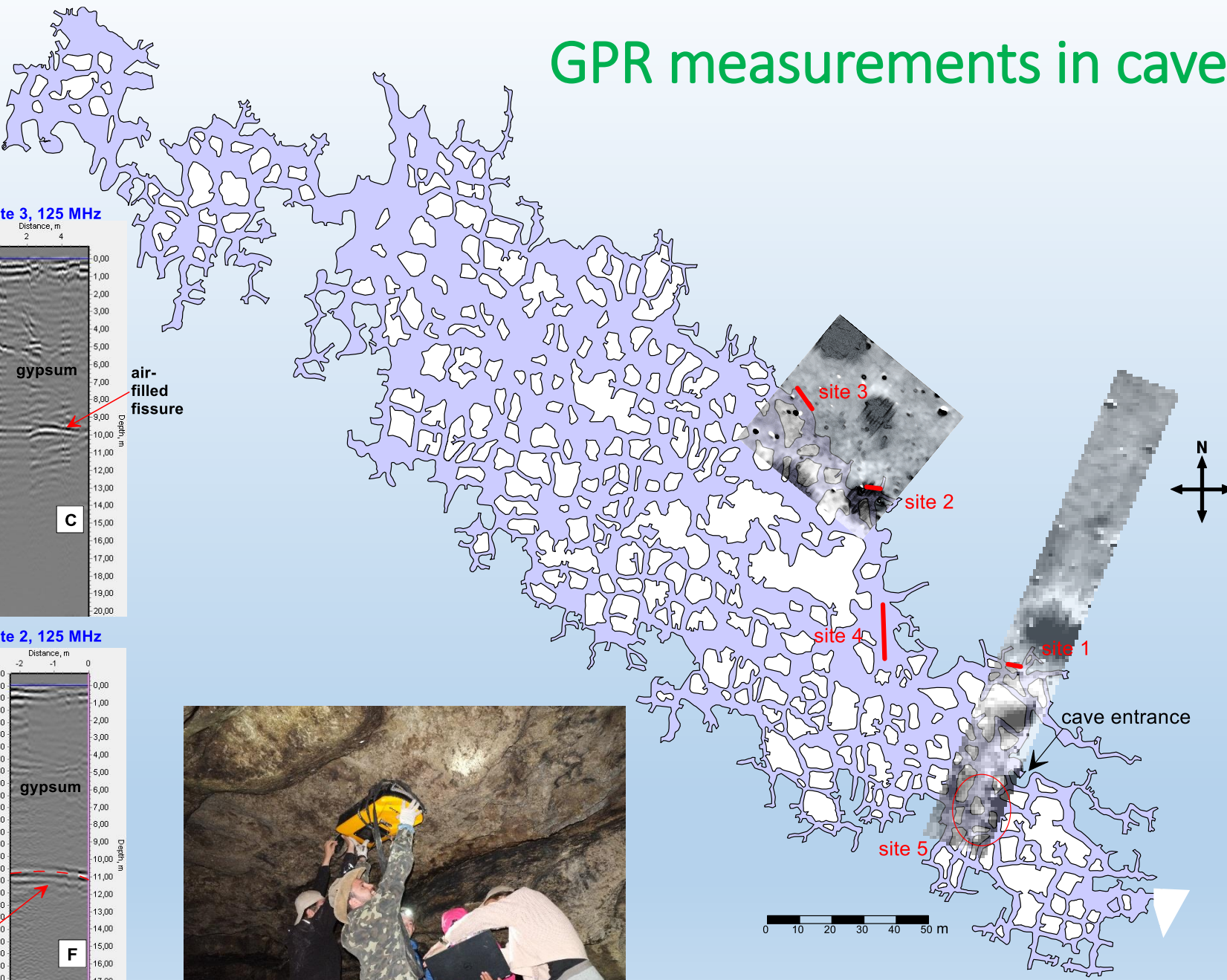
# GPR results on the surface



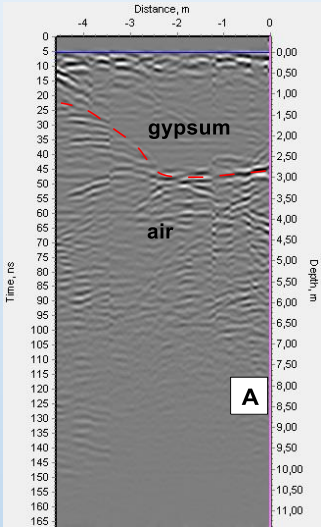
The survey was conducted within two polygons over the cave and near it (Fig. 3). The GPR instrument **VIY-3-125i** (Transient Technologies) has been used. As evidenced by radarograms from the both polygons, soil effectively adsorb electromagnetic waves providing poor depth of GPR exploration. Thus no information was obtained from surface GPR measurements.



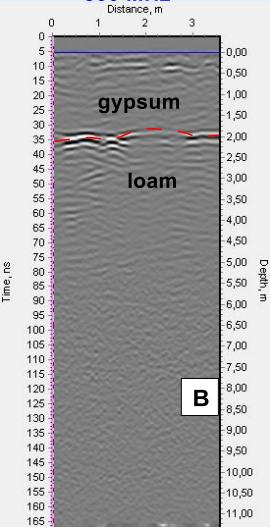
# GPR measurements in cave



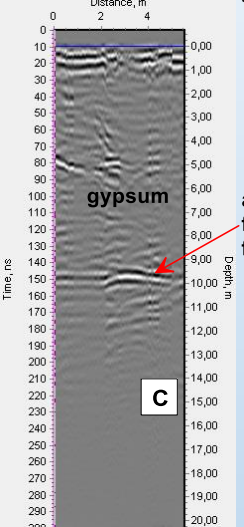
record by gypsum column  
300 MHz



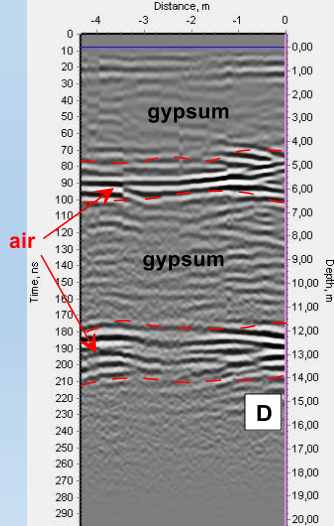
record by gypsum ceiling  
300 MHz



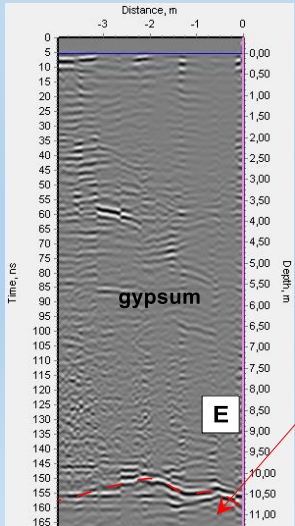
site 3, 125 MHz



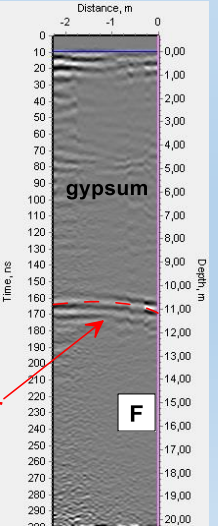
site 1, 125 MHz



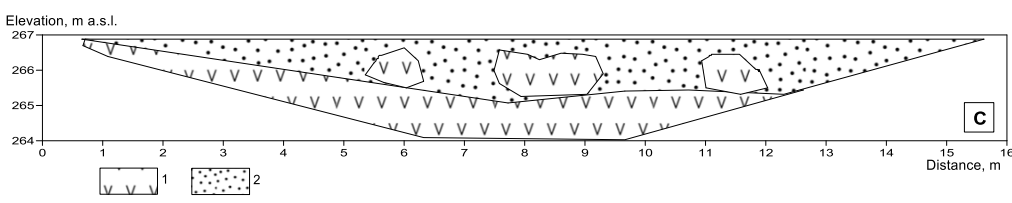
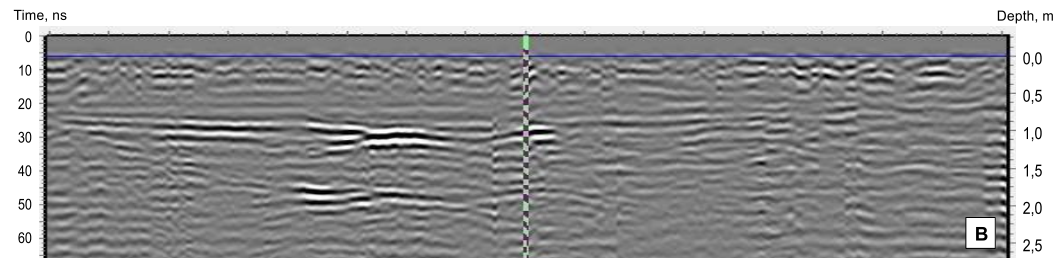
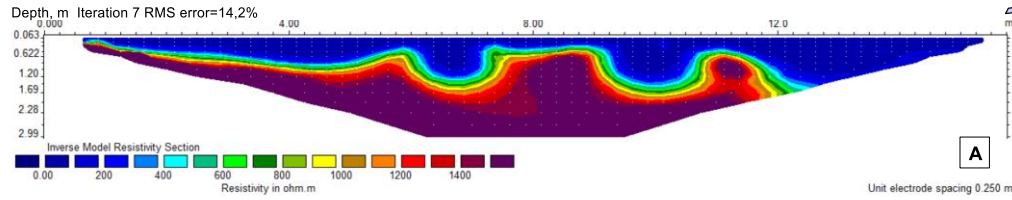
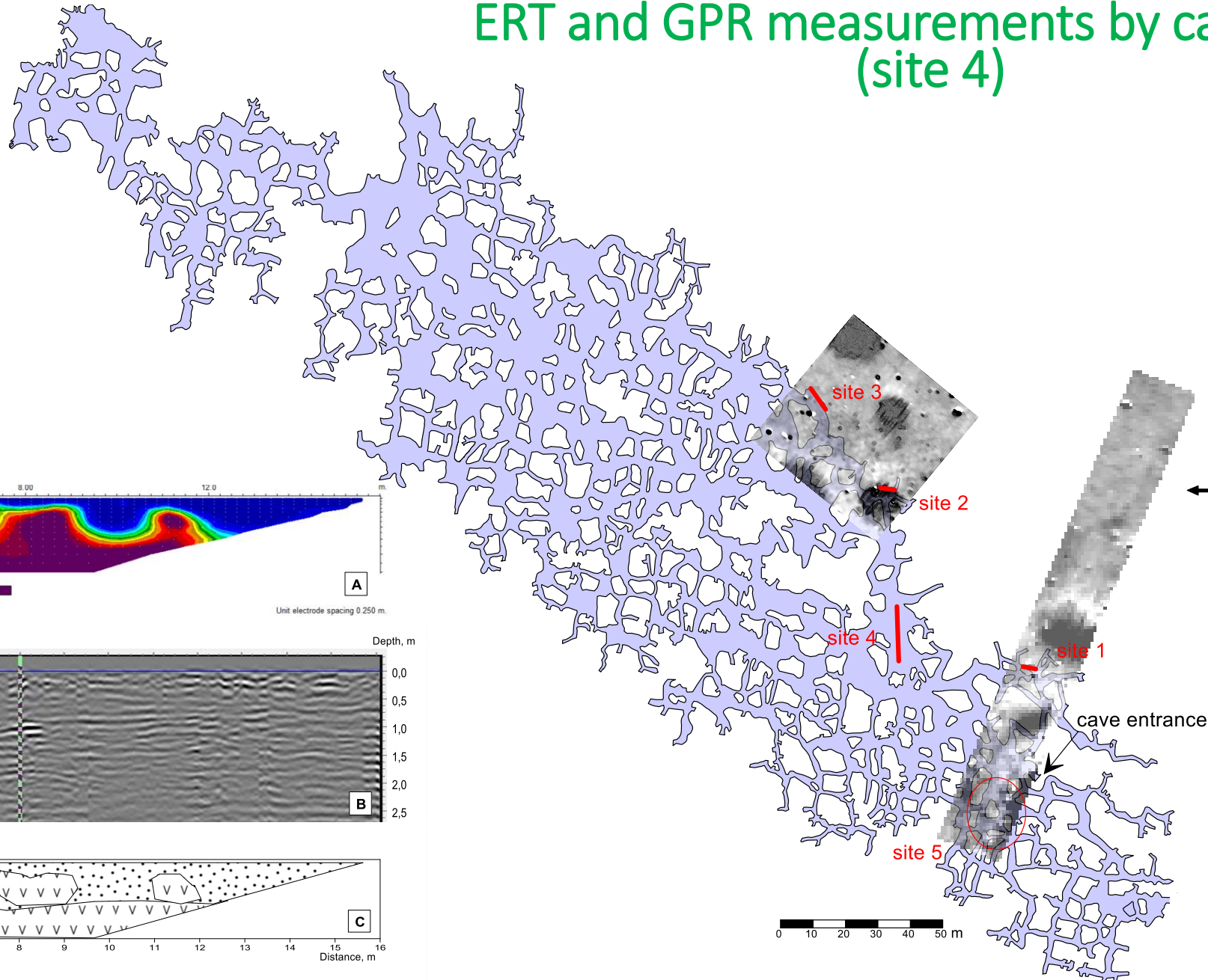
site 2, 300 MHz



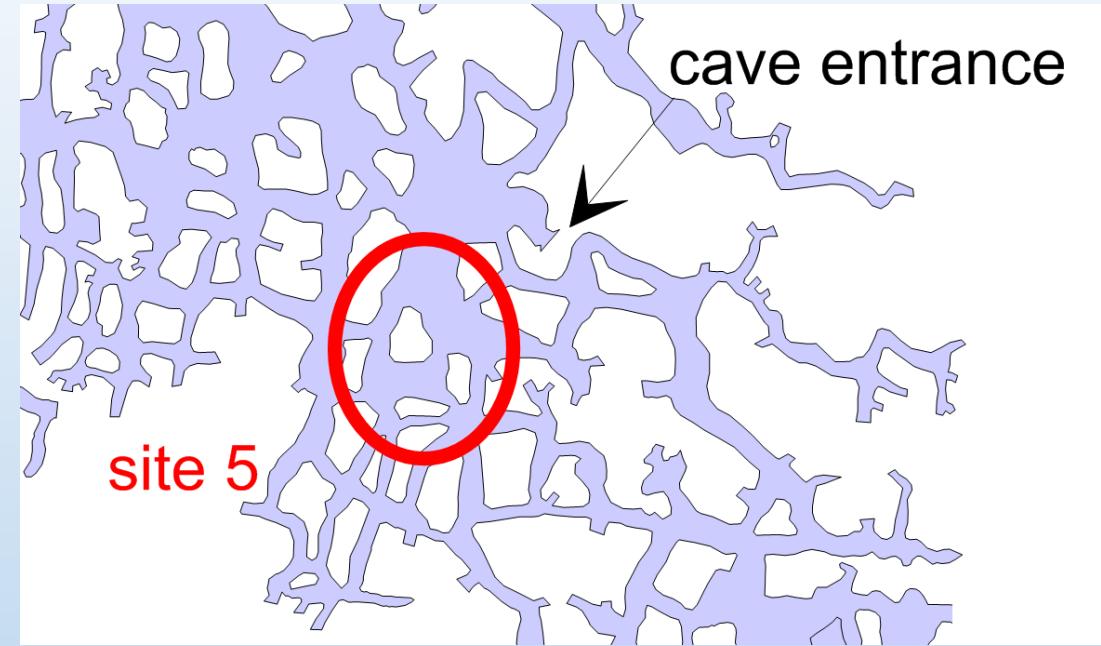
site 2, 125 MHz



# ERT and GPR measurements by cave floor (site 4)



# Magnetic survey inside the cave



The underground survey was performed in Archaeological district of the cave in manual mode.

A traverse interval was chosen with 0.5 m.

Interval between points on the line was 0.25 m.

The ends of each line were geolocated using Leica Disto X310 laser distance meter with an upgrade kit which adds a compass and clinometer.

Another the same cesium magnetometer was utilized to record variations during survey.

It operated in the sampling rate of 1 meas/sec.

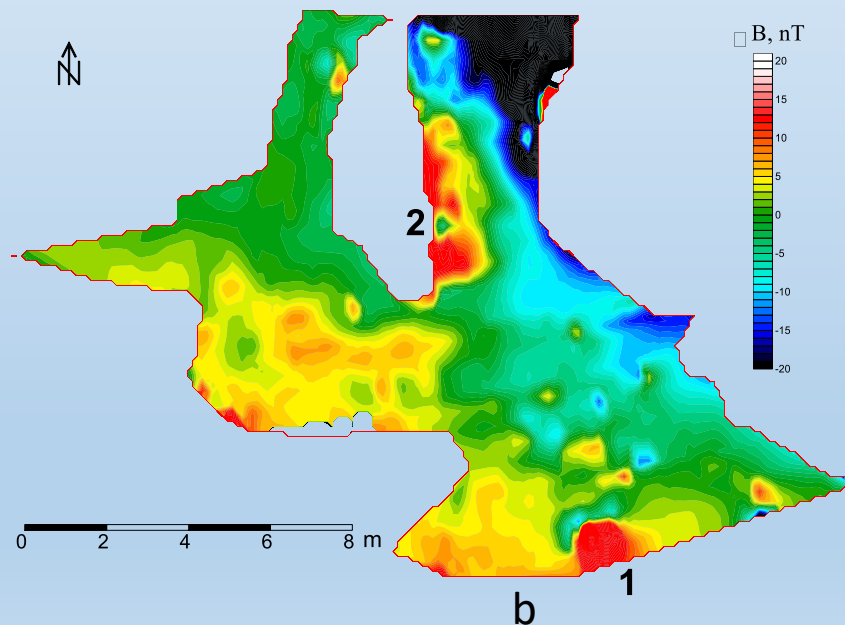
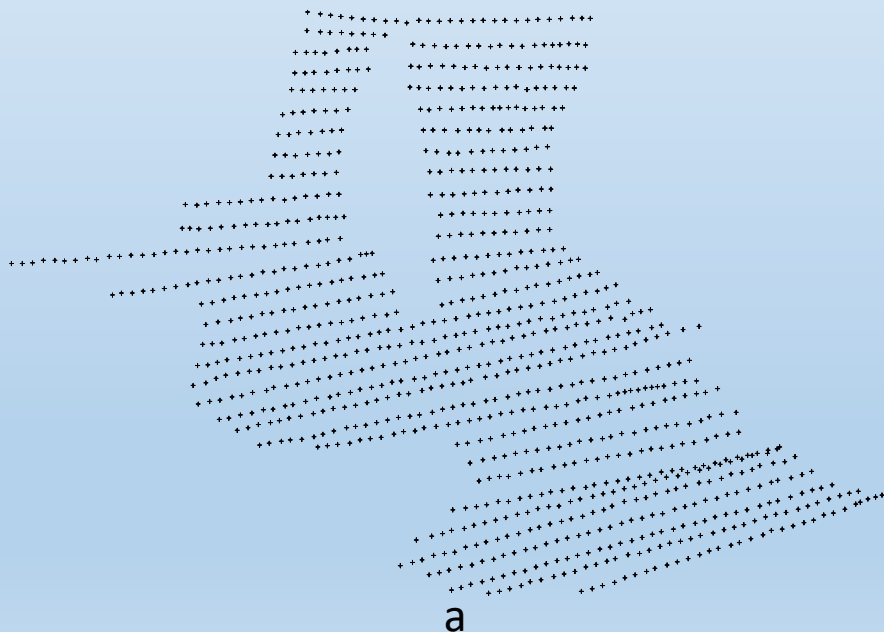
At the processing stage the variation was subtracted from the measured values along the profile.

All measured points were organized in an irregular grid about 0.25x0.5m and interpolated to the regular grid 0.12x0.12 m.

## Results of magnetic survey in cave



Decrease of the geomagnetic field in the eastern direction is observed. The reason for this phenomenon may be the proximity (about 10 m) of the measuring plot to the iron entrance door of the cave, which created the corresponding anomaly. Complex anomaly 1, probably, is of archaeological origin. The source of the complex anomaly 1 can be an object with 0.7 m size, laid on a shallow depth. The expected depth to the upper edge of the object is about 0.5 m. The anomaly 2 could correspond to clay bed, such as known near the walls in other places of the cave.



*Verteba cave, Archaeological chamber. Scheme of survey points (a) and magnetogram in rainbow scale (b), raster 0.5x0.25 m interpolated to 0.12x0.12 m, dynamics of the total magnetic field 49510+/-20nT*



# Выводы

Геофизическими признаками наличия карстового процесса на территории являются:

- 1) магнитные аномалии диаметром 10-25 м и интенсивностью 15-20 нТл, преимущественно округлой формы, соответствующие в пещере высыпкам, а на поверхности – затянутым провальным воронкам. При этом высокая скученность таких воронок говорит о сильной порушенности гипсового слоя и, как следствие – отсутствии пустотного пространства;
- 2) наличие в высокоомном ( $>1000$  Ом) гипсовом слое зон ураганно высоких сопротивлений ( $>2600$  Ом) говорит о наличии значительной по величине пещеры, пригодной для заселения человеком;

Перспективными для поиска новых ходов следует признать направления вдоль бортов пещеры, где по данным георадарного сканирования стен выявлены вертикальные границы в гипсовой толще, особенно в тех случаях, когда присутствуют признаки границы гипс-воздух.

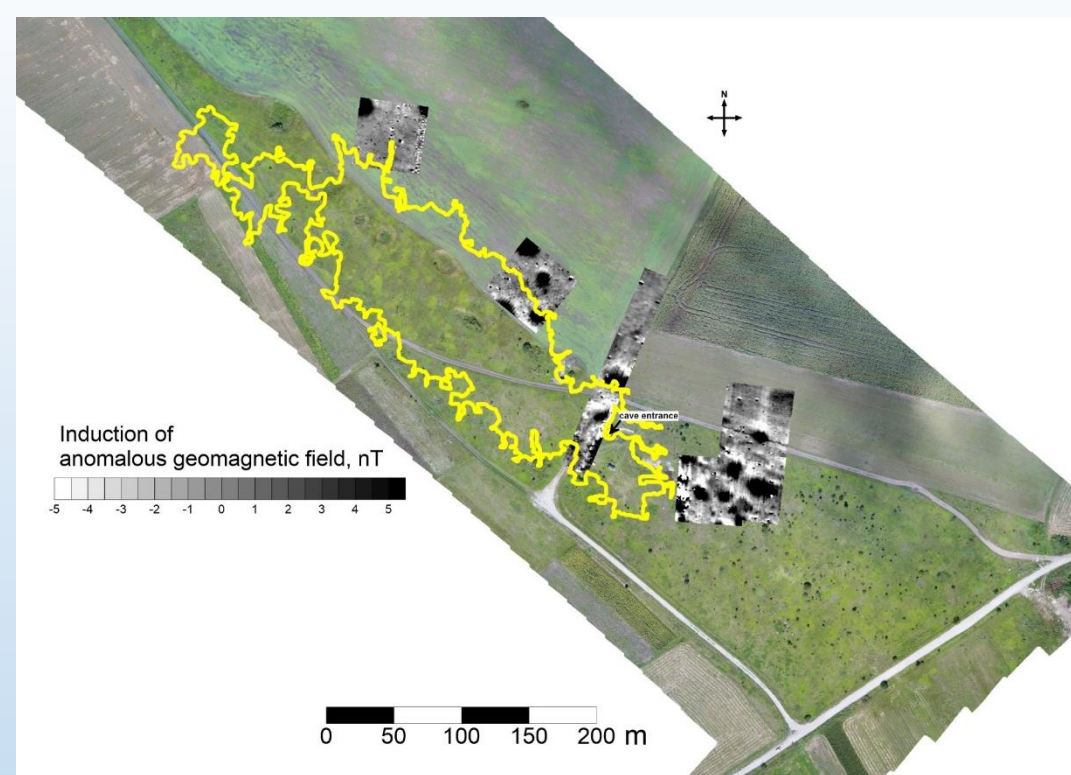


# Выводы

Возможные зоны развития пещеры предполагаются на территории к северу от ее центральной части, непосредственно вдоль северо-восточного борта по магнитным данным и результатам георадарного сканирования стенок внутри пещеры.

В толще глинистого заполнителя пещеры при помощи магниторазведки успешно выявляются обожженные археологические объекты. Томография электрического сопротивления на постоянном токе и георадар могут быть использованы для исследования структуры пола пещеры в тех случаях, когда состояние поверхности и геометрия хода позволяет сделать измерения по достаточным по длине профилям.

Геофизическая разведка на поверхности не выявила следов энеолитического поселения, что лишний раз доказывает, что люди использовали пещеру в качестве убежища или святилища.



Thank you for attention!  
Спасибо за внимание!

