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DETERMINATION OF LOCATION OF THE HISTORICAL OBJECTS USING PHOTOGRAMMETRIC METHODS AND METHODS OF NON-DESTRUCTIVE GROUND RESEARCH

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Aim of this work is to establish and display the territory of the mass graves at the Raylivka village on modern maps using the archive data. To define the place of mass executions and burials during the World War II using interpretational properties of the archival aerial images obtained by the Germans in 1944 and ground geophysical researches. **Methods.** There is proposed the method of determining the locations of mass graves by World War II that combines remote methods (interpretation of images) and ground non-destructive methods (geophysical research). Photogrammetric processing of archival aerial images in 1944 was divided into the following three stages: transformation of the used materials to one coordinate system (in the case of archival aerial images transformation was performed by reference points that were preserved); and overlaying of the images on this territory at different times to determine the true boundaries of burial; and finally preparation of the final data. At the first stage archived aerial image and modern space images were registered using software ErdasImagine with errors up to 3 meters were stored in a format GeoTIF. Then there was implemented the interpretation of archival aerial images and transfer of defined boundaries of mass graves into the current situation. The final stage of this method is the generation of the resulting research materials. Input data of the geophysical research was the data that were obtained by the photogrammetric method. During the field works the following studies were carried out: a magnetic survey; research by TER; georadar, and soil research. As a result of studies a large number of artifacts from World War II were found and the boundaries of mass graves defined by photogrammetric method were substantially confirmed. **Results.** The places of mass executions and burials of the World War II were preliminarily determined based on the interpretation of archival aerial images obtained in 1944. With ground geophysical studies confirmed the fact of mass executions in the experimental area on the base of discovered casings from German arms. Also confirmed by photogrammetric identification method was the location of the mass graves. **Scientific novelty**. The proposed method that combines the remote photogrammetric and ground geophysical research determination of mass graves of World War II allows reliably and with reasonable accuracy determining its territory on modern maps. **The practical significance.** Developed cartographic materials and researching results can be used to display historical events that occurred in the area. The results of this work can be transferred to the Department of preservation of cultural heritage of Lviv as the annex to the passport of cultural heritage object.

Key words: archival aerial image; remote sensing data; geophysical researches; ground penetrating radar; photogrammetric researches; mass graves.

Introduction

In modern cities and villages of Ukraine can be found many cases of neglect of historical and cultural heritage. Through exploring the history of monuments and their functions in the past, society learns to understand their historical value and their role in the future, the need for their preservation or restoration. Memorial places relating specifically to such objects of historical and cultural heritage need to be preserved in the memory of the tragic events to prevent their recurrence in the future.

From the archival bibliographic sources we know that in 1942 Jewish ghetto was created in Sambor, where Jews of Sambor was forcibly herded. With the liquidation of the ghetto in 1943 all Jews were transported to the forest, located near village

Radlovitse (Ralivka) and there were shot dead [http://www.jewishheritage.org.ua].

Until now there was only information about the approximate location of mass graves of Jews from the destroyed ghetto, which were based on the testimony of witnesses. Methods are based on the interpretation of archival images combined with non-destructive ground research can answer the questions about the exact location of mass graves and the the descendants of the victims finally can receive a response where their ancestors are buried.

Aim

The aim of this work is to establish and display the territory of the mass graves at the Raylivka village on modern maps using the archive data. To define the place of mass executions and burials during the World War II using interpretational properties of the archival aerial images obtained by the Germans in 1944 and ground geophysical research.

Methods

The method of determining the locations of mass graves from World War II combines remote methods (interpretation of images) and ground non-destructive methods (geophysical research) was presented.

The mapping of historical objects on the base archival graphic materials were engaged a large number of both domestic and foreign scientists, among which mention the labors of Dyshlyk O. Makarov S., M. Jasinski, M. Telegin, Hnery V., E. Schmidt, Tolstova C ., N. Meyer, Kryvonovova I. Shishkin K., Arnoud de Boer, Bartonek D., Garouani A. El, Alobeid A., Matejicek L., Matoušek V., Remondino F. and others. These researches reflected objects that have survived to our times, or objects specified in combination of remote sensing methods and archeology. Knowing what to do when conducting archaeological research is impossible and the remote sensing methods do not give 100 % results? The answer on for this question is the prepared technological scheme for determining the mass graves from World War II through combining remote sensing research methods with ground non-destructive methods.

Ralivka experimental areas located near the eponymous village that near Sambir (Lviv region) (Fig. 1).

The area represents a group of the mass graves located in the forest of 40 to 150m from the concrete road that leads to the abandoned military base.

Fig. 1. Location of research area Ralivka

Within the area is also situated a memorial complex, created in 1999-2001. In the forest there are concrete columns, which according to the testimony of local residents are remnants of fences established by farmers around fraternal graves of Jews murdered by the Nazis.

To determine the boundaries of the mass graves the proposed technological scheme combines photogrammetric research with metal detects and ground geophysical research (Fig. 2). Results of photogrammetric technology research in this scheme are the input data for subsequent ground surveys.

Photogrammetric research

The main input materials for research to determine the boundaries of mass executions and burials as they were until 1944, served: a German archival aerial image of this area in 1944; a plan created in 2010 at a scale of 1: 1000; and a modern space image of the research area that was obtained from GeoEye-1 in 2009Interpreting the German archival aerial image the damaged areas that likely represent the mass graves are clearly visible, given the number of Jewish population exterminated in this area by Nazis during the retreat.

The technology processed image data to establish the true boundaries of mass executions and burials [Arnoud de Boer, 2010, Bartoněk D., 2012, Matoušek, V., 1994]. All work was performed in MapInfo software and was conditionally divided into 3 phases:

- transphormation of materials used in a conventional uniform coordinate system (in the case of archival aerial image carried out by transphormation anchor points, and preserved);
- unification of the images of this area for different dates and to determine the true limits of burial;
- preparation of finished materials.

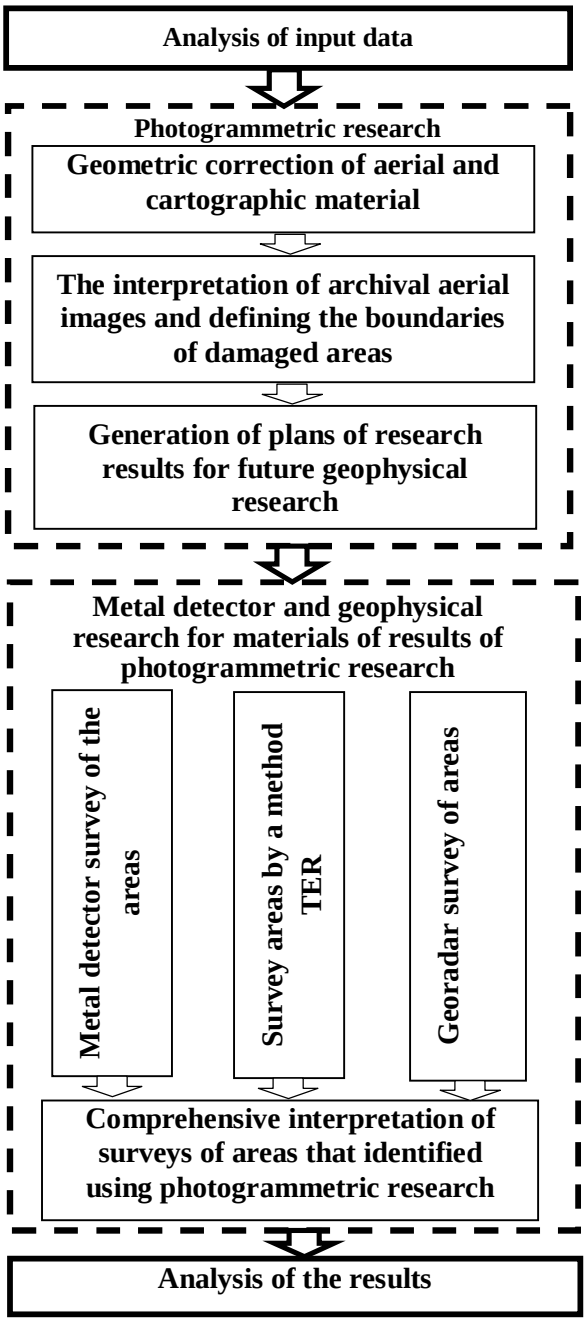

Fig. 2. Technological scheme of determination of the places mass graves using photogrammetric, metal detector and geophysical research

Transformation of materials used to conventional uniform coordinate system.

With the help of MapInfo Professional all graphic materials listed above were reduced to a uniform conventional coordinate system in the internal projection applications Layout (meters). Accuracy anchor graphical materials are as follows:

- Plan created in 2010 at the scale 1:1000 – 1 pixel that is a valid value as the previous calculation accuracy amounted to 2 pixels;
- Archival aerial image obtained in 1944. (US National Archives) – a preliminary geometric correction of the image was conducted using Erdas Imagine in consequence of which the image was transformed;
- The correction was performed for 9 reference points with mean square error to 2 pixels that are within an allowable value since the previous calculation accuracy was to 5 pixels;
- A modern space image of the research area obtained from the GeoEye-1 satellite in 2009. A preliminary geometric correction of the image was carried out with the help of Erdas Imagine. The correction was performed over 9 reference points was obtained with a mean square error to 1 pixel, which is within the permissible value, since the preliminary accuracy calculation was up to 2 pixels.

Combining the images on this area for different times and determination the true boundaries of graves [Blažková, T., Matoušek, V.,2008, Remondino, F., 2006].

Combining of images performed in the following sequence:

- combined a plan created in 2010, scale 1 : 1000 and German archival aerial image obtained in 1944, from which was moved deciphered boundaries forest areas;
- combined modern space image and archive German aerial image obtained in 1944, from which was moved deciphered boundaries of possible burials.

Preparation of finish materials

The finished materials of plans were reduced to a scale of 1: 1000. All graphical documents have been prepared using MapInfo and reduced to A2.

The final result is a graphical documentation for further ground research:

- Photoplan the territory of modern situations in 2010 that marked on the aerial image in 1944, Ralivka, Sambir district, Lviv region (Fig. 3).
- Plan of the modern situations in 2010 with the marked of the boundaries of fraternal graves in 1944, Ralivka, Sambir district, Lviv region (Fig. 4).

Methods of ground research

Ground studies included a metal detector search and geophysical measurements on the areas of fraternal graves deciphered with archival aerial photographs. Also measurements were performed on other possible locations of graves, these include that from local residents with uncertain reliability of sources.

Geophysical performed was using various methods.

In order to study the vertical structure elements of the burial complex, included finding mass graves and determining their size and depth. This study was performed by ERT – electric resistivity tomography using multi-installation [Khomenko et al., 2013] with a step of 0.5 and 0.25 cm between electrodes.

Georadar observations were executed using the device VIY-2 production "Transient technologies" (Kyiv, Ukraine), which has a frequency of 300 MHz.

Magnetic research was performed using cesium magnetometers PKM-1 (Heolohorazvedka, Russia).

Accordingly topographic plan geophysical surveys were carried out along profiles and the sites indicated in Fig. 5.

In the vicinity of the Memorial was made 5 rides which included conducting specialized geophysical observations, magnetometric, and georadar (WP1-PR5). According to one account laid rides ERT.

Most of the mass graves, were laid from aerial images deciphered in 1944 from three profiles (PR11-PR13), which allowed georadar and geoelectrical study.

At Tomb 4 (photogrammetric surveys) the area is marked with dimensions 18×27 m. Within the area magnetometric and georadar observations were made.

In Grave 5 (determined from dubious sources) a detailed magnetic surveys and georadar measurement plane and a profile of ERT was performed.

Also magnetic surveys with an area of 15×15 m at the Tomb 6 were made (determined from dubious sources). Within the area a failure depth of 1.2 m was recorded probably the root system of a tree that fell (similar failures are found).

Fig. 3. Reduced example of Photoplan in modern situation for the year 2010 put on aerial image obtained in 1944

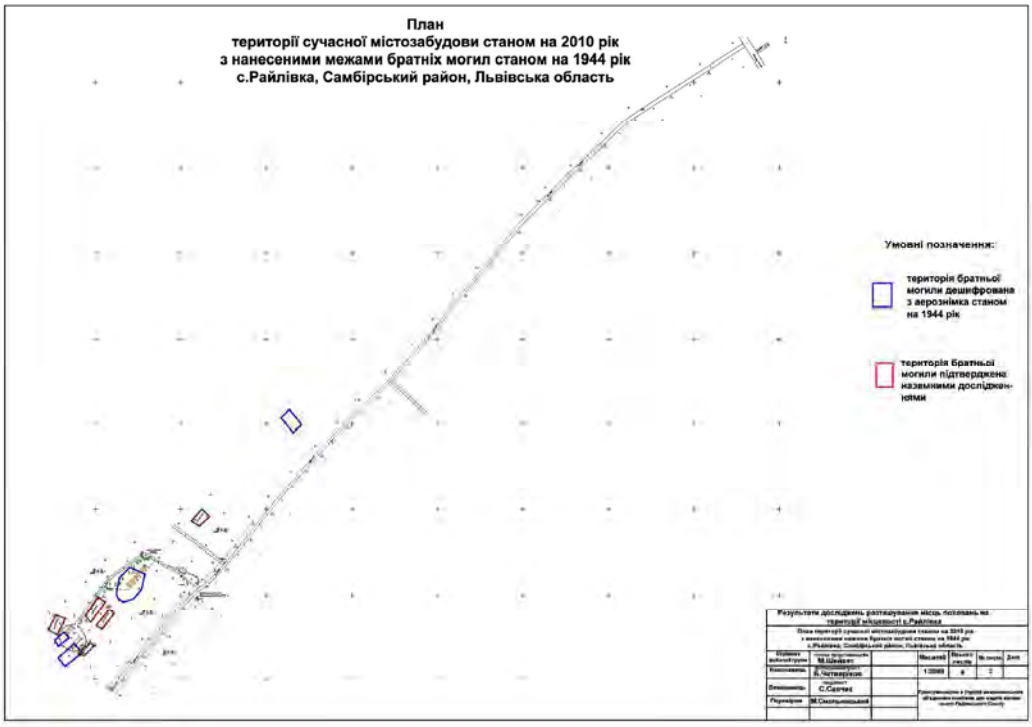

Fig. 4. Reduced example of the plan of the modern situation for the year 2010 coated outside of fraternal graves as of 1944

Results

The results of the metal detector survey

In addition to debris inn the area by using the metal detector 30 artifacts were discovered from the Second World War. This included a sleeve from a Mannlicher rifle and a Mauser, a TT pistol, ammunition, a coin dated 1941, and metal clothes elements (Fig. 6).

The most informative finding for setting places of shooting is sleeve because it is actually at the scene of the crime.

Within the surveyed sites eight shell casings from bullets and four cartridges 50 x 8 to R rifles Manlihera 1886/90, 1888/90, 1895 were found. After the seizure of Austria by Nazi Germany in 1938, a significant number of captured rifles Manlihera Austrian military depots entered service German security and police forces, including special groups formed for the destruction of the Jewish population in the occupied territories of the USSR: aynzatshrupy (Ger. Einsatzgruppen der Sicherheitspolizei und des SD, shorten. EG – target groups, group expansion); of the Auxiliary Police (Hilfspolizei) and subordinate battalions punitive Schutzmannschaft-Bataillonen (Ger. shorten. Schuma – security team from Schutzmann – shooter) [Kashevskyy, 2004].

Within the research area come five cartridges and one bullet of Mauser rifles and carbines 1888, 1898, 1898k. The Mauser rifle 1898k was the main weapon of ground forces of the Third Reich [Beetle, 1992; Shaulskyy et al., 1997].

Sleeves of Mannlicher rifles and Mauser centered around the fraternal graves which were deciphered from aerial photographs. Balls of these rifles and ammunition pistol TT, and items of clothing were found far from the graves.

Results of geophysical investigations and their complex interpretation

In order to understand what geophysical markers may be declared as characteristics of mass graves it is necessary to clarify the question of the construction of graves and conducting executions.

The construction involves primarily the grave's destruction of the natural soil structure. If filling graves differ in their physical properties from the surrounding soil, the device records the corresponding geophysical anomaly. It should be taken into account that natural genetic soil horizons significantly differ in chemical, physical and electrical properties.

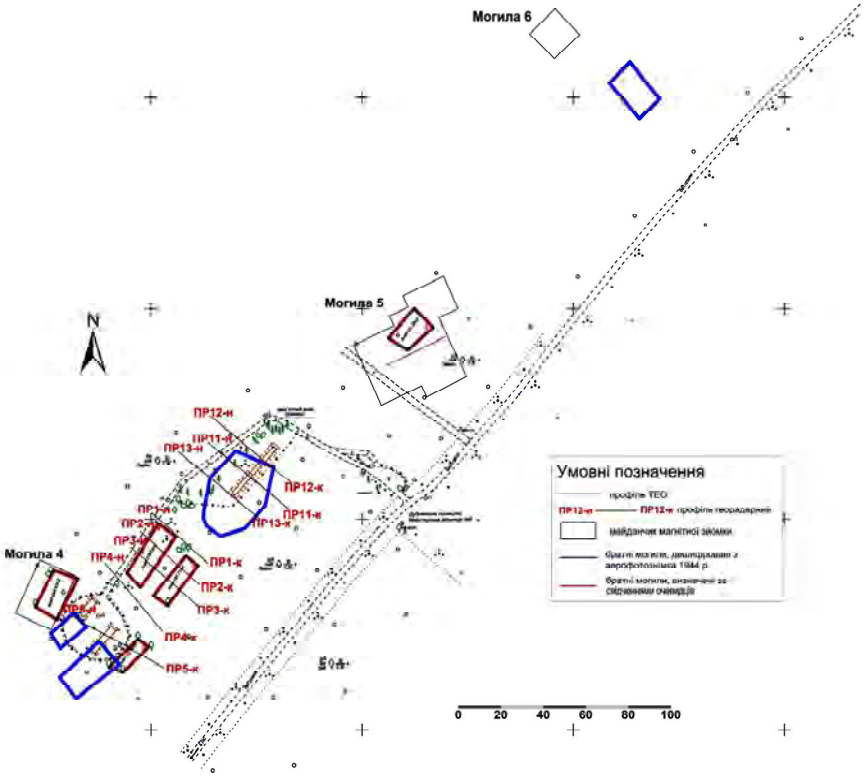

Fig. 5. Scheme of the areads and profiles of geophysical studies on topographical plans of the places of mass executions near the village Ralivka

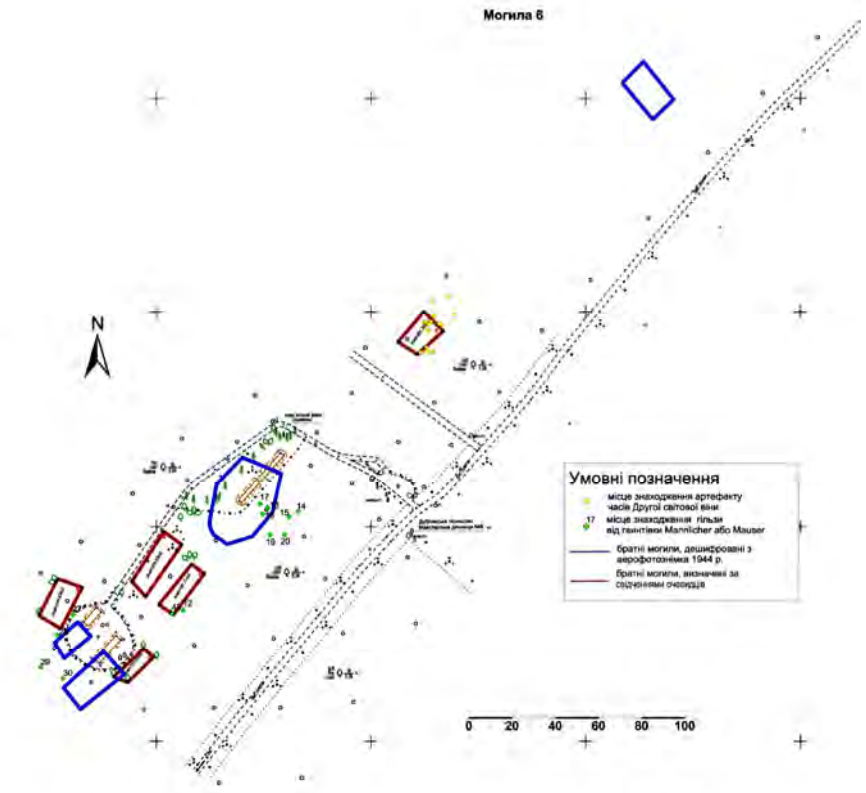

Fig. 6. The spatial distribution of the findings on the topographical plans of places of mass shootings near the village. Ralivka

Soil study site is sodpodzolic. Its main feature is the presence of alluvial horizons. Within podzolic clay particles, mineral and organic substances were made with water from the upper alluvial layer of soil deposited in the lower part, forming a kind of barrier, or boundary, which is diagnosed using probing geophysical methods. The alluvial horizon is a light, sandy texture, density with moving electric charges that are very low, hence high resistance [Banton et al., 1997, Pozdnyakov et al., 1996, Ardekani et al., 2014].

An example is the background geoelectrical section PR2 (Fig. 7), which has a three-layer structure: the top (eluvial) layer (0–0.7 m) is characterized by high electrical resistance values (60-300 Homme), in the low layer, but at depths > 2.5 m its resistance increases again.

Thus, a sign of the natural structure of this geoelectrical section in the area of research is the availability of a high-resistance layer at the top.

However, remember that layers with high resistance can be created artificially. A striking example is the embankment on the macadam path and around the symbolic graves. They are illustrate a good georadar method.

Comparison electrical resistance tomography results and profiles on georadiolocation PR11, PR12 and PR13 geophysical criteria were used to determine the presence of mass graves. Hereis the availability of high-resistance breaks in the continuity of the upper layer. It should be borne in mind that the data recorded by visual inspection and georadiolocation macadam mound anomalies can also create high resistance on the surface of a mass grave (Fig. 8–9).

Thus, the profiles PR11 undisturbed alluvial horizon is present only in the eastern part, ranging from 23 m at the beginning of the profile.

In a high-profile the PR12 horizon disappears in 12 m and reappears in the range of 20.5–25.5. Other areas associated with high resistance path include poured gravel, and crushed stone “pads” near the symbolic burial mound. In strict compliance with all criteria on geophysical profiles PR12 can identify the boundaries of two separate pits (Fig. 9).

The high contrast horizons cut by electrical resistance within PR13 profile do not allow to perform the field data inversion method with a regularized objective function combined with the weighted average method of least squares [Binley and Kemna, 2005], which implemented the program ProfileR. Thus, in Fig. 9, and the results are presented using the Occam inversion program ZondRes2d.

In areas where precision made magnetic pickup, anomalies that may be associated with mass graves, were found.

Thus, geophysical methods significantly limit one of the fraternal graves in the memorial complex where at least two trenches were found.

Using the results of geophysical studies failed to clarify the binding of aerial images in 1944. Focus was shifted 11 meters to the northeast, which compared with the previous, desk geometric correction.

Refined topographical situation on the memo is shown in Fig. 11.

Important markers to establish the spatial limits of executions carried out superficial findings during World War II. Evidence of acts of destruction of the Jewish population in the village Ralivka includes shells and bullet ammunition.

The illustrations clearly show the material (liner) and intangible (geophysical) evidence of mass graves confined to the area of the memorial complex.

The biggest brotherly grave, marked with resulting photogrammetric studies and confirmed by geophysical methods, allowed confident stating the effectiveness of the combination of these two technologies.

Scientific novelty and practical significance

The technique that combines photogrammetric and remote ground geophysical surveys in determination of mass graves from the World War II, with reliably and with sufficient accuracy to determine the memorial places on modern maps.

This technique complements the results of remote sensing methods for determining destroyed historical sites that do not provide 100 % accuracy of their location, together with ground nondestructive investigations in the case where the archaeological survey impossible.

The resulting cartographic materials and research results should be used to display historical events that occurred in the study area. Results of this work offer property preservation of the cultural heritage department of the Lviv regional council, as an object of cultural heritage passports.

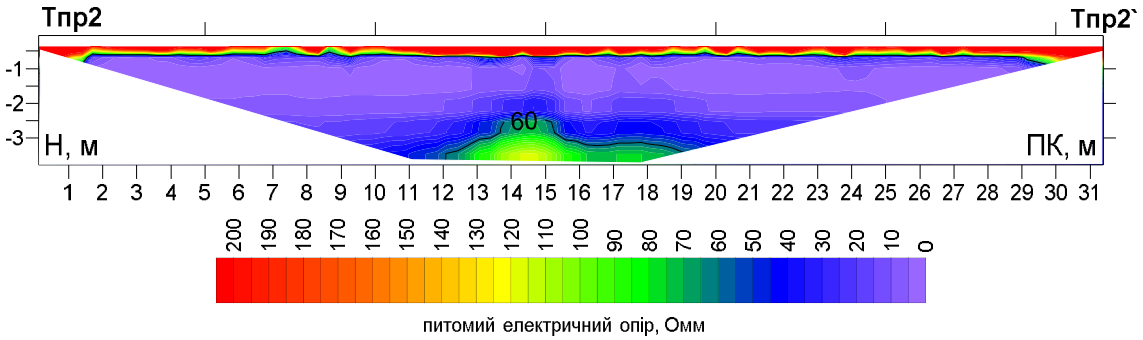

Fig. 7. Example of background geoelectrical section Ralivka area. Profile PR2 inversion performed using ProfileR software

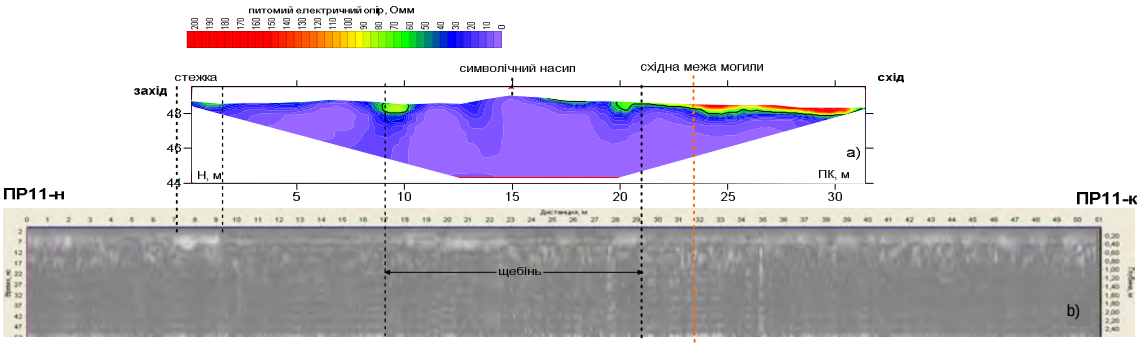

Fig. 8. Geophysical models of the structure of the subsurface of the section in the profile PR11n-PR11k according to the ERT (a) and georadiolocation (b)

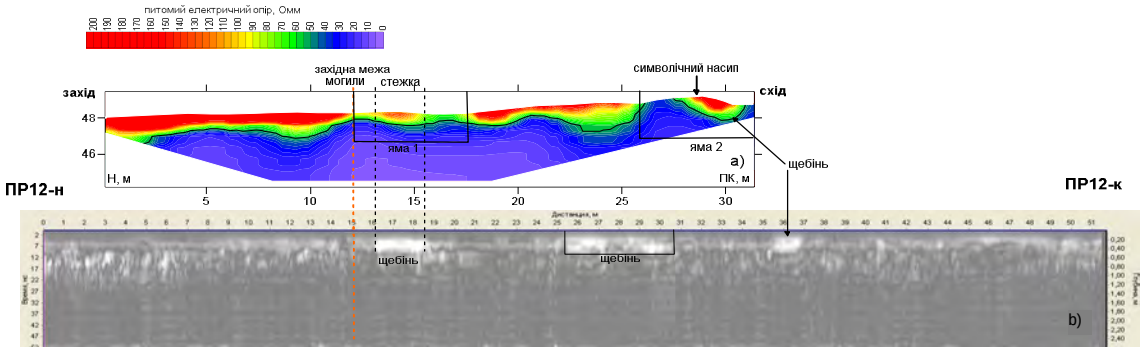

Fig. 9. Geophysical models of the structure of the subsurface of the section in the profile PR12n-PR12k according to the ERT (a) and georadiolocation (b)

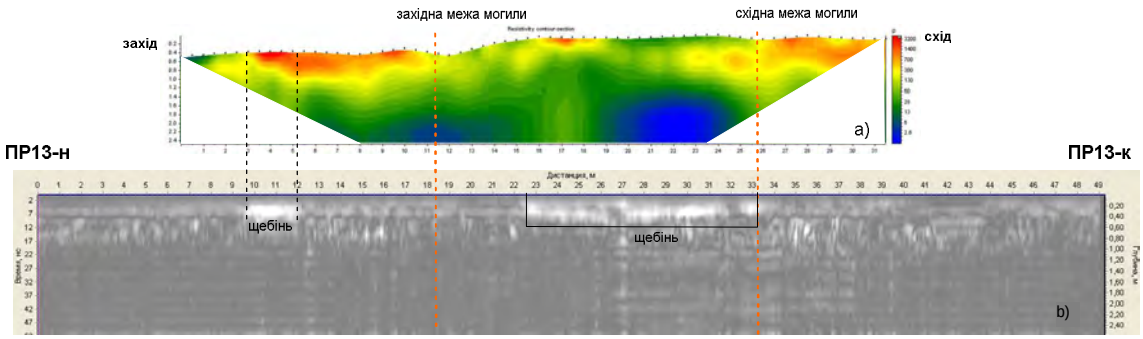

Fig. 10. Geophysical models of the structure of the subsurface of the section in the profile PR13n-PR13k according to the ERT (a) and georadiolocation (b)

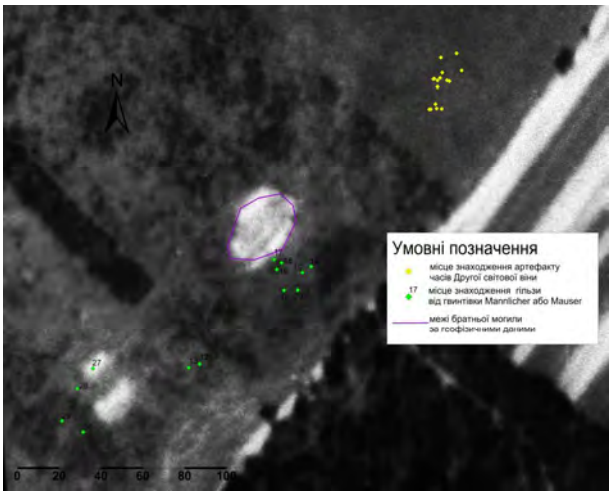

Fig. 11. Specified boundaries of fraternal graves in the results of photogrammetric and geophysical of research in the plan of the place of mass executions during the Holocaust at the village Ralivka

Conclusions

As a result of the processing, the complex technology contained a compatible combination of distance learning methods for determining the mass graves following metal detector and geophysical surveying which discovered perturbed terrain, and received the following:

- in GIS MapInfo and Erdas Imagine are created inspection plans for such perturbed land areas as in 1944, which is likely mass grave territories including events that occurred in the area during World War II.
- metal detection determined by examination of the spatial distribution of the findings from the Austrian rifle cartridges and shotgun Manlihera system "Mauser" gave a marked search area of the mass graves, which actually was a zone of executions in 1944
- unification of results obtained by methods of electrical resistance tomography and georadiolocation accounts allows geophysical criteria to recognize the presence of mass graves having a high-resistance gap in the continuity of the upper layer. It should be borne in mind that the data recorded was by visual inspection and georadiolocation macadam mound anomalies can also create high resistance on the surface of a mass grave. Integrated use of these methods avoid erroneous interpretations.
- as a result of the comparison data geophysical observations with modern topographic situation and archival aerial images in 1944 established the location of one of the graves, and binding of the specified picture.

Ground inspection area defined by photogrammetric study results revealed a significant number of artifacts from World War II, confirming the holding of mass executions in the area. Also, geophysical methods confirmed the location of the largest mass graves identified using the photogrammetric method.

The foregoing suggests the effectiveness of the proposed method combining two technologies at research sites of mass executions and burials without destructive interference in the soil layer, which is important for the Jewish religious community.

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ВИЗНАЧЕННЯ РОЗТАШУВАННЯ ІСТОРИЧНИХ ОБ'ЄКТІВ ЗА ДОПОМОГОЮ ФОТОГРАММЕТРИЧНОГО МЕТОДУ ТА МЕТОДІВ НАЗЕМНИХ НЕРУЙНІВНИХ ДОСЛІДЖЕНЬ

Мета роботи – запропонувати та опрацювати комплексну методику поєднання дистанційного методу з наземними неруйнівними методами для встановлення та відображення території братських могил біля с. Ралівка, на сучасних картографічних матеріалах. **Методика.** Запропоновано методику визначення місць масових поховань часів Другої світової війни, що поєднує дистанційні методи (інтерпретація знімків) та наземні неруйнівні методи (геофізичні дослідження та металодетекторний пошук). Фотограмметричне оброблення архівних аерознімків 1944 року містить три етапи: прив'язка матеріалів, що використовувались до єдиної умовної системи координат (у разі архівного аерознімка геометрична корекція виконувалась за опорними точками, що збереглися); синтезація зображень на цю територію за різні часи та визначення істинних меж поховань; підготовка вихідних матеріалів. На першому етапі зареєстровано архівні аерознімки та сучасний космічний знімок у програмному пакеті ErdasImagine з похибками до 3 метрів і збережені в форматі GeoTIF. Далі відбувалась інтерпретація архівного аерознімка та перенесення меж дешифрованих братських могил на сучасну містобудівну ситуацію. Кінцевим етапом цього методу є генерація результуючих матеріалів досліджень. Вхідними даними для проведення геофізичних досліджень були результати геометричної корекції та дешифрування на аерознімках територій масових поховань. Під час робочих виїздів виконувалися такі дослідження: магнітне знімання; металодетекторний пошук на всій території загалом та перевірка магнітних аномалій; дослідження методом томографії електричного опору; георадарні та ґрунтознавчі дослідження. **Результати.** На основі інтерпретації архівних аерознімків 1944 року попередньо встановлені місця масових розстрілів та поховань часів Другої світової війни. За допомогою металодетекторного обстеження підтверджено факт масових розстрілів на дослідній території на основі знайдених гільз від німецької зброї. Наземними геофізичними дослідженнями також визначене розташування самих братських могил, що, своєю чергою, дало змогу уточнити просторову прив'язку цих та інших об'єктів на аерознімках 1944 року. **Наукова новизна.** Запропонована методика, що об'єднує дистанційні фотограмметричні та наземні металодетекторні і геофізичні дослідження визначення масових поховань часів Другої світової війни дає змогу достовірно та з достатньою точністю визначати меморіальні місця на сучасних картографічних матеріалах. Ця методика доповнює результати дистанційних методів визначення зруйнованих історичних об'єктів, що не дають 100 % точності їхньої локалізації, наземними неруйнівними дослідженнями у випадку, коли археологічні обстеження неможливі. **Практична значущість.** Отримані картографічні матеріали та результати досліджень доцільно використати для відображення історичних подій, що відбулись на досліджуваній території. Застосована комплексна методика дала змогу підтвердити факт масових розстрілів і наявність поховань без руйнівного втручання до ґрунтового шару, що має велике значення для представників єврейської релігійної громади. Результати цієї роботи пропонуються відділу збереження культурної спадщини Львівської обласної ради як додаток до Паспорта об'єкта культурної спадщини.

Ключові слова: архівний аерознімок; дані дистанційного зондування Землі; геофізичні дослідження; фотограмметричні дослідження; братські могили.

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