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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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The aim of the research was to determine the territory of the mass graves near Ralivka village (Lviv region) using archival data and to display them on modern maps. To define the place of mass executions and burials from the World War II period applying ground geophysical methods on the locations pre-defined from the archival aerial images obtained by the Germans in 1944. **Methods.** The methodology for determining the locations of mass graves combines remote sensing (interpretation of aerial images) and ground non-destructive methods (geophysical techniques and metal detecting). Photogrammetric processing of archival aerial images from 1944 was divided into the following three stages: 1) transformation of the used materials to one coordinate system (in the case of archival aerial images transformation by preserved reference points was performed); 2) overlaying of the images from different dates to determine the true boundaries of graves; 3) preparation of the resulting maps. At the first stage archived aerial image and modern space images were georeferenced using Erdas Imagine software with errors up to 3 meters and stored in GeoTIF format. Then the interpretation of archival aerial images was performed and defined boundaries of mass graves were transferred on modern maps. The final stage was the generation of the resulting materials. Input data for the geophysical research was the data obtained by the photogrammetric method. During the field work the following studies were carried out: metal detecting of WWII artifacts, magnetic survey; electrical resistivity tomography (ERT); ground penetrating radar (GPR). 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 confirmed and refined. **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. Metal detecting revealed presence of gun cases from German weapon. These finds support the suggestion about mass executions on the territory. Ground geophysical studies confirmed the location of mass graves and improved georeferencing of other objects from old aerial images. **Scientific novelty**. The proposed methodology that combines photogrammetric and geophysical techniques for determination of mass graves of World War II time allows to locate them reliably and with reasonable accuracy on modern maps and on the ground. **The practical significance.** The obtained cartographic materials and research results should be used to study the historical events that took place on the territory. The applied complex technique allowed to confirm the fact of mass shootings and the presence of burials without destructive intervention to the soil layer, which is of great importance for representatives of the Jewish religious community. The results of this work are offered by the Department of Preservation of the Cultural Heritage of the Lviv Regional Council as addition to the Cultural Heritage Site Passport.

Key words: archival aerial image; remote sensing data; geophysical techniques; ground penetrating radar; electrical resistivity tomography; mass graves.

Introduction

Many examples of demolition by neglect of historical and cultural heritage objects can be found in modern cities and villages of Ukraine. 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 tragic events of WWII must be carefully investigated and preserved to prevent their recurrence in the future.

The village of Ralivka witnessed the massacre of many Jews in the WWII period, who were brought here from the neighboring towns of Stary Sambir (Old Sambir) and Sambir (Sambor), including their outskirts. From the archival bibliographic sources we know that in 1942 Jewish ghetto was created in Sambor, where Jews of Staryi Sambir were forcibly herded. With the liquidation of the ghetto at 9th of June 1943 all Jews were

driven out to the forest near Ralivka (4-5 km from Sambir) and gunned down [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. Based on the interpretation of archival images combined with non-destructive ground research the exact location of mass graves can be defined and the descendants of the victims finally can receive a response where their ancestors were buried.

Aim

The aim of the research was to determine the territory of the mass graves near Ralivka village (Lviv region) using archival data and to display them on modern maps. To identify the place of mass executions and burials from the World War II period applying ground geophysical methods on the locations pre-defined from the archival aerial images obtained by the Germans in 1944.

Methods and study area

The methodology for determining the locations of mass graves that combines remote sensing (interpretation of aerial images) and ground non-destructive methods (geophysical techniques and metal detecting).

The mapping of historical objects on the base archival graphic materials were engaged a large number of both domestic and foreign scientists, among which should be mentioned Dyshlyk O. Makarov S., M. Jasinski, M. Telegin, Hnera 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 researchers have identified objects that survived to our times, or objects specified through combination of remote sensing methods and archaeology. When planning archaeological research it is often impossible to obtain all necessary information from the remote sensing methods only. In case of WWII mass graves it does make sense to act according to methodological scheme combining remote sensing research methods with ground non-destructive methods.

Ralivka experimental area is located near the eponymous village in the vicinity of Sambir city (Lviv region) (Fig. 1).

There is a group of mass graves on the area located in the forest in 40 to 150 m from the concrete road going to the abandoned military base.

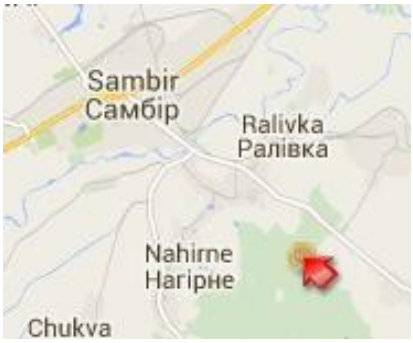

Fig. 1. Location of the research area Ralivka

The Memorial complex, created in 1999-2001 is situated within the area. There are also small concrete columns in the forest, 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 methodological scheme was applied (Fig. 2). It combines photogrammetric research with on-ground metal detecting and geophysical research. Results of photogrammetry serve as a base for subsequent ground surveys.

Photogrammetric research

The input materials to determine the boundaries of mass graves were: German archival aerial image from 1944; the topographic plan created in 2010 at a scale of 1:1000; modern space image of the research area that was obtained from GeoEye-1 satellite in 2009. Interpreting the German archival aerial image one can clearly see the damaged areas that likely represent the mass graves of Jewish population exterminated in this area by Nazis during the retreat.

The technology of image processing in order to define the true boundaries of mass graves [Arnoud de Boer, 2010, Bartoněk D., 2012, Matoušek, V., 1994]. The work was performed in MapInfo software and was conditionally divided into 3 phases:

- transformation of materials and georeferencing to uniform coordinate system (in the case of archival aerial image carried out by reference points corresponding to preserved objects);
- collecting and comparing images of different dates in order to determine the true boundaries of burials;
- preparing of resulting cartographic materials.

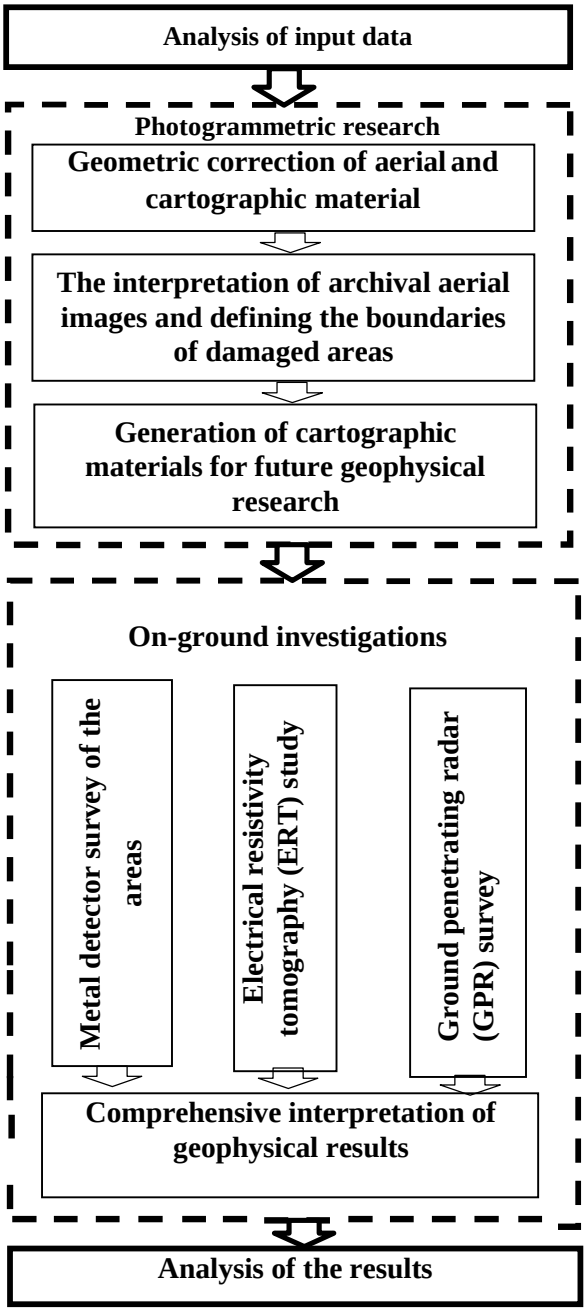

Fig. 2. Methodological scheme for determination of the mass graves locations using photogrammetric, metal detector and geophysical investigations

Transformation of materials and georeferencing to uniform coordinate system.

With the help of MapInfo Professional all graphic materials listed above were georeferenced to uniform conventional coordinate system in the internal projection applications Layout (meters). The graphical materials had the following accuracy:

- 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;
- 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 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 the area of different dates and determination the true boundaries of graves [Blažková, T., Matoušek, V.,2008, Remondino, F., 2006].

Combining of images was performed in the following sequence:

- overlaying of the topographic plan created in 2010, scale 1 : 1000 with German archival aerial image obtained in 1944, from which it became possible to decipher forest area boundaries;
- combining modern space image and archival German aerial image obtained in 1944, from which it became possible boundaries of possible burials.

Preparing of resulting materials.

The resulting topographic plans were generated at a scale of 1: 1000. All graphical documents have been prepared using MapInfo and reduced to A2 page size.

The following graphical documentation was generated for further ground research:

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

Methods of ground research

Ground studies included metal detector survey and geophysical measurements on the areas of fraternal graves deciphered from archival aerial photographs. Measurements were also performed on other possible locations of graves, these include places shown by local residents or obtained from other unverified sources. Such graves are marked with red lines on Fig. 3-6.

Geophysical investigations were performed using various methods.

In order to study the vertical structure of the burial complex, finding mass graves and determining their size and depth, we made 2D ERT (electric resistivity tomography) measurements using multi-electrode device [Khomenko et al., 2013] with a distance of 0.5 and 0.25 cm between electrodes.

GPR (ground penetrating radar) observations were carried out using VIY-2-300 device by "Transient technologies" (Kyiv, Ukraine), which has 300 MHz frequency antenna.

Magnetic measurements were performed using cesium magnetometers PKM-1 (Heolohorazvedka, Russia).

Geophysical measurements were carried out along profiles and within the areas indicated on Fig. 5.

In the vicinity of the Memorial, five clearings were made in the forest, in which we conducted profile geophysical observations - magnetometric, and GPR (ПР1- ПР5) and one ERT profile.

GPR and ERT studies were conducted along three profiles (ПР11- ПР13) crossing the largest grave deciphered from the aerial image of 1944.

On the grave 4 (by photogrammetric data) magnetometric and GPR observations were made within the area of 18×27 m.

On the graves 5 and 6 (determined from unverified information source) a detailed magnetic survey, GPR and ERT measurements were performed.

Results

The results of the metal detector survey.

30 artifacts from the WWII time were discovered within the study area using the metal detector. There were gun cases from Mannlicher and Mauser rifles, TT gun ammunition, a coin dated by 1941, and metal elements of clothes (Fig. 6).

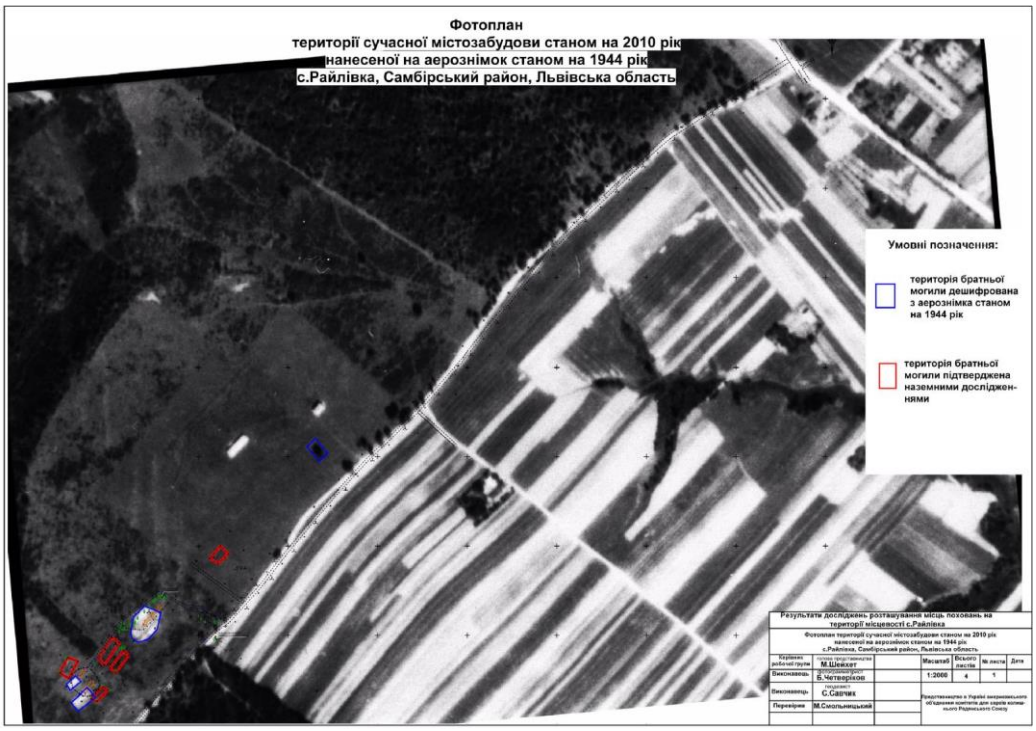

Fig. 3. Photoplan of modern situation for the year 2010 put on aerial image obtained in 1944 with fraternal graves deciphered from aerial image (blue lines) and obtained from unverified sources (red lines)

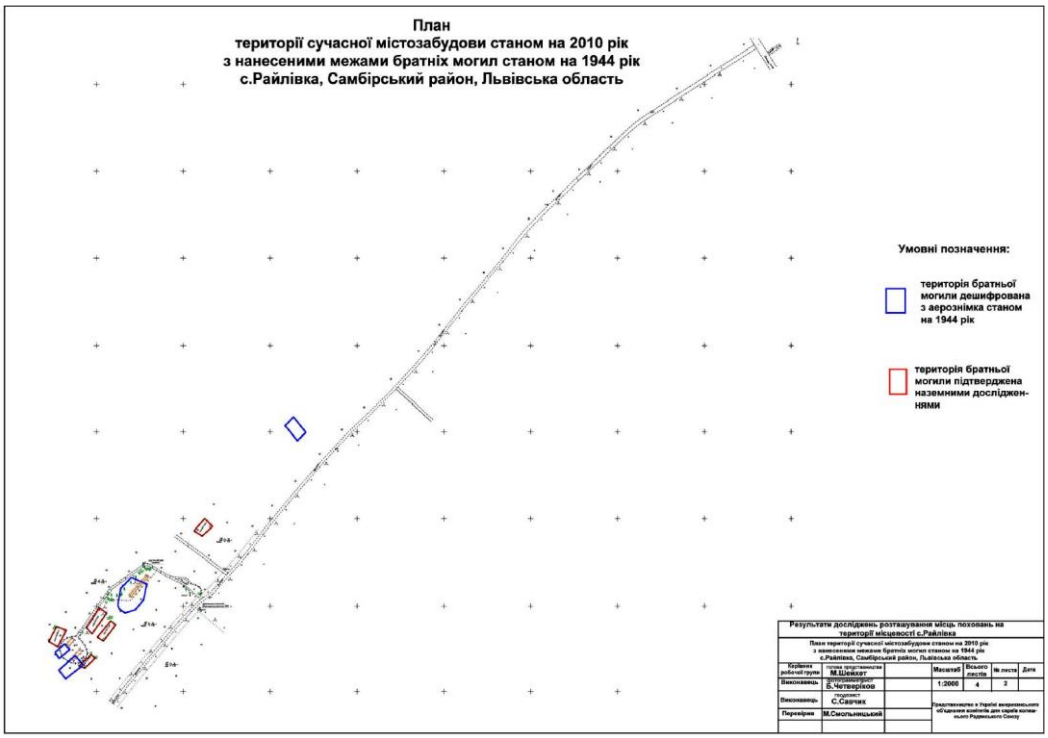

Fig. 4. Topographic plan of the modern situation for the year 2010 with fraternal graves deciphered from aerial image (blue lines) of 1944 and obtained from unverified sources (red lines)

The most informative finding for determing places of shooting is a gun case because it remains actually at the scene of the crime.

Within the surveyed sites eight gun cases and four bullets from cartridges 50x8R for Mannlicher rifles 1886/90, 1888/90, 1895 were found. After the occupation of Austria by Nazi Germany in March 1938, a significant number of captured Mannlicher rifles form Austrian military depots entered service with German security and police forces, including special groups formed for the annihilation of the Jewish population in the occupied territories of the USSR: einsatzgroups (Ger. Einsatzgruppen der Sicherheitspolizei und des SD, shorten. EG – target groups, expansion group); auxiliary police services (Hilfspolizei) and subordinate punitive forces Schutzmannschaft-Bataillonen (Ger. Schutzmannschaft shorten Schuma – security team from Schutzmann – shooter) [Drobyazko, 2005; Kashevskyy, 2004].

From 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 [Shaulskyy et al., 1997].

Gun cases from Mannlicher and Mauser rifles and carbines were concentrated around the fraternal graves which were deciphered from aerial photographs. Bullets of these rifles, Soviet TT gun ammunition, and items of clothes were found far from the graves (Fig.6).

Results of geophysical investigations and their comprehensive interpretation

In order to understand what geophysical and non-geophysical features may serve as indicators of mass graves it is necessary to clarify the question of the construction of graves and conducting executions.

First of all, the construction of grave leads to destruction of the natural soil layers. If the filling of the grave differs significantly in their physical properties from the surrounding soil, the geophysical device records the corresponding geophysical anomaly. It also should be taken into account that natural genetic soil horizons significantly differ in chemical, physical and electrical properties.

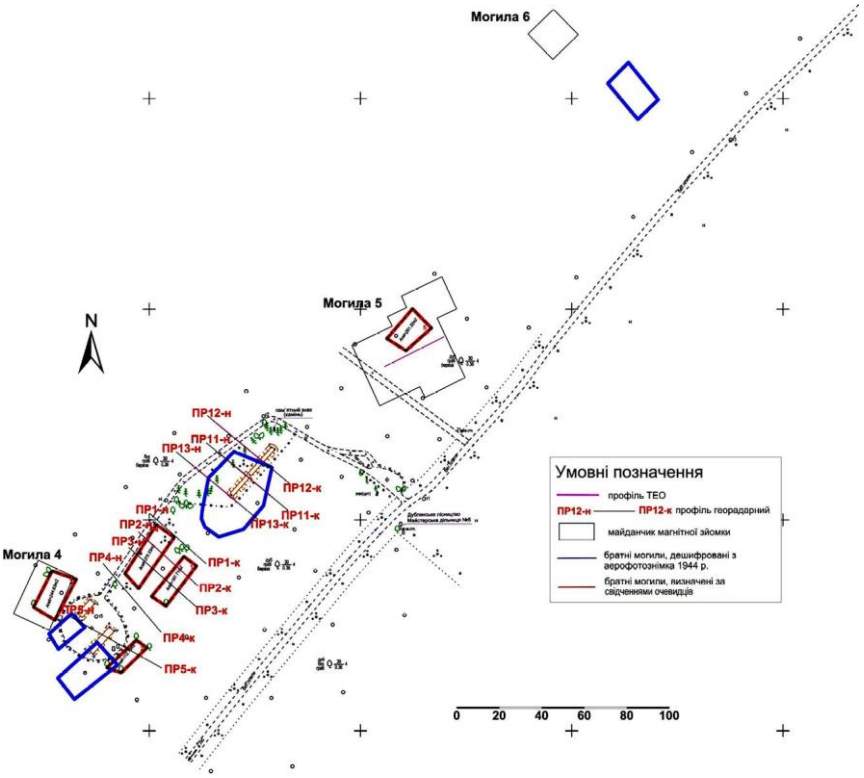

Fig. 5. Scheme of the areas and profiles of geophysical studies on the topographical plans of the mass executions site near Ralivka village

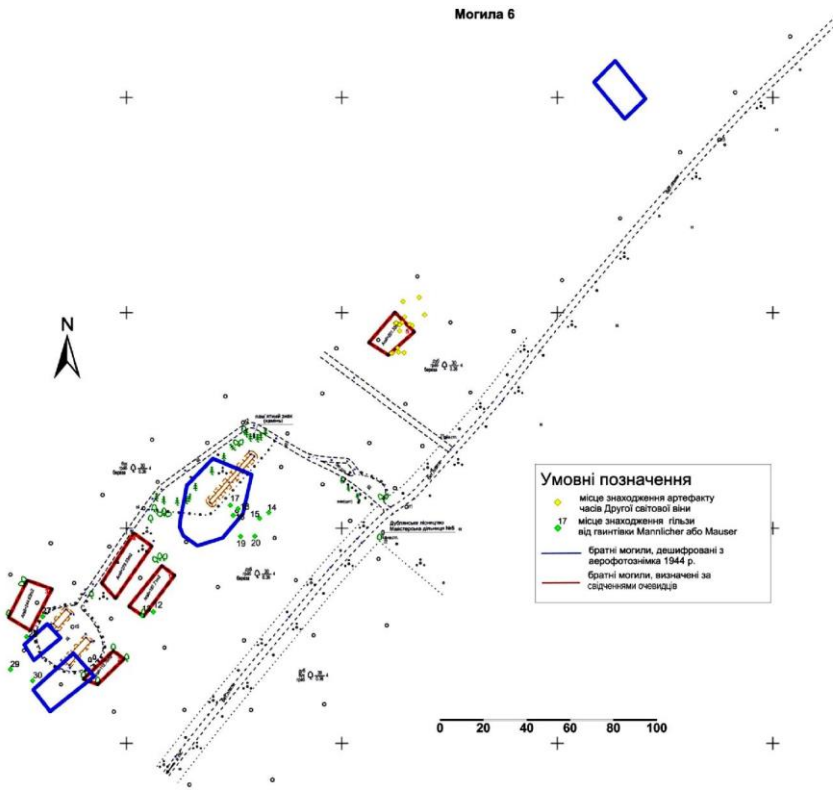

Fig. 6. The spatial distribution of metal findings (gun cases-green dots, bullets etc.- yellow dots) on the topographical plan of the mass executions site near Ralivka village

The soil on the study area is sodpodzolic with eluvail and illuvial horizons in its structure. In the process of podsolization, clay particles, minerals and organic matter, drawn by water from the upper eluvial layer of soil, were deposited in its lower layer (in the illuvial horizon), forming a peculiar barrier, the boundary which could be determined by sounding geophysical methods. The eluvial horizon has a light, loamy mechanical composition, the density of mobile electric charges is very low, hence it has the high resistivity. In the lower, illuvial horizon, saturated with clay particles and cations $Fe^{+2/+3}$, Al^{+3}, Mn^{+5}, the resistivity decreases significantly. [Banton et al., 1997, Pozdnyakov et al., 1996, Ardekani et al., 2014].

As an example of the background geoelectrical section the ПР2 profile could be considered (Fig. 7). It consists of three layers: the top (eluvial) layer (0–0.7 m) is characterized by high electrical resistivity values (60-300 Ohm*m), the middle layer has low resistivity, but at a depths > 2.5 m it increases again.

Thus, a high-resistivity layer at the top serves as indicator of the natural structure of geoelectrical section in the area.

However, we must remember that layers with high resistivity can be created artificially. A striking example is the crushed-stone bedding of the path and around the symbolic mounds. It is well-defined by GPR method.

Comparing ERT and GPR results on the profiles ПР11, ПР12 and ПР13 gives us reliable geophysical criterion, which can be used to determine the mass grave in particular conditions. This is a break in the continuity of the high-resistivity upper layer. It should be borne in mind that the crushed-stone bedding well-defined visually and GPR, can also create high resistivity zones on the surface above the mass grave (Fig. 8–9).

Thus, the profiles ПР11 covers undisturbed eluvial horizon only in the eastern part, ranging from 23 m from the beginning of the profile.

On the profile ПР12 the high-resistivity horizon disappears on 12 m and reappears in the interval of 20.5–25.5 m. Other zones of increased resistivity associate with path and crushed-stone bedding near the symbolic burial mound. In strict compliance with geophysical criterion the boundaries of two separate pits can be identified on the profile ПР12 (Fig. 9).

The significant contrast in the resistivity of soil horizons within ПР13 profile does not allow to perform the apparent resistivity inversion with ProfileR software [Binley and Kemna, 2005]. Thus, the result of Occam inversion in ZondRes2d software is presented (Fig. 10).

High-resolution magnetic measurements did not reveal any anomalies that might be associated with mass graves.

Thus, geophysical methods helped to identify reliably one of the fraternal graves in the Memorial complex, where at least two trenches were found.

Using the results of geophysical studies it was possible to refine the georeferencing of aerial image of 1944. The image was shifted 11 meters to the northeast comparing to previous photogrammetric georeferencing.

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

Finds of gun cases and bullets from World War II time are important markers to identify the spatial limits of shooting zone.

The illustrations clearly show the material (gun cases) and non-material (geophysical) evidences of mass graves confined to the area of the Memorial complex.

The biggest mass grave, defined from photogrammetric studies, was confirmed using ground geophysical methods. This suggests the effectiveness of combining these two technologies.

Scientific novelty and practical significance

. The proposed methodology that combines the remote photogrammetric and geophysical techniques for determination of mass graves of World War II allows to locate them reliably and with reasonable accuracy on modern maps and on the ground.

The obtained cartographic materials and research results should be used to study the historical events that took place on the territory.

The applied complex technique allowed to confirm the fact of mass shootings and the presence of burials without destructive intervention to the soil layer, which is of great importance for representatives of the Jewish religious community. The results of this work are offered by the Department of Preservation of the Cultural Heritage of the Lviv Regional Council in addition to the Cultural Heritage Site Passport.

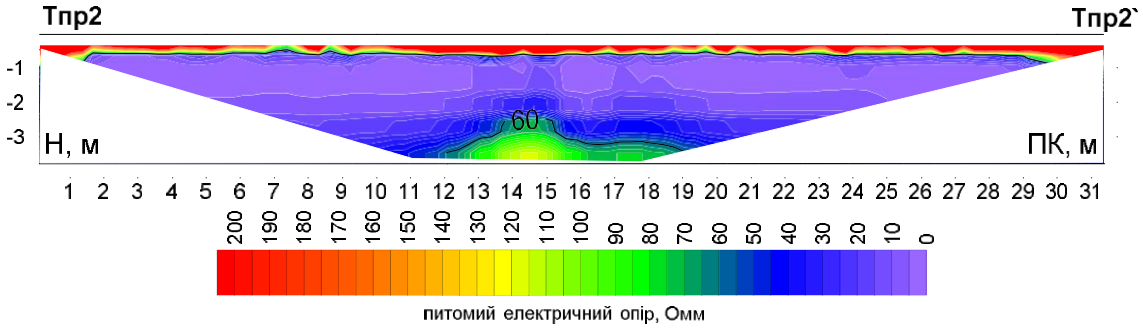

Fig. 7. Example of background geoelectrical section on Ralivka area. Inversion was performed using ProfileR software

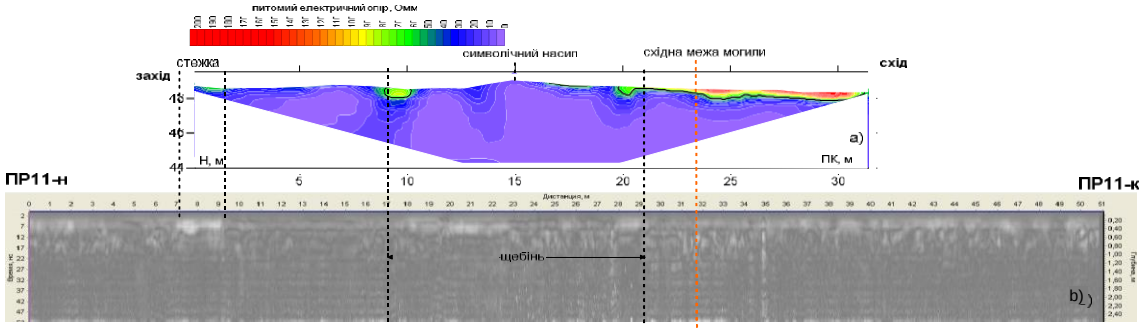

Fig. 8. Geophysical model of the subsurface along the profile ПР11н-ПР11к according to the ERT (a) and GPR (b) measurements.

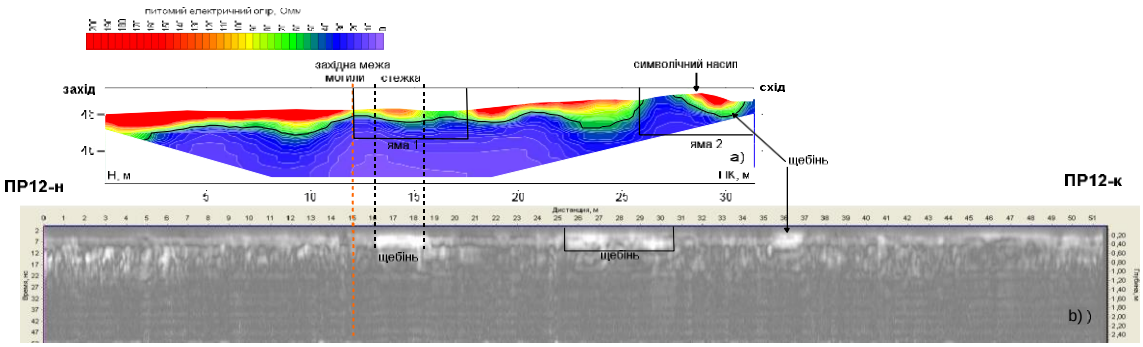

Fig. 9. Geophysical model of the subsurface along the profile ПР12н-ПР12к according to the ERT (a) and GPR (b) measurements

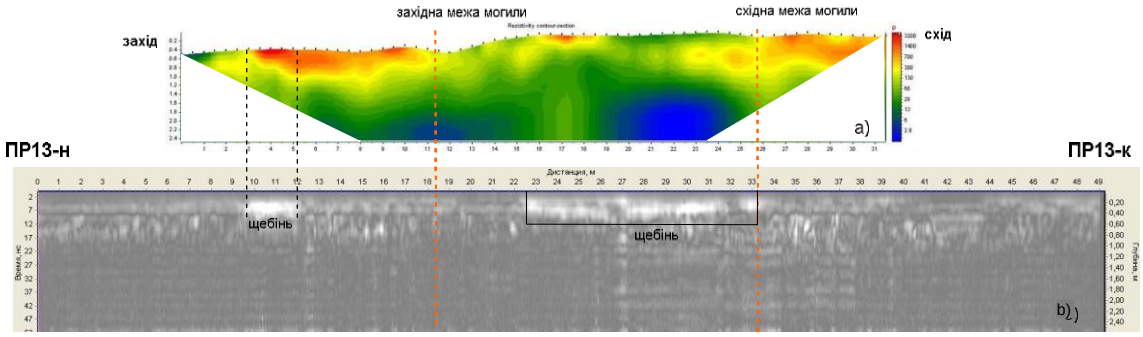

Fig. 10. Geophysical model of the subsurface along the profile ПР13н-ПР13к according to the ERT (a) and GPR (b) measurements

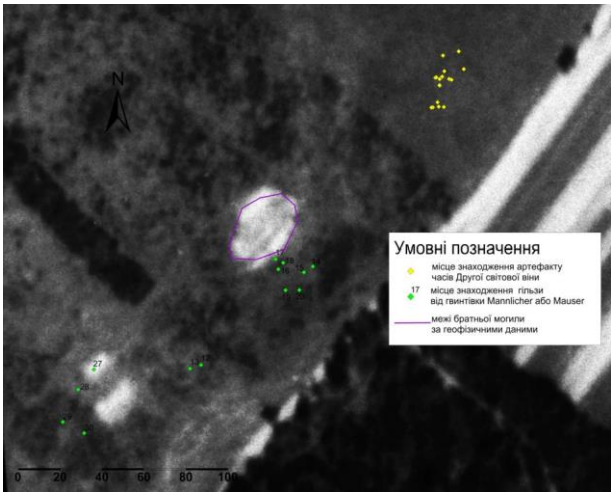

Fig. 11. Refined boundaries of fraternal grave based on complex interpretation of photogrammetric and geophysical data on the photoplan of the place of mass executions during the Holocaust at the village Ralivka

Conclusions

As a result of investigations of places of mass shootings during the Holocaust near the village of Raļivka, in order to determine the location and boundaries of graves using photogrammetric and ground-based methods, the authors managed to identify important search features and evaluate the informativeness of each method.

The MapInfo and Erdas Imagine GIS tools have been applied to display perturbated land in 1944, which is likely to be site of mass grave, taking into account the events that took place in this area during the World War II.

The spatial distribution of the findings of guncases from the Austrian rifle Mannlicher and the Mauser carbine allowed to outline a search area for mass graves, which was actually the shooting area in 1944.

Combining ERT and GPR results on the profiles allows us to recognize the presence of the break in the continuity of the high-resistivity layer as a geophysical criterion for the mass graves. The natural soil cover is destroyed here. However, it should be borne in mind that the crushed-stone bedding indicated by GPR and visually, may also create anomalies of high resistivity on the surface above the mass grave. Comprehensive application of methods avoids misinterpretation.

As a result of comparing geophysical observations with the current topographical situation, as well as archival aerial photographs in 1944, the location of the largest grave is established, as well as the georeferencing of the image refined.

Ground investigations on the territory determined by of photogrammetric studies revealed a significant number of artifacts from the World War II time, confirming the mass shootings on this territory. Also, geophysical methods confirmed the location of the largest mass grave determined by the photogrammetric method.

The foregoing suggests the effectiveness of the combination of these two technologies in the study of places of mass shootings and the search for burials without a destructive intervention to the soil layer, which is of great importance for representatives of the Jewish religious community.

REFERENCES

Ardekani, M. R.; Signal and Image Centre, Royal Military Academy, 30 Avenue de la Renaissance, 1000 Brussels, Belgium; Druyts, P. ; Lambot, S. ; De Coster, A. ; Neyt, X. (2014) Recovering the structure of a layered soil, including layer thickness and dielectric permittivity, using the interfaces and objects backscatter detected in GPR B-scans Ground Penetrating Radar (GPR), 2014 15th International Conference on. Abstract book., pp. 397-400, doi: 10.1109/ICGPR.2014.6970454

Arnoud de Boer. Processing old maps and drawings to create virtual historic landscapes e-Perimetron, 2010, vol. 5, no. 2, pp. 49–57.

Banton, O., M. K. Seguin, and M. A. Cimon. Mapping field-scale physical properties of soil with electrical resistivity. SoilSci. Soc. Am. J. 1997, 61, pp. 1010–1017.

Bartoněk D. Prediction model to identify the significant development periods of the historical objects. FIG Working Week 2012. May 6–10, 2012, Rome, Italy.

Binley, A. and A. Kemna, 2005, Electrical Methods, In: Hydrogeophysics by Rubin and Hubbard (Eds.), 129–156, Springer.

Blažková, T., Matoušek, V. Picture and Reality: Studies of the Modern Landscape in Vedute of Thirty Year´s War´s Battlefields of Bohemia. In: P. Szabó – R. Hédl (eds.), Human Nature. Studies in Historical Ecology and Environmental History, Brno, 2008, pp. 52–61.

Digital sourse. Available at: http://www.jewishheritage.org.ua/ua/1913/ralivka.html

Drobyazko S.I. *Pod znamyonami vraga. Antisovetskije formirovanija v sostave germanskih vooruzhennyh sil 1941-1945*. [Under the banner of the enemy. Anti-Soviet units as part of the German armed forces]. *Moskow*, 2005

Kashevskiy V. A. *Pehotnoe oruzhie Vtoroy Mirovoy voynyi* [Infantry weapons of World War II]. *Minsk, OOO "Harvest", 2004.*

Khomenko R., Bondar K., Popov S. *Nova malohlybynna bahatoelektrodna ustanovka vymiryuvannya elektrychnoho oporu.* [New Multifilament Multicellular Electric Resistance Measurement] *Visnyk Kyyiv. un-tu. Heolohiya.* 2013, issue 2(61), pp. 36–40.

Matoušek, V. Die Höhlenbesiedlung des Böhmischen Karstes vom Neolithicum bis zum Mitteralter, FAP 20, 1994.

Pozdnyakov, A. I., Pozdnyakova L. A. And A. D. Pozdnyakova. Stationary electrical fields in soils. (In Russian.) KMK Scientific Press, Moscow, 1996.

Remondino, F. Image-based modeling for object and human reconstruction. Ph.D. Thesis, ETH No 16562, Institute of Geodesy and Photogrammetry, ETH Zurich, Switzerland, Mitteilungen, 2006, no. 91. ISBN 3-906467-61-9, 174 p.

Shaulskiy E. V., Lebardin A. G., Berdnik P. V., Guz- dup V. A. *Kleyma na patronah i oruzhii. Spravochnoe posobie dlya ekspertov-kriminalistov* [Hallmarks on chucks and weapons. A guidebook for criminal experts.]. Mozhaysk, 1997.

Wilding, L. P., Smeck N. E. and G. F. Hall (ed.). Pedogenesis and soil taxonomy. I. Concepts and interactions. Developments in Soil Science, 11 A. Elsevier. Amsterdan, Oxford, New York, 1983.

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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 металоде- текторного 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 фотограммет- ричні 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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