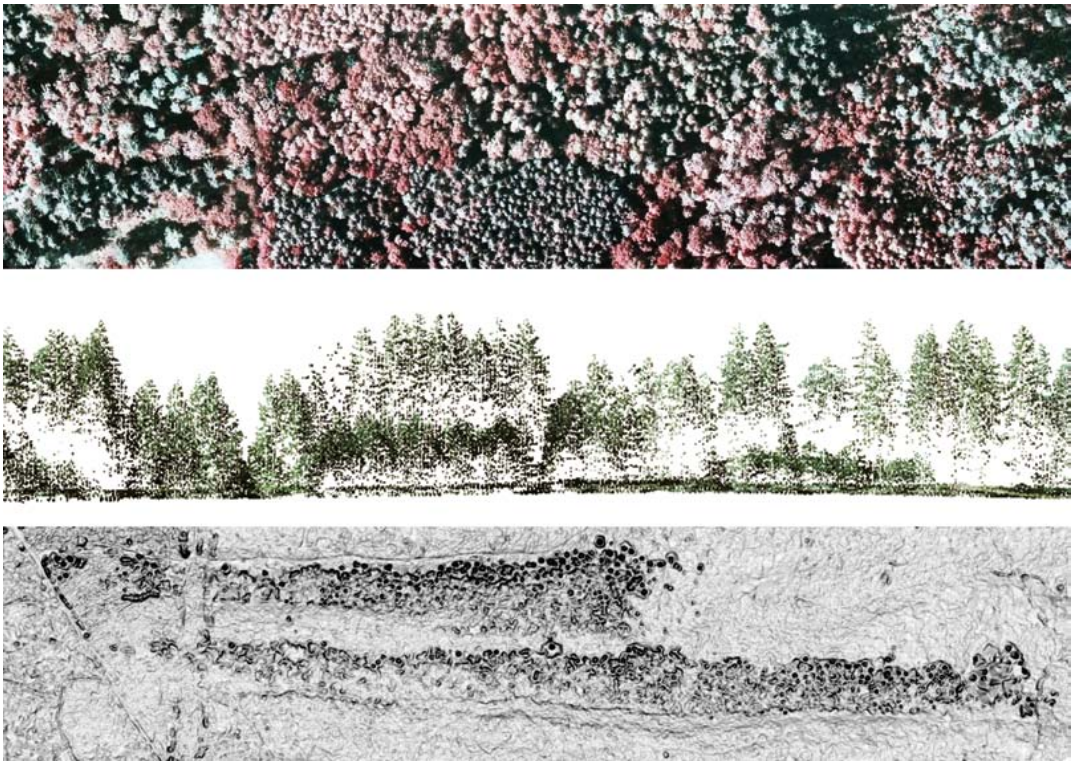
LASEROWI ODKRYWCY



LASER DISCOVERERS

NON-INVASIVE EXAMINATION AND DOCUMENTATION
OF ARCHEOLOGICAL AND HISTORICAL OBJECTS
IN THE ŚWIĘTOKRZYSKIE VOIVODESHIP

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STARE BABICE 2014

Laser Discoverers – non-invasive examination and documentation
of archeological and historical objects in the Świętokrzyskie Voivodeship

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Data analysis, on-site verification and an interpretation attempt

Bogumił Szady[10], Rafał Zapłata[11]

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1. DETAILED SITE-SPECIFIC WORK WITH DATA – SOCIETY AND SPECIALISTS

Non-invasive identification and inventory of objects of historical interest, particularly archaeological ones, in the "Laser Discoverers" project refers to the following two basic methods: (1) airborne laser scanning, and essentially the methods of processing and visualisation of geodata acquired by ALS (airborne laser scanning – hereinafter ALS) under the "IT System for Protecting the Country Against Extraordinary Threats" (hereinafter ISOK), and (2) surface studies.

Non-invasive studies based on the aerial laser scanning and data obtained as a result of measurements with the use of the said method, used in the identification, analysis and inventory of cultural heritage resources, are based on several key elements: (1) field work – collecting data (measurements), (2) processing and (3) the analysis and interpretation of acquired data, (4) field verification of obtained results obtained, and (5) the adjustment of geodata on the basis of field observations.

The first element, i.e. acquisition of data within the project, was carried out in the early stages of activities and based on the ALS data obtained from the resources of the Central Geodetic and Cartographic Documentation Centre which was generated under aerial measurements made for the purposes of the ISOK project. The second stage consisted in the processing of acquired data, including the reclassification of point cloud, which was also obtained in the earlier stages of work, in order to create a basis for the recognition of historic resources. The analysis and interpretation of the acquired and processed geodata was the third stage of work. The fourth element of the research procedure consisted in the field verification and summary of work results.

The correction of geodata based on field observations constituted the last stage. Each of these stages consisted of partial elements, such as the assessment of data quality, selection of DTM generation method, etc. Non-invasive methods of identifying anthropogenic objects include methods for finding potential monuments which directly relate to detailed site-specific work. There are two main approaches to searching and locating potential immovable historical monuments – the visual analysis of generated

geo-information products and the automatic and/or semi-automatic analysis (Possel, Lindenbergh, Storms 2010; Trier, Zortea, Larsen 2012; Bakuła, Ostrowski, Zapłata 2013). With regard to the project implemented, the recognition of historical resources was based on the visual analysis, both in relation to Internet users as well as professionals. Therefore, an essential element of actions taken under the project was to process and visualise geodata which was to provide as optimum material for the identification of potential historical objects as possible.

In the research process, the fundamental interpretation work starts from the moment of data processing and visualisation, when the researchers conduct work related to the identification of potential anthropogenic (historical) objects. In the research literature on the subject, there is a number of methods for the processing and visualisation of geodata, including hill-shading (hereinafter HS) and hill-shading from multiple directions (hereinafter HSMD), local relief model (hereinafter LRM), sky view factor (hereinafter SVF) as well as the principal component analysis (hereinafter PCA) (selected sources on the above-mentioned processing and visualisation of geodata Hesse 2010a; Hesse 2010b; Hess 2012; Donesu 2013).

In order to make the data available for analysis and interpretation in a most effective manner, the researchers selected the data visualisation method based on the hill-shading function (hill-shading from multiple directions), as this type of processing of geodata is largely intuitive, and thus understandable for an average project participant (a lower-secondary school student). Perception of an image which represented the simulation of a natural phenomena could also facilitate the interpretation process of Internet users (more information in chapter 4). Other types of geodata processing and visualization applied in the project, on the basis of the literature on the subject, among other things, were associated with the most effective geoinformation tools, including the local relief model filter (Benet et al. 2010; Kokalj, Zakšek, Oštir 2013; Zapłata, Ostrowski, Bakuł 2014; Zapłata, Borowski 2013).

The basic form of identifying potential objects of historical interest consisted in visual analysis on the screen of a computer, palmtop, etc. In the case of Internet users, it was based on shared online visualisation of the model of land surface processed with the

use of the hill-shading function (HSMD – 8 directions of insolation of the surface), displayed in the form of tiles – fragments of an area of 200×200 m (more information in chapter 4). With regard to the work of specialists, the visual analysis was based on several types of geodata processing: point cloud with applied texture, Digital Terrain Model, elevation map, shaded NMR map, and map generated with the use of the local relief model filter. The analysis of the research area was also carried out on the basis of contemporary maps, including topographical maps, selected archival materials and available remote sensing data.

Detailed site-specific work was also conducted based on publicly available data and information concerning the area of research – forests. On the basis of the above-mentioned data, the researchers primarily identified contemporary topographic objects of the area (roads, rivers, houses, etc.), which displayed on the geomatic visualisations, classifying this group as objects outside of the set of potential historical objects.

In order to perform detailed verification and compilation of the results of work of Internet users, as part of a partial task, an independent identification and documentation of potential historical objects was conducted on the basis of shared: (1) generated DTM, (2) elevation map, (3) results of the processing of geodata (LRM and HS/HSMD), and (4) point cloud. In the first place, the identification and designation of objects on the basis of the shaded map was performed. This was followed by the identification of the area based on the remaining results of geodata processing.

Under the project, relief shading maps (DTM) were generated – hill-shading maps for the entire area, based on which the researchers performed visual identification and selection of potential objects / groups of objects designated for further field verification. In total, based on the above-mentioned processing results, at the initial stage of work as many as 3157 potential historical objects were identified: 2751 oval, 285 linear, 8 unspecified, 19 linear unspecified, 48 square objects, 19 objects associated with the extraction of natural raw materials (including mines which existed even in the 20th century, but are currently closed)[12], and 27 linear objects / war trenches.

[12] The total reported number refers to particular clusters rather than individual objects, e.g. potential wells, pits or ore holes.

At the same time, maps based on the processing with the use of the local relief model (hereinafter: LRM) were generated under the project for the entire area, on the basis of which the visual identification and indication of potential objects was performed. Based on the LRM processing results, the following types and amounts of potential historical objects were identified: 5304 oval, 840 linear, 8 unspecified, 19 linear unspecified, 48 square objects, 19 objects associated with the extraction of natural raw materials (including mines which existed even in the 20th century, but are currently closed)[13], and 27 linear objects / war trenches. As part of detailed site-specific work, elevation map was also applied and served as the basis to complement and support the analyses and interpretations of the results of HS/LRM processing.

The work also included the analysis and interpretation of the point cloud in the form of "forest" data (textured data), which mainly enabled the researchers to perform additional and complementary identification of the context of occurrence of objects, as well as additionally supported the identification of potential objects, particularly in relation to the analysis of the surface and low vegetation, branches lingering on the area, and other elements which could be classified as the surface of the area. Generally, this type of work was performed in specified places on indicated areas.

The analysis of processed geodata provided results which are presented in three groups of objects. Groups of objects intended for field verification based on the results of analyses performed by specialists:

group I – objects and/or clusters of objects with specific features (and elements) known from archival data (e.g. post-mine objects with specific or approximate location) and potential objects or clusters with specific features (and elements) (e.g. probable charcoal piles);

group II – objects and/or clusters of objects with ambiguous features (e.g. contour, cross-section) and/or vague elements (e.g. resulting from low density of point cloud at the ground level);

[13] As above

group III – areas in the case of which no objects were identifies, among others due to low density of points on the surface.

During the detailed site-specific work was identified a problem with the quality of ISOK data. Referring to the previous chapter, where there was a discussion on the accuracy of the ALS method, it is very important to note the land cover laser measurement diversity.

In many places the measurement of the land is very rare. This fact partly or even (in certain areas) completely eliminates the possibility indication of any anthropogenic objects at various processing.

This situation indicates the needs for repeated measurements of ALS, aimed at supporting the diagnosis for potential monuments.

2. THE CONDUCT OF SURFACE SURVEYS AND RESEARCH METHODOLOGY – THE AVAILABILITY OF SURFACE SURVEY AREA AND OBSERVATION CONDITIONS

Surface work was carried out with reference to the results of the detailed site-specific work whose principal aim was to identify and indicate potential historical objects. At the stage of detailed site-specific work (with the participation of Internet users), several thousand potential anthropogenic objects were identified (to be discussed in more detail later in the text), also indicating selected areas for which the ALS measurement proved to be insufficient due to weather conditions and situation on the ground (dense vegetation, etc.) during the measurements.

Therefore, the general research procedure was applied, postulating such approach in future research work with the use of the ISOK data:

1. analysis and interpretation of the processed resource of geodata/ALS (detailed site-specific work),
2. indication of potential anthropogenic/historical objects (detailed site-specific work),

3. verification of indicated objects in the trial/test areas,
4. verification of test areas (group III) with low density of points on the ground (Zapłata 2014b) .

Field verification of the indicated objects was performed in the growing season, which also allowed for the correlation of historical objects with plants growing directly above the monuments as well as in their neighbourhood.

As regards the field work, the project could not take into account the verification of objects in various growing seasons, therefore, such performance of work was adopted which focuses on partial verification with a research postulate that further verification work is to be carried out under different vegetation conditions.

Another argument connected with partial verification of the set of potential objects included the field conditions, cost estimate, as well as the duration of verification work. These elements formed an essential criterion based on which the designation of specific areas and objects for field verification was made.

The argument in favour of the selection of the aforementioned periods of performing field work was the performance of verification work in the growing season, which makes it possible to avoid the destruction of vegetation (e.g. in the case of work involving the exposition of plant litter), which also is impossible during leafless periods.

It is commonly adopted in archaeology to take into account the so-called soil distinguishing features in relation to the interpretation of aerial photographs. Observations of flora during surface studies constitute another element facilitating the identification of underground historical structures. Distinguishing features of vegetation (positive and negative) are therefore complementary to the analytical procedure.

An example of taking into account negative distinguishing features of vegetation (flora analyses) is presented on photo no. 1 on which low growth of vegetation was recorded in the area of occurrence of the alleged remains of historical buildings.

Photograph 1. Example of diversified development of low vegetation (nettle – Lat. *Urtica L.***) in the presence of remains of historical buildings – the Starachowice Forest District (photo by R. Zapłata)**

Photograph 2. Example of diversified development of vegetation on the same area, resulting from different soil conditions. On the left: bilberry (*Vaccinium myrtillus L.***) – the Starachowice Forest District (photo by R. Zapłata)**

Apart from the distinguishing features of vegetation, another equally crucial element of the field research process were the distinguishing features of soil, which were of particular importance in identifying the remains of wood-processing locations – charcoal manufacturing sites (e.g. remains of charcoal piles).

Photograph 3. Visible charcoals exposed in the places of formation of windthrows – the Ostrowiec Świętokrzyski Forest District (photo by S. Bochyński)

Photograph 4. Remains of an object associated with the processing of raw wood (charcoal pile) – the Ostrowiec Świętokrzyski Forest District (photo by S. Bochyński)

Due to a large number of individually occurring objects in particular categories (e.g. charcoal piles), field identification of selected and sample objects from the entire set was performed, whereas in respect of clusters of objects most likely being the remains of sites of exploitation of natural resources, the researchers carried out verification of the entire "object," especially of the boundaries of the occurrence of such cluster (e.g. mine pits).

Research work was carried out on all types of ground, except for fenced areas, areas which are hard to reach or inaccessible due to dense vegetation or other conditions unfavourable to penetration (e.g. wetland). Areas where investment activity is carried out (e.g. construction areas) as well as protected areas with prohibited access were also excluded from potential identification. In respect of plants and areas under protection, work was carried out in consultation with forest district authorities as well as with the IBL employees involved in the project.

Therefore, surface studies were primarily limited to non-invasive observation of the surface and sites where the (cultural) layers under the plant litter (forest floor vegetation) were exposed due to previous natural processes and human activities. In the case of remains of war trenches – in consultation with the Historical Preservation Officer of the Świętokrzyskie Voivodeship – local field examination was applied with the use of metal detector, which did not result in the identification of locations of metal objects (historical monuments).

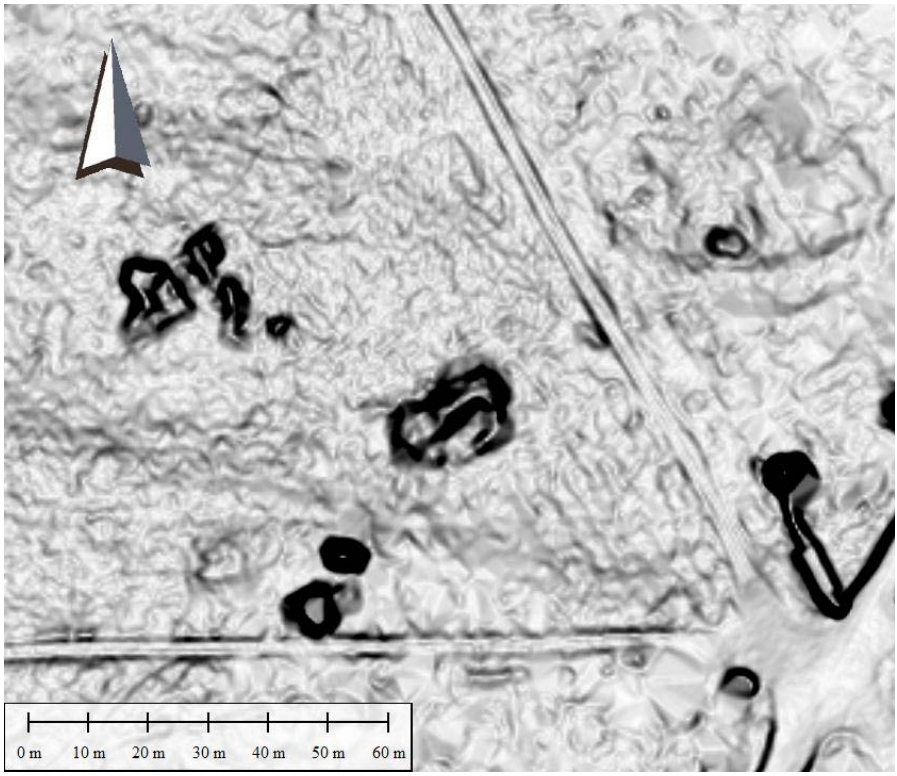
The following general principles of identification and documentation were adopted for all identified objects: (1) local inspection (location and identification of remains of potential historical objects) and analysis of the context; (2) identification of visible cultural layers, movable historical monuments and characteristic features; (3) acquisition of movable historical monuments and samples (optional); (4) measurement – determination of coordinates; (5) description of finding/object; (6) optional – documentation on a photograph (drawing/sketch); (7) determination of the function and chronology of the object; (8) flora characteristics (optional). Research work included also consultations and interviews among local community, as well as among people professionally related to the research area, i.e. foresters. These activities resulted in the

indication of sites of remains of historical settlements, economic activities as well as military operations.

Particularly valuable information was obtained from foresters who indicated a number of objects being the result of modern human activities. It is also worth mentioning the identification of objects which were not recorded during detailed site-specific work and which are not broadly described in acquired cartographic materials or the written sources and publications.

The assistance resulted in the identification of many objects as well as the indication of places associated with human settlement in the past, e.g. on the basis of analysis of habitats and species of individual plants. Examples include objects of the now non-existent inn/tavern (photo no. 5).

Photograph 5. Remains of a well (?). The Starachowice Forest District – the so-called "Murowanka" inn – the Starachowice Forest District (photo by R. Zapłata)



Il. 1. Location of buildings remains – the "Murowanka" inn – the Starachowice Forest District (source: IBL)

Field work was carried out in accordance with the applicable rules of conducting surface studies, regulations concerning access to the forest, as well as on the basis of developed guidelines – *Laser Discoverers – Methodology of surface studies in forest areas. Selected problems in the conduct of verification surface studies* (Zapłata 2014b).

Due to the large concentration of historical objects of the same category on a substantial surface of the research area, including several AZP areas, as part of the documentation of findings (in consultation with the Historical Preservation Officer of the Świętokrzyskie Voivodeship in Kielce) separate KEZA files (archaeological monument files) were created for clusters of objects reported within one AZP area. The specific nature of objects and their intensity make it necessary to treat a set jointly, but with division into the existing AZP system distinctions.

As a result of the juxtaposition of the results of work of Internet users with the detailed site-specific work of a specialist, the following potential objects were selected for verification:

1. 19 objects associated with the extraction of natural raw materials (probably remains of sites of the exploitation of natural resources) – Il. 11, 13, 15-18;
2. 5304 oval objects (remains of potential charcoal piles) – Il. 6-7;
3. 840 linear objects (remains of potential roads and forest tracks) – Il. 20-21;
4. 27 linear objects with side-elements (likely the remains of war trenches which occur in two main clusters) – Il. 9;
5. 48 square objects (likely the remains of fences used in forestry) – (chapter 4 – Il. 11);
6. oval concave objects (several clusters and numerous individual objects) (lack of initial interpretation) – Il. 23;
7. 8 unspecified objects (lack of initial interpretation);
8. 19 linear unspecified objects (lack of initial interpretation);
9. remains of railway embankments (narrow gauge railway) – Il. 3-5;
10. other (areas) – several places/areas.

The above-mentioned set of objects selected for field verification contained only general terms concerning the probable function. At the stage of detailed site-specific work these objects were treated as potential historical objects whose function was confirmed to some extent by surface studies and interpretations, primarily based on several characteristic features[14]:

1. shape (e.g. regular, irregular, oval);
2. measurements – size (e.g. surface, diameter, length, cross-section, depth – hight differences, dimensions of individual elements);
3. context of occurrence and/or co-occurrence with other objects;
4. topographic location;
5. arrangement of particular elements (e.g. regularity, frequency of occurrence or distribution, place of occurrence);
6. cultural layer and/or movable historical monuments (depending on the field conditions).

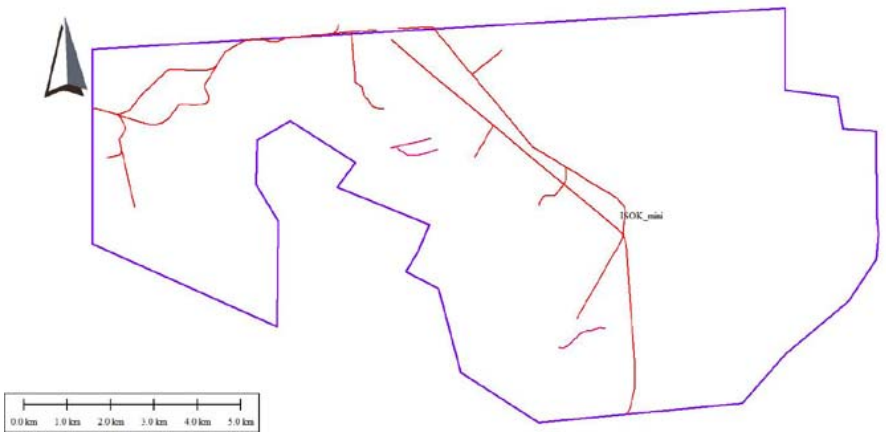
[14] Features defining particular categories of objects are the result of information gathered in the research literature on the subject, historical sources and data from the project work.

On the basis of the above-mentioned elements two main groups of objects were created: (1) objects with (conventional) specified nature and (2) objects of indefinite nature (anthropogenic objects, natural objects or errors connected with the processing of data). Verification of obtained results of object recognition was also performed with reference to: (1) the results of current archive and library inquiries, as well as (2) other available cartographic, archival and remote sensing materials. The said verification made it possible, *inter alia*, to eliminate some of the identified natural objects, such as (1) watercourses located in forest areas (topographic maps, satellite images), (2) traces of forest ploughing (e.g. satellite images), or enabled positive initial verification of such identified objects as (3) remains of inactive – historic mines (the basis for verification: literature on the subject and archival documents).

Based on the processed geodata – ALS/ISOK, the researchers also recognised, identified and documented several categories of objects which were considered special due to their specific nature. First of all, a separate category of objects was created for (1) the remains of tracks – embankments etc. of narrow gauge railway. Another category of objects includes (2) the remains of settlements and farm objects which still existed in the 20th century. A category of objects constituting (3) the remains of forest roads (associated with industrial activity in these areas) was also distinguished.

Some of the above-mentioned objects are not recorded on contemporary cartographic maps or are recorded only partially and are the subject of interest of local communities dealing with the past of their region (http://starachowice.travel/pl/swietokrzyskie_hity/starachowicka_kolej_waskotorowa/1.html). Some of these objects are identified and registered and have various documents and records, which is the reason to treat them differently under the study than the previously discussed objects. Other objects of the above-mentioned categories include elements of industrial infrastructure, settlement system or forestry built in the past (e.g. at the beginning of the 20th century), which to some extent are still used today (e.g. narrow gauge railway).

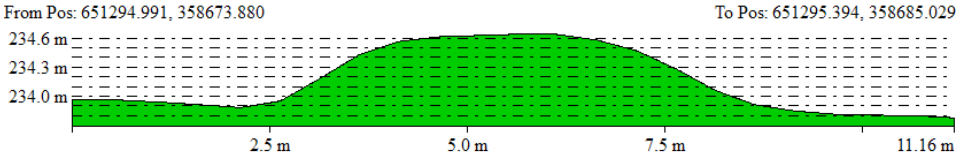
Group I – remains of tracks and reinforcements of narrow gauge railway



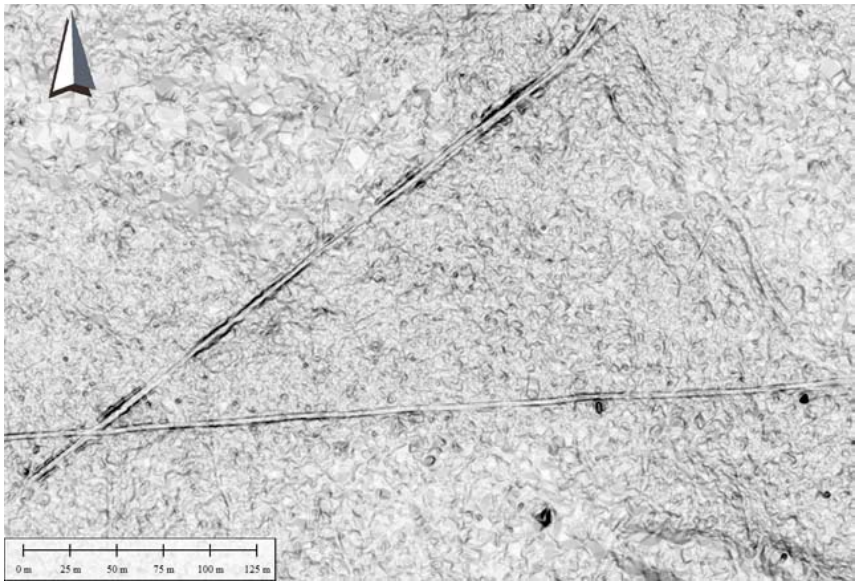
Il. 2. Distribution (based on the ISOK data) of selected, identified and potential embankments of narrow gauge railway (developed by R. Zapłata)

In light of the processed ALS data, this group of linear objects is characterized by a linear form of variable length (of up to several kilometres) with a characteristic uplift in the central part and depressions extending along the embankment, or a depression with external embankments, created as a result of the establishment of railway line in particular places.

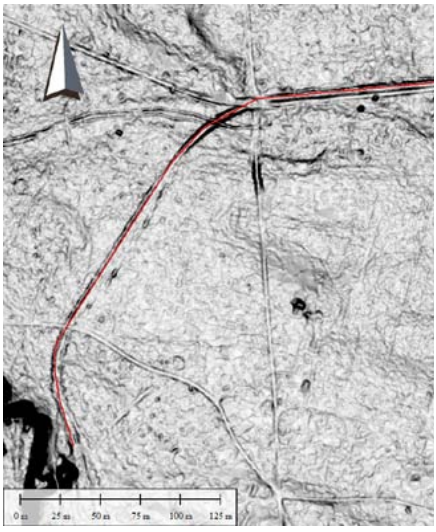
These objects are approximately 5 metres wide (embankment). A set of narrow gauge railway sections was identified (along with a historic part in the municipality of Brody), with a total length of more than 30 kilometres (excluding railway tracks used today).



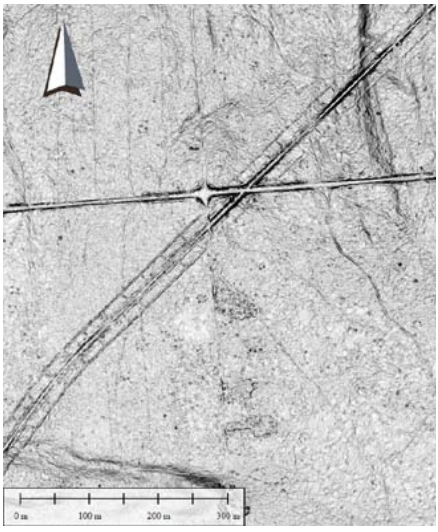
Il. 3. Sample cross-section of the remains of a narrow gauge railway embankment. Data source: IBL/FCG.



Il. 4. Visualisation of remains of a narrow gauge railway embankment – linear object marked on the topographic map as a forest road. Vicinity of a limestone mine. Data source: IBL/FCG



Il. 5A. Visualisation of shading map with the contour of preserved narrow gauge railway embankment – neighbourhood of the Klepacze mine – object not registered on contemporary topographic map. Data source: IBL



Il. 5B. Visualisation of a fragment of inactive narrow gauge railway line (shading map) based on the ALS/ISOK data. Data source: IBL

Embankments and tracks constitute a group of objects whose location is mostly known from archival materials, previous site inspections and field work, but their documentation and inventory, especially of the present status, has not been yet made on the basis of comprehensive and accurate ALS measurements. These objects are to some extent specified on topographic maps as inactive remains of narrow gauge railway.

Photograph 6. Fragment of narrow gauge railway tracks – the Starachowice Forest District (photo by R. Zapłata)

Group II – remains of settlements and farm objects

The research areas contains numerous remains of the already non-existent settlements dating back to the 1st half of the 20th century or to the 19th century. Information about these objects is obtained e.g. from written sources or archival cartography and iconography materials. The exact location of objects is often unknown, and in some cases the location of local community is known. Therefore, this group of objects was

treated in a special way, and the analysis of geodata mainly consisted in recording the preserved relief, and less in searching it.

Group III – remains of forest roads

The last group of special objects consists of the remains of forest roads which do not feature in contemporary cartography studies. These are objects created in the past which are often used even today. The group of these objects was distinguished, without creating documentation, similarly to archaeological objects.

Research work was conducted in the area of 115 sq. kilometres in total. Most of the land consists of forest areas with few agricultural areas, pastures, built-up areas, and industrial and farm areas (e.g. Zębiec SA – mining and steel plant in Zębiec). The research area was accessible in approx. 95%. Observation conditions were diversified, especially in view of the growing season (the leaf growing season). Some objects were so visible that it was possible to identify them in the field, and particularly to determine height differences which were often decisive in finding objects.

Due to dense and lush vegetation, the remaining objects were unavailable for observation and documentation. The surface of the research area, due to its characteristics – forest area, was covered with forest plant litter and forest floor vegetation, which in many cases rendered it impossible to observe the humus, cultural layers and movable historical monuments. Exceptions included agricultural areas as well as forest areas subjected to cultivation – areas ploughed in preparation for planting. Apart from the above-mentioned situation, cultural layers were visible in the areas exposed as a result of natural (e.g. growth of trees and roots, wash outs, activity of burrowing animals) and anthropogenic processes. Identification of objects based on the distinguishing features of vegetation (issue discussed in this chapter) was an additional element conducive to observation.

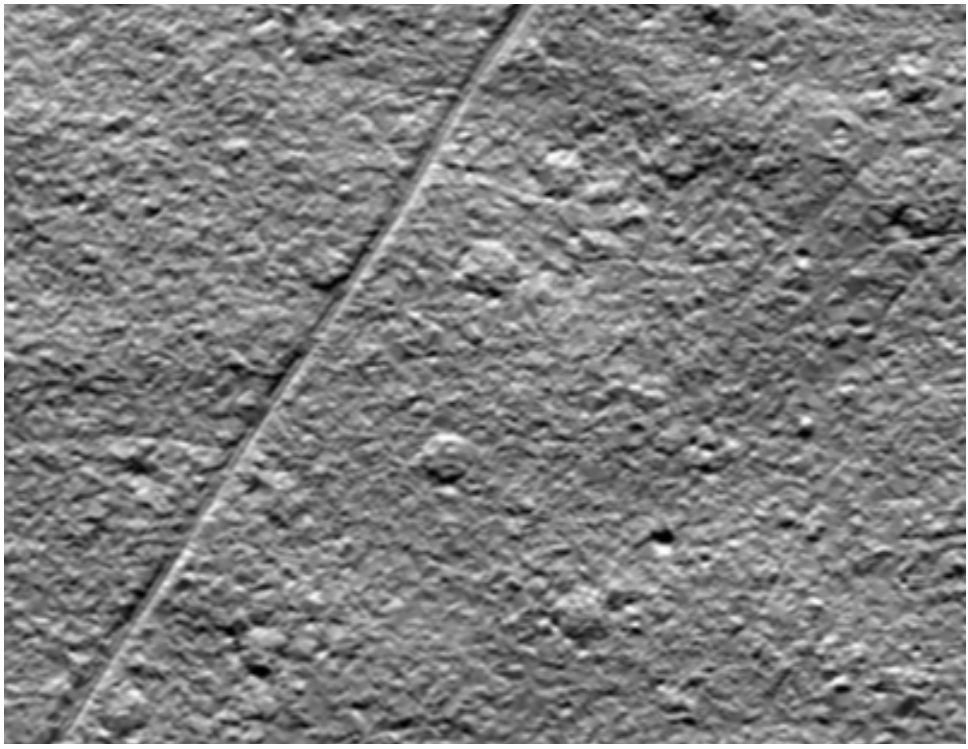
The studies performed resulted in positive verification of over 400 objects (including the so-called clusters of objects – this refers to the remains of sites of exploitation of natural resources) whose recognition in the field should be differentiated in terms of legibility (visibility). Accordingly, several categories of the legibility of objects in the field were introduced:

1. well legible objects with visible cultural layer (e.g. remains of charcoal piles);
2. well legible objects without visible cultural layers and movable historical monuments;
3. poorly legible objects;
4. illegible objects;
5. objects/sites/traces identified on the basis of movable historical monuments;
6. other objects.

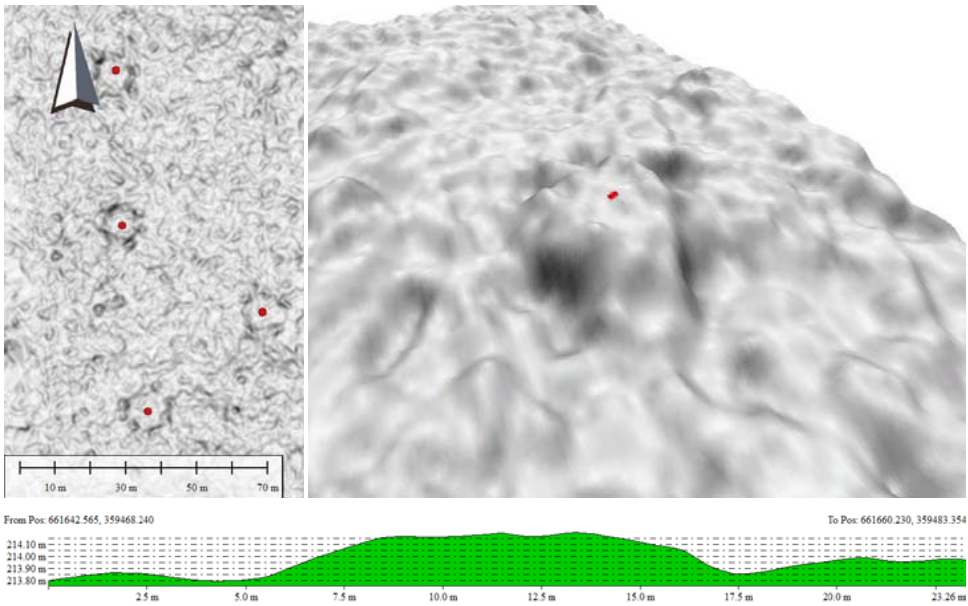
Oval objects – remains of objects related to the processing of wood, most probably to charcoal firing, which is the reason to classify them as charcoal piles (they could also serve as tar kilns or birch tar plants) – in total, 361 objects were identified and documented in the area. According to relative dating based on trees growing on the objects, it can be assumed that these objects were used before or in the first half of the 20th century. Historical premises indicate the operation of such facilities during the period of the Old Polish Industrial Region (more information later in this paper), and even earlier (Orzechowski 2013; Zapłata 2013).

Photograph 7. Charcoals on the site of locating one of the oval objects (remains of a charcoal pile) – the Starachowice Forest District (photo by R. Zapłata)

These objects are characterised by an oval construction with numerous regular surrounding pits. Dimensions: diameter – from a few to several metres, depth of surrounding pits – from a few to several dozen centimetres, dimensions of oval pits – length of approx. 100 cm and width of approx. 50 cm. A typical feature of the cross-section is an often repeating elevation of the central part, with a hight ranging from several to several dozen centimetres. Charcoals and characteristic dark brown humus lying on the surface of the object are typical of many of these objects. A layer of burnt material is often visible on deforested areas, subjected to forest cultivation (tillage) as well as in places where charcoals mixed with dark brown humus are present as a result of natural processes (washing away of soil, activity of burrowing animals, growth of root systems) and contemporary human activities.



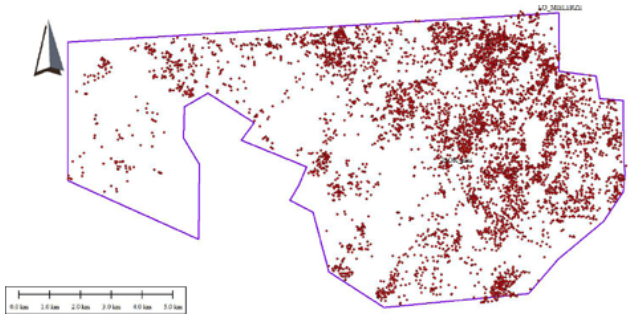
Il. 6. Visualisation of DTM exposed to processing based on the hill-shading function. Example of potential remains of objects associated with the production of charcoal – charcoal piles. Source: IBL



Il. 7. Visualisation of DTM exposed to processing based on the hill-shading function. Example of potential remains of objects associated with the production of charcoal – charcoal piles. Top: flat projection and 2.5D visualisation; bottom: cross-section of the object. (Source: IBL)

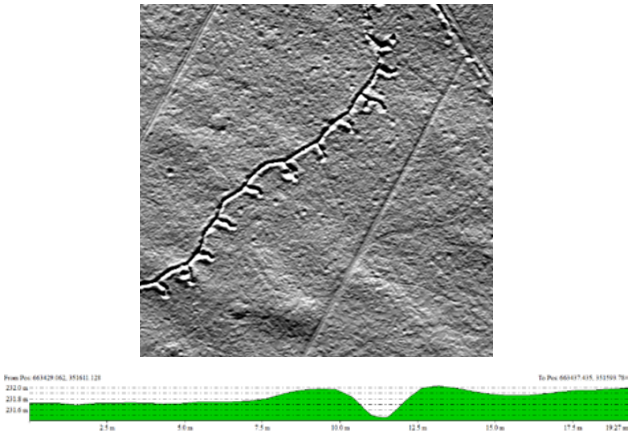
Positively verified objects identified in the field, as well as other objects indicated during detailed site-specific work are characterised by similar features, as recorded on the basis of the processing of geodata. This allows to state with high probability that the remaining objects (of the entire set of 5304) are also remains of former charcoal piles which were the primary source of producing energy resource in the region for a long time.

The characteristics observed and their proposed interpretation are confirmed in the research literature on the subject, featuring archaeologically examined objects of this type (Radwan 1959; Bielenin 1959; Samojlik 2010; Lisdorf 2011; Kałagate, Osypiński, Stachowiak 2012; Rösler et al. 2012; Orzechowski 2013), as well as in written sources (more information later in this paper) documenting both the characteristic features of charcoal piles and the process of charcoal production. Archival iconographic material also confirms a number of features typical of the identified remains of charcoal piles (Marszałek, Kusiak 2013).



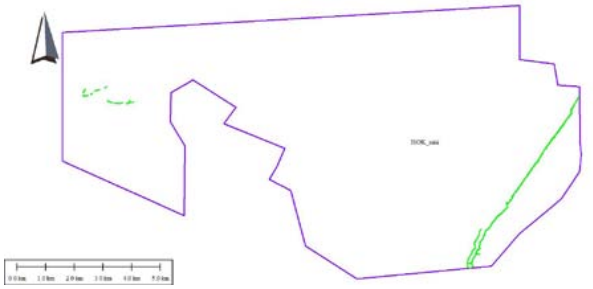
Il. 8. Map of the distribution of oval objects identified as part of detailed site-specific work, partially verified and classified into the group of charcoal piles (developed by R. Zapłata)

Linear objects with side-elements (military trenches) – in total, two objects were identified and documented (two rows of linear objects which should probably be treated as the remains of two compact systems of trenches). Analysis of the structure, dimensions and location suggest that these objects are to be associated with the First and/or Second World War. The first object is located in the south-western part of the research area, extending in the NE-SW line from Dębowe Pole, with characteristic parallel lines of trenches in the southern part. The object is over 7 km long, in some parts more than 1 metre deep and over 2.5 metres wide. The second row of trenches was located in the western part of the research area. The identified object has a length of approx. 1 kilometre.



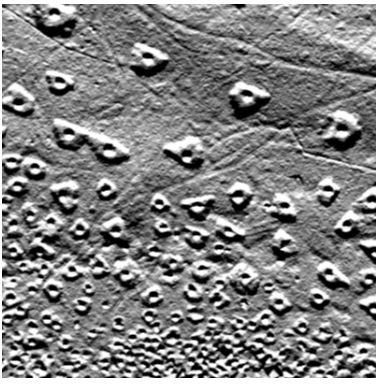
Il. 9. Visualisation of DTM exposed to processing based on the hill-shading function. Example of potential remains of war trenches. At the bottom – sample cross-section of such object. Source: IBL

The shape and nature of objects is confirmed, among others, in the analysis of historical sources, including archival instructions on how to construct this type of objects, e.g. "Feld-pionierdienst aller Waffen".



Il. 10. Distribution of identified linear objects with side-elements – objects identified and classified in the field as war trenches (developed by R. Zapłata)

Objects associated with the exploitation of raw materials / former workings and mines – in total, over 30 clusters of objects were identified and documented, which consist of a set of oval objects with characteristic pits and surrounding heaps. Among these objects, remains of the Henryk mine were documented. Apart from mines whose dates of establishment or operation are known, as in the case of the "Henryk" mine (20th century), the remaining objects – most likely related to the exploitation of natural resources – at this stage of work and their identification cannot be accurately classified in terms of chronology which also requires further research work.



Il. 11. Visualisation of DTM exposed to processing based on the hill-shading function. Example of potential remains of sites of exploitation of natural resources. The "Henryk" mine. Source: IBL

The analysis of all remains of workings makes it possible to specify some of their types: (1) objects associated with opencast exploitation of raw materials, such as the Strzelnica or Sadłowizna mine which operated in the 20th century; (2) objects with surrounding heaps or their remains of various sizes; (3) concave objects with poorly preserved surrounding rim (heap) or without it. The remains of former workings – individual objects – are also characterised by the fact that they occur in clusters, being arranged densely and close to each other. Clusters count from a few to several thousand oval remains of old workings. The determination of the total number of given workings is difficult, as many shafts were filled up or destroyed as a result of the construction of other ones in close proximity. Natural and backfilling processes as well as subsequent human activities also led to the levelling of the mining relief. Objects existing in the 20th century, e.g. the "Henryk" mine, had a distinctive feature, namely the systematic nature of drilling individual shafts and of their layout.

Most of the identified objects are, however, characterised by a rather chaotic layout, which is most likely to result from the gradual exploitation of the deposit, in accordance with its occurrence, as well as from the use of other mining technique. The largest of the identified objects are characterised by heaps exceeding 2 metres and diameter exceeding 40 metres. The smallest objects identified among the recognised clusters (old workings) include objects with pits of several centimetres, of a diameter amounting to several dozen centimetres, and without a preserved and legible elevation on the rim (uncovered workings).

It is worth mentioning that this type of arrangement and layout of objects indicates that they are probably older. First of all, it is confirmed in the literature on the subject which features descriptions of exploitation techniques characteristic of older (e.g. medieval) methods of obtaining raw materials. Following Paweł Król and Jan Urban, "at that time [in the Middle Ages], a commonly used method of underground exploitation was the multi-shaft system which consisted in digging shallow shafts (usually reaching the level of groundwater) and extracting ore from the shaft walls within a few metres" (Kowalczewski 1972 after: Król P., Urban J., 2003: 11). The multi-shaft system of densely located workings is also characteristic of older objects, such as mines

from the period of Roman influence, e.g. Rudki in the Mazowieckie Voivodeship (Orzechowski 2013 – more detailed literature to be found there), or the period of the Stone Age and the Bronze Age, e.g. Krzemionki Opatowskie in the Świętokrzyskie Voivodeship (Borkowski 2010 – further literature there). Unambiguous designation of individual objects as workings or mines is a crucial matter which is difficult to do on the basis of surface studies and ALS data. Such workings as the "Henryk" mine which are the remains of mining activities are an exception. Remains of objects identified on the basis of characteristic brick fragments likely to be parts of entry to the gallery, as well as pits present in its proximity, indicating the mining nature should be interpreted similarly. A separate, yet hard to be perceived in the present situation, issue is the exploitation of raw materials (e.g. ores) with the use of surface methods.

In addition to the recognised shape, layout of objects and their dimensions, a number of features defining individual objects were specified based on the field research. Some of the objects are characterised by a heap – mound on the rim, built of anthropogenic made grounds probably created from the deposit of exploited raw materials and/or in connection with construction activities (photos no. 8-9). Crushed rocks were reported next to some objects (photo no. 10).

Photograph 8. Remains of one of the workings of natural resources. Example of flooding of objects with rainwater – the Starachowice Forest District (photo by R. Zapłata)

Identification of the nature of some objects based on surface studies, especially in the case of forest areas, is a separate issue. Visible concave forms may be the remains of workings, as well as the result of post-deposit processes, secondary processes and ones not related to the exploitation process resulting from the processes of ground collapsing – i.e. the so-called collapsing craters, formed in the places of former shafts. Unfortunately, some objects are characterised by the lack of surface remains of exploitation process, remains of output and shredded raw material, which is mainly related to the specific forest environment. Literature on the subject distinguishes several types of mines and methods of exploitation of natural resources. Objects serving to acquire natural resources, such as flint, in prehistory are divided in the literature by the system of exploitation activities: (1) pit exploitation system – pit mines, (2) extensive underground mining system – niche mines, (3) pillar deep mining system – pillar-chamber mines, and (4) deep chamber mining system – chamber mines (Borkowski 2000: 140–154). Objects mentioned today are characterised by a specific surface form – the mining relief (more information in: Borkowski 2000), often legible during field examination, aerial photography, or laser scanning. In the above-cited publication, Paweł Król and Jan Urban distinguish morphological types of traces of old mining which involve the exploitation of raw materials (ores of copper, zinc and iron) in the Middle Ages (for the areas of Miedziana Góra and the Ławęczna hill in the Świętokrzyskie Voivodeship).

Photograph 9. Remains of the shaft hole of the "Henry" mine – the Starachowice Forest District (photo by R. Zapłata)

Researchers distinguish five types of surface remains of historic mining, for which we find similarities in the research area:

1st type of post-mining forms – "shaft holes of the shape of an inverted cone, pointed or rounded at the lower end and of a diameter of 4-16 metres (typically above 8 m) [...]. Heaps surrounding such conical holes are in the shape of embankment of about or over 2 metres, with a flat horizontal upper surface and steep slopes. In individual cases, such heaps are not accompanied by shaft hollows which were completely filled up. The shape and size of holes reflect considerable horizontal dimensions and depth of shafts, whereas the size of heaps indicates that they were formed as a result of exploitation with the use of the pillar mining system (aimed at acquiring material of high volume). Therefore, these objects constitute the remains of exploitation in the 19th century (possibly at the end of the 18th century) and exploration carried out in the 20th century which can be identified from the workings marked on old mining plans" (Król, Urban 2003: 21–22);

2nd type of post-mining forms – "objects (morphological forms) of smaller sizes and different shapes [...]. These are pits of 3-8 m in diameter; they are 1-3 m deep, and most often have a rounded bottom. The pits are accompanied by heaps most often having the shape a rather low (approx. 1 m) embankment surrounding the pit like a ring. Some of these objects are strongly levelled, i.e. they have shallow pits surrounded by very low (though usually visible) rings of heaps. Described forms are the traces of exploitation conducted with the use of the multi-shaft system, and therefore of ore mining (copper and zinc ores) older than from the 19th century, or possibly the remains of shallow exploitation of limonite ores of iron cap" (Król, Urban 2013: 22;

3rd type of post-mining forms – "quite numerous small (3-4 m in diameter) and sometimes conical pits not accompanied by heaps [...]. These pits certainly include collapsing craters formed in the places of collapsed shafts or other underground mining workings. However, they may as well be the traces of opencast exploitation of rock minerals or some other, non-mining human activity" (Król, Urban 2013: 22–23);

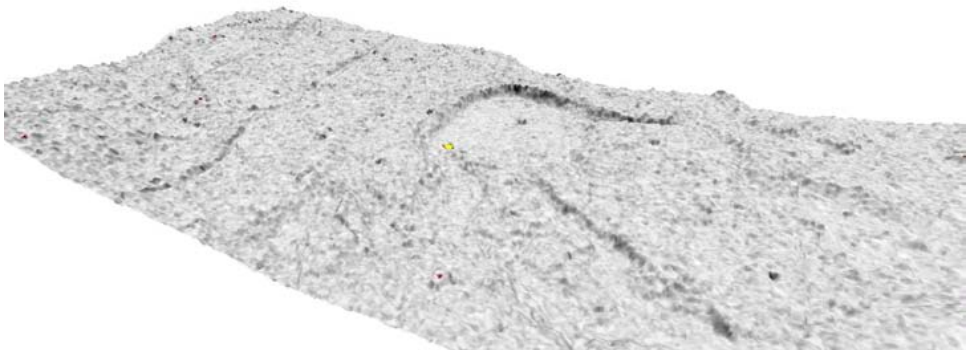
4th type of post-mining forms – this type includes "pits on the slopes of hills, which resemble small and larger slope rock quarries of not always explicit origin" (Król, Urban 2013: 23);

5th type of post-mining forms – "other artificial forms of the area morphology which do not fall within any of the remaining groups. Some of them are the remains of mining which have been heavily modified by subsequent human activity [...]. It is indicated by the rock material present in their proximity, which is identical with the material encountered on mining heaps. Some objects may represent pits formed as a result of the tightening of underground workings" (Król, Urban 2013: 23).

Literature on the subject also pays attention to changes in mining techniques, particularly in the methods of extracting ores, which are found by us in the history of the region associated with Starachowice. The simplest method consisted in the exploitation through the so-called pits – approx. 2-metre deep holes from which output was thrown out until the walls began to slide.

It is worth noting that the medieval mining was also characterised by the extraction of raw material from sites exposed naturally as a result of the activity of water or natural erosion (in Polish: *smugi*). No objects of this type were identified in the research area, but proper names existing in the research area – Sarni Smug, Czarny Smug, Długi Smug, or Gęsty Smug – may be a trace of this historical form of exploitation.

Quarries are a separate issue discussed in the literature on the subject. They are sites of extracting stone raw materials, and a type of surface workings, which should also be associated with the region. This problem was more broadly discussed in relation to the Middle Ages and Lower Silesia by Ewa Lisowska, who presented, among others, methodological issues of the identification of such objects as well as the issues of historical mining technology (Lisowska 2011 – more detailed references to be found there).



Il. 12. Visualisation of shaded DTM – Sarni Smug in the area of the Ostrowiec Świętokrzyski Forest District (Source: IBL/FCG)

In the later period, the "pits" were replaced by larger mining holes, and these, in turn, were replaced by shaft mines, i.e. objects with galleries and structural elements made of wood and brick. In the research area as well as in the neighbourhood of Starachowice, we observe the occurrence of the majority of mines which operated from the Middle Ages to the present day. Some of these objects are characterised by the occurrence of several types of old workings, and some are dominated by one of their kind. The literature on the subject also mentions objects being the remains of the gutter ore mining and exploitation in the so-called ore pits or trenches, which have not yet been identified in the research area (Orzechowski 2013: 41–44).

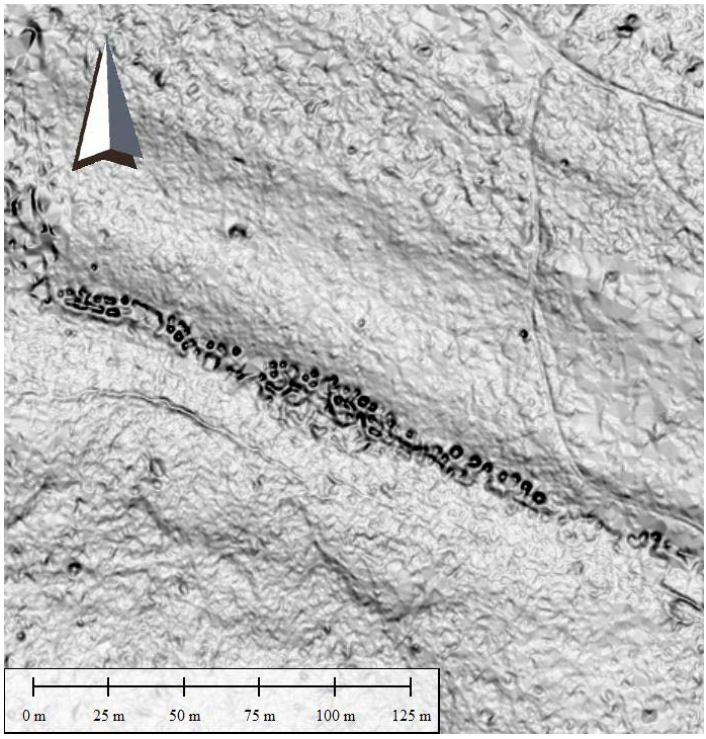
Photograph 10. Debris on the territory of former exploitation of natural resources (iron ores ?) – the Starachowice Forest District (photo by R. Zapłata)

Individual clusters of workings were located near the town of Henryk, in the southern, western, south-eastern part, adjacent to the eastern edges of forest areas, as well as north of the town – e.g. objects with preserved and visible elements of brick structure. Smaller clusters of oval, concave objects with poorly preserved surrounding embankment are one of the southernmost objects in the area of Henryk. Other post-mining objects located on the NW-SE line in the eastern part of the research area include the remains of several well-known, already inactive opencast mines: the limestone mine, Strzelnica, Władysław, Kutery, Wierzbeczki, Klepacze, Doły Kamienne and Sadłowizna. A separate cluster of probable remains of old workings was identified in the vicinity of Staw Kunowski. A number of other sites and objects resembling old workings were also located during the research, but due to the lack of many features and poor legibility in the field, they have not been recorded as objects of former exploitation at this stage. Analysing the materials gathered, it could be stated that most of the objects are associated with the exploitation of iron ores. It should be noted that due to the specific nature of the region which is characterised by ore mining, as well as on the basis of field observations, at the present stage, most objects are to be associated with the exploitation of ores in historic times, but not excluding the interpretation of some workings as the remains of older exploitation aimed at the acquisition of other raw materials.

Photograph 11. Oval pits in the area of former exploitation of natural resources – the Starachowice Forest District (photo by R. Zapłata)

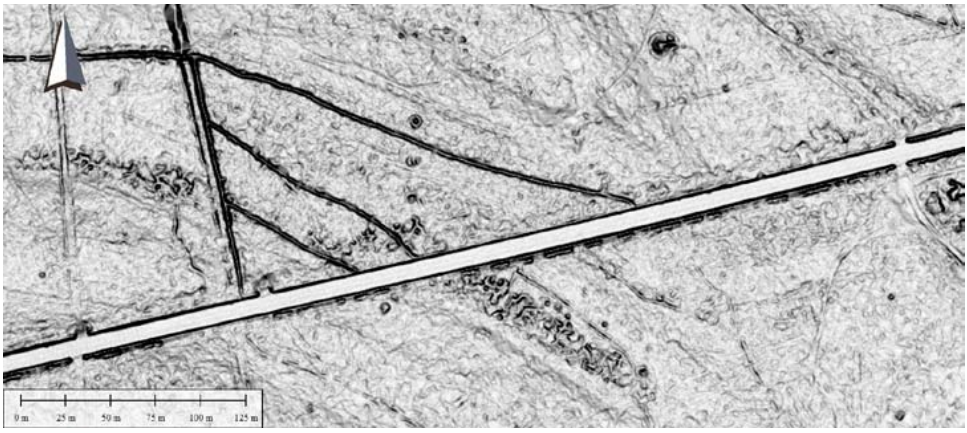
Clusters of workings in the vicinity of the town of Henryk – general characteristics of individual groups:

1. Group of objects located in the forest area (like all others). Objects are situated on the NW-SE line, at a length of over 500 m, in a belt which is over 60 m wide. Workings were located on the right side of the road leading to the buildings of Henryk-Szyb, approx. 500 m south of the said buildings.



Il. 13. Visualisation of shaded DTM – remains of oval objects associated with the exploitation of natural resources – the Starachowice Forest District (Source: IBL, FCG)

2. Two groups of clusters of objects located next to the road leading from Lubienia to Starachowice, west of the "Henryk" mine. Groups of objects extending over a length of about 400 m each, with up to 30 m wide mining relief. Heavily damaged groups of objects – partially levelled. Objects are located along the NW-SE line.

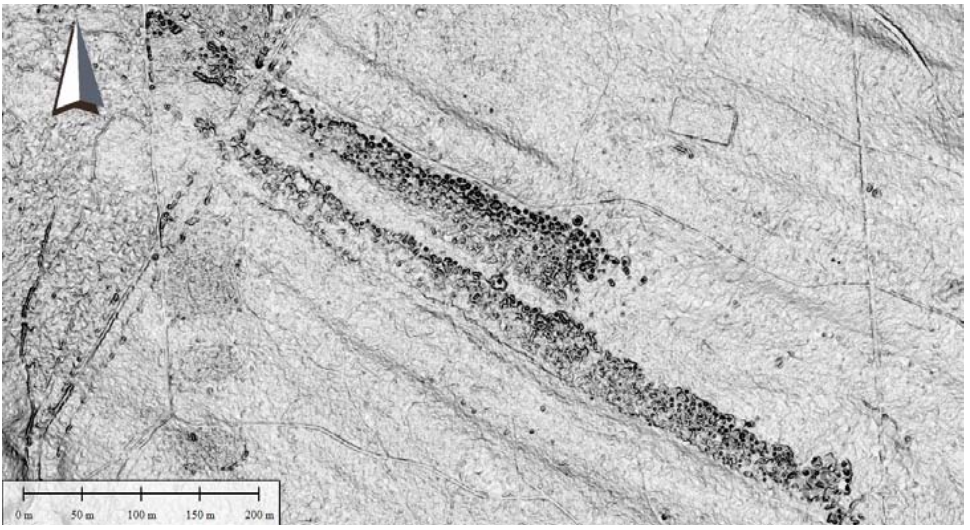


Il. 14. Visualisation of shaded DTM – remains of oval objects associated with the exploitation of natural resources on the road leading from Lubienia to Starachowice, west of the "Henryk" mine – the Starachowice Forest District (Source: IBL, FCG)

3. Groups of several dozen clusters (12 in total, including the Henryk mine) adjacent to former workings of the Henryk mine. Cluster immediately adjacent to the Henryk mine, extending along the NW-SE line – with a length of up to approx. 3 km, merging with two smaller clusters in the eastern part. In the SE part, further groups of clusters of workings were located (9 in total), extending along the N-S line on the length of up to 2.5 km. In some places, the width of these groups exceeds 120 m.

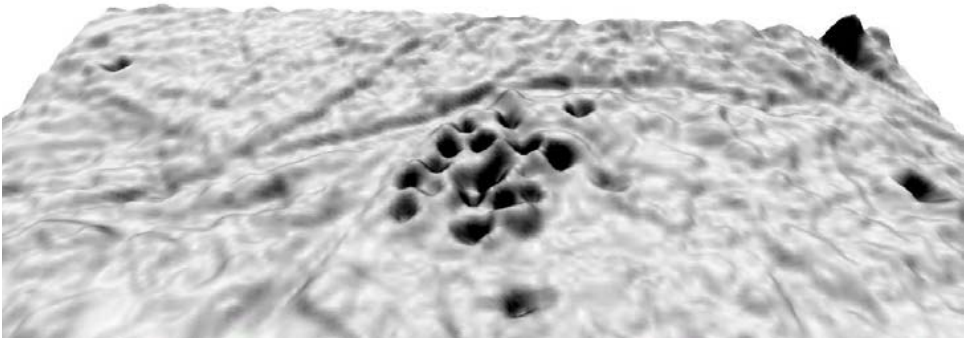
Il. 15. Visualisation of shaded DTM – remains of oval objects associated with the exploitation of natural resources, the "Henryk" mine – the Starachowice Forest District (Source: IBL, FCG)

4. Two groups situated parallel to each other and to the Henryk mine, and approx. 500 m away from the latter. Remains of workings extending over a length of approx. 500 m and over 600 m, with up to 70 m wide mining relief.



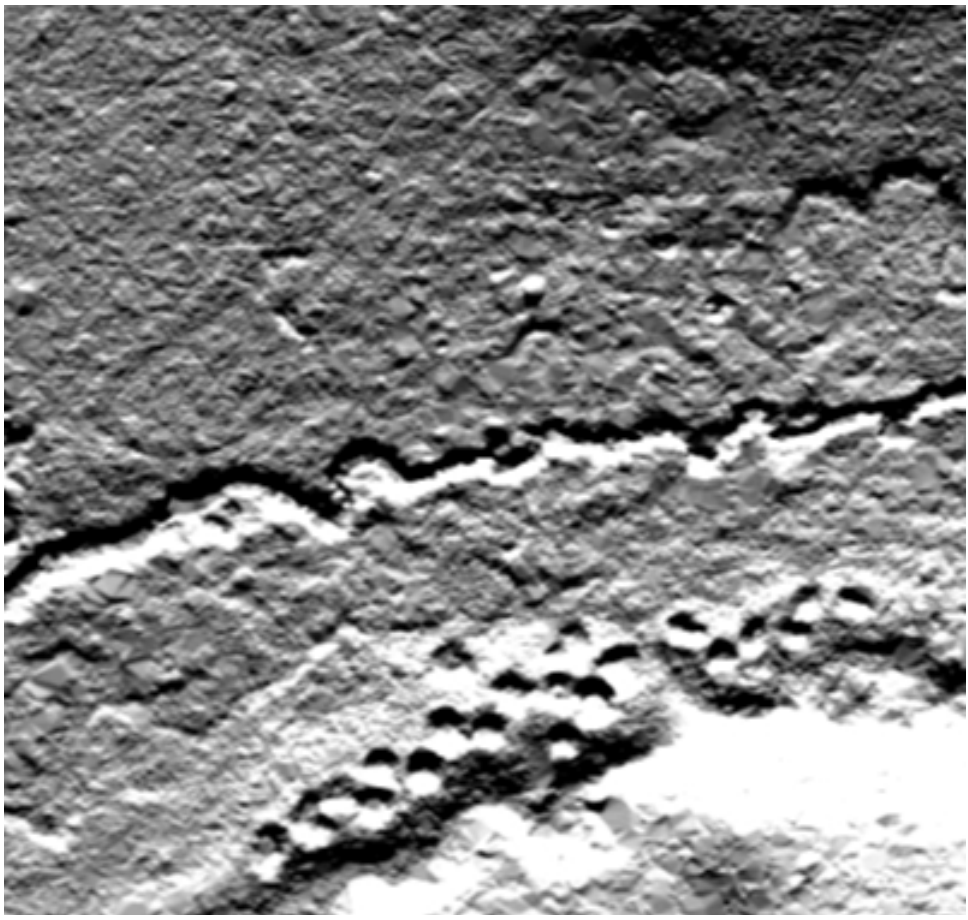
Il. 16. Visualisation of shaded DTM – remains of two clusters of oval objects associated with the exploitation of natural resources – the Starachowice Forest District (Source: IBL, FCG)

5. Three groups of less numerous objects: first – NW of the above-mentioned groups, approx. 700 m apart, on the NW-ES line; second - to the SE of the above-mentioned groups, approx. 300 m from their edge, with scattered objects – clusters include approx. several dozen objects.



Il. 17. Visualisation of shaded DTM – remains of oval objects associated with the exploitation of natural resources – the Starachowice Forest District (Source: IBL, FCG)

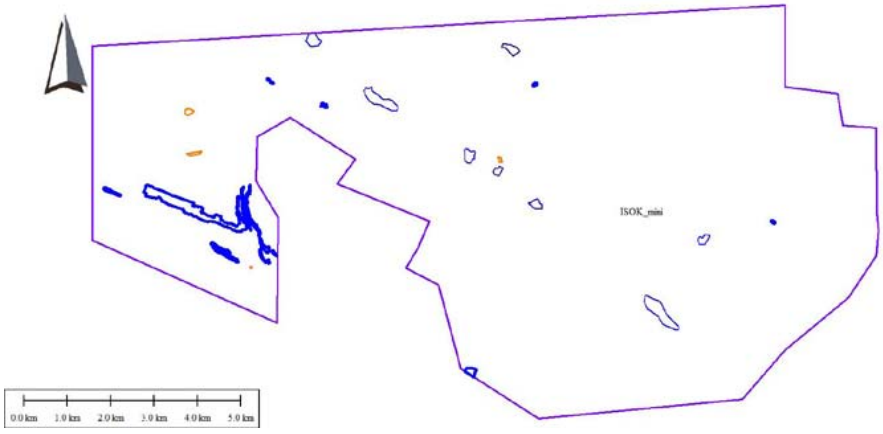
6. Group of more than twenty objects located approx. 1 km NE of the town of Połągiew. Cluster of oval pits of regular diameter. Diameter of objects approx. 5-10 m. Cluster extends along the SW-NE line at the length of approx. 150 m – in a band which is up to 35 m wide.



Il. 18. Visualisation of shaded DTM – remains of oval objects associated with the exploitation of natural resources – the Ostrowiec Świętokrzyski Forest District (Source: IBL, FCG)

7. Group of objects with visible elements of brick entrance located approx. 800 m north from the edge of the "Henryk" mine, at a distance of approx. 800 m from the road leading from Lubienia to Starachowice. Objects extend along the slope of a hill, along the W-E line, at a distance of approx. 300 m and a width of 30 m.

Photograph 12. Fragments of brick lintel - likely the entrance to the gallery(?) – the Starachowice Forest District (developed by R. Zapłata)



Il. 19. Distribution of sites of exploitation of natural resources identified on the basis of the ALS/ISOK data and positively verified (developed by R. Zapłata)

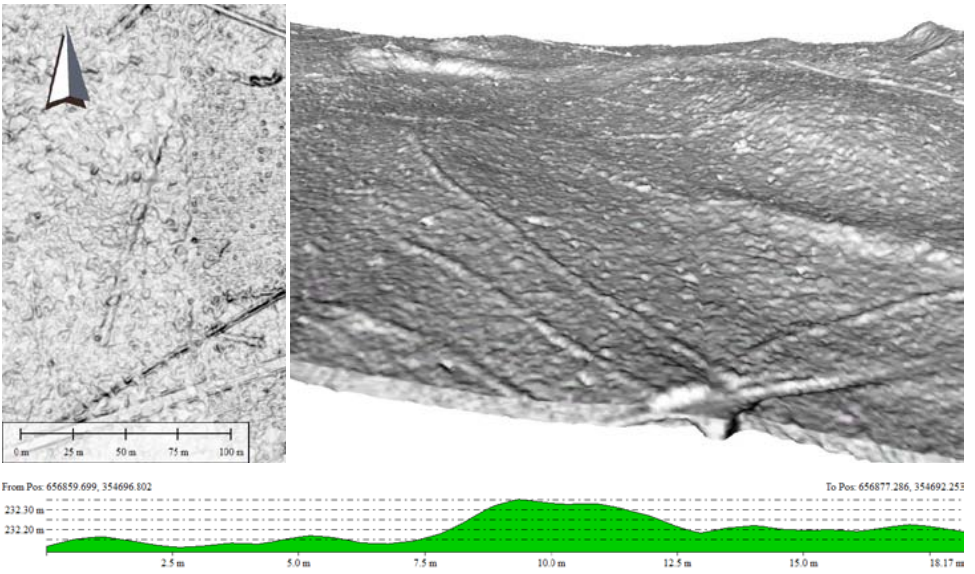
Linear objects / remains of roads and forest tracks related to silviculture – altogether 28 objects out of a total group of 840 were identified and documented in the field. No chronology has been determined for this type of objects; they have been recorded as unspecified. Based on some information and the co-occurrence in the same area with the above-mentioned objects (charcoal piles), it can be assumed that they were created and operated in a similar time frame.

Photograph 13. Fragment of a linear object - remains of a road / forest tract associated with silviculture – the Starachowice Forest District (photo by R. Zapłata)

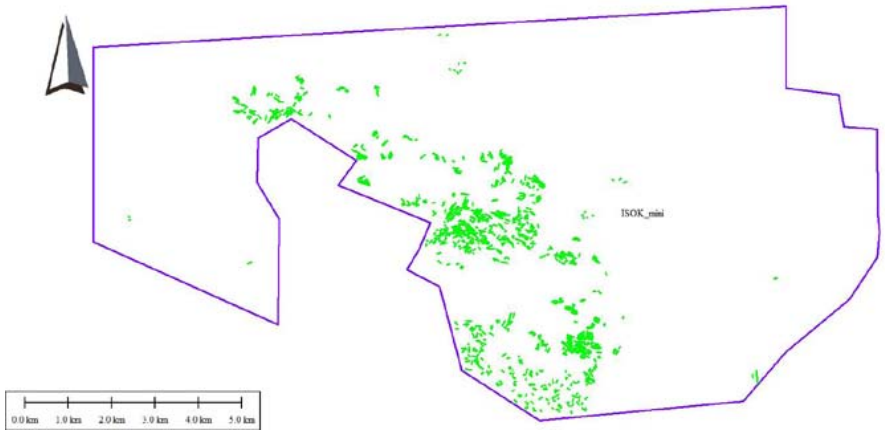
The objects discussed are mostly concentrated in an over 3 km wide belt, extending along the NW-SE line, at a length of over 11 km. A distinctive structure – elevation of the ground with trenches running parallel along the object, usually approx. 5 m wide. The length of these objects varies from a dozen to several hundred metres. Objects have different orientation, and it is believed that their distribution is associated

with adaptation to local conditions in the past. The height of the central elevation (hump) in some places exceeds 50 cm, but most of these objects are significantly levelled, which hinders their observation and identification.

Il. 20. Visualisation of DTM exposed to processing based on the hill-shading function. Example of potential remains of linear objects associated with silviculture. Source: IBL

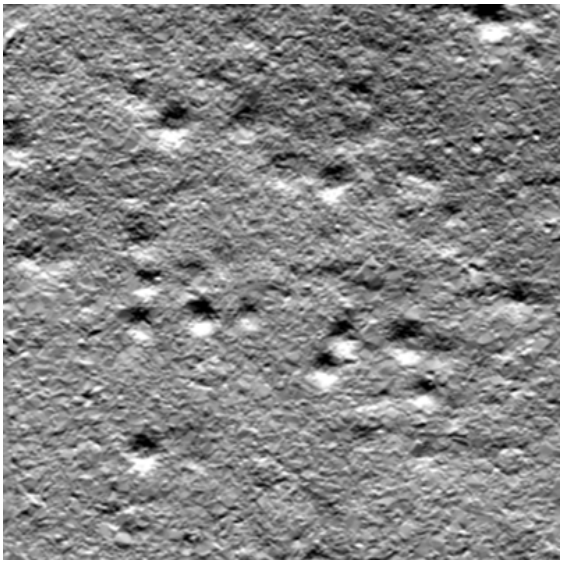


Il. 21. Visualisation of DTM exposed to processing based on the hill-shading function. Top left: example of potential remains of objects associated with silviculture. Top right: 2.5D visualisation of potential remains of the above-mentioned objects. Bottom: cross-section. Source: IBL



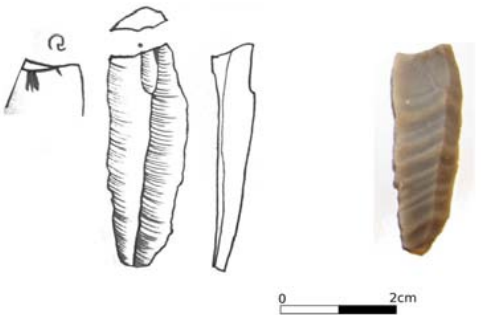
Il. 22. Distribution of linear objects indicated for field verification and partially identified – likely forest tracts and roads associated with transport of natural resources (developed by R. Zapłata)

The next group of objects includes oval, concave, several metres long forms, occurring separately or in groups. Pits of various dimensions ranging from a few/several centimetres to over 1 metre. These objects have been assigned to the set of unspecified objects.



Il. 23. Visualisation of DTM exposed to processing based on the hill-shading function. Example of visualisation of unspecified pits occurring in groups. Source: IBL

During field work, tree sites to be associated with the Stone Age have also been identified in the research area. The movable monuments found occurred: (1) in the exposed (agricultural) in the western part of the study area (chip flint – the younger Stone Age), (2) a forest area (harvested area), where discovered, among others, flint flake with retouch edge, (3) as well as in exposed field area in the forest, two cores of flint, made in the Levallois technique (chocolate flint) from the stone age - middle Palaeolithic (consultation prof. J. Libera and Mr. A. Olszewski).



Il. 24. Flint chip (striped flint) – the Neolithic Era / the Bronze Age (developed by A. Olszewski).

Several sites were also identified where the remains of modern settlement were discovered. Fragments of ceramic vessels serve as the basic material defining these sites. Fragments of slags were recognised, as well, for which, however, no closer chronology is known. Furthermore, the researchers identified and verified in the field remains of a building – the so-called "Murowanka" inn, located at the fork of forest roads in the north-eastern part of the research area.

Photograph 14. Fragments of ceramic vessels occurring within the remains of the so-called "Murowanka" inn – the Starachowice Forest District (photo by R. Zapłata)

Unspecified objects – several objects were identified and documented, whose function cannot be determined on the basis of collected data and site inspection. This type of objects was also designated for further verification.

The above list of objects identified and inventoried during the study does not include the entire set of objects, nor their full characteristics, which will be the subject of separate papers. The following attempt to present their interpretation from the archaeological and historical perspective of the region complements the characteristics of discovered objects.

3. CULTURAL HERITAGE IN THE LIGHT OF THE LASER DISCOVERERS PROJECT – EXAMPLES OF INVENTORIED OBJECTS OF HISTORICAL INTEREST AND AN ATTEMPT TO INTERPRET THEM FROM A WIDER PERSPECTIVE

Archaeological discoveries, also those conducted with the use of non-invasive studies, significantly complement research on the cultural and anthropogenic landscape of the past. Material remains occurring in mass numbers and wide territorial range may refer to the phenomena which played an important role in the daily life of inhabitants of the region examined. On the other hand, the location of important individual objects may be a reference to historical events, often associated with armed conflicts (uprisings, guerrilla warfare, frontline route).

The inquiry carried out for the research area indicates that both of these categories of objects are present. In quantitative terms as well as in terms of the frequency and range, objects related to human economic activity dominate in the area. From the very beginning, these studies emphasise the role and importance of the broadly understood silviculture in the everyday life of inhabitants of the research area. The above-mentioned "broad understanding" of silviculture results from a completely different role and function served by compact forest complexes in the Middle Ages and Modern Times (until the 19th century), compared to the present situation, when forest in the general perception is mainly associated with timber economy. At the same time, it should be remembered that archaeological inquiry (especially non-invasive study) must be supplemented by information concerning the status of research conducted in various

fields, including archaeology, history, metallurgy and geophysics, which is well reflected in the main studies devoted to the archaeology of these areas written by Kazimierz Bielenin and Szymon Orzechowski.

Charcoal piles

As many as approx. 5 thousand different types of potential remains of charcoal piles were identified in the research area. Production of charcoal was important for many aspects of human life (from the issue of preparing food to the steel industry) since antiquity. In the steel industry, charcoal was the main fuel until mid 18th century, and even the introduction of new manufacturing techniques changed little in this regard (Orzechowski 2013: 65). The main element which influenced the nature of economic exploitation of forests between the Kamienna river and Iłża were deposits of minerals, mainly metal ores: iron, manganese, copper, zinc and lead, occurring in the Świętokrzyskie region. Iron ores were of particular importance for the economic development of the area, as they were extracted there since antiquity, in the Middle Ages and the modern period. In the context of general overview of the development of mining and metallurgy in the Świętokrzyskie region, selected research area was located just north of the main mining centre (triangle: Łysogóry, Pasmo Jeleniowskie, Kamienna river) – according to recent studies, the belt on the southern edge of the forests of Starachowice constituted the northern border of the Świętokrzyskie metallurgical centre (Orzechowski 2007: 123).

Any contact of areas north of the Kamienna river with major metallurgical centres in the Świętokrzyskie Mountains can already be related to antiquity (the Early Roman Period). It is worth mentioning the findings of Roman coins recorded in the towns Nietulisko Duże and Nietulisko Małe located just south of the research area (Orzechowski 2007: 114, 128). On the maps attached to papers devoted to the history of mining and iron industry, the research area is considered a part of the range of the ancient mining of the Świętokrzyskie region (Zieliński 1965: 67; Bielenin 1992: 12). In the absence of field studies and excavations in the forests of Iłża, it is only possible to use analogies and knowledge from the studies conducted by teams led successively by Mieczysław Radwan, Kazimierz Bielenin and Szymon Orzechowski in the areas located south of the Kamienna river.

Forest areas located between Iłża and the Kamienna river, east of Starachowice, were undoubtedly a very important fuel supply base for the growing iron industry in the area. At the same time – according to the analyses of Szymon Bielenin – the examined area was free from ironworks of the Old Polish Industrial Region, which may indicate that the main economic exploitation of forests located south of Iłża began only in the 19th century, or that burned charcoal was transported to the south west, where the main centre of metallurgy in the Świętokrzyskie region was situated or to the areas near Mirzec, Tychów and Jasieniec, where bloomery stations were also located (the occurrence of iron slag) (Bielenin 1992: 10–123; Orzechowski 2007: 33). It is worth noting that research concerning the Iłżeckie Foothills and the forests of Starachowice in the context of development of ancient metallurgy was proposed by Szymon Orzechowski, who also suggested to treat this area – despite some associations with the economic complex of the Świętokrzyskie Mountains and the Świętokrzyska Upland – as a "separate economic entity". Additionally, he stated that "it is not known for certain what can be found in the forests of Siekierzyn and Starachowice" (Orzechowski 2007: 13, 114).

Szymon Orzechowski made an attempt to reconstruct the original forest cover "as a fuel supply base for ancient metallurgy in the Świętokrzyskie region". He proposed a thesis, undoubtedly a correct one, that the location of steel industry and raw material supply base is closely correlated. In his opinion, "making use of raw material located at such a considerable distance (from a few to over 20 km) would be unjustified" (Orzechowski 2007: 178-191). This statement suggests that both the location of ore workings as well as production facilities (bloomeries, forges) should be associated with the vicinity of discovered charcoal piles. Distance measurements indicate that it is possible to propose a thesis that the charcoal piles discovered in the forests of Iłża and Starachowice confirm that these forests could serve as a raw material supply base not only for metallurgical centres near Mirzec, Tychów and Jasieniec, but also for the ironworks of the Old Polish Industrial Region of the Kamienna river valley (from Starachowice to Ostrowiec). Such opinion would to some extent correct the above-mentioned view on the "separate economic activity" north of the Kamienna river. Forests located north of the Kamienna river were likely to provide fuel for metallurgical centres situated in the northern part of the Old Polish Industrial Region. It is partially

confirmed by the lack of traces of coal production in the vicinity of the examined metallurgical stations of the Przeworsk culture. Szymon Orzechowski attributes this to the status of research, but the location of charcoal piles at some distance from the bloomery stations can also be assumed. The risk caused by the location of charcoal piles resulted in moving the production of charcoal to a safe distance from settlements, bloomeries and forges (Orzechowski 2013: 67).

The above-mentioned theses are confirmed by the analysis of the map of Maksymilian Strasz, *Karta położenia Zakładów Górniczych Rządowych w Królestwie Polskiem. Okręg Wschodni [Location of the State Mining Plants in the Kingdom of Poland. Eastern Region]*, scale approx. 1:126 000 (Wójcik: 3), and the list concerning the use of forests of the Starachowice plants featured in the study of Franciszek Krzeszowski (Krzeszowski: 166).

Table 1. Forests of the Starachowice Plants in 1675 (Krzeszowski: 166)

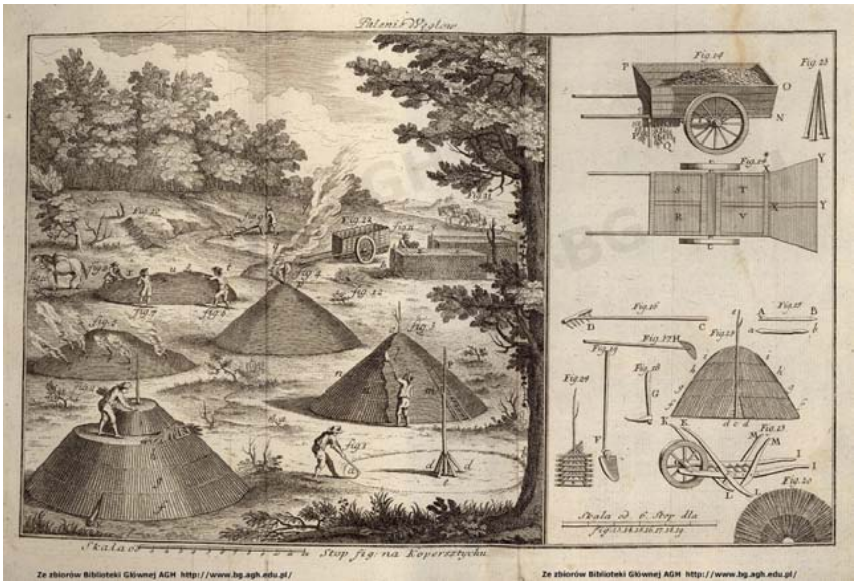
Area	Type of wood	Mass of trees in the area estimated in the forest stand		Annual use in the railway industry		
		chopped	not chopped	90 years old	100 years old	120 years old
		usable wood, cut wood, logs	branches, stump-wood, dry twigs	fathoms of 85.75 cubic feet		
		fathoms	100 feet			
D. Jasieniec	coniferous trees	48,658	11,769	2,426	2,089	1,815
E. Błaziny	coniferous trees	95,673	19,162	3,506	3,117	2,713
F. Kruki	coniferous trees	72,715	17,900	2,880	2,420	3,111
G. Borsuki	coniferous trees	70,483	17,931	3,115	2,593	2,260

I. Lipie	birch, conifers, oak	40,144	6,632	1,951	1,655	1,464
K. Ruda	pine, birch, oak	70,406	10,200	3,396	2,968	2,936
L. Lubienia	conifers, oak	50,167	9,574	2,506	2,128	1,898
M. Kutery	pine, oak	78,981	19,022	3,374	2,891	2,563
N. Klepacze	pine, birch, oak	55,427	9,748	2,596	2,213	1,970
O. Fryzel	pine, birch, oak	55,814	14,006	2,552	2,158	1,855
P. Myszki	pine, birch, oak	59,543	13,543	2,693	2,264	1,988
R. Połągiew	pine, birch	40,206	8,027	2,024	1,679	1,475

As results from the onomastic analysis of terminology recorded on maps originating from the 18th century, especially on the map of Karol Perthées of 1791, there was another important branch of production in the forests of Iłża. It notes seven settlements which in the Polish language are called *Maziarze* (from Polish *maź* - a tar-like substance), including Maziarze Iłżeckie and two times Maziarze Kunowskie. Although the most common type of charcoal piles was intended for burning charcoal, their second type is also known – one intended for the production of birch tar, tar and turpentine (smokehouses). The method of production of charcoal and tar substances (birch tar, wood tar) was similar, but the wood material used (dry birch bark, resin pine wood, the so-called stumpwood) was different.

Literature on the subject describes two types of charcoal piles used to produce charcoal: ground and pit charcoal piles. Szymon Orzechowski states that "the analysis of coal production objects found in the Świętokrzyskie Mountains as well as on some Silesian sites showed that they represent rather a transitional form between the pit charcoal pile and ground charcoal pile". A cone-shaped pile of wood, surrounded by a "tire" of leaves, turf and soil, was placed in a round pit. Giving the examples of descriptions of charcoal pile construction from different historical periods and different parts of Europe, Orzechowski also states that there was a common technical idea for this kind of

production, which had not changed since ancient times to the 19th century. The most characteristic charcoal piles in the territory of the Świętokrzyskie Mountains are concave, circle-shaped objects with a diameter of up to 3 m, and up to 1.2 m deep (cylindrical, curved, stepped, shaped like an inverted cone) (Orzechowski 2013: 65–72; Bielenin 1992: 154–164). Numerous objects of circular shape discovered in the research area have a much larger diameter, which may indicate their subsequent dates of origin. The volume of the charcoal pile stack could be varied, as it depended on local practices and current needs. Discovered objects classified as charcoal piles of approx. 12 meters in diameter indicate very large hearths in the research area. It should also be noted that these objects quite significantly differ from those known from the study of charcoal piles located in the vicinity of bloomeries carried out by Kazimierz Bielenin and Mieczysław Radwan – there were only dark spots on the sites in Stara Słupia (Bielenin 1959: 467-472; Radwan 1959: 473-476). The book entitled *Sztuka węglarska [The Art of Coal Production]* by Duhamel du Monceau, published in the Polish language in 1769, informs that "a worker makes circles for furnaces, and if they want to make large furnaces, they measure off eight units in diameter, and less in the case of smaller furnaces" (Duhamel du Monceau 1769: 18).



Il. 25. Palenie Węglów [Burning Coals] (Duhamel Du Monceau 1769).

Unknown linear objects

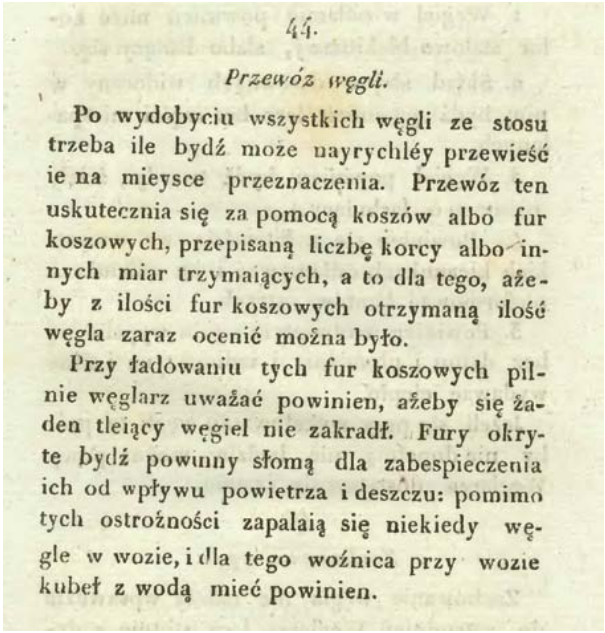
The biggest doubts are raised by a series of linear objects discovered as a result of analysis, which is very difficult to interpret without excavations. Certain analogies can be found with other coal production objects described recently by Szymon Orzechowski – hearths with stones which formed characteristic linear arrangements (Orzechowski 2013: 71).

Similarity of this objects to auxiliary objects accompanying metallurgical production is also possible. These were piles of roasted ore, which had a circular or an oblong shape. One of such oblong roasted ore formations was found on the northern slope of Łysa Góra – it was an 80 cm deep elongated pit of 2×1.2 metres. The oblong shape rather excludes the fact that they are the so-called furnace cavities, as they were usually spherical (Bielenin 1992: 131–133).

It is less likely, but also possible, that the interpretations of unknown linear objects may indicate the sites of extraction of iron ores by ore miners. Despite the lack of records and detailed archaeological studies, it appears that the extraction of iron ores took place with the use of opencast methods (the mine in Rudki is probably an exception). The case is hindered by the difficulties in dating and the fact that a large part of workings may be associated with the modern phase of extraction (18th/19th century) (Orzechowski 2007: 163, 176).

The most probable interpretation of so many linear objects in the research area, however, is that they are some smaller or larger fragments of old roads and tracts for the transport of wood and charcoal. Given that the forest area was often swampy, the embankments observed could play such a role.

The descriptions of charcoal production, both in the aforementioned French source (Duhamel du Monceau) as well as in *Wykład praktyczny węglarstwa stosowanego [Practical Lecture on Pile Coal Production]* by Juliusz Brinken of 1825 mention both the transport of timber to charcoal piles and the need for the transportation of manufactured charcoal to bloomeries or other metallurgical facilities.



44.

Przewóz węgli.

Po wydobyciu wszystkich węgli ze stosu trzeba ile bydź może nayrychléy przewieść ie na mieysce przeznaczenia. Przewóz ten uskutecznia się za pomocą koszów albo fur koszowych, przepisaną liczbę korcy albo innych miar trzymaiących, a to dla tego, ażeby z ilości fur koszowych otrzymaną ilość węgla zaraz ocenić można było.

Przy ładowaniu tych fur koszowych pilnie węglarz uważać powinien, ażeby się żaden tleiący węgiel nie zakradł. Fury okryte bydź powinny słomą dla zabespieczenia ich od wpływu powietrza i deszczu: pomimo tych ostrożności zapalaią się niekiedy węgle w wozie, i dla tego woźnica przy wozie kubeł z wodą mieć powinien.

Il. 26. Excerpt from J. Brinken's work entitled Wykład praktyczny węglarstwa stosowego [Practical Lecture on Pile Coal Production] (Warsaw 1825) on the transport of charcoal: *"After taking all the coal away from the pile, it should be transported to the place of destination as soon as possible. This transport takes place in baskets, based on the number of which the amount of produced coal can be estimated. When loading these baskets, charcoal burners should be careful not to load any smouldering coal. The baskets should be covered with straw in order to prevent the coal from exposure to air and rain. Despite these precautions, coal in the cart sometimes ignites, so the driver should always have a bucket of water".*

Just as Szymon Orzechowski studied links between the residential and economic zone (steel mills, smelting sites), it should be considered to carry out studies of the zone of raw materials (charcoal), mining (ore mines), metallurgy (bloomeries), settlement (housing) and the probably connected industrial zone (blacksmith's shops).

Sites of exploitation of natural resources – mines

The above-described link between charcoal production and the melting of iron ores, and possibly of other minerals, is supported by finding several objects in the research area which can be interpreted as mines. The most popular ores in the Świętokrzyski region, which were the basis of local steel industry, include hematite (red ironstones), siderite and limonite (brownish ironstones), very often with an addition of flint (Ra-

dwan 1963: 22-23). The classification of ores with an indication of their location by Józef Osiński originating from the end of the 18th century describes the ore present in the studied region as follows:

> *Reddish ore, exploited on the sixth fathom; does not spread over a large area, but is not small either. Water interferes with its extraction; the ore is light, and when it is mixed with another ore, good iron is formed. The last ore is situated in the Sandomierskie Voivodeship, in the property of the Cistercians of the Wąchock Monastery, near a village called Marcinków; in the village there is a bloomery in which the ore is melted. The said ore can also be found in Brody [Ruda Bród – author's annnotation], a village belonging to the Communists of Kielce, as well as near Chybice in the Sandomierski Poviat, from where the ore is transported to the bloomery called Stryków (Osiński 1782: 34–35).*

Deposits of limonite (brownish ironstones) are located mainly on the left side of the Kamienna river, stretching in a form of a belt leading through Jastrzębie, Mirów, Tychów, Ostrowiec, Bodzechów and Ćmielów, and they determined the mining and metallurgical development of the area (Krzeszowski: 4–5).

A detailed analysis of natural resources for metallurgy in the Świętokrzyskie region was conducted by Szymon Orzechowski in his monograph. Thorough studies, also regarding the mining technologies, were carried out in the Staszic mine in Rudki near Święty Krzyż, where traces of hematite mining can still be found. In general, it can be assumed that extraction was performed with the opencast mining method (outcrops, subsurface layers). These were usually simple pits, the so-called ore holes, with a depth of up to several metres. Continuous open pits were also used, and they were filled up after the completion of extraction. Little is known about the sizes of mine shafts. On the site in Szeligi, a 4.6×5.7 m cavity was discovered with a depth of 2.5 m, whose shape was similar to a funnel. It is believed that it was a so-called ore hole (Orzechowski 2007: 147-163). The monograph by Hieronim Łabęcki of 1841 devoted to mining

and metallurgy in Poland refers to this type of workings as *rudokopy [ore digging holes]* (Łabęcki 1841: 34).

The exact date of the beginnings of iron ore mining, and thus of metallurgy, in the region is unknown, but it certainly dates back to antiquity. The extraction of iron ores in the Middle Ages and in the Modern Times was not the task of regalia, but was performed by private individuals and the clergy – the Cistercians of Wąchock were granted a privilege by Bolesław the Chaste to search for mining deposits already in 1249, whereas ironworks from the region are recorded in historical sources dating back to the 14th century (document of 1333) and to the 15th century (*Liber beneficiorum* by Jan Długosz, the Wola Krzyżowa mine) (Krzeszowski: 11). In the keys of Iłża, Brody and Stara Ruda which were assigned by the Bishop of Cracow to the seminary of Kielce conducted by the Apostolic Union of Secular Priests (Communists), bloomeries in Brody and Stara Ruda were created in the 18th century and operated until 1784. Then, with the consent of the archdeaconry of Kielce, the lessee of the bloomeries, Nowosielski, put up a large furnace and two forges in Brody (Łabęcki 1841: 313–330). Franciszek Krzeszowski treats this as a revival of the ancient industrial initiative of the Cracow bishops who already in the 16th century had a bloomery and ironworks in the Krynki parish (Krzeszowski: 32).

The most important and also the largest object in the research area are the remains of the old Henryk ore mine. It belonged to the Old Polish Industrial Region which "was born from the mining and smelting of iron ores in the Roman times". It was situated, like the "Majówka" mine, in the area of exploitation of loamy ironstone deposits, located in the vicinity of Ostrowiec and Starachowice (Zieliński 1965: 128). It is clearly marked on the map by Maksymilian Strasz, *Karta położenia Zakładów Górniczych Rządowych w Królestwie Polskiem. Okręg Wschodni [Location of the State Mining Plants in the Kingdom of Poland. Eastern Region.]*, scale approx. 1:126 000 (Wójcik: 3, cf. chapter 3).

This mine was established in the 19th century, at the time of the takeover of the steel industry in the Kingdom of Poland by the Polish Bank. According to study by Hieronim Łabęcki, the Henryk mine (or Tomkowski Smug, Brody) was founded in 1838. In 1840, the Ignacy gallery was constructed according to the design of the head of the Mining

Department at the Polish Bank, Aleksander Pollini (iron ore was melted in furnaces in Starachowice). The Henryk mine, probably like the remaining mines supplying plants in Starachowice, did not work in a continuous mode ("świątkówki" [holidays], i.e. numerous breaks in work were arranged) (Łabęcki 1841: 380; Krzeszowski: 106, 161).

Apart from the Henryk mine, already described in the literature on the subject, in the course of research other objects which can be identified as iron ore mines were discovered, as well.

Il. 27. Presumable iron ore mines in the research area
(on the basis of the map of the Military Geographical Institute of 1938)

They are younger and originate from the 20th century. They are located along the narrow gauge railway built from the beginning of the 20th century in order to provide both iron ore as well as charcoal to Starachowice. The route of the railway is visible on the maps of the Military Geographical Institute and in the post-war cartographic sources. On the research area, the railway lead south of the Lipie village, alongside the Dębowa Góra and Łaziska elevations and reached the Zębiec ore mine (now a wooded area, narrow gauge railway siding in the north, only traces of the tracks remained) and the Lubienia-Strzelnica mine (also called Leopold, on the MGI marked with a mine sign next to Ruda, without a name). Other narrow gauge railway sidings lead from the main line in the direction of the Władysław, Kutery, Kutery II (including the timber store) and Klepacze mine. The Starachowice narrow gauge railway ended its course next to the Jaźwiny storehouse in the village of Bór Kunowski, just west of the Stefania ore mine, visible on the maps of the Military Geographical Institute (Cygan: 1–4).

War trenches

Apart from the objects associated with the settlement and economic human activity, archaeological and archival inquiry shows the remains of acts of war which took place in the forests of Iłża and Starachowice. The border and disputable nature of the research area (see chapter 3) certainly affected the armed conflicts which took place there as early as in the Middle Ages and in the modern period. However, as results from the interpretation of objects located in the eastern part of the research area, they should rather be associated with the events of the First and Second World War (Austrian and German trenches).

Il. 28. Location of potential war trenches in the research area (on the basis of the map of the Military Geographical Institute of 1938)

The war operations which took place in the forests of Starachowice and the resulting devastation are extensively described by Marian Langer in his monograph (Langer 1993). The author mentions the devastation caused in the area during the First World War – cannon balls and armament pieces which can be found are the remains of these events. The trenches marked on the map are probably related to the siege in the autumn of 1944 of the Iłżec troop commanded by Lt Wincent Tomasik.

Historical sources mention German troops digging trenches along the road leading to Ostrowiec (Langer 1993: 300–301, 308). This was probably a part of the trenches which were to surround the Home Army troop and part of preparations for the battle of Piotrowe Pole which took place on 1 October 1944 (it was one of the greatest bat-

tles fought by the Home Army on the land of Radom). The Germans occupied the forest area with a perimeter of 22 km – as estimated, with approx. 11,600 people (division). The origin of the remains of war trenches in the eastern part of the research area is less clear.