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## Application of GPR Survey in the Investigation of a Plane Crash from the Second World War

### ABSTRACT

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The article discusses the use of a ground-penetrating radar (GPR) for locating objects originating from the war period. It also presents the results of GPR research, showing the presence of a World War II aircraft wreck located in the subsurface layer in Krościenko Wyzne, Krosno County, Podkarpackie Voivodeship. Excavations carried out later have confirmed these surveys. The remains of the aircraft were documented in spots in which anomalies were indicated by the GPR. The conducted archaeological work made it possible to assess the effectiveness of the georadar technique.

**Key words:** GPR research, post-war objects, archaeology

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### Introduction

The GPR method is included among available radiowave geophysical methods. It is a non-invasive technique that analyzes subsurface layers and provides information on the presence of subsurface objects. It can be used differently depending on the frequencies of the used antennas (Karczewski 2007). It has a wide application: from geological and engineering surveys or environmental protection to archaeology or criminalistics (Rajchel 2011). Recently, it has been increasingly used to search for various objects beneath the surface, such as military equipment left underground following military operations. This topic is also discussed in the article.

### Research objectives

The main purpose of the measurements was to determine the location of a Junkers Ju-87 Stuka aircraft wreck, which had crashed

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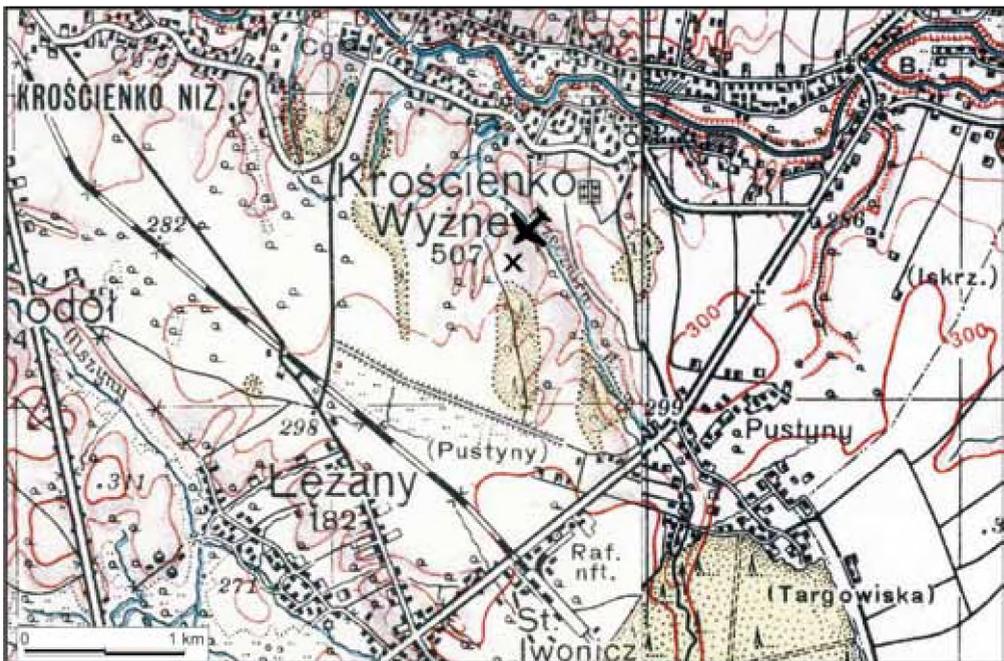
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during World War II, as well as to determine its location and the depth of its deposition. The article presents the results of georadar measurements carried out in the field and compiles them with the results of archaeological research. In addition, the effectiveness of the georadar technique is assessed in accurately determining the location (depth, outline, arrangement) of the identified elements from the plane's remains. One valuable aspect of this project in terms of the usefulness of the georadar technique in this type of research is linked to the fact that it has been possible to confirm non-invasive measurements with invasive research. Excavation works were carried out by the Private Museum of Podkarpacie Battlefields in Krosno – the main initiator of the entire project.

#### Junkers Ju-87 D3 plane crash in light of archival documents and eyewitness accounts

The plane crash took place on February 11, 1944 at the airport in Łężany (currently called „Iwonicz”, Fig. 1), which was Krosno's spare

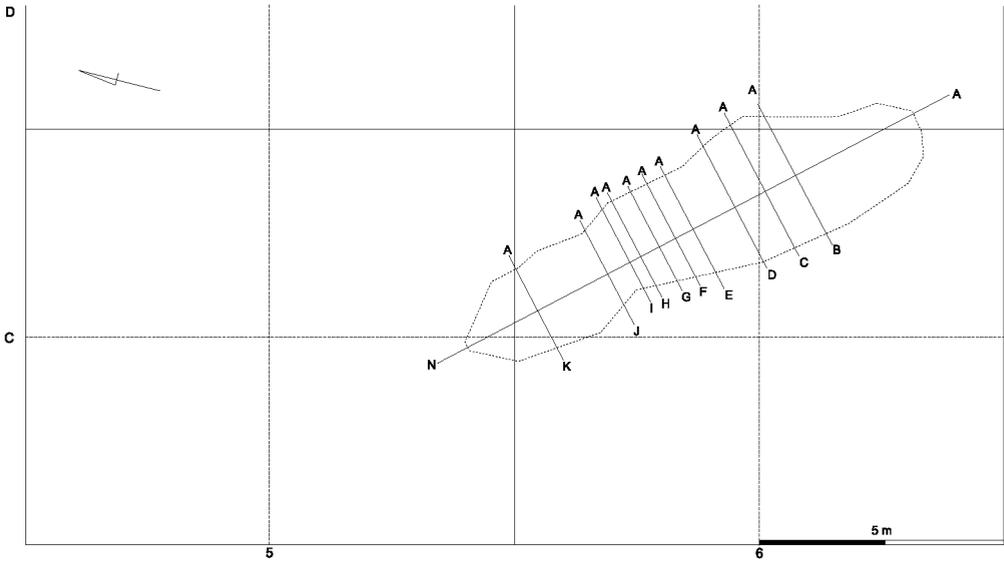


**Fig. 1.** A section of a 1:10 000 scale WIG map (sheet P50 S33 Jasło and P50 S34 Sanok) with the location of the plane crash

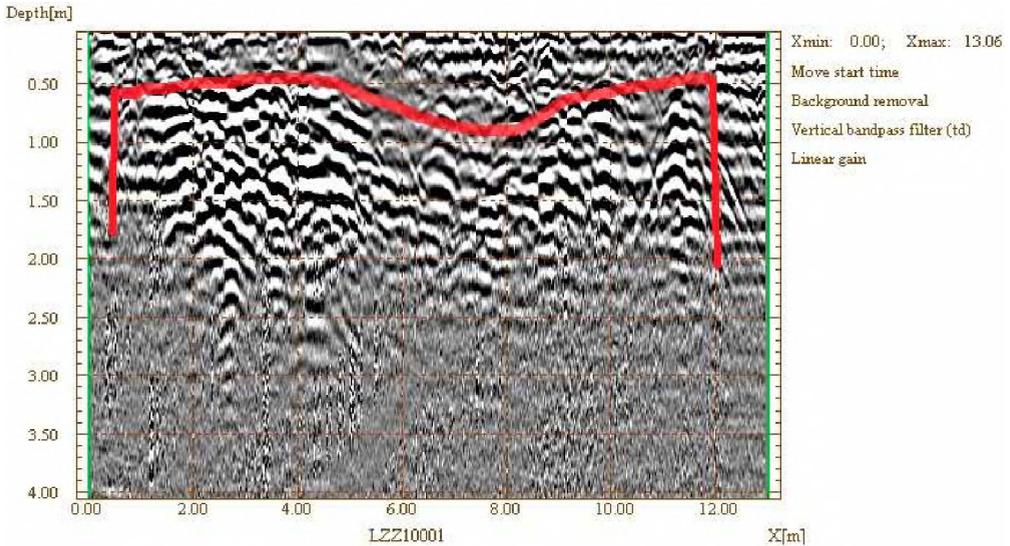
airport (Fryc 2009). The plane was piloted by staff sergeant Ioan Clop, born on February 26, 1921 in Romania in the village of Andrei Saguna, Arad district, in western Romania (Kubit 2016). In early February 1944, he arrived at the airport in Krosno together with a group of Romanian pilots to train on German Junkers Ju-87 planes, which were also used by the Romanian air forces. The described crashed plane was the German dive bomber Junkers Ju-87 D3 (Dora) Wek No. 110757, produced in 1943, which had completed a total of 161 flight hours and conducted 226 landings. The flight was of a training nature and its aim was to bomb a target located on the outskirts of the airport in Łężany. For unknown reasons, the plane did not release the suspended practice bomb and they hit the ground together. According to eyewitnesses, the crash was accompanied by a bang and an explosion, and a crater appeared at the place of impact. Shortly after the incident, an attempt was made to extract the aircraft wreck by the airport's German technical services. However, it was unsuccessful, and only a part of the fuselage was extracted along with the rear tailplane. Some fragments of the plane (e.g. a fragment of the wing) were abandoned and remained lying in a nearby forest until the 1970s.

## Research methodology

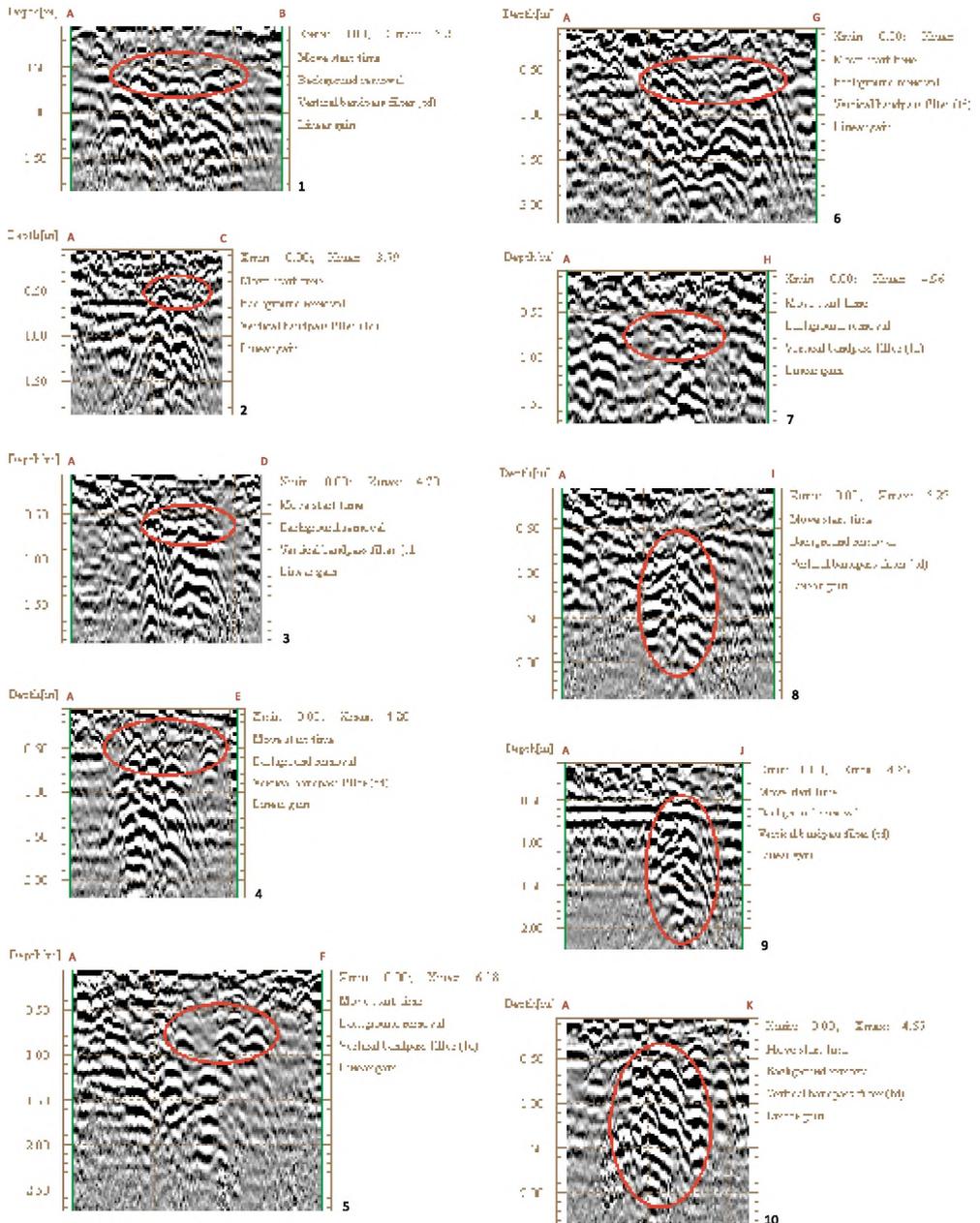
The georadar Detector Duo (made by the Italian company IDS) was used for georadar measurements. It works with two antennas (hence the name "Duo") with 250 MHz (so-called "deep") and 700 MHz (so-called "shallow") frequencies. This portable radar can locate objects in the ground up to a depth of 6 m, which was a sufficient range for conducting the search. Additionally, a RIS-ONE georadar was used (the same company), with an 80 MHz bistatic antenna (depth range of up to 14 m); however, it did not indicate any objects below 6 m. Weather conditions before and during GPR measurements were adequate – dry and warm, and therefore the soil was not hydrated. The research area was properly prepared – the grass had been cut on the fallow field. Trees did not grow in the discussed area. The aforementioned weather and terrain conditions made it possible to carry out accurate GPR measurements without the electromagnetic signal being suppressed by high humidity or recording unnecessary anomalies originating e.g. from the roots of trees.



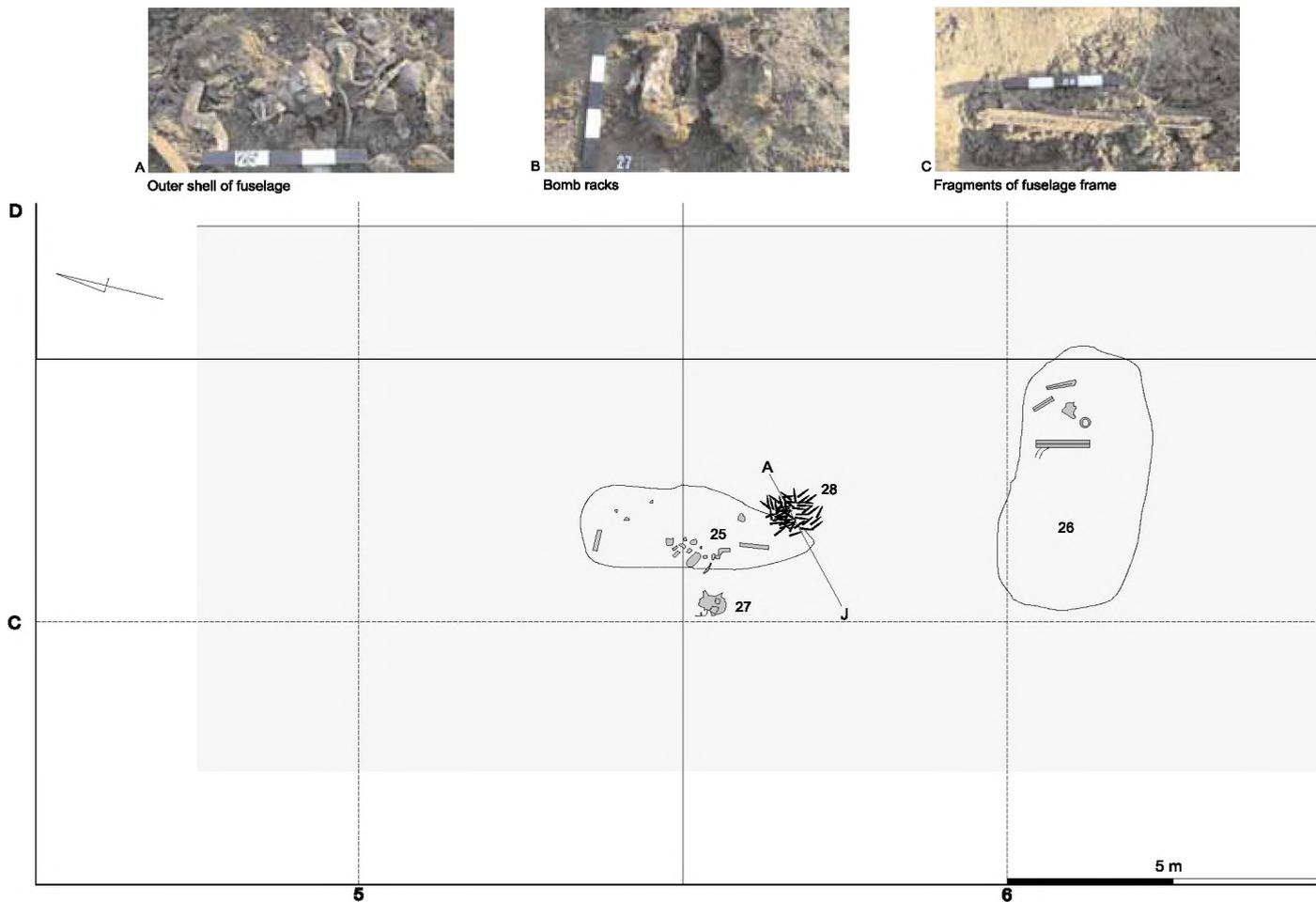
**Fig. 2.** Krościenko Wyżne, Krosno County, Ju-87D3 plane crash site. The location of the echograms and the range of anomalies indicated during georadar research is provided in grey



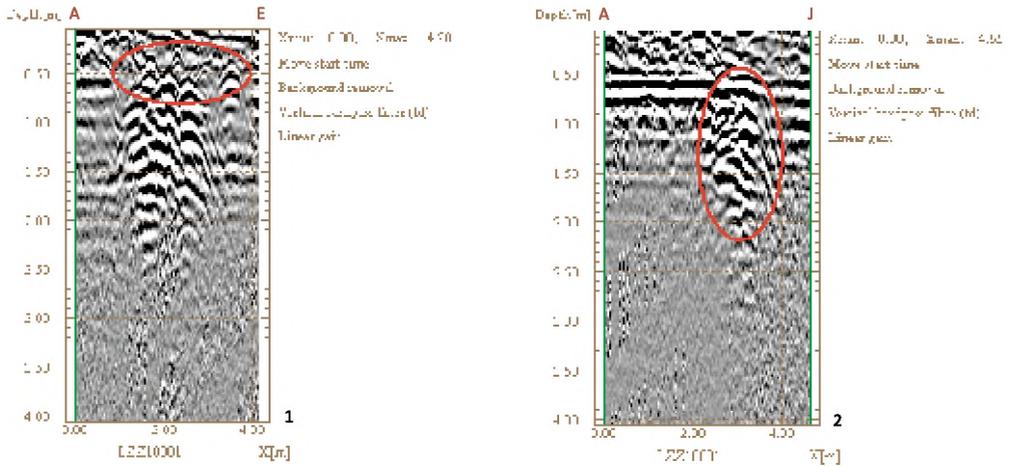
**Fig. 3.** AN echogram. Measurements taken of the long side of the localized object's outline. IDS / GPR apparatus, 700 MHz shielded antenna. The red line depicts the set of anomalies originating from the aircraft wreck



**Fig. 4.** Krościenko Wyżne, Krosno County, Ju-87D3 plane crash site. Compilation of AB – AK echograms. IDS / GPR apparatus, 700 MHz shielded antenna



**Fig. 5.** Krościenko Wyzne, Krosno County, Ju-87D3 plane crash site. Planigraphy of metal objects at a depth of 0–40 cm from the surface and the location of georadar profiles (archaeological trench marked in grey)



**Fig. 6.** Krościenko Wyżne, Krosno County, Ju-87D3 plane crash site. AE (1) and AJ (2) echograms. Measurements taken of the shorter side in the middle part of the localized object's outline. The visible anomalies, marked with a red line, originate, among other things, from large amounts of ammunition. IDS / GPR apparatus, 700 MHz shielded antenna

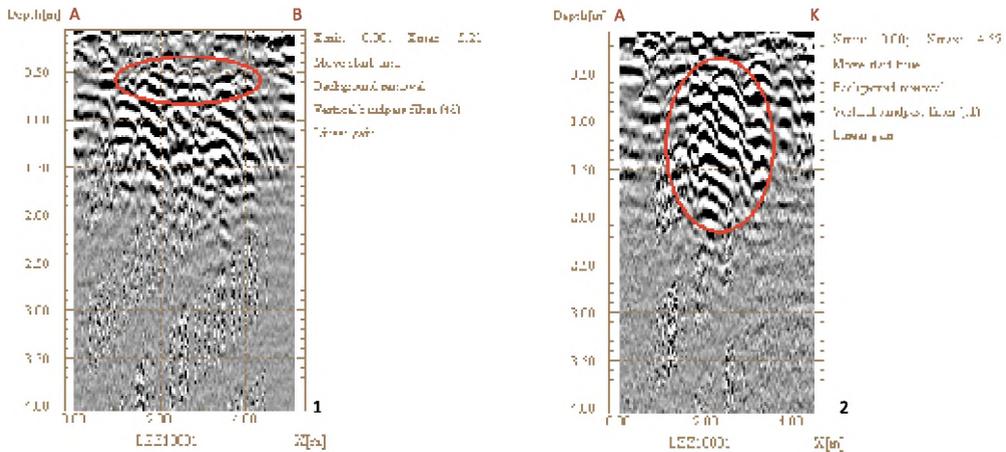
GPR measurements were carried out over the course of two days. On the first day, a measuring grid was established in an area covering approximately 900 m<sup>2</sup>, after which preliminary measurements were made at a distance of 2 m from each other vertically and horizontally. After these measurements, the search area was narrowed down to the spot where clear anomalies had been noted during the preliminary tests. This was an area about 11.5 m long and 3 m wide (Fig. 2–4).

On the next day of research, additional GPR measurements were carried out in the designated area in order to confirm the presence of an object giving a strong electromagnetic signal and a more accurate determination of the depth of the object in the ground. Next, the surveyor designated the geodetic points of the spot where this object was located. These points were plotted onto a map.

### Georadar and excavation research results

At the spot previously selected during the georadar study, a 10×17 m trench was established. Already after removing 50 cm, dozens of small objects were found, as well as several larger ones coming from the outer shell of the fuselage. In area 6C, the barrel of a MG 17 caliber 7.92 mm

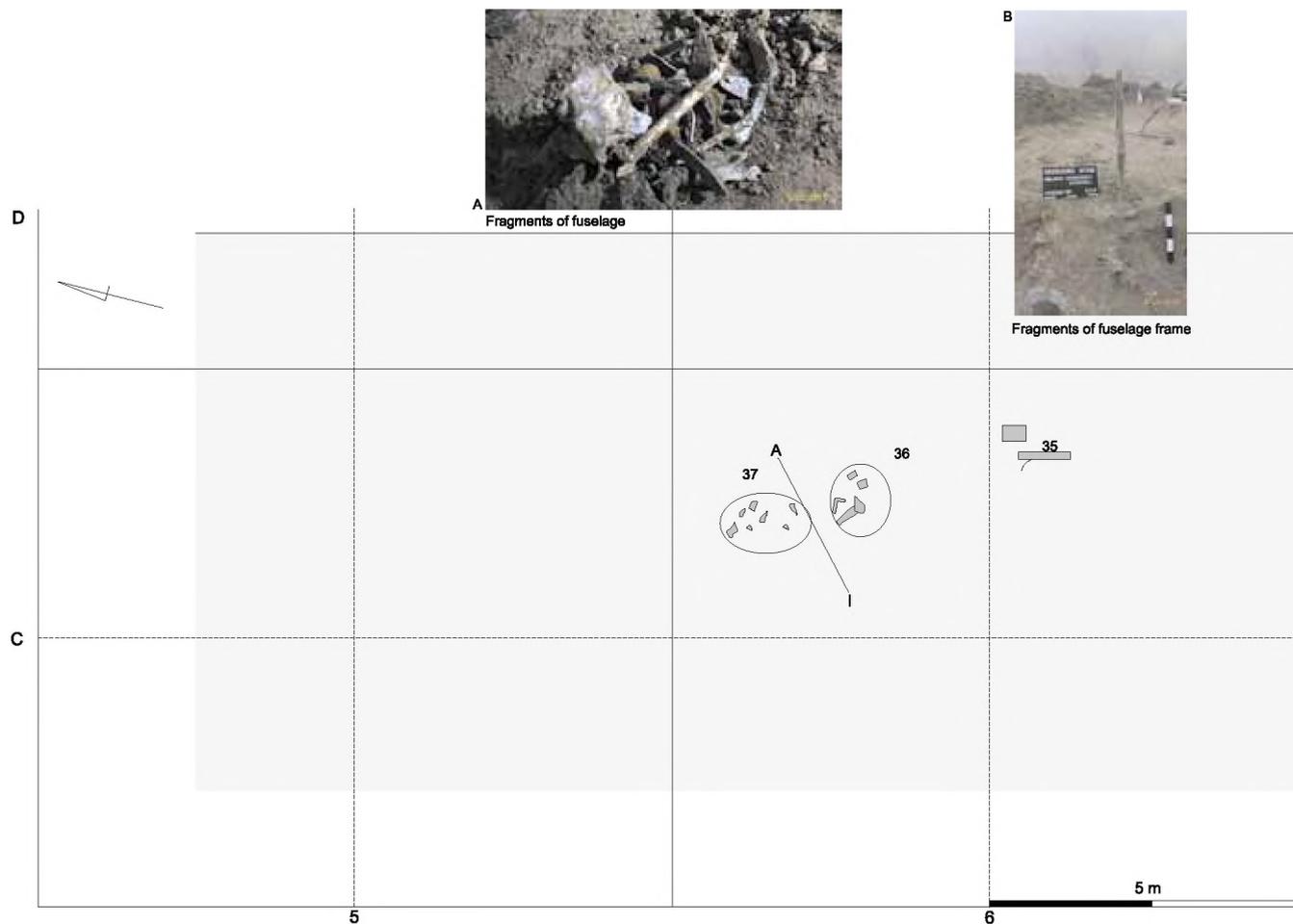




**Fig. 8.** Krościenko Wyzne, Krosno County, Ju-87D3 plane crash site. AB (1) and AK (2) echograms. Visible anomalies originating from the armour plating and armour elements (AB echogram) and from the air cylinders (AK echogram). IDS / GPR apparatus, 700 MHz shielded antenna

machine gun was uncovered that was stuck almost vertically into the ground (Fig. 5). A fragment of an engine mount beam was located nearby. In its vicinity, there was a concentration of large amounts of ammunition (several hundred pieces), heavily deformed due to the impact and sometimes showing traces of having exploded automatically as a result of fire. These objects were visible in echograms A–E and A–J (Fig. 6) and were marked as an area with distinct anomalies.

At a short distance, another element was found with concentrated mass, which in fact turned out to be the aircraft's aileron balance weight and air cylinders from the wing (Fig. 7). It can be assumed that they were visible in the AK echogram as an anomaly appearing at a depth of 0.5–1.0 m (Fig. 8: 2). In subsequent profiles, anomalies were present at a depth of 0.5 m, reaching a depth of 2.5 m. at the ends (Fig. 4, 8: 1). There were a few larger sheets constituting the outer shell of the fuselage and various structural elements (a fragment of the frame - in the centre wing carrying the loads from the wings, a fragment of the rear part of the fuselage). What is more, 6-mm-thick rectangular steel plates were uncovered measuring 35×45 cm in dimension, as well as one crescent-shaped sheet 40×40 cm in dimension, which were fragments of the armour plating protecting the crew from shelling from the ground (Fig. 7, 9).



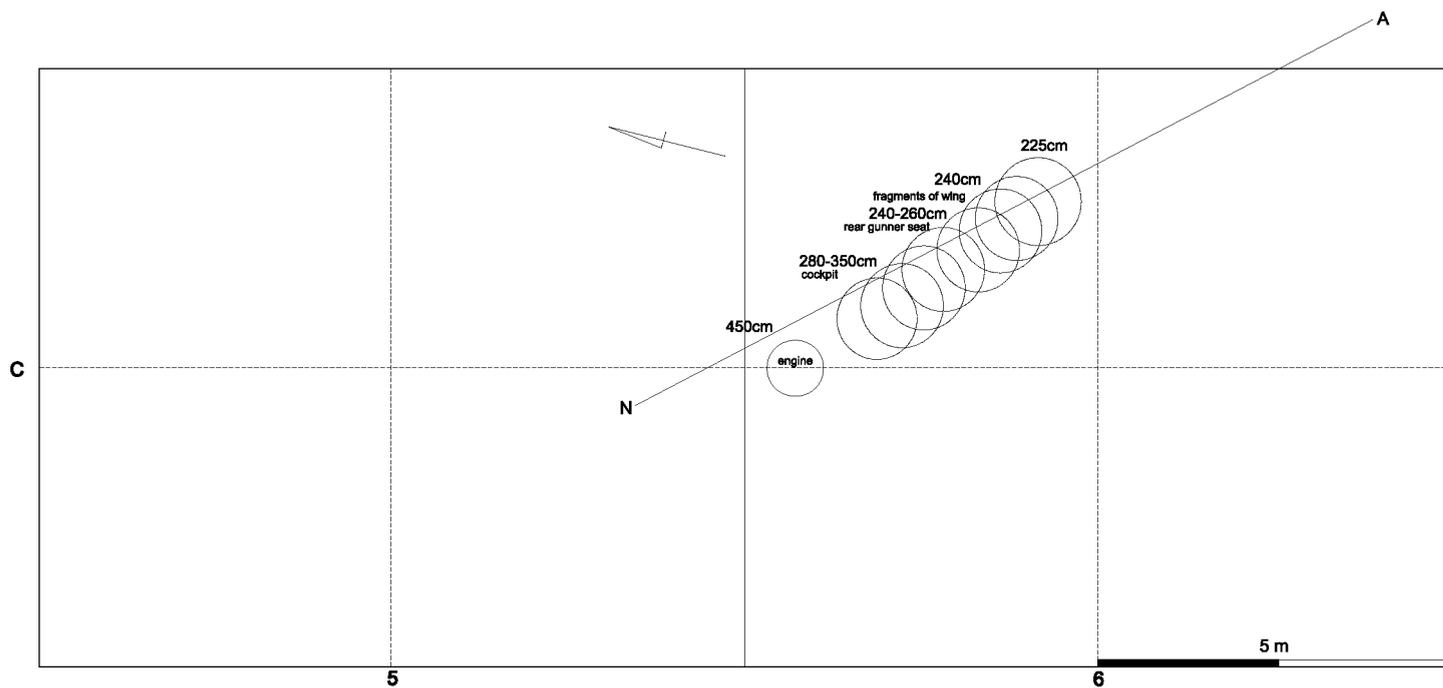
**Fig. 9.** Krościenko Wyżne, Krosno County, Ju-87D3 plane crash site. Planigraphy of metal objects at a depth of 60–70 cm from the surface and location of georadar profiles (archaeological trench marked in grey)



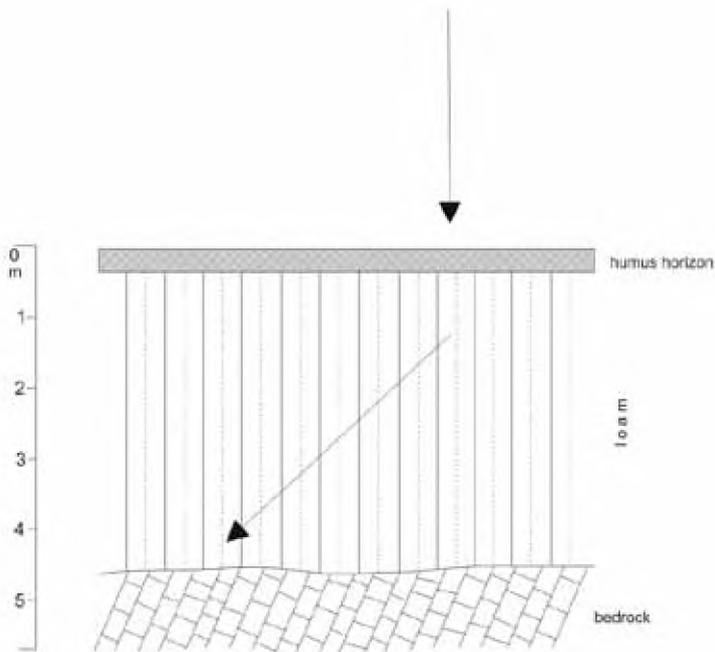
**Fig. 10.** Krościenko Wyżne, Krosno County, Ju-87D3 plane crash site. Aircraft fuselage remains at a depth of 300 cm (including various engine equipment)

There was some interference at a depth of more than 2.5–3.0 m. Initially it was assumed that this might be caused by anthropogenic liquid substances or water. After carrying out invasive works, it was found that the interference was caused by aviation fuel, coming from both wing tanks, as well as from the overflow tank located on the inner wing.

The aircraft's cabin part was located starting at a depth of approximately 2.3 m. This was poorly observable in the geowave survey due to the accumulation of large amounts of tiny elements within a small area. As a result of forces acting on the plane when it hit the ground, the cabin part was “flattened”. Considering its original length, i.e. nearly 3 m (measured from the point behind the rear gunner's cabin to the pilot's cockpit), it was reduced to a block about 1.5 m in diameter and less than 0.8 m thick. The last large elements of the plane discovered during the excavation included the hub of a three-blade propeller,



**Fig. 11.** Krościenko Wyżne, Krosno County, Ju-87D3 plane crash site. Schematic drawing showing the aircraft wreck at various depths, taking into account its larger and more characteristic elements



**Fig. 12.** Krościenko Wyżne, Krosno County, Ju-87D3 plane crash site. Reconstruction of aircraft flight path and fuselage displacement after impact with the ground

a large piece of the concrete practice bomb, and a Jumo 211J type aircraft engine. The engine was found on its side, at a depth of about 3–4.5 m from the surface (Fig. 10).

It could not penetrate deeper into the ground due to the bedrock consisting of layers of sandstone. As we can see from the preserved arrangement of the remains, the plane struck the ground almost vertically (Pasterkiewicz *et al.*, 2015). Torque force and ground resistance caused the engine, as it moved into the ground to a depth of about 4.5 m, to change its angle from 90 degrees to about 60 degrees while simultaneously deviating to the right by about 30 degrees (Fig. 11, 12).

## Conclusions

1. The use of the GPR method enabled establishing the location in the ground of the JU-87D3 plane wreck, which had crashed in the final stages of World War II in Krościenko Wyżne.

2. Invasive excavations confirmed the presence of individual parts of the crashed airplane at the designated spots of the georadar anomalies.
3. GPR is an effective device for precisely locating objects made of metal (including duralumin, steel) and rubber.
4. The use of a GPR allowed the researchers to plan the excavation carefully and limit the work to the zone indicated by the georadar.

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