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The main measuring point of the first Polish geodetic network on the summit of Łysica in the Świętokrzyskie Mountains in the light of verification archaeological research

ABSTRACT

The first professional geodetic network on Polish soil was established in 1829-1835. It was created for the mines and factories of the Old Polish Industrial District, which remained the largest centre of mining and metallurgy in Poland until the end of the 19th century. The main measuring point was established on the summit of Mount Łysica in the Świętokrzyskie Mountains. However, it was promptly destroyed and, despite detailed data published by one director of the project, Professor F.S. Armiński, it has only recently been rediscovered. Test excavations undertaken in 2019 revealed numerous inconsistencies between the archival data and the actual construction of the uncovered foundations.

KEYWORDS

Old Polish Industrial District, geodesy, triangulation, Łysica, Świętokrzyskie Mountains

Even well-documented historical facts can gain a more detailed perspective when verified by archaeological research. Archaeologists and historians have long cooperated closely whenever the methods of the two disciplines complement each other and a fuller picture of the past can be obtained, one that would be inaccessible to the other if they were to act separately. An example of just this kind of research is the test excavation of relics of a measuring point from the 1st half of the 19th century, carried out on Mount Łysica in 2021.

Łysica is the highest massif in the Świętokrzyskie Mountains (Fig. 1). It has two summits: the western one, considered to be the proper peak, with an altitude of 613.6 metres a.s.l., and the eastern one, called Skała Agaty, or Zamczysko, which is in fact slightly higher (613.97 metres a.s.l.). Unlike the western summit, Zamczysko is more difficult to access, as it takes the form of a steep rocky perch (Hajdukiewicz, Romanyszyn 2022). The top parts of Łysica are subject to erosive processes such as frost weathering of quartzite rocks and intensive surface erosion of residual soils, especially marked in freshly deforested areas. This factor played an important role in uncovering the relics of the structure that is the subject of this study.

Łysica is one of the earliest-surveyed mountains in Poland. It was the highest peak in the Kingdom of Poland (also known as Congress Poland), and it was also a convenient orientation and measuring point. This determined the location of the central point of a triangulation network established for surveying the adjacent areas of the Old Polish Industrial District, the largest mining and metallurgical centre in Poland at the time. This was the first undertaking of this kind to be commissioned and carried out by Polish surveyors over such a vast area (Banasik, Bujakowski 2018).

FIG. 1. Mount Łysica localization

The earliest altimetric measurements of the summit of Łysica were performed by the barometric method: in 1806 using the uncalibrated method, and in 1825 and 1829 using the calibrated method.[1] The 1829

1 The barometric method exploits the relationship between height above sea level and

measurement was made for the purpose of establishing a triangulation network for the aforementioned mining operations in the Świętokrzyskie region, as reported in detail by Franciszek Serafin Armiński (Armiński 1830). Altimetric measurements of this peak were repeated several more times in the next century, mainly for military maps, while in 1935 another detailed topographic survey of the entire Łysica massif was performed for the needs of a forest management map. It shows the heights of the western and eastern peaks of the massif at 612.13 m and 612.30 m a.s.l., respectively (Białokur 1935).

A geodetic marker used in this survey has survived in the village of Lipowe Pole, fixed in a field in the form of a structure resembling a roadside shrine, a valued monument to the history of surveying. Remains of another such marker were found on the western summit of Łysica (Armiński 1830; Banasik, Bujakowski 2018; Kozak 2019). This site marked the origin of the coordinate system for the first detailed triangulation network on Polish soil, created in 1829-1835 for the Old Polish Industrial District.

It is worth noting that the tradition of mining and metallurgy in the area between the Vistula, Pilica and Nida Rivers, which is where the district was located, can be traced back many thousands of years (Zientara 1954; Pazdur 1962; Radwan 1963). Various mineral resources were extracted and processed here: mainly iron ores and ores of non-ferrous metals (copper and lead with an admixture of silver), as well as various types of rock (flint, limestone, sandstone, loam and ceramic clay). Haematite used as a dye for ritual purposes was mined on the banks of the Kamienna River as early as the Palaeolithic (Schild *et al.* 2011). In the Neolithic and Early Bronze Age, large flint mines operated there, in which chocolate flint, Świeciechów flint, and, above all, banded flint were extracted (Balcer 1975; Bąbel 2015). In late antiquity, the largest centre of iron production beyond the Roman limes operated on the north-eastern fringes of the Łysogóry Range (Bielenin 1992; Orzechowski 2007).

In the medieval and post-medieval periods, lead, silver and copper ores were mined, mainly on the estates of the Bishops of Kraków. However, the most important activity was the mining and smelting of iron. In the second half of the 16th century, more than 40% of the forges under the Polish Crown

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atmospheric pressure and at the time (early 19th century) it required the use of a bulky mercury barometer. The results were burdened with an error of several to tens of metres, depending on the calibration of the measurement to the current atmospheric conditions: the pressure system, temperature and humidity.

(Polish part of the Polish-Lithuanian Commonwealth) operated here (Guldon, Kaczor 1994). It was also here, at the beginning of the 17th century, that Italian specialists from Lombardy implemented, for the first time on Polish soil, the blast-furnace technique (Bobrza, Samsonów, Umer), an innovation which revolutionised the metallurgical industry (Miczulski, Nosek 1989).

The heyday of the district came in the first half of the 19th century, when a complex of industrial plants for the mining and processing of iron was established along the Kamienna River. In addition to numerous ore mines, industrial facilities like blast furnaces, forges, and rolling mills were built and put under the administration of the Bank of Poland in 1833. The director of this project was Stanisław Staszic, and his work was continued by Franciszek Ksawery Drucki-Lubecki (Wójcik 1999; Szczepański 2019). As late as 1878, the district still yielded around 90% of the pig iron production of the Kingdom of Poland. However, by the turn of the 20th century the development of modern mining and processing in the Dąbrowa Coal Basin led to its gradual decline.

In view of the importance of this industry to the economy, the Government Commission of Revenue and Treasury of the Kingdom of Poland decided in 1827 to carry out geodetic and a cartographic survey of the mining estates of the Old Polish Industrial District. Ensuring adequate accuracy of measurements in the difficult terrain of the Świętokrzyskie Mountains meant creating a triangulation network. The task was entrusted to Wojciech Niemyski, the general surveyor at the Department of Estates and Government Forests, and Professor Franciszek Serafin Armiński (1789-1848), the astronomer in charge of the observatory at Royal Warsaw University. Having familiarised themselves with the terrain and the progress of the work done, they considered it necessary to create a rectangular coordinate system, on the basis of which the locations of survey points were to be determined. The axes of this system were to be two perpendicular lines – a meridian and a parallel – intersecting at the point that would become the origin of the system and at the same time provide the best possible observation conditions. The western summit of Łysica was considered the optimal location. In September 1828, the base of the survey station was built there, and residential and service buildings were erected. Inclement weather delayed the completion of the construction until October 1829. At that time, the latitude of the summit of Łysica and the direction of the meridian crossing it were determined based on astronomical observations, as were the azimuth to the tower of the monastery church on Święty Krzyż, and – based on barometric measurements – the height of the western summit of

Łysica, which was established as 606.08 m above the level of the sea at Gdańsk (Armiński 1830; Kosiński 1959; Włodarczyk 2016; Banasik, Bujakowski 2018).

The control point on Łysica had the form of a square stone pedestal. According to an illustration published in *Pamiętnik sandomierski*, its lower part, sunk into the rocky ground to a depth of approx. 2.6 m, was slightly wider (approx. 4.6 m) than the aboveground part. The latter was a cuboid on a square plan with sides of approx. 3.6 m and a height of approx. 2.3 m, which served as a pedestal for the observation post. In its centre was placed a brick base for the measuring device (approx. 0.8 m in diameter and approx. 1.6 m high) topped with a marble slab with a mark (called 'centre'). The post was provided with a temporary wooden enclosure, including a roof, which was removed by means of a crane for measurements. A residential barrack (approx. 8.1 m x 4.9 m) was built nearby, connected to the measuring point by a covered corridor approx. 11.5 m long. An additional freestanding rain shelter was erected next to it (Armiński 1830; Berezowski 1984; Kozak 2020) (Fig. 2).

After completion in 1829, the structure was secured by enclosing the base of the measuring device with an octagonal pyramid topped with an iron cross. As soon as 1830 the structure was destroyed, to be rebuilt in 1834 (with an accuracy of within two inches of the original). The structure was still in existence in 1854, after which it was demolished again under unknown circumstances. A wooden military observation post was then erected in its place, and this was destroyed in a storm in August 1904 (Armiński 1830; Dybczyński 1909; Berezowski 1984; Kozak 2020).

For many years the exact location of the historic structure from 1828 remained unknown. Its remains were only discovered in 2019 by one of the authors of this paper (Kozak 2019). At the top of the mountain, in the immediate vicinity of the wooden cross erected there by the local population in the interwar period, the outline of a stone plinth with a side of approximately 3.6 m was then identified, and brick fragments were also encountered nearby (Fig. 3: 1). The discovery was indirectly aided by an unprecedented act of vandalism carried out in 2013: the illegal felling of more than a dozen trees which triggered intense erosion processes in the uncovered area. In just two years from the time the trees were cut down and the structure of the turf stabilising the ground was disturbed, about 15 cm of the sediment has eroded away, partially exposing the outline of the structure.

Archaeological research carried out on the summit of Łysica in October 2021 aimed to determine the exact location of the described structure and details of its construction. Due to the destruction of the aboveground part of the pedestal, which was the base for the observation post, the focus was on its foundation part, partly visible at the present-day ground level. To enable detailed measurements an attempt was made to trace the outlines of the foundation around its perimeter, removing loose stones and loess clay lying on the surface in the process. The pedestal was roughly square in plan, with sides of approximately 3.6 m. Except for the southern and partly western side, it was possible to trace its outline along its entire length. The SE and SW corners were damaged at this level, and further exploration at these points was abandoned due to the thick layer of stone rubble lying there. However, the eastern and northern sides, where the damage was least extensive, were clearly discernible.

One of the main objectives of the verification work was to determine the depth at which the pedestal was founded. A 1m x 1.5m test pit was opened at the best-preserved corner of the structure at the north-east. After removing a few-centimetre layer of heavily eroded forest humus, the exploration proceeded with the removal of quartzite sandstones of various sizes. The structure of this fill was very loose, allowing various objects – mainly modern rubbish – to penetrate it. In some of the free spaces between the stones yellow loess clay was present.

The initial boundary of the excavation could only be maintained on the side of the pedestal. Along the other sides large stone slabs made it difficult, and sometimes impossible, to continue exploration. This was the case in the NW part of the excavation, where a large boulder blocked further work. At a depth of about 100 cm, the footing of the stone foundation was identified. To make sure that there were no anthropogenic layers below, the exploration was continued for another 10 cm.

The uncovered stone foundation was patchy, and it took the form of a dry wall without any traces of mortar binding the stones. It was made up of large, well-fitted quartzite boulders (30x40x50 cm), between which smaller stones were laid, while trying to keep the face of the wall fairly even. In the W section, the foundation rested on a large irregular stone slab lying *in situ*, which cannot possibly have been removed due to its size (Fig. 3: 2).

Rather than resting directly on the rock, as suggested by the drawing in *Pamiętnik sandomierski*, the structure rested on a layer of loess clay, which should be considered the natural bedrock. Only in part E did the foundation trench reach about 10 cm below the footing of the pedestal. This layer, which was clearly darker than the bedrock, contained a charcoal-saturated deposit and small lumps of lime mortar. No artefacts were found at this level.

The work revealed significant discrepancies between the drawing of the measuring point on Łysica presented by Armiński and the actual state of affairs. According to the linear scale on the drawing, the foundation was supposed to be 4.7 m wide and the above-ground pedestal only 3.6 m wide. During the research, however, it was found that the foundation part did not differ in size from the unpreserved above-ground part: the pedestal was 3.6 m wide and was no wider in the foundation part.

The depth at which the wall was founded also differs from that shown on the drawing. The foundation was supposed to rest at a depth of about 2.6 m, directly on the bedrock, which was depicted as sloping and fractured layers of stones (Armiński 1830). Yet the footing of the uncovered wall was recorded at a depth of only about 1 m from the present ground surface. No rocky bedrock was found at this level either. Instead, a layer of loess clay of undetermined thickness was found. Such an arrangement of layers is typical of the summit parts of the Łysogóry Range, where, in the periglacial period, large amounts of loess dust accumulated at the base of quartzite nunataks towering over the ice sheet.

The data obtained allow us to reconstruct the likely method of construction of this part of the structure. In all probability, work began with the levelling of the ground at the highest point and the excavation of a large trench for the foundation of the structure. This means that the original height of the summit may have been lowered at that time. Due to the nature of the subsoil, which was made up of quartzite rock rubble, an irregular pit, considerably larger than the planned foundation, had to be excavated. It was quickly found that huge boulders prevented a deeper excavation and the footing of the wall began to be laid no deeper than about 1 m below the surface, in some places directly on stones that could not be removed. This is confirmed by our observations in the NW corner of the test trench, where the foundation partly rested on a large boulder. It was also probably decided that the foundation did not need to be as large as originally envisaged and a size matching the dimensions of the aboveground part of the pedestal was deemed enough. The poor weather conditions reported by Armiński, which made it impossible to complete the work in 1828, may also have influenced this decision. After the foundation was laid, the trench was backfilled with quartzite rubble, bringing the area back to its original level.

In light of the facts cited, the described sketch by Armiński should be considered inaccurate and even misleading. Perhaps it was only an initial design, not fully realised due to the aforementioned problems. It is highly unlikely that the reconstruction undertaken in 1834 after the original structure had been damaged in 1830 involved a change of the foundation. Indeed, Armiński's account shows that it was reconstructed to within two inches of the original (Berezowski 1984). Nor can it be ruled out that these inaccuracies were due to an incorrectly drawn linear scale. In fact, the proportions marked on the drawing do not at all indicate any significant differences between the foundation and the above-ground part.

The presence of control point relics on the summit of Łysica poses another very important interpretative problem. For, in the light of the observations made, it can be assumed that the low elevation traditionally regarded as the culmination of the western summit of the mountain, may be – at least partly – anthropogenic in nature (Kozak 2020). This undermines the validity of the measurement results of the points lying in the immediate vicinity of the cross (Krzyż-Góra Łysica 613.223 m a.s.l. and Kamień-Góra Łysica 613.614 m a.s.l.) (Romanyshyn, Hajdukiewicz 2019) as reflecting the correct height of the massif. In view of the probable destruction of the natural summit, the original height might theoretically be measured on the upper surface of the foundation of the former pedestal from 1828 (approx. 4.6 m x 4.6 m), which, according to the drawing in *Pamiętnik sandomierski*, was supposed to be at the level of the adjacent ground (Armiński 1830; Kozak 2020). However, due to the different shape of the foundation, as revealed by the excavations, this concept has to be discarded because the lack of this reference point.

There remains the question of associated infrastructure visible on Armiński's plan in the form of outbuildings dating from 1828-29. These were, according to the drawing, structures in the form of sheds built on the ground surface (Fig. 2). The only structure possibly sunken into the ground was the rain shelter. Evidence of their presence may be found in two irregular depressions, approximately 4 m x 4 m in size and approximately 1 m deep, located approximately 30 m south-east of the control-point relics (Kozak 2020).

Finally, it is worth briefly addressing the technique used to document the surveyed area. The materials available for Łysica in the Central Geodesy and Cartography Database, i.e. digital elevation models and digital surface models obtained by photogrammetric survey using the ALS (Aerial Laser Scanning) technique, were insufficiently detailed to measure the site. In order to visualise the uncovered elements of the structure with stereophotogrammetric imaging, control measurements of the height of the surveyed area were made with the GNSS and tachymetric methods, and a photogrammetric aerial survey was carried out with a DJI Mavic 2 Pro drone. Due to the significant

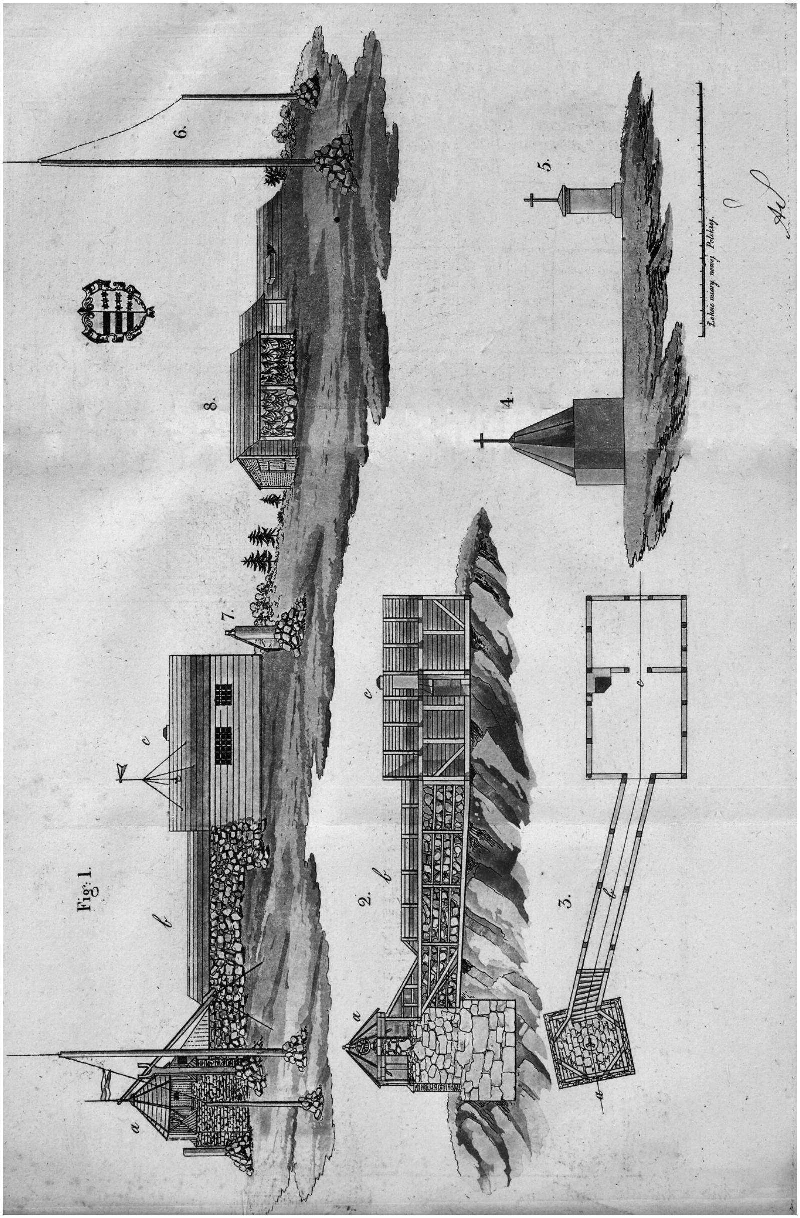

FIG. 2. Buildings from 1828 on the western summit of Łysica, and the planned forms of consolidation of survey points on Łysica (4) and near Rudki and Lipowe Pole (5); (Armiński 1830, https://polona.pl/item/pamietnik-sandomierski-pismo-poswiecone-dzieiom-i-literaturze-oyczystey-t-2-posz-7,MTEwMDE1NTkz/63/#info:metadata [20 I 2023])

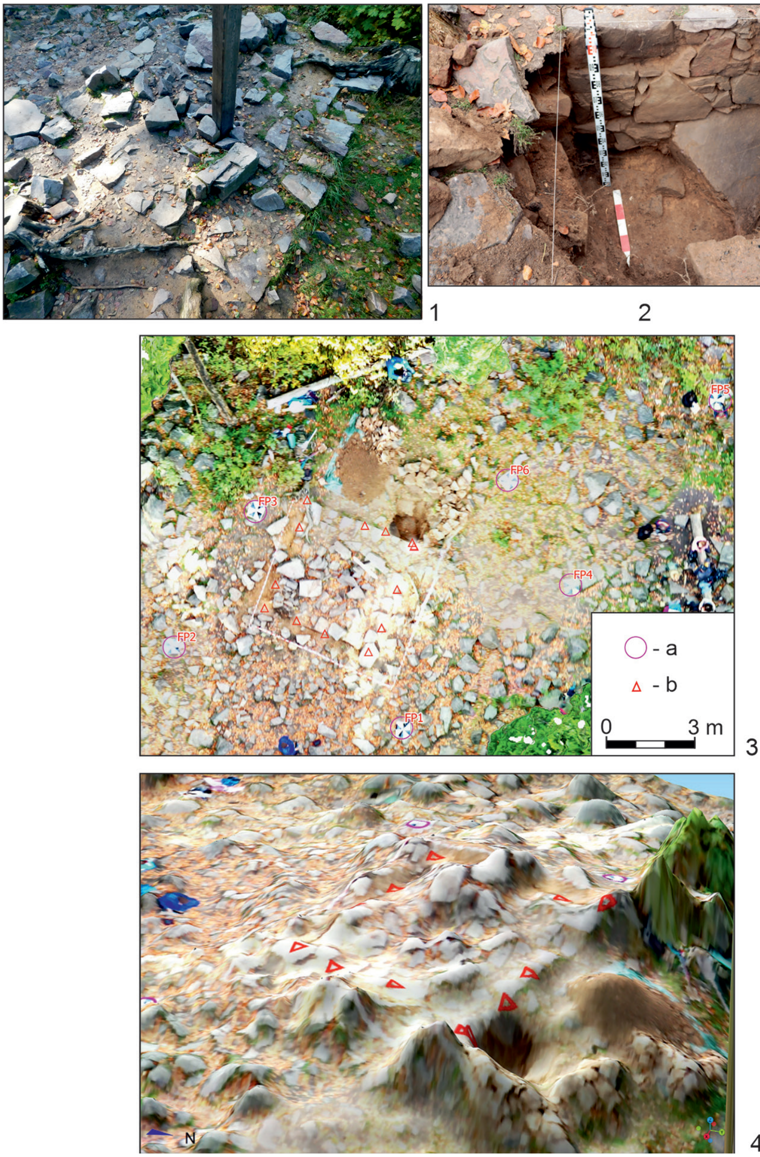

FIG. 3. 1. Outline of the pedestal of the main measuring point from 1828 on the western summit of Łysica, view from the north-east (photo B. Kozak 2019); 2. Test trench at the NE corner of the foundation of the measuring point on Łysica – profile N (photo S. Orzechowski 2021); 3.The site on the mosaic of UAV images and the locations of ground control points: a – GCP; b – spot heights; 4. 3D visualisation of the archaeological site model – view from ENE, vertical scale with 1.5 times elevation; marked points as in Fig. 3: 3 (photo. M. Hajdukiewicz 2021)

forest cover of the area, the survey was carried out with double overlap (two sets of rows, perpendicular to each other), and images were taken obliquely at 70 degrees. A photogrammetric warp (set of ground control points - GCP) was established on the ground surface in the form of contrasting marks measured in the field using the GNSS RTK method in the PL 2000 S7 coordinate system. (Fig. 3: 3). The aerial images were processed using Agisoft Metahape 1.6.5 software.

The achieved accuracy of the alignment of the photo set to the GCP network can be expressed by the RMS (x, y, h) error of the position of the points, at 0.007 m, 0.004 m, and 0.002 m, respectively. This was made possible by the high resolution of the photos (0.01m/pixel). As the accuracy of the GNSS RTK measurement is almost an order of magnitude lower, it can be assumed that the resolution and geometric features of the photographs did not affect the accuracy of the elevation measurement on the DSM obtained from this survey. The resolution of the DSM in the form of a regular grid was 0.0363 m/pixel, as visualised in Fig. 3: 4. The situational accuracy of the model and the orthophotomap developed with it was 0.04 m (RMS error), which is comparable to the accuracy of GNSS RTK measurements.

High-resolution photogrammetric methods have already been successfully used to document archaeological fieldwork in the past (Boroń *et al.* 2004). However, the technique used (ground photogrammetric camera) made it very labour intensive. Nowadays, non-metric cameras installed on unmanned aerial vehicles (UAVs) are increasingly used for this purpose, allowing for reduced expenses while maintaining satisfactory accuracy in the representation of measured objects (Markiewicz *et al.* 2018).

Despite the very limited scope of the excavations, the verification research carried out on the summit of Łysica produced important information on the nature and details of the construction of the first base survey point built on Polish soil for a large professional geodetic network. Metrical data on the construction and size of the foundation part of the structure were detailed. This allowed us to verify the picture of the site based on iconographic sources as inaccurate.

Excavation work on Łysica should be continued in order to confirm the data obtained and to acquire additional information on the infrastructure built for the site. The activities undertaken so far provide a positive example of creative cooperation among specialists of various disciplines, enabling one of the most interesting episodes in the history of Polish geodesy to be reconstructed more comprehensively.

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