

Piotr Banasik

## CARTOGRAFICAL AND GEODETICAL ASPECTS OF THE KRAKUS MOUND IN CRACOW\*

AGH University of Science and Technology.  
pbanasik@agh.edu.pl

**Key words:** Krakus Mound, archival maps, astro-geodetic network

### Abstract

In this work the fate of the Krakus Mound, the oldest of all existing Krakow's mounds, has been presented. The work was carried out based on selected iconographic, cartographic and geodetic documents. Using as an example old views, panoramas of the city and maps, various functions that the Krakus Mound was fulfilling over its long history were shown. An attempt was made to document the military significance of this mound and the surrounding hills. The particular astro-geodetic importance of the Krakus Mound on the scale of the city and southern Poland region was widely discussed. The Krakus Mound also inscribed itself in the history of the use of GPS technology as well as research on the local determination of the geoid in the area of Krakow.

## KARTOGRAFICZNE I GEODEZYJNE ASPEKTY KOPCA KRAKUSA W KRAKOWIE

**Słowa kluczowe:** kopiec Krakusa, archiwalne mapy, sieć astronomiczno-geodezyjna

### Abstrakt

W pracy przedstawiono losy najstarszego z istniejących krakowskich kopców, kopca Krakusa. Pracę wykonano na przykładzie wybranych dokumentów ikonograficznych, kartograficznych i geodezyjnych. Na przykładzie dawnych widoków, panoram miasta i map pokazano różne funkcje, jakie kopiec Krakusa pełnił w swojej wieloletniej historii. Podjęto próbę udokumentowania militarnego znaczenia tego kopca i okalającego go wzgórza. Szeroko omówiono szczególnie znaczenie astro-geodezyjne kopca Krakusa, w skali miasta i regionu południowej Polski. Kopiec wpisał się także w historię stosowania techniki GPS na obszarze Krakowa i w badania dotyczące lokalnych wyznaczeń kształtu geoidy.

## 1. INTRODUCTION

The Krakus Mound has a particular place in the history of Krakow. It is one of the oldest among the known five Krakow's mounds. It is in the group of prehistoric mounds, together with the Wanda Mound (Fig. 1). The modern mounds are the mounds formed in the last two centuries: the Kościuszko Mound and Piłsudski

Mound. The fifth Krakow's mound, called the Esterka mound was destroyed, nevertheless its location can be given with accuracy (Banasik, 2010). The history of the Krakus Mound, probably the oldest mound in Krakow and undoubtedly the one of the most interesting objects of the Krakow's landscape was totally different.

The Krakus Mound is a relatively small heap of soil of a conic shape. Its height is 16 m and diameter is 57 m

\* Developed within the framework of the statutory research No. 11.11.156.006.

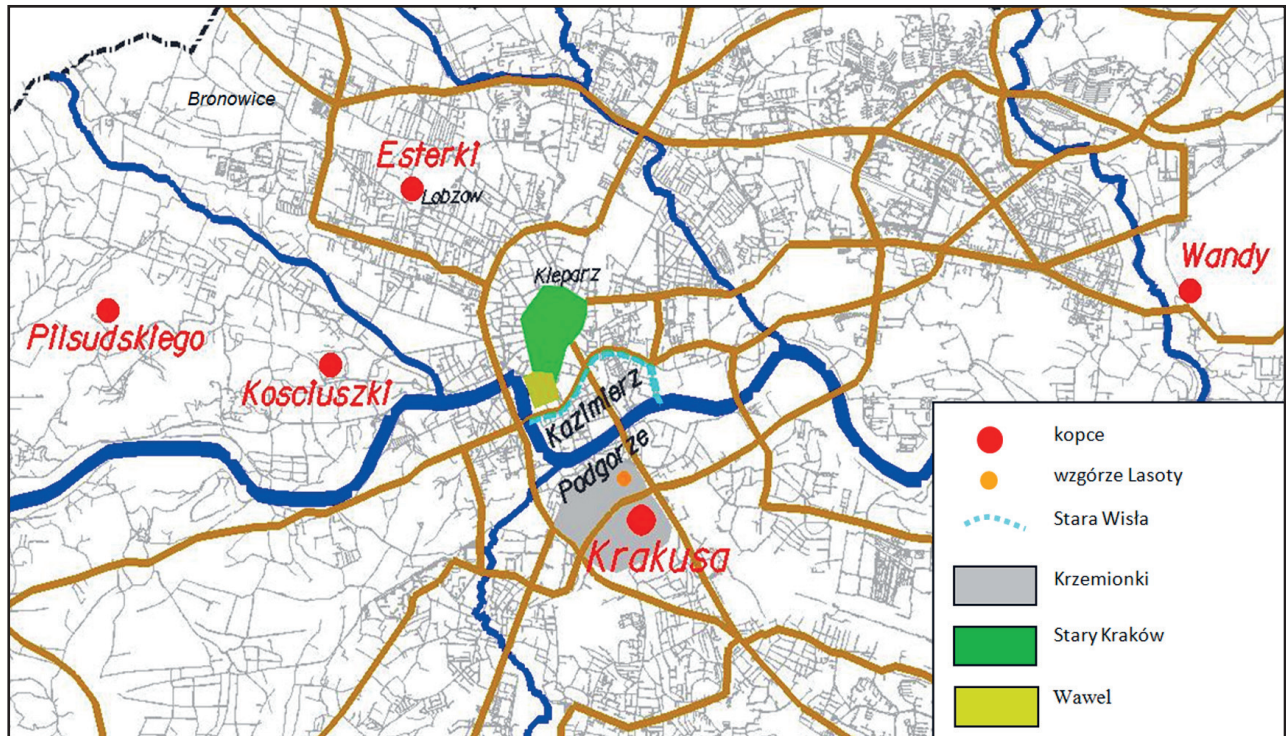


Fig. 1. Localization of the Krakow's mounds in the contemporary Krakow

Rys. 1. Lokalizacja kopców krakowskich na obszarze współczesnego Krakowa

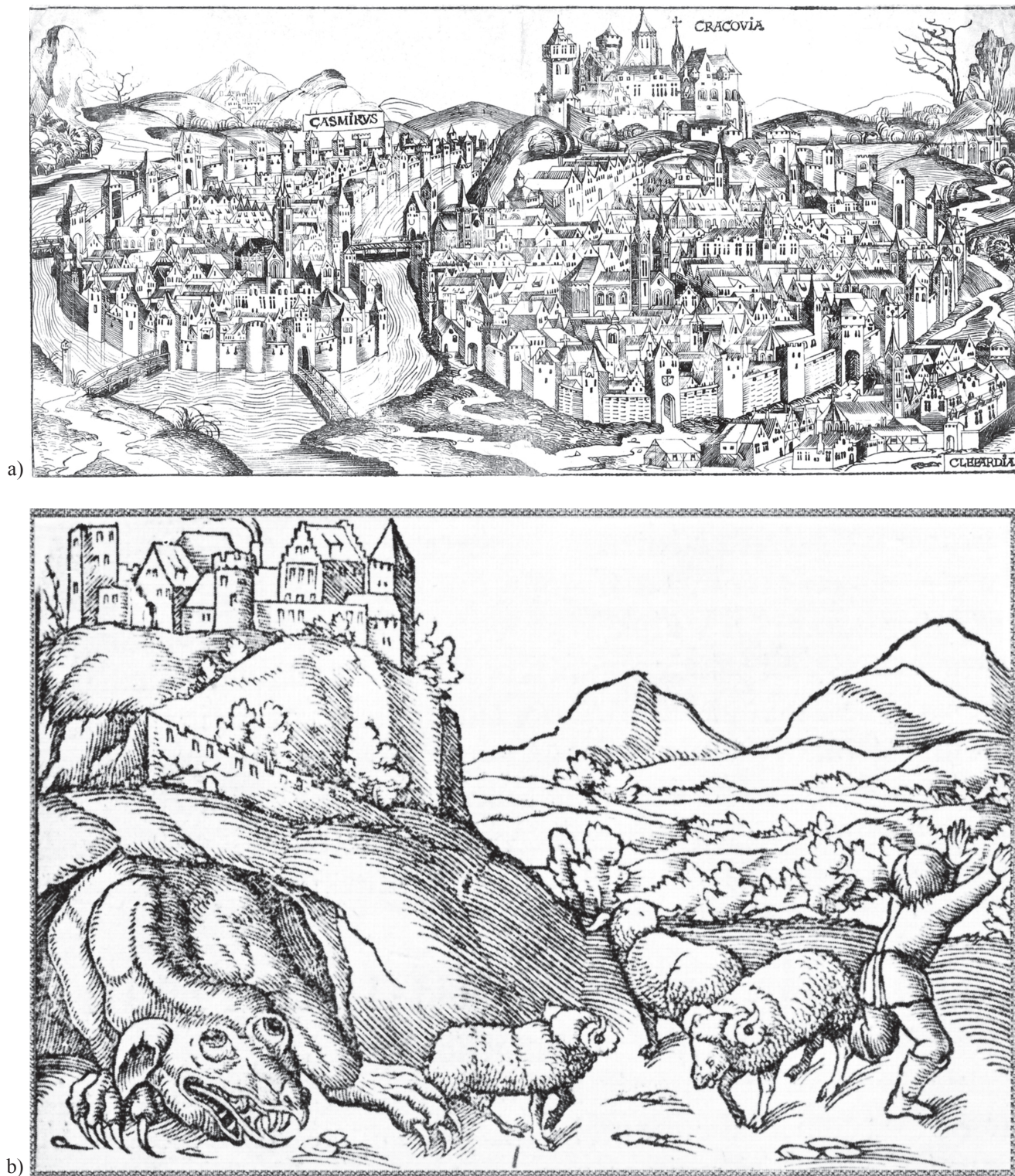
at its base. The mound is situated near the crossing of the streets Wielicka and Powstańców Śląskich, very close to Cmentarz Podgórski (the Podgórze Cemetery). It was constructed on one of the hills of Krzemionki Podgórskie, built of the Jurassic limestones. Their altitude a.s.l. is 250 m and the chain of these hills surrounds Krakow from the south. Due to such situation, in the past, the hill with the mound made a good place to see Krakow from the south. Limestone base of the mound, its situation and its durable construction, made it the most stable among all the Krakow's mounds, so far.

Nowadays the mound is a characteristic point in the routes of foot trips, viewing point and the place of outdoor meetings of the residents. The history of the Krakus Mound and its primary functions have always been the subject of interest. It is worth mentioning that the mound was mentioned in the Chronicle by Jan Długosz, as a grave of Duke Krak, in 1930s there were archaeological explorations of the mound and nowadays there are hypotheses about its geo-informatic significance (Góral, 2006). Since 15<sup>th</sup> century the Krakus Mound has had a particular significance in the iconography of Krakow, due to so-called views and panoramas made

for selected Polish cities of those times. For many years it was also a characteristic orientation point in old maps of Krakow. The Mound had also an important role in the development of astronomy, surveying and cartography in this part of Poland. The objective of this paper is to present additional not very well known functions of this characteristic object of Krakow.

## 2. THE KRAKUS MOUND IN OLD PICTURES AND MAPS OF KRAKOW

In the topography of Krakow's Krzemionki there are two hills, situated relatively close one to another. The lower, northern is called *Góra Lasoty* (Mount Lasota, Lasota's Hill) and there is St. Benedict's Church there. The higher hill is on the south and has the Krakus Mound on the top (Fig. 1). The areas of Krzemionki, and in particular the hill with the mound have been affected by human activities for a long time. During the archaeological research wooden and stone artefacts were found. Their location on different levels inside the Krakus Mound indicates that the present form of this construction was



**Fig. 2.** Views of Krakow; a) semi-imaginary view of a so-called “Krakow Tricity” – woodcut put in *Schedel’s World Chronicle* by H. Schedel of 1493; b) imaginary view of the Wawel Hill – woodcut of “*Cosmographia*” by S. Münster of 1544

**Rys. 2.** Widoki Krakowa; a) półfantastyczny widok tzw. “trójmiasta krakowskiego” – drzeworyt zamieszczony w *Kronice Świata* H. Schedla z 1493 r.; b) fantastyczny widok Wawelu – drzeworyt z “*Kosmografii*” S. Münstera z 1544 r.

formed in several stages, over many centuries. The archaeological data indicate that the process of making the mound was connected with the settlement of the Lusatian culture, Slavic culture and finally Christian culture (Jamka, 1965). The subsequent „users” of these areas took the hill with the mound and probably „upgraded” it according to their needs. The geological structure of this mound indicates that the axis of its conic shape was also moved. The results of archaeological research allow the assumption that the area of the Krakow’s Krzemionki is one of the oldest inhabited regions of Krakow. Today the surroundings of the mound are known of the Feast of Rękawka, held every year on Tuesday after Easter, as well as a quarry situated near-by called Liban, the gloomy history of which was presented in Spielberg’s film: „*Schindler’s List*”.

The oldest documented traces of the Krakus Mound are seen in the illustrations of medieval books, in the form of the city views and in the later maps of Krakow. The mound itself, as a high hill in the vicinity of the old Krakow was also used as the place of making one of the most interesting panoramas of the city and its vicinity from the southern side.

City panoramas made in 15<sup>th</sup>–28<sup>th</sup> century for many European cities, made introduction to later city maps. Several city views of this kind were made for Krakow and now they are valuable sources of knowledge on architectural changes in the landscape of this city (Dąbrowska-Budziło, 1990). Among the elements of the architecture of Krakow presented in such views, the Krakus Mound is also present. It had orientation function in the drawing and made a characteristic element of the city landscape. The oldest known panorama of

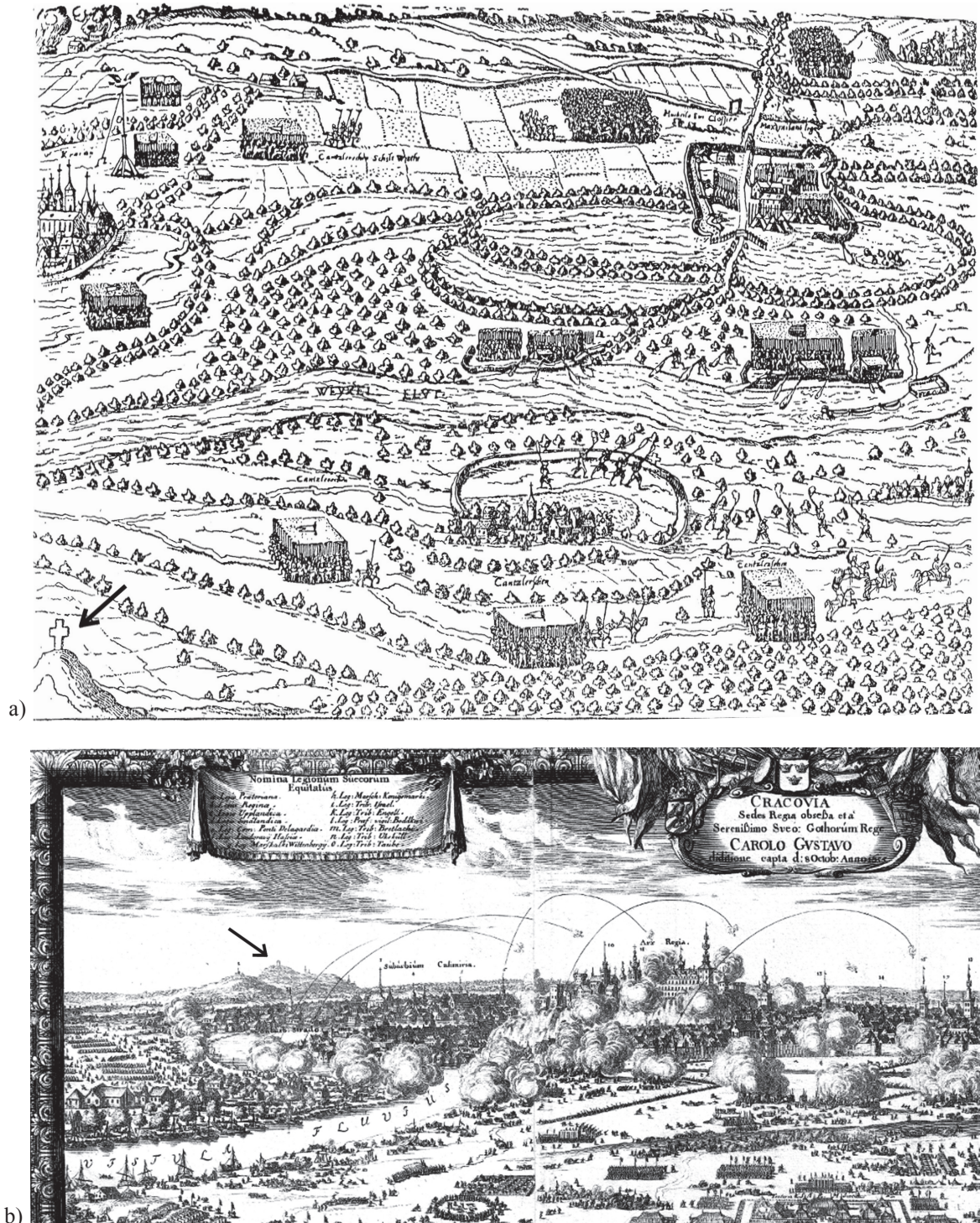
Krakow can be found in “*Schedel’s World Chronicle*” by Hartmann Schedel (Fig. 2a). This view belongs to so called semi-imaginary views, drawn not from nature, but based on descriptions and the author’s imagination. The panorama presents general urban layout of Krakow with distinct suburban settlements of Kazimierz and Kleparz (Banach, 1983). Subsequent parts of the drawing were presented in a multifarious form, so that the observer can get a sense of detail, although not very faithfully reproduced, inside of urban structure. The view is illustrated in such a way that the observer looks at Krakow from the north, probably from the near-by hills of Bronowice. Further, behind the city walls of Kazimierz the author put hills, which could be interpreted as Krzemionki, with the mound situated there. Similar interpretation can refer to the drawing from “*Cosmographia*” by Sebastian Münster (Fig. 2b). In the foreground there is the Wawel Hill with the Dragon’s Cave. Two hills on the right-hand side of the drawing can suggest the near-by Lasota’s Hill and a hill with the mound. Although such interpretation is not certain, it is true that both hills of Krzemionki were distinct on the south horizon of the environs of Krakow in those times, and in both views the hills are presented in the right place. It would be hard to imagine that these hills closest to the Wawel, very distinct in the horizon could have been omitted in the illustrations of the city.

In this group of the illustrations the one worth mentioning is the panorama of Krakow contained in the official work of 1581: *Konstytucje, statuta i przywileje na walnych sejmach koronnych od r. 1550 do r. 1581* [Constitutions, statutes and privileges on general crown sejms since 1550 to 1581] (Fig. 3). Krakow was shown



**Fig. 3.** The fragment of the woodcut of 1581 found in “*Konstytucje, statuta i przywileje na walnych sejmach koronnych od r. 1550 do r. 1581* [Constitutions, statutes and privileges on general crown sejms since 1550 to 1581] (Banach, 1983, p. 30)

**Rys. 3.** Fragment drzeworytu z 1581 r. zawartego w *Konstytucje, statuta i przywileje na walnych sejmach koronnych od r. 1550 do r. 1581* (Banach, 1983, s. 30)



**Fig. 4.** Fragments of the views of Krakow of military character; a) siege of Krakow by Archduke Maximilian Habsburg in 1587, according to A. Lautensack (*Wimmer, 1955, p. 37.*); b) siege of Krakow by the Swedish army in 1655 – E. Dahlberg, according to copperplate by W. Swidde (*Dąbrowska-Budziło, 1990, p. 126*)

**Rys. 4.** Fragmenty widoków Krakowa o charakterze militarnym; a) oblężenie Krakowa przez arcyksięcia Maksymiliana Habsburga w 1587 r. wg A. Lautensacka (*Wimmer, 1955, s. 37.*); b) oblężenie Krakowa przez wojska szwedzkie w 1655 r. – E. Dahlberg, wg miedziorytu W. Swidde (*Dąbrowska-Budziło, 1990, s. 126*)

from the lower point of view than in previous illustrations – from the north-west.

On the right-hand side of the drawing there are the buildings of Kazimierz, and just behind them – under the emblem of Krakow there are hills of Krzemionki. On one of those there is a structure in the shape of a tower. This must be St. Benedict Church on the Lasota hill, marked symbolically or a tower-like structure on the Krakus Mound. Both structures were many times marked on the views of Krakow and the maps of the city also made in the following century. The examples can be city views of military character made in more modern technique of copperplate. They illustrate the course of several sieges of Krakow that took place in 16<sup>th</sup> and 17<sup>th</sup> century (Fig. 4). In the first copperplate we can see a tall cross on the *Krakus Mound* (fig. 4a). A similar building on the mound – a shrine or cross can be seen in the panorama from the times of the Swedish invasion, although the elements of drawing had the sides swapped (Fig. 4b). The existence of such a Christian building in the place of earlier Pagan rituals is highly probable and was connected with the empowering of the new religion. The traces of such a religious building on the Krakus Mound are still visible in the maps of

1750s. Later drawings of the mound from the beginning of 19<sup>th</sup> century do not have any buildings. During the archaeological research carried out on the mound in the interwar time, among other things, the pieces of birch wood were found, which could be remnants of e.g. a Christian cross (Szafer, 1935).

An example of a military map marking the Krakus Mound and Lasota Hill is the map of the siege of Krakow of 1657, drawn by an Italian military engineer Isidoro Affaita (Fig. 5). He illustrates the topography of the closest vicinity of Krakow in the accepted scale with the southern orientation.

The elements of relief particularly distinctly marked are the ones of military significance. In a distinct form on the map there are the hills of Krzemionki with St. Benedict's Church (upper part of Fig. 5).

Subsequent two Krakow's panoramas are connected with the Krakus Mound as a viewing point. Both come from a multi-volume work "*Civitates orbis terrarum*", being a kind of an album of the European cities (Banach, 1983). The panoramas have also a character of portrait views, thus they are definitely more accurate than the ones discussed earlier. The first one, entitled "*Królewskie miasto Kraków w Polsce*" [Royal City of



Fig. 5. The siege of Krakow by the Swedish army in 1657 according to I. Affaita (Wawel, 2015)

Rys. 5. Oblężenie Krakowa przez wojska szwedzkie w 1657 r. wg I. Affaita (Wawel, 2015)

Krakow] is a view of the city from the south. It was made from the observation, the city was portrayed from the Krakus Mound (Firlet, 1989). This is the example of a rather uncommon perspective, although the mound was a good place for the observation of the city. The following example of such a wide panorama made from the Krakus Mound was made in the era of photography i.e. in 1866 by Jędrzej Brydak (Banach, 1983). It has to be mentioned that every old panorama of the city was made of several drawing of the city, made from a close distance and combined into one with the reference point selected for the observer. The outline of the Krakus can be seen in the views of Krakow, drawn from the north or north-west.

The primary pattern for such views of the city was the second panorama of Krakow found in the work "*Civitates...*". It was painted in 1603–1605 by Egidius van der Rye and engraved by Georg Hoefnagel (Banach, 1983). The drawing of Krakow and its closest environs was shown rather in detail, with numerous descriptions of subsequent city buildings. The panorama shows both the Krakus Mound with a small tower, Lasota hill, with a Church, as well as already non-existent Esterka Mound in the park surrounding the Łobzów palace. This panorama was a model for many later authors. The best copy of the panorama of "*Civitatis...*" is a 2m long panorama made in 1619 by Matthäus Merian entitled

"*Kraków, miasto całej Polski najludniejsze i najświetniejsze, wyróżniające się królewskim zamkiem i Akademią*" [Krakow, the most populated and the most prominent city of the whole Poland, distinct of the Royal Castle and the Academia] (Fig. 6). Like the previous one, it was made on the order of one of the Dutch publishers. In the right part of the panorama the hills of Krzemionki can be seen, lower with St. Benedict Church and higher with the Krakus Mound described: "*Tumulus dictus Rekawka*" (Fig. 6). Later panoramas of Krakow e.g. of 1638 and 1702 had almost identical view of these hills (Dąbrowska-Budziło, 1990).

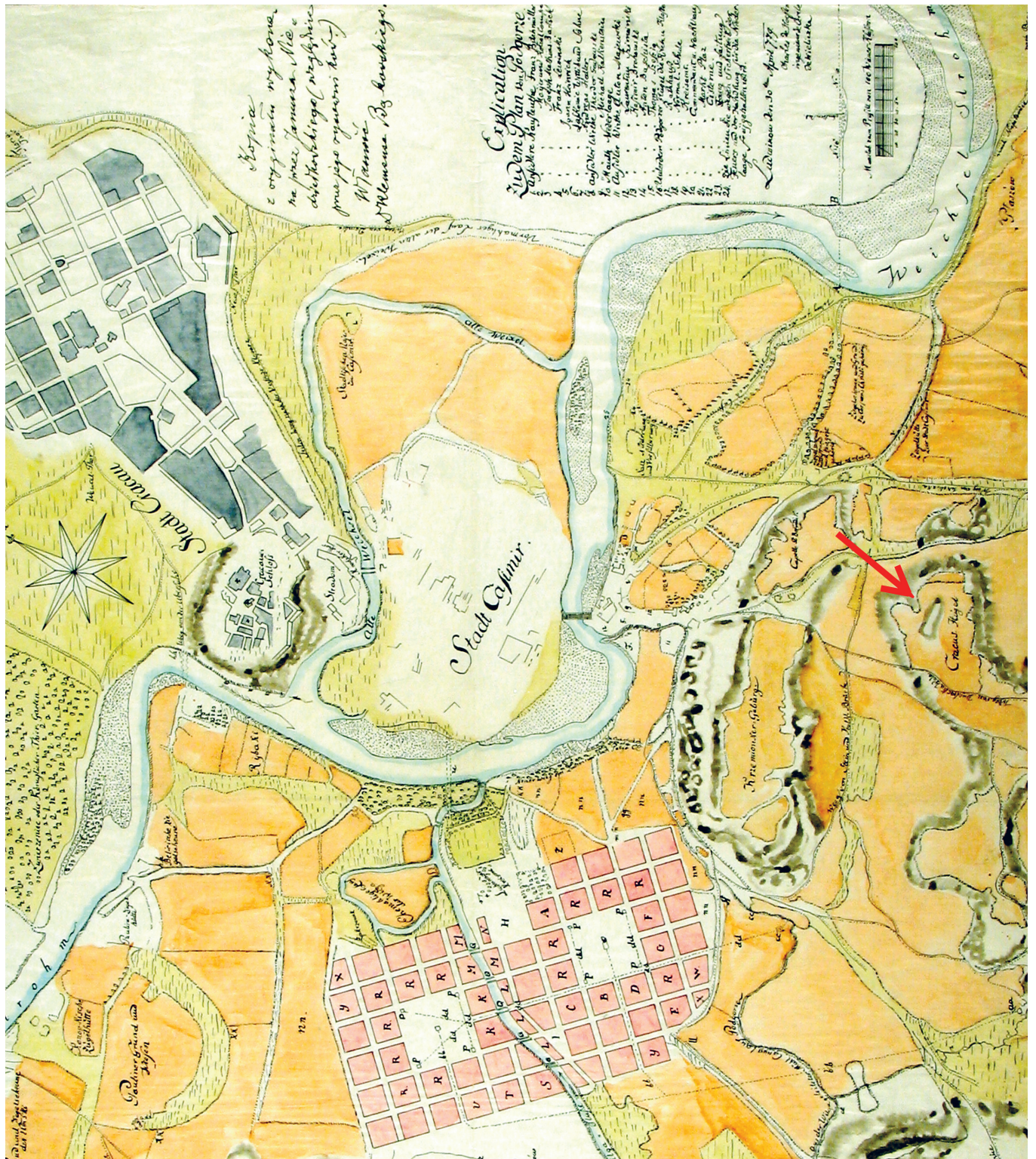
Ending the description of Krakow's panoramas with the Krakus Mound, more 19<sup>th</sup> century works are worth mentioning: "*Widok doliny Wisły i Krakowa z Bielan*" [The view of the Vistula Valley from Bielan] – oil painting by Jan Hruzik of 1857 and "*Widok Krakowa i mogiły Krakusa z Krzemionek*" [The view of Krakow and the Krakus tumulus] – woodcut according to the drawing by Alfred Schouppe of 1864 (Dąbrowska-Budziło, 1990).

Distinct traces of the Krakus Mound are visible in two detail maps of the second half of 18<sup>th</sup> century (Fig.7). The first one was made by an Austrian engineer Karl de Hoefern And comes from 1779. It was also an urban project of building on the right bank of the Vistula river a new city, competitive to Krakow (Fig. 7a,



**Fig. 6** Fragments of the panorama of Krakow by M. Merian, with the Krakus Mound (Wawel, 2015)

**Rys. 6** Fragment panoramy Krakowa M. Meriana, z kopcem Krakusa (Wawel, 2015)



a)





b)

Fig. 7. The fragment of the maps with the Krakow Mound marked (Wawel, 2015); a) the fragment of the map of Krakow and the environs of 1779 r.; b) fragments of the Prussian Map of Krakow and environs of 1794

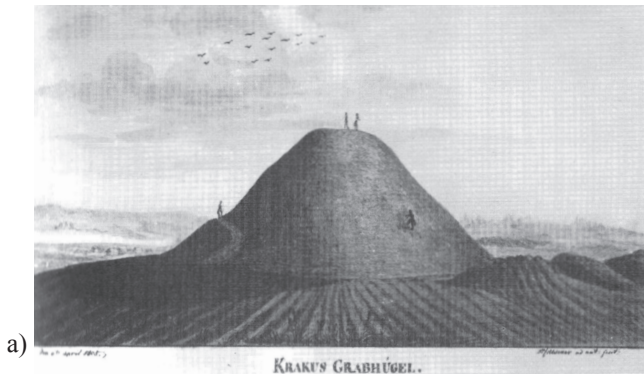
Rys. 7. Fragment planów kopcem Krakowa z zaznaczonym kopcem Krakowa i okolic z 1779 r.; a) fragment planu Krakowa i okolic z 1779 r.; b) fragment Planu Pruskiego Krakowa i okolic z 1794 r.

fragment to the left is marked pink). The areas of the right bank of the Vistula, after the second partition of Poland belonged to Austria, and the border was alongside the Vistula. The Krakus Mound, or rather its hill is clearly marked (Cracus Hügel), although with no buildings (Fig. 7a). The second map called “Prussian”, is

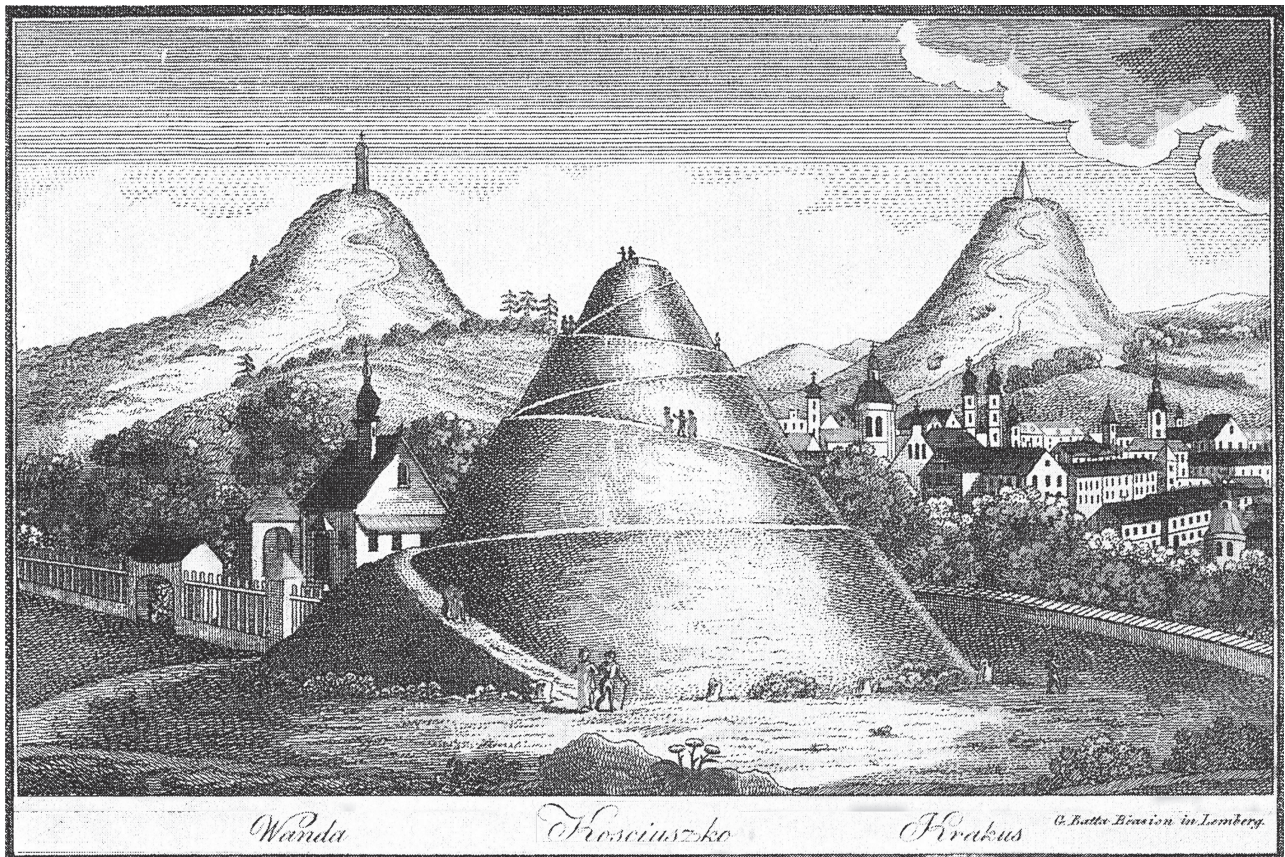
connected with the time after the Kościuszko uprising, when Kraków was taken by the Prussian army (Fig. 7b).

The map includes much bigger area with the suburbs of the city. The drawing is more precise and we can see the situation of the mound, additionally supplemented with the note “*Krakus Berg*” (Fig. 7b). It is difficult to say based on the two maps if a mysterious construction present in the mentioned before documents in those times did not exist or was omitted. Moreover, on both maps also the outline of St. Benedict’s Church is absent on the neighbouring Lasota Hill. It can, however be mentioned that at the time both maps originate, the existence of this church was threatened and the very structure of the church was in a state of a ruin. The church was finally rebuilt, but the structure on the Krakus Mound could have been less lucky.

The evidence of this hypothesis is provided by the drawings of the mound from the beginning of 19<sup>th</sup> cen-



a)



b)

**Fig. 8.** Drawings of the Krakus Mound; a) the view of the mound in 1805 from the south according to F.P. Usener; b) three Krakow’s mounds of 1830 r. – copperplate according to G.B. Biasioni (Wawel, 2015)

**Rys. 8.** Rysunki z kopcem Krakusa; a) wygląd kopca w 1805 r. od strony południowej wg F.P. Usenera; b) trzy krakowskie kopce z 1830 r. miedzioryt wg G.B. Biasioniego (Wawel, 2015)

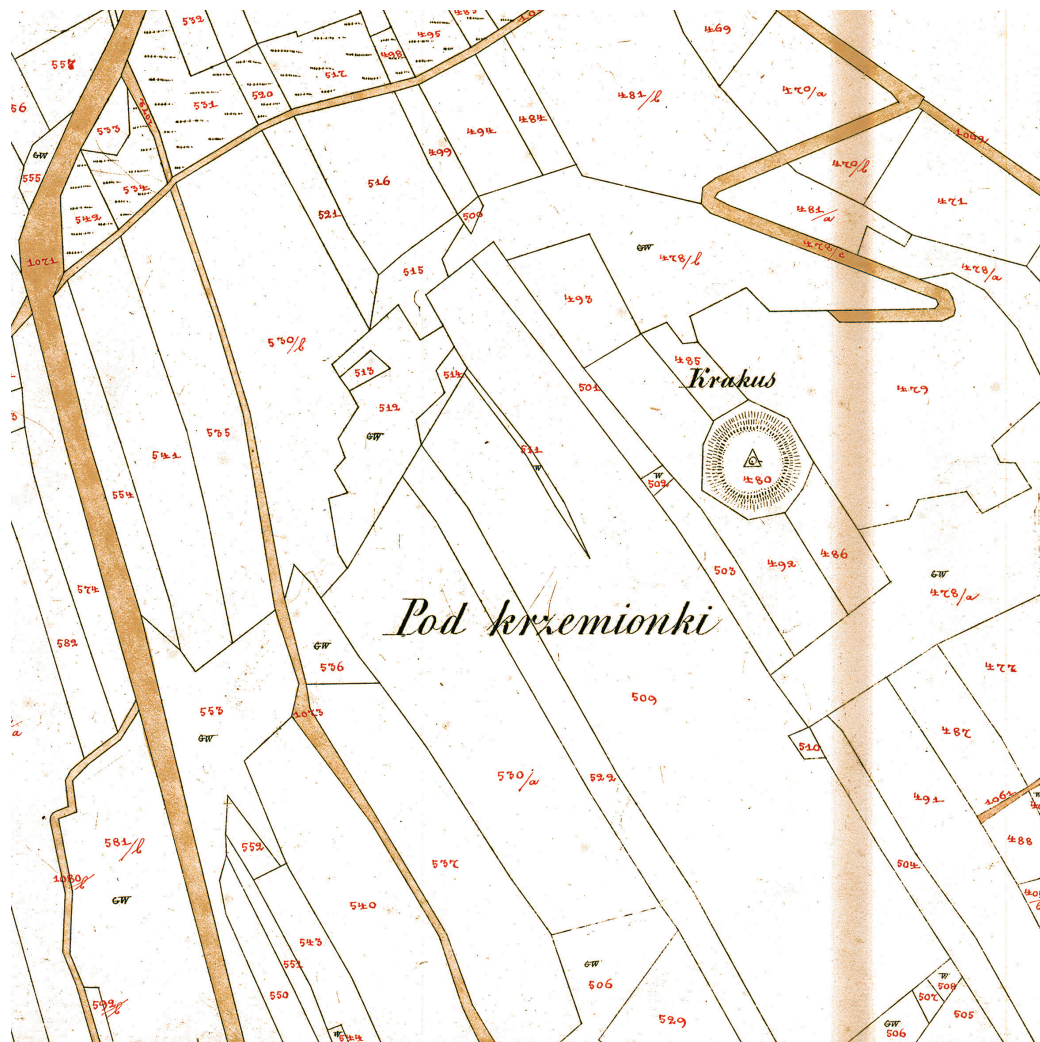
tury made from personal viewing by a German amateur artist Frederik Philip Usener (Pieniążek, 1995). They show the crown of the Krakus Mound without any construction (Fig. 8a). Several hand-made drawings made from different sides it can be concluded that the mound made only one of several viewing points near to the newly developing city of Podgórze, nowadays a southern quarter of Krakowa.

Subsequent years brought a complete change in the functionality of the mound. It can be seen in an imaginary, but full of realistic details view of Krakow made by a graphic artist coming from Italy and living in Lviv – Gian-Battista Biasioni (Fig. 8b). Three Kra-

kow's mounds can be seen there: on the left the Wanda mound, in the Centre – newly built Kościuszko mound and Krakus Mound. On the latter there is an openwork construction, resembling a triangulation station, making the structure of the surveying point.

### 3. CARTOGRAPHIC AND GEODETIC SIGNIFICANCE OF THE KRAKUS MOUND

A new significance of the Krakus Mound resulted from the interest in this hill as a suitable place for the stabilization of the point of a surveying grid, called tri-



**Fig. 9** South-east fragment of sheet *WC XXXIX ce* of a cadastral map of 1848, scale 1:2880 from the area of Podgórze in Kraków, with a marked surveying point on the Krakus Mound

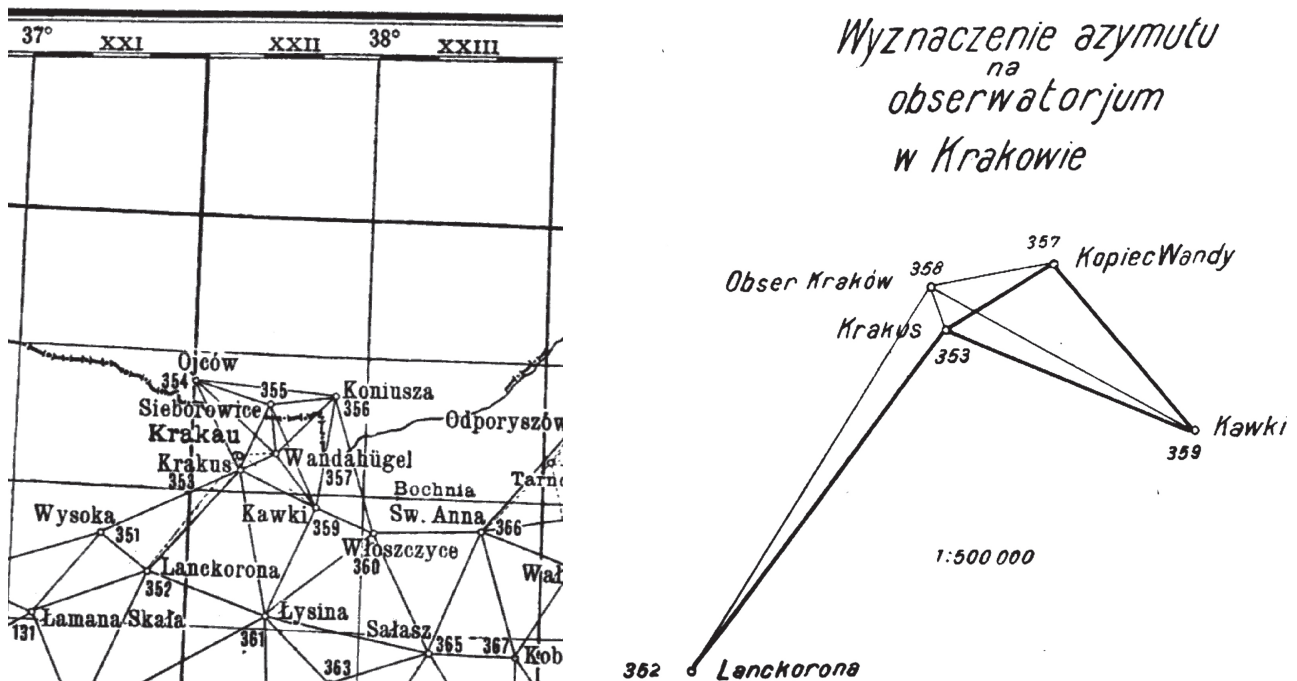
**Rys. 9** Południowo-wschodni fragment arkusza szczegółowego *WC XXXIX ce* mapy katastralnej z 1848 r., w skali 1:2880 z obszaru Podgórze w Krakowie, z zaznaczonym punktem geodezyjnym na kopcu Krakusa

angulation grid, and later also the area for the fortifications of the fortress of Kraków. The mound and its closest vicinity could fulfil both functions. In the second decade of 19<sup>th</sup> century in the area of the Austro-Hungarian Empire the cadastre reform was made, to sort out the property situation of land. To carry out the reform detail maps based on surveying should be made. For this reason in 1817–1830 and 1841–1858 in the area of Western Galicia, where Kraków was situated, triangulation measurements were made and so-called *cadastral triangulation* was applied.

The surveying was made to establish one of the first systems of cadastre coordinates, called *Lviv system*, with the starting point on the High Castle in Lviv and south-west orientation of XOY axis (Murzewski, 1936). The calculation of cadastre coordinates (XY) of the points in this surveying network, necessary to make maps was carried out on the plane, after the reduction of the measured angles and sides, calculated from the

solution of triangles, without the application of the rules of any cartographic mapping. The point on the Krakus Mound belonged to a small group of the most important points of 1<sup>st</sup> order, characterized by the highest accuracy of coordinates. Points of cadastral triangulation from Krakow obtained coordinates referred to the beginning of the system in Lviv, i.e.  $X \approx 30$  km, and  $Y \approx -300$  km and made mathematic base for surveying maps. The example of such a map is a sheet from the region of the Krakow quarter Podgórze marked as *WC XXXIX ce*, with the surveying point on the Krakus Mound (Fig. 9).

Due to quickly made cadastral triangulation the obtained results of surveying and calculations, although sufficient for cadastral maps, did not fulfil the accuracy conditions for basic control lines. Due to this, in 1860–1898, among others, in the area of Galicia a second measurement and making a so-called *triangulation for the angular measurement* was carried out. It was then calculated that for the selected triangulation points,



**Fig. 10.** The sketches of the astro-geodetic network from the point *Krakus* on the Krakus Mound (Murzewski, 1936); a) the fragment of the sketch of the triangulation network from the environs of Krakow, so-called *triangulation for the angle measurement* made in 1860–98 (longitude measured from the meridian *Ferro austriackie*); b) the sketch of the development of the triangulation network to determine azimuth in the direction *Astronomic Observatory – Krakus*

**Rys. 10.** Szkice sieci astro-geodezyjnych z punktem *Krakus* na kopcu Krakusa (Murzewski, 1936); a) fragment szkicu sieci triangulacyjnej z okolic Krakowa tzw. *triangulacji dla pomiaru stopni* wykonanej w latach 1860–98 (długości geograficzne mierzone od południka *Ferro austriackie*); b) szkic rozwinięcia sieci triangulacyjnej w celu wyznaczenia azymutu kierunku *Obserwatorium Astronomiczne – Krakus*

**Pas 48 słup 30 — K r a k ó w**  
elipsoida Bessela, punkt wyjścia Hermannskogel.

		DŁUGOŚĆ OD FERRO AUSTR.			
18	Koniusza . . . . .	1	50° 10' 55" 5635	37° 53' 57" 1201	—
18a	Sieborowice . . . . .	1	50 9 42.9821	37 42 41.2462	—
19	Kopiec Wandy . . . . .	1	50 4 14.8588	37 44 11.6660	242
20	Kraków, obs. asir. . . . .	1	50 3 51.1156	37 37 27.4190	212
21	<u>Kopiec Krakusa . . . . .</u>	1	50 2 19.1283	37 37 36.7930	276

.....

Współrzędne Soldnera. Początek układu — Kopiec Unji we Lwowie.

		x	y	
38	Kopiec Wandy . . . . .	+	32302.023	284184.424 239.7
39	Sowiniec . . . . .	+	32026.864	300029.073 355.4
40	Krakus, mira . . . . .	+	32005.24	292239.04 235.6
41	Kraków, wieża kościoła Mariackiego . . . . .	+	31855.120	293466.586 212.6

.....

49	<u>Kopiec Krakusa . . . . .</u>	+	29152.08	292220.97 271.2
----	---------------------------------	---	----------	-----------------

.....

22	Lwów, Kopiec Unji . . . . .	0	0	—
23	Lwów, obserwatorium . . . . .	—	358.2	+ 523.7

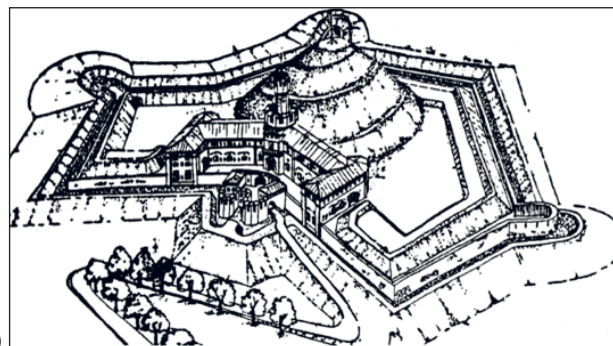
**Fig. 11.** Fragments of *Katalog Punktów Trygonometrycznych* containing, among others, surveying coordinates ( $\varphi, \lambda$ ) and cadastral coordinates ( $x, y$ ) of the point on the Krakus Mound, mistakenly called Soldner coordinates (Biernacki, 1934)

**Rys. 11** Fragmenty *Katalogu Punktów Trygonometrycznych* zawierające m.in. współrzędne geodezyjne ( $\varphi, \lambda$ ) oraz katastralne ( $x, y$ ) punktu na kopcu Krakusa, nazwane przez pomyłkę współrzędnymi Soldnera (Biernacki, 1934)

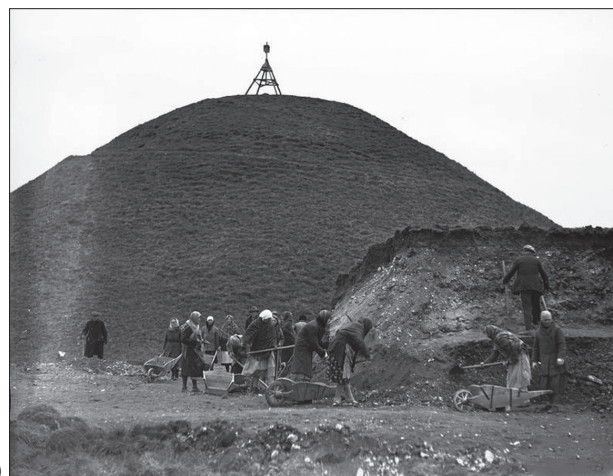
their astronomic coordinates and geodetic coordinates ( $\varphi, \lambda$ ) referred to the meridian Ferro (Austrian) and fundamental point Hermannskogel (Vienna). From this period there are sketches of the triangulation network with its local Kraków's extension (Fig. 10) and geodetic coordinates collected in the published in the interwar period "*Katalog punktów trygonometrycznych*" [Catalogue of Trigonometric Points] (Fig. 11) (Michałowski J., Sikorski T., 1932).

In the second half of the 19<sup>th</sup> century the area around the Krakus Mound was already a military area of the newly built *Fort no. 33 Krakus*. It made one of several dozen fortification buildings of the Krakow Fortress. The first construction works in the ground around the Krakus Mound started already in 1848 and the fort was completed in 1857. The fort had a character of a closed ring and centrally situated in its courtyard Krakus Mound fulfilled the functions of the observation hill, preserving also the function of the surveying point (Fig. 12a). Due to the military character of the building, the access of the residents to the mound as the viewing point was limited.

On the scheme of the fort and the photographs from the inter-war exploration of the mound geodetic con-



a)



b)

**Fig. 12.** The closest vicinity of the Krakus Mound in 19th century; a) scheme of the Krakus Fort from the Krakus Mound (Brzoskwina W., Wielgus K., 1991); b) archaeological works carried out on the Krakus Mound in 1933 r. (NAC, 2015)

**Rys. 12.** Najbliższe otoczenie kopca Krakusa w XIX w.; a) schemat fortu Krakus z kopcem Krakusa (Brzoskwina W., Wielgus K., 1991); b) prace archeologiczne prowadzone na kopcu Krakusa w 1933 r. (NAC, 2015)

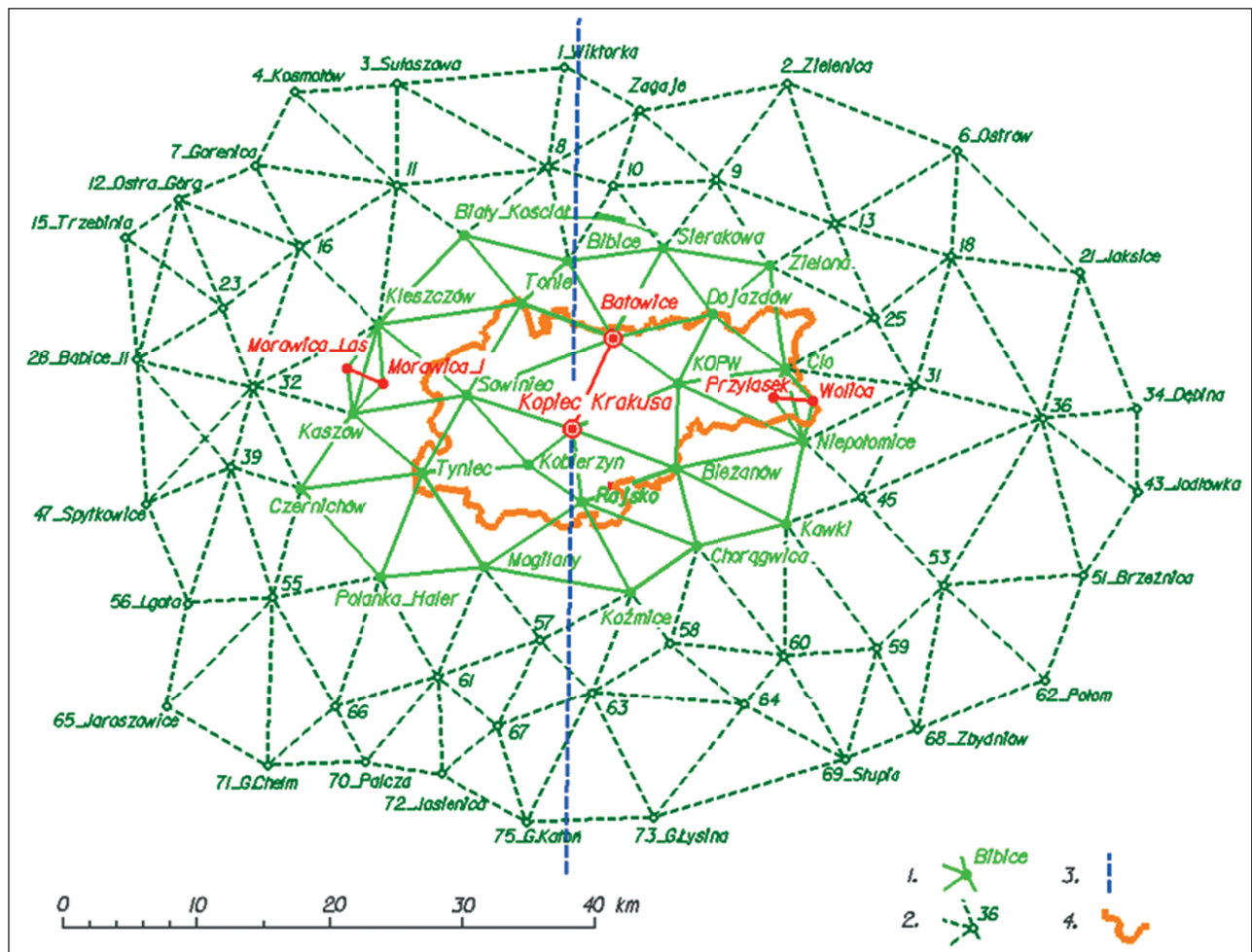
structions on the point in the form of the wooden triangulation station – a so-called triangulation signal (Fig. 12). *Fort 33 Krakus*, as the majority of Krakow's forts did not play any significant role in the First World War and during the Second World War the object had already a historic value.

In the inter-war period on the Krakus Mound first comprehensive archaeological works were carried out. The scientific supervision was taken by the Committee of the Studies on the Krakus Mound, created in the framework of the Polish Academy of Learning (PAU). The studies were financed by Mieczysław Dąbrowski – the owner of the press concern *Ilustrowany Kurier Codzienny*. The leaders of the archaeological team

were Associate Professor Józef Żurowski and Engineer Franciszek Jakubik. The mound was partially dug up in the form of a funnel reaching its base (Żurowski, 1934). Inside the mound, numerous traces of prehistoric human activities were found. After the end of the archaeological works the dismantled triangulation point was rebuilt and its coordinates were marked again by precise angular measurements. The mound remained in such a state for the whole period of WWII.

The geodetic point on the Krakus Mound preserved its particular significance in the Krakow's surveying also after the WWII. In 1950s all over Poland, there was an action to put in order the existing urban geodetic control lines and establishing new ones (Włoczewski,

1959). The purpose was to prepare the control line to make detail maps for the needs of larger cities. In the framework of these works, in Krakow, in 1955–1960, a local 3-row angular network was established (Fig. 13). The first row consisted of 24 points of the state triangulation network made in 1952–53. To build the urban network in Krakow the results of angular measurements of the filling network and the geodetic coordinates and flat coordinates in the state system of coordinates *Borowa Góra* were given. Among the adopted points there was a centrally situated point in the Krakus Mound (K). This point was selected as the main geodetic point applied together with the neighbouring point in Batowice (B) to the orientation network. The azi-



**Fig. 13.** The triangulation network in the area of Krakow (1 – network of 1<sup>st</sup> order – a so-called city network made in 1955–60; 2 – network of 1<sup>st</sup> order for the Krakow Voivodeship of 1973; 3 – meridian of the Krakus Mound in the reference system *Borowa Góra*; 4 – borders of Krakow)

**Rys. 13.** Sieć triangulacyjna na obszarze Krakowa (1 – sieć I rzędu tzw. miejska powstała w latach 1955-60; 2 – sieć I rzędu dla województwa krakowskiego z 1973; 3 – południk kopca Krakusa w układzie odniesienia *Borowa Góra*; 4 – granice Krakowa)

muth orientation ( $\alpha_{K-B} = 22^{\circ}25'48.72''$ ) was calculated from the geodetic solution of the „reverse” task based on geodetic coordinates of both points in the system *Borowa Góra* ( $\varphi_K = 50^{\circ}02'18.1457''$ ,  $\lambda_K = 19^{\circ}57'38.5200''$ ,  $\varphi_B = 50^{\circ}06'03.2387''$ ,  $\lambda_B = 20^{\circ}00'02.9903''$ ). The scale of the network was given by two linear bases established by west and east end of the network, reduced into the medium level of the Krakow area. The point on the Krakus Mound became also the initial point to calculate flat coordinates of all the remaining points of the network in a temporary system of coordinates called *working system*. The following flat coordinates of the mound were taken:  $X_K = 5545064.90$  m from the system *Borowa Góra* and the conventional positive value was  $Y_K = 500000$  m. Angular and linear elements of the network were reduced to the plane, according to the rules of Gauss-Kruger projection, accepting as the surface of the original Bessel ellipsoid, central meridian of the projection belt going through the point on the Krakus Mound, and the scale on the south meridian equalling 1.0. As a result of the solution of such a flat network the coordinates  $X, Y$  of all the remaining points in the *working system* were calculated (Banasik, 2001). The local coordinates of the points of the Krakow network in a so-called *Local System of Krakow* (ULK) were calculated by isometric transformation of the *working system* to the above mentioned cadastral system (Lviv). *Układ Lokalny Krakowa* was functioning in the area of Krakow until 2011, when it was replaced by state system „2000” (Banasik et al., 2012).

Progress in the area of surveying measurement techniques started in 1990s made triangulation stations not necessary and traditional triangulation was replaced with satellite measurements. This process also referred to the point on the Krakus Mound. First satellite measurements with GPS technique were made on the mound in 1991 by the team of the staff from the AGH University of Science and Technology in Krakow and University of Agriculture and Technology in Olsztyn (Beluch et al., 1993). The point on the mound made one of four resistance points of the geodetic network made, among others, for the needs of the existing calibration base of electro-optic total stations localized on the embankment of the Vistula River. Since then the point on the Krakus Mound, due to favourable conditions for the observation of GPS signals, (i.e. open horizon) was regularly used in satellite measurements. Precise coordinates of surveying points of the Krakus

Mound and Wanda mound marked with GPS technology in the system ETRF89 are: the Krakus Mound  $\varphi_K = 50^{\circ}02'17.112''$ ,  $\lambda_K = 19^{\circ}57'30.328''$ ; the Wanda Mound  $\varphi_W = 50^{\circ}04'12.770''$ ,  $\lambda_W = 20^{\circ}04'05.164''$  (Góral, Zdunek, 1998).

In 1993 the point on the Krakus Mound was included to surveying network to determine the component values of the deviation of the line from the vertical in the area of Krakow, based on geometric and satellite GPS levelling. The surveying mark on the mound was connected by precise levelling with the node marks of the basic altitude control line and was given the altitude in the compulsory state altitude system Kronsztadt'86 with the accuracy of millimetres (Boczar et al., 1995). The obtained mean values of the components of the deviation of the lines from the vertical confirmed the values determined from the independent astro-geodetic method applied in other points in the area of Krakow. Due to the precise and satellite levelling measurements, the point on the Krakus Mound was included into the network of geodetic points on which the deviations of a quasi-geoid from ellipsoid in the reference systems ETRF89 and Kronsztadt'86. Due to this the first local model of the surface of a quasi-geoid in the area of Krakow was made, describing the shape of the fragment of the Earth globe in the area of Krakow (Banasik, 1996).

It is worth mentioning that the geodetic points stabilized on other Krakow's mounds had also geodetic significance. Still in 1990s on all the four existing Krakow's mounds there were geodetic marks included into the state basic horizontal control line. As a result of disastrous rainfall in 1996–97 the Kościuszko Mound and Piłsudski Mound were significantly damaged. During the restoration the geodetic marks were destroyed. A similar situation took place on the Wanda Mound. The geodetic point on the Krakus Mound was destroyed only in 2013 r. The mound itself, after many years of existence and archaeological exploration, is in a very good shape.

#### 4. CONCLUSIONS

Nowadays, after nearly 200 years of geodetic functionality and in the era of permanent GNSS, the significance of the Krakus Mound, in surveying, as a reference is smaller and smaller. However other interesting meaning of this mound in the remote past was discovered. The analysis of the situation of the old-

est Krakow's mounds showed that the Krakus Mound and the Wanda Mound mark the line of sunrise and sunset taking place on the days dividing the year into two almost equal parts (Góral, 2006). Together with the days of spring and autumn Equinox divide year into eight equal parts. It cannot be excluded that the situation of these two prehistoric mounds made reference points in the calendar of the first residents, which in pre-Slavic times lived in the area of the Krakow's Krzemionki. In this aspect it is interesting that inside the Krakus Mound, on a significant depth the rows of wooden stakes were found, running symmetrically in the direction N-S, as well as centrally placed remains of a stake (Jamka, 1965). These constructions can also be connected with the observations of astronomic phenomena made on the Krakus Mound by the first inhabitants of Krakow.

## LITERATURE

- Banach J., 1983, *Dawne widoki Krakowa*, Wydawnictwo Literackie, Kraków.
- Banasik P., 1996: *Wstępna aproksymacja quasi-geoidy niwelacyjnej w rejonie Krakowa*, Geodezja 2, Wyd. AGH, Kraków, p. 35–43.
- Banasik P., 2001: *Analiza Krakowskiego Układu Lokalnego pod kątem jego transformacji do państwowych układów współrzędnych 1992 i 2000*. Materiały X Sesji Naukowo-Technicznej: „Aktualne problemy naukowe i techniczne prac geodezyjnych”, Piwniczna, 10–12.05.2001, p. 6.2–6.10.
- Banasik P., 2010: *Lokalizacja kopca Esterki w świetle dawnych materiałów kartograficznych z obszaru Krakowa*, Rocznik Krakowski, T.LXXVI, Towarzystwo Miłośników Historii i Zabytków Krakowa, Kraków, p. 35–44.
- Banasik P., Bujakowski K., Kolińska M., Michalik D., Nowak J., 2012: *Geodezyjne porządki w Krakowie – Konwersja zasobu geodezyjnego i kartograficznego miasta Krakowa do obowiązujących układów współrzędnych i wysokości*, Geodeta no. 1–2, p. 14–18.
- Beluch J., Bujakowski K., Góral W., Mróz J., Oszczak S., Pokrzywa A., Szczutko T., 1993: *Pomiary eksperymentalne GPS na terenie Krakowa*, Zeszyty Naukowe AGH, Geodezja 118, Kraków, p. 13–22.
- Biernacki F., 1934: *W sprawie współrzędnych katastralnych w Małopolsce*, Wiadomości Służby Geograficznej, no. 8, p. 547–555.
- Boczar S., Góral W., Szewczyk J., 1995: *Odchylenie pionu na obszarze Krakowa*, Geodezja 1, Wyd. AGH, Kraków, p. 11–15.
- Brzoskwinia W., Wielgus J., 1991: *Spojrzenie na twierdzę Kraków*, Oficyna Wydawnicza Ostoja, Kraków.
- Dąbrowska-Budziło K., 1990, *Wśród panoram Krakowa: o przemianach widoków i o tym, jak je ocalić*, Wydawnictwo Literackie, Kraków.
- Firlet E.M., 1998, *Najstarsza panorama Krakowa*, Muzeum Historyczne Miasta Krakowa, Kraków.
- Góral W., 2006: *Aspekty geoinformatyczne i astronomiczne prehistorycznych kopców krakowskich i kopca Kraka w Krakusowicach*, Geodezja vol. 12, issue 2/1, UWND AGH, Kraków, p. 209–220.
- Góral W., Zdunek R., 1998: *Poligon geodynamiczny w rejonie Krakowa i Wieliczki*, Geodezja vol. 4, issue 2, UWND AGH, Kraków, p. 13–19.
- Jamka R., 1965: *Wyniki badań wykopaliskowych na kopcu Krakusa w Krakowie*, Slavia Antiqua, vol. XII, Warszawa-Poznań, p. 183–233.
- Michałowski J., Sikorski T., 1932: *Katalog punktów trygonometrycznych*, Biblioteka Służby Geograficznej, vol. 8, Sekcja Geograficzna Towarzystwa Wiedzy Wojskowej, Warszawa.
- Murzewski W., 1936: *Rozwój triangulacji na południu Polski*, Wiadomości Służby Geograficznej, no. 10, Warszawa, p. 208–238.
- NAC, 2015: <http://www.audiovis.nac.gov.pl/haslo/446:12/>
- Pieniążek-Samek M., 1995: *Widoki Krakowa w albumie Friedricha Philippa Usenera*, Rocznik Krakowski, vol. LXI, Towarzystwo Miłośników Historii i Zabytków Krakowa, Kraków, p. 27–58.
- Szafer W., 1935: *Sprawozdanie z poszukiwań botanicznych na kopcu Krakusa wykonanych w roku 1934*, Sprawozdania z czynności i posiedzeń, Polska Akademia Umiejętności, 1936, Kraków, p. 84–98.
- Włoczewski F. 1959, *Polska sieć triangulacji wypełniającej i zagęszczającej*, Przegląd Geodezyjny, no. 7, Warszawa, p. 263–269.
- Wawel, 2015: *Kraków wczoraj i dziś*; [http://www.wawel.net/images/750-lat\\_lokacji/lokacja.htm](http://www.wawel.net/images/750-lat_lokacji/lokacja.htm)
- Wimmer J, 1955: *Odparcie najazdu arcyksięcia Maksymiliana w 1587–8 r.*, Wydawnictwo Ministerstwa Obrony Narodowej, Warszawa.
- Żurowski J., 1934: *Dotychczasowe wyniki badań nad Kopcem Krakusa*, ([www.rcin.org.pl](http://www.rcin.org.pl), 2015).