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THE ROLE OF MORPHOGENETIC AND ANTHROPOGENIC PROCESSES IN THE DEVELOPMENT OF GULLIES AND METHODS OF THEIR PREVENTION (ON THE EXAMPLE OF THE VICINITY OF KAZIMIERZ DOLNY)

Abstract: The vicinity of Kazimierz Dolny is characterised by the occurrence of large denivelations and thick loess covers. Due to that, as well as to the characteristic properties of loess and frequent occurrences of torrential rains, the region is marked by numerous dissections by valleys. Not without importance is agriculture, whose intensification brought about the creation of new relief forms. Gully erosion is a serious threat for the inhabitants of the region; on the other hand, it is impossible to eliminate it. For that reason it is necessary to use modern anti-erosion measures.

Key words: denivelations, thick loess covers, valley, downflow, suffosion, torrential rains, silting, anti-erosion measures.

The issue of gully erosion and anthropopressure, in the broad sense of these words, has been for several years the object of interests for geographers, geomorphologists and geologists from various research centres. Since 1950s the vicinity of Kazimierz Dolny became – mostly because of its landscape valour – a topic of discussion both in the field of lithology and stratigraphy and in that of gully erosion (Pożaryski, 1953; Maruszczak, 1973). The role of torrential rains and of sudden snow melting in the formation of the contemporary relief of this region was often noted (Maruszczak, 1986; Rodzik et al., 1998); the role of human actions and of the related development of new forms, adding variety to the landscape of loess uplands, was also emphasised.

Kazimierz Dolny is located around 14 km south of Puławy, near the confluence of a small brook Grodarz to the Vistula River. From the physico-geographical point of view it is situated in the western part of the Nałęczów Plateau, which constitutes the northwestern mesoregion of the Lublin Upland (Kondracki, 1998).

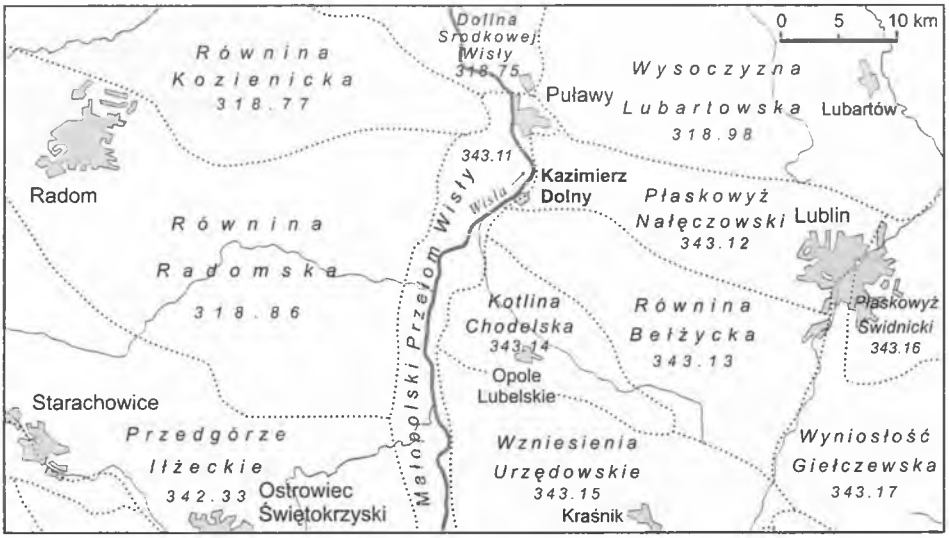

Fig. 1. Localisation of Kazimierz Dolny with respect to mesoregions (based on: Kondracki, 1998, revised)

The loess cover plays the key role in the formation of the contemporary relief of the region in question. Morphologically, its character is not uniform: it consists of several loess stretches whose thickness in the Kazimierz region reaches even 30 m. The measure of variety of the western part of the Nałęczów Plateau are its numerous denivelations. The most impressive ones can be found on the valley sides of the Vistula River, where they reach 90 m. The above-mentioned factors, together with the characteristic properties of loesses – mostly their low content of carbonates and silt fraction – cause a very strong internal dismemberment of the area. The density of the network of valley forms, primarily of the young gullies, reaches as much as over 5 km/km^2 in the Kazimierz region (in some places even over 10 km/km^2) making it a unique area on the European scale.

The western part of the Nałęczów Plateau is a region where torrential rains occur relatively frequently. This phenomenon depends to a large extent on the loess edge built up on the side of the waterlogged Vistula river valley, as well as on an almost parallel dissection of the plateau by the valleys of the Bystra and Grodarz Rivers. The overlaying of the factors listed above makes the Kazimierz Dolny region predisposed for the development and formation of contemporary morphogenetic processes. Extreme phenomena, such as torrential rains, play a particularly important role in the development cycle of the gullies, and therefore also in the contemporary evolution of loess areas. Gully erosion is, however, a serious economic problem, threatening to a large degree the inhabitants of the region.

Both natural gullies and road gullies add variety to the Kazimierz Dolny region. The former are characterised by a complicated system with numerous

side gullies. In the outlet segment they cut in to the depth of over 70 m. The course of the latter, on the other hand, approaches a straight line, without branching on the sides. Their almost vertical sides reach the height of 9 m and their flat bottom lacks vegetation. Road valleys developed on dirt roads leading from the Grodarz river valley to the hilltop, where fields and neighbouring village are situated. Due to the longitudinal location of the road gullies in the transverse profiles, it is possible to observe a climatic asymmetry, caused by the stronger watering of the slope with western exposure (Fig. 2).

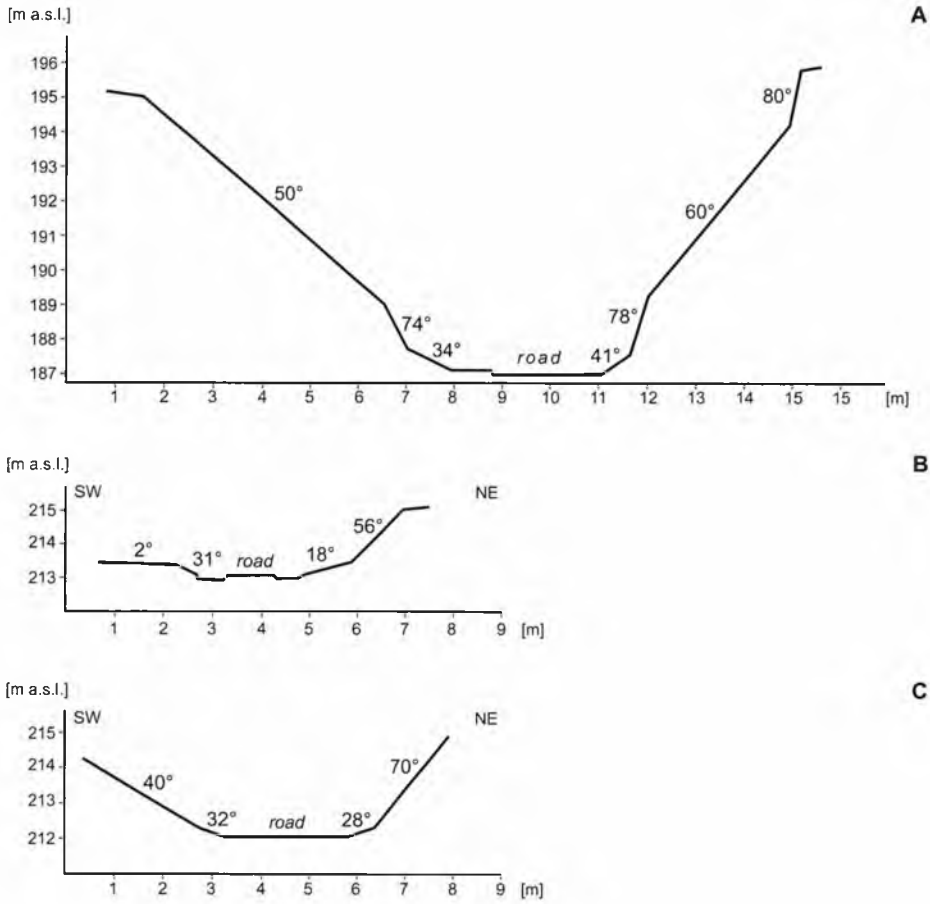

Fig. 2. Comparisons of transversal profiles from the gully Opolska Droga. Localisation of the profiles is shown on Fig. 3

The erosion and accumulation forms, which are frequently created and become active after torrential rains and intense spring snow melting, result from a few processes. Suffosion forms, admitting the form of sinks, wells and

tunnels develop within spurs between side branches of gullies and between two gullies in their outlet segments. For this reason, these regions, most often self-forested, are excluded from agricultural use. The accumulation of suffosion forms may sometimes lead to the creation of "badlands" and the process itself is the main factor triggering the movement of rock-debris in the gullies.

Spring thaw after a long, cold and snowy winter leads to the development of gravitational processes, which, however, take place – although to a smaller extent – during the entire year. Colluvial covers, resulting from these processes, occur commonly at the foot of tall and steep walls characteristic for road gullies (Opolska Droga, Korzeniowy Dół). They take the form of loess blocks of varying size lying side by side.

The existence of erosion furrows and potholes in the bottom of the gullies, formed as a result of turbulent water movement is a symptom of intense washing away. The depth and width of the forms may reach 2-3 m. At the bottoms of road gullies, where the slope, especially in the outlet segment, is steep, erosion and evorsion potholes and gaps may form sequences up to several tens of metres in length. Forms of such parameters can be found in Norowy Dół.

When weakly permeable or impermeable deposits occur in the substratum and a significant dissection of the loess cover exists, sliding processes take place. Bottoms of most gullies are eroded in boulder clay which, as a result of change in resistance or stratification, form structural escarpments in the bottom of the gully (e. g., Chałajowy Dół). Sliding is triggered by excessive water saturation of the material on the slope. Sometimes the landslide tongue leads to the barricading of the part of the gully so that the gully becomes impassable (as it happened in Opolska Droga in 1996).

The eroded material is brought out of the slopes and bottoms of the gullies and accumulated at the foot of the slopes and at the bottom of the valleys. Both proluvial and deluvial cones are marked by differentiated parameters. As a rule, the latter are smaller forms with the radius of 3-5 metres. The area of the proluvial covers, on the other hand, can reach even several hundred square metres and more. The outlets of the road gullies are characterised by proluvial road walls. Their oblong shape is the result of the equalised profile of the road, enabling transport of material to very distant places.

A significant development of the main gully systems falls for the period from the mid-15th to the mid-17th century. The main assumptions concerning the communication system of the town come from those times and they are related to the intense development of Kazimierz as an important corn trade centre. Roads connecting Kazimierz, situated in the deep valley of the Grodarz river, with fields under cultivation located on the hilltop and, in later times, with villages being developed there constituted a large part of the communication system. Even in modern times borders of cornfields and main roads can be recognised in the landscape of the western part of the Nałęczów Plateau.

The formation of a dirt road almost always leads to the creation of a new relief form. This is connected with an intense and concentrated downflow on impermeable ground, mechanical impact of vehicle wheels and sometimes also of animal hooves. Wide track of wheels and large dimensions of agricultural machines caused the widening of gullies relatively quickly. As a result of slope undercutting and purposeful levelling of the bottom the gullies destabilise and movements, visible mostly as rockfalls and landslides, develop. The pressure of tyres on plastic ground creates grooves reaching sometimes the depth of over 30 cm.

Torrential rains occur exceptionally frequently in Kazimierz Dolny. They were recorded in the years: 1936, 1976, 1981 and 1997 (Rodzik et al., 1998). The mean value for the belt of the uplands in southern Poland is 2-3 times per century (Maruszczak, Trembaczowski, 1958; Buraczyński, Wojtanowicz, 1974). In the strongly eroded loess areas, such as the vicinity of Kazimierz, material of volume up to 40 000 m^3/km^2 can be eroded during one century (Maruszczak, 1973).

Of particular importance during torrential rains are road gullies, which take over the function of intermittent streams. Very quick formation of a concentrated precipitation downflow leads to silting of land plots and farms situated at the bottom of the valley. Within the rivers and reservoirs not only debris eroded from the catchment area, but also pollutants originating from substances and precipitation washed away or washed out by surface downflow are deposited.

Observations, data from the Township and Borough Office in Kazimierz and measurements served to estimate the degree of endangerment of the town (Gardziel et al., 1998). Depending on the intensity of precipitation or snow melting on the streets of the town, 100 to several thousands of cubic metres of alluvium is deposited. Deposition of sediments of so large a volume takes place during torrential rains with precipitation ranging from 50 mm outside the full vegetation to about 100 mm during the full vegetation (Józefaciuk A., Józefaciuk Cz., 1984, Rodzik, 1984, Gardziel et al., 1996). It should be emphasised that the deposition of as little as 100 cubic metres of sediments after a torrential rain or moderate snow melting necessitates its removal a few times during the year. Precipitation of the order of 100 mm causes catastrophic results of significant spatial scope. It leads to strong erosion of gully bottoms and dirt roads, flooding of basements and ground floors of buildings, displacement of vehicles and power poles and tearing off of the road surface.

Documentation work, aiming at presentation of a plan of anti-erosion safeguards, was performed several times in the vicinity of Kazimierz Dolny (Gardziel et al., in print). A change of land use in individual catchment basins comes here to the fore. For this purpose, permanent grasslands such as pastures and hay-growing meadows should be introduced, while areas with significant inclination should be afforested. Organisation of outflow is necessary, since despite of the self-forestation of land plots in the closest

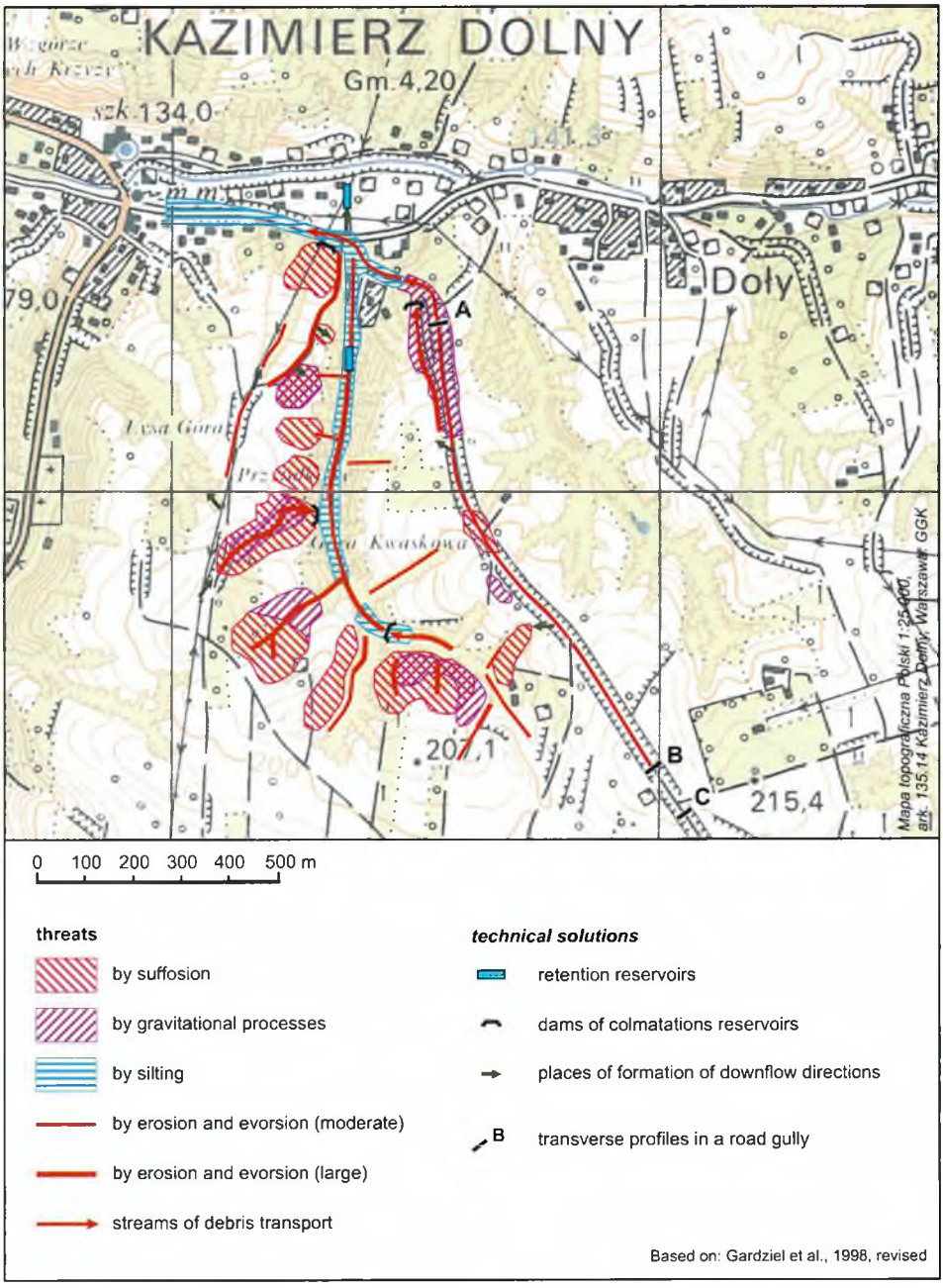

Fig. 3. Threats posed by the contemporary morphogenetic processes in the region of Kwaskowa Góra and proposed technical solutions

proximity of the gullies, old downflow lines along boundary strips and furrows still exist. Constraining gully erosion is possible by means of eliminating the concentrated downflow of water from agricultural lands to the gullies. Related to this is a change of the direction of croplands to one parallel to the gully edge. In the catchment area of Kwaskowa Góra there are a few crucial points where it is possible to easily redirect the flow from dirt roads (Fig. 3). In the case of Opolska Droga one of such places is the segment of the valley, nowadays running wild, located west of the one used nowadays, as well as the side branch of the Chałajowy Dół. From the Przytułków ravine the flow can be directed both to the side gullies of the Chałajowy Dół and to the forms located west of the ravine.

Plant consolidation is regarded as the main safeguard. To preserve the most active gullies (in particular the edges of young road gullies) one should introduce appropriate plant species, for instance, shrub vegetation, whose roots do not penetrate very deeply, thus do not strain the gully edge too much. Additionally, shrubs on the border between fields and forests don't shadow the fields and don't have an adverse impact on the crops.

Certain technical solutions can be suggested to limit dangers. Modern and ecologically acceptable measures would allow for hardening of the fragments of gully bottoms, which are most vulnerable to the erosion and evorsion. Hardened segments would at the same time organise outflow systems. At the outlet of the most eroded branches, which don't have a significant landscape value, one should localise colmatation reservoirs (Fig. 3), whose function would be interception and retention of the debris in the catchment area. A retention reservoir with the capability of periodic mechanical extraction of sediments would serve to deposit part of the debris taken out from the catchment area (Gardziel et al., 1998).

A complete elimination of erosion from the region of Kazimierz is impossible and has no purpose. Gullies are a valuable, protected and characteristic element of the Kazimierz Landscape Park. Keeping the gullies, in particular the road gullies, in its present state is recommended for landscape-related reasons. In principle, they should develop naturally. It is important to separate gullies that don't constitute a danger to the town and to leave them without intervention. Road gullies are an impermanent landscape element and have to be maintained and conserved. Otherwise, their communication function will be lost, the erosion processes will intensify and, as the result, the gullies will run wild (Gardziel, Rodzik, 2000).

REFERENCES

Buraczyński J., Wojtanowicz J., 1974, Rozwój wąwozów lessowych w okolicy Dzierzkowic na Wyżynie Lubelskiej pod wpływem gwałtownej ulewy w czerwcu 1969 roku [The Development of Loess Gullies in the Vicinity of Dzierzkowice on the Lublin Upland under the Influence of a Sudden Rain in June 1969; in Polish], *Ann. UMCS*, Sec. B, 26, 135-168.

Gardziel Z., Harasimiuk M., Jezierski W., Pawłowski A., Zgłobicki W., in print: *Erozja wąwozowa w zachodniej części Płaskowyżu Nałęczowskiego (Wyżyna Lubelska)* [Gully Erosion in the Western Part of the Nałęczów Plateau (Lublin Upland); in Polish].

Gardziel Z., Rodzik J., 2000, Warunki rozwoju, użytkowania i ochrony wąwozów drogowych okolic Kazimierza [Conditions of Development, Use and Protection of Road Gullies in the Vicinity of Kazimierz; in Polish], [in:] *Problemy ochrony i użytkowania obszarów wiejskich o dużych walorach przyrodniczych* [Issues of Protection and Use of Rural Areas with Important Natural Qualities; in Polish], Janów Lubelski, 249-255.

Gardziel Z., Harasimiuk M., Rodzik J., 1998, Syntetyczna mapa morfodynamiczna jako podstawa projektu zabezpieczeń przeciwerozyjnych (na przykładzie okolic Kazimierza) [Synthetic Morphodynamic Map As a Basis of the Plan of Anti-Erosion Safeguards (On the Example of the Vicinity of Kazimierz); in Polish], [in:] *IV Zjazd Geomorfologów Polskich*; in Polish], Lublin, 403-409.

Gardziel Z., Harasimiuk M., Rodzik J., 1996, *Dynamika procesów geomorfologicznych w zlewni Grodarza i związane z nimi zagrożenia dla Kazimierza Dolnego. Małopolski Przełom Wisły – walory, zagrożenia, ochrona* [Dynamics of Geomorphological Processes in the Grodarz River Catchment Basin and Dangers to Kazimierz Dolny Related to them. Little Poland Vistula River Gap – Qualities, Threats, Protection; in Polish], Kazimierz Dolny, 21-31.

Józefaciuk A., Józefaciuk Cz., 1984, *Program zagospodarowania zlewni potoku Grodarza pod kątem ochrony miasta Kazimierza przed skutkami erozji. Melioracje przeciwerozyjne podstawą racjonalnego użytkowania terenów wyżynnych* [A Program of Management of the Grodarz River Catchment Area from the Point of View of the Protection of the City of Kazimierz from the Consequences of Erosion. Anti-Erosion Agricultural Drainage As the Basis of Rational Use of Upland Areas; in Polish], Puławy, 5-13.

Kondracki J., 1998, *Geografia regionalna Polski* [Regional Geography of Poland; in Polish]. Wyd. Naukowe PWN.

Maruszczak H., 1973, Erozja wąwozowa we wschodniej części pasa wyżyn południowopolskich [Gully Erosion in the Eastern Part of the *South*-Polish Upland Belt; in Polish], *Zesz. Probl. Post. Nauk Roln.*, 181, 15-30.

Maruszczak H., 1986, Tendencje sekularne i zjawiska ekstremalne w rozwoju rzeźby małopolskich wyżyn lessowych w czasach historycznych [Secular Trends and Extreme Phenomena in the Formation of Relief of the Little Poland Loess Uplands in Historical Times; in Polish], *Czas. Geogr.*, 51,2, 117-145.

Maruszczak H., Trembaczowski J., 1958. Geomorfologiczne skutki gwałtownej ulewy w Piaskach Szlacheckich koło Krasnegostawu [Geomorphological Consequences of Sudden Torrential Rain in Piaski Szlacheckie near Krasnystaw; in Polish], *Ann. UMCS*, Sec. E, 13, 145-193.

Pożaryski W., 1953, Plejstocen w przełomie Wisły przez wyżyny południowe [Pleistocene in the Vistula River Gap Through the Southern Uplands; in Polish], *Prace Inst. Geol.*, 11.

Rodzik J., 1984, Natężenie współczesnej denudacji w silnie urzeźbionym terenie lessowym w okolicy Kazinierza Dolnego [The Intensity of Contemporary Denudation in Loess Area with High Relief in the Vicinity of Kazimierz Dolny; in Polish], [in:] *Przewodnik Ogólnopolskiego Zjazdu Tow. Geogr.*, Lublin, 2, 125-130.

Rodzik J., Janicki G., Zagórski P., Zgłobicki W., 1998, Deszcze nawalne na Wyżynie Lubelskiej i ich wpływ na rzeźbę obszarów lessowych [Torrential Rains in the Lublin Upland and Their Impact in the Relief of Loess Areas; in Polish]. *Dok. Geogr.* 11, Geomorfologiczny i sedymentologiczny zapis lokalnych ulew [Geomorphological and Sedimentological Record of Local Torrential Rains; in Polish], 45-66.

English translation: Małgorzata Mikulska