The Middle Vistula River Section as a geotourist attraction

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The Middle Vistula River Section is one of the most attractive places of our country. It is also marked by its excellent landscape and cultural values as well as interesting geological structures. The heart of this whole region is Kazimierz Dolny, the little town with various traditions, numerous antiquities, magic and unique atmosphere (Baran-Zgłobicka & Harasimiuk, 2007), situated on a high scarp above the longest Polish river Vistula which is the axis of the region (Fig. 1). Going alongside the Vistula River valley it is easy to find lots of geological exposures, geomorphologic objects and relics of the past (Zgłobicki et al., 2007). The ruins of magnate residence in Janowiec and duke's town Puławy with the historical monuments dated from the 17th to the 19th century are only the small part of attractions situated nearby. Several kilometers east of Kazimierz Dolny, in Nałęczów, there is a calm and peaceful health resort with peculiar microclimate and mineral waters useful in the heart disease rehabilitation.

For protection, preservation and popularization of landscape and cultural values, landscape parks are being formed. In the region discussed there are two of them: Kazimierz and Wrzelowiec (Pawłowski, 2002). First of them has been created in 1979 on the area of almost 15,000 ha around Kazimierz Dolny, the second, established in 1990 is situated between Józefów and Piotrawin on the area of 5000 ha. Both of them include terrain with diversified surface features, mostly agricultural; forests take about 20–30% of their total area. Another forms of landscape preservation, created for better and complete protection are landscape protective areas. These forms cover distinctive fields with different types of ecosystems. In the Middle Vistula Valley region there are three of them. The Chodelsk Protective Area is situated along the right bank of the Vistula. The lowest part of the Vistula Gorge and part of geomorphologic interesting Chodelka River valley are

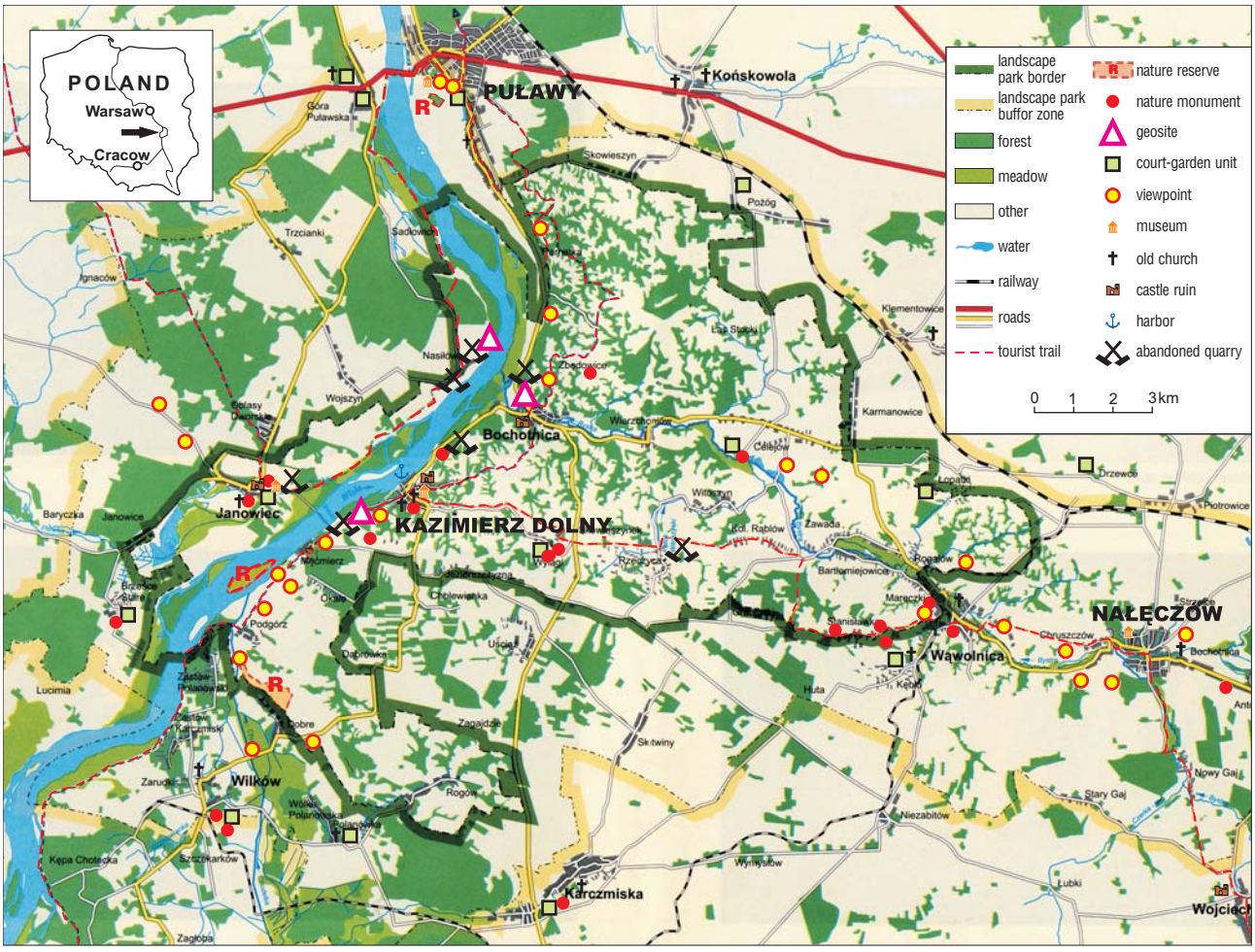

Fig. 1. Location of selected geosites and geotourist attractions in the Kazimierz Dolny region (after Pawłowski, 2002, partly modified)

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situated in its range. The next two protective areas are placed on the left bank of the Vistula. The Landscape Protective Area of Zwoleńka Valley is a naturally formed valley with highly meandering river and very rich in fauna and flora representatives. Next to this area and farther southward there is Solec Protective Area. This is a terrain on the west bank of the Vistula and in its borders it has a part of plateau cut with deep ravines and part of the wide Vistula valley.

The Vistula River valley is one of the most important ecological corridors in Europe enabling nesting and passage of birds. Because of that reason major parts of it joined the European network NATURA 2000. The Vistula Gorge segment also plays a peculiar climatic role enabling penetration between climatic influences from the north and south. Climate inside the valley is much milder than on the surrounding plateaus.

The Middle Vistula River Section

It stretches for 80 km along the Vistula River course, from Zawichost to Puławy. In the part discussed the river constitutes a natural border between two geographic lands: Lublin Upland on the east, Iłża Foreland and Radom Plain on the west. The valley width changes from 1 km in the narrowest point near Kazimierz Dolny to over 10 km where the Vistula valley meets Chodel Kettle. The relief of the valley highly depends on lithological diversity of rock material that is built of and its erosion susceptibility (Głodek et al., 1967).

The area is placed within the Mesozoic fringe of the Holy Cross Mountains, passing north-eastwardly into the Lublin Basin, which constitutes the southern part of the Marginal Trough Deposits of the Middle Jurassic to the Upper Cretaceous in age.

Geological structure of deep, Pre-Mesozoic basement is, until now, very weakly recognized. Major part of the area lies within the borders of the Radom-Kraśnik zone, built of Silurian and Devonian rocks. Mesozoic rocks are represented mainly by Upper Cretaceous (Maastrichtian) opokas, limestones, marls and chalks. Thickness of the rocks in this region is not higher than 80 m (Pożaryski, 1951b). They are locally overlain by the oldest Tertiary deposits such as gaizes with limestone intercalations and marls with thicknesses not higher than 20 m. These well preserved exposures in the Kazimierz Dolny area are unusual at the European scale (Pożaryska, 1952). Quaternary deposits cover almost the whole surface of this terrain directly overlying Upper Cretaceous and locally Tertiary deposits. The oldest of them are sands with gravels, Pre-Pleistocene river loams and tills of the South Poland Glaciation found only in boreholes.

Silts, clays, and fluvioglacial sands, gravels, boulders, and moraine tills are the remnants of the Middle Polish Glaciation. Locally, in the Polanówka village region, esker sands and gravels occur. The Eemian deposits contain fluvial sands and gravels up to 20 m thick, which infill the Vistula River paleovalley, whereas paleosols of this age locally crop out on slopes of the uplands.

Upper Maastrichtian opokas have been used for ages as building stones in the whole region (Fig. 2). They may be easily found in historical buildings of Kazimierz Dolny, Janowiec and other towns and villages. Owing to high durability, excellent technical parameters and easy processing, they are still used as a traditional building material

Fig. 2. Local scale exploitation of opokas used as traditional building material — one of several active quarries in the Kazimierz Dolny area. Photo by B. Bąk

(Dziedzic, 2007). After World War II opokas were also used to regulate the Vistula course.

The following sections of the Middle Vistula Valley (from S to N) can be distinguished:

- Zawichost-Solec — resistant Jurassic bedrocks as well as Cretaceous (Turonian, Coniacian, Santonian) opokas and limestones.
- Solec-Zastów Polanowski — the river valley is distinctly widening, changing into the vast Chodelska Valley towards the east. This denudation is caused by the poorly resistant Maastrichtian marls in the bedrock.
- Zastów Polanowski-Podgórz-Janowiec-Puławy — it is the narrowest section of the Middle Vistula Valley eroded in the resistant Upper Maastrichtian and Danian gaizes.

The gorge section of the Vistula River was formed during the Pliocene as a result of the Carpathian orogenic movements and intensive fluvial erosion. These movements also reached the Middle Polish Uplands (the meta-Carpathian swell). The Vistula River cut them at that time forming a narrow trough between Zawichost and Puławy. The gorge section of the river, which formed at the end of the Pliocene, connected the Carpathian Foredeep with the Mazovian Basin.

The Vistula River Basin during the South and Middle Polish Glaciations was situated directly in the glacial accumulation zone. The outflow of waters was blocked by the ice-sheet increasing sediment accumulation in the valley. The Pleistocene and Holocene history of the Vistula River Basin is a sequence of accumulation phases separated by phases of cutting and removal of the rocky material. Under

the periglacial climate within the valley slopes mechanical weathering of rocks together with geodynamic movements took place. At the same time on the top of the hills loess accumulation proceeded. It resulted in very thick loess cover around the river valley, particularly well visible in the Nałęczów Plateau. During the warmer and wetter phases erosional processes dominated over accumulation. These conditions were favorable for forming valleys in the bedrock. At the narrow section of the Vistula Gorge lateral erosion dominated causing damage of the Pleistocene terraces and outcrops of old Mesozoic bedrock. The height of the Visulian scarps at the deepest sections of the gorge nearby Janowiec and Kazimierz reaches nearly 80 m (Fig. 3).

Younger Holocene accumulation is strictly associated with climatic changes. Current river activity has both accumulative and erosional character (Warowna, 2007). Natural, unregulated river current causes fast growth of numerous islands and sandbars. One of them, the Cow's Island with an area of 62.3 ha is under the reserve protection. Essential changes in the Vistula Valley are caused by sudden, intense and irregular floods (spring and summer; especially in June and July), causing transformations of lower Holocene terraces and changes in the river-bed and current.

Visiting this enormous picturesque and interesting Polish region it is worth seeing at least one of its numerous geosites. Let's go then.

The Vistula valley in the southern portion of the gap runs along a dislocation, which separates the Rachów anticline located on the right river bank near Annopol (Fig. 4). This tectonic element is genetically linked to the Holy Cross Mts. orogen. The Rachów anticline is built of marls, sandstones, shell limestone conglomerates, marly dolostones, and shell limestones of the Kimmeridgian and Portlandian. They are the oldest Jurassic rocks in the area of the Lublin Upland. In the anticline crest area occur quartzitic sandstones and yellow and red sands passing into glauconitic sands of Albian and Cenomanian age. These sands contain phosphate concretions. They were explored before the World War II and shortly after it in the vicinity of Annopol. Today they have no economic value. Cenomanian deposits terminate with glauconitic marls overlain by Turonian marls, which surround the whole anticline and older rocks. The anticline zone passes gradually northward into a monocline with younger rocks outcropped (Fig. 4). Depending on the state of an exposure, outcrops of this anticline can be observed on the right-hand slope of the valley, which is being undercut by the Vistula River along 4–5 km long section ranging from a bridge in Annopol to the north.

From Annopol to Solec slopes of the Vistula Valley are rather steep and up to 40 m in height what underlines the gorge character of this river section. The slopes are built mainly of very resistant gaizes with black flintstones and overlaying them platy gaizes with cherts. These two varieties are of Turonian age. In one of the quarries in Opoczki one of the biggest ammonite specimens (*Pachydiscus peramplus*) in Poland, exceeding 1 m in diameter, was found (Błaszkiewicz, 1980; Walaszczyk et al., 1999).

The steep slopes are covered with dense network of young, short dissections of erosive origin, mostly dry due to the very high penetrability of the lime bedrock by water. The biggest dissections occur nearby estuaries of the Vistula River tributaries. The bottom of the valley is built of low Holocene terraces, and a winding riverbed favors formation of sandy islands. Varied morphology of the area as well as rich vegetation increase the landscape values.

Carbonate rocks building the Vistula River scarps were exploited at many sites along the whole gorge section. One of the biggest exposures is a quarry in Piotrawin. The open-pit is 300 m long and up to 40 m high. In its walls a quite monotonous series of Upper Cretaceous (Lower

Fig. 3. High bank of the middle Vistula Valley by Kazimierz Dolny. Photo by B. Bąk

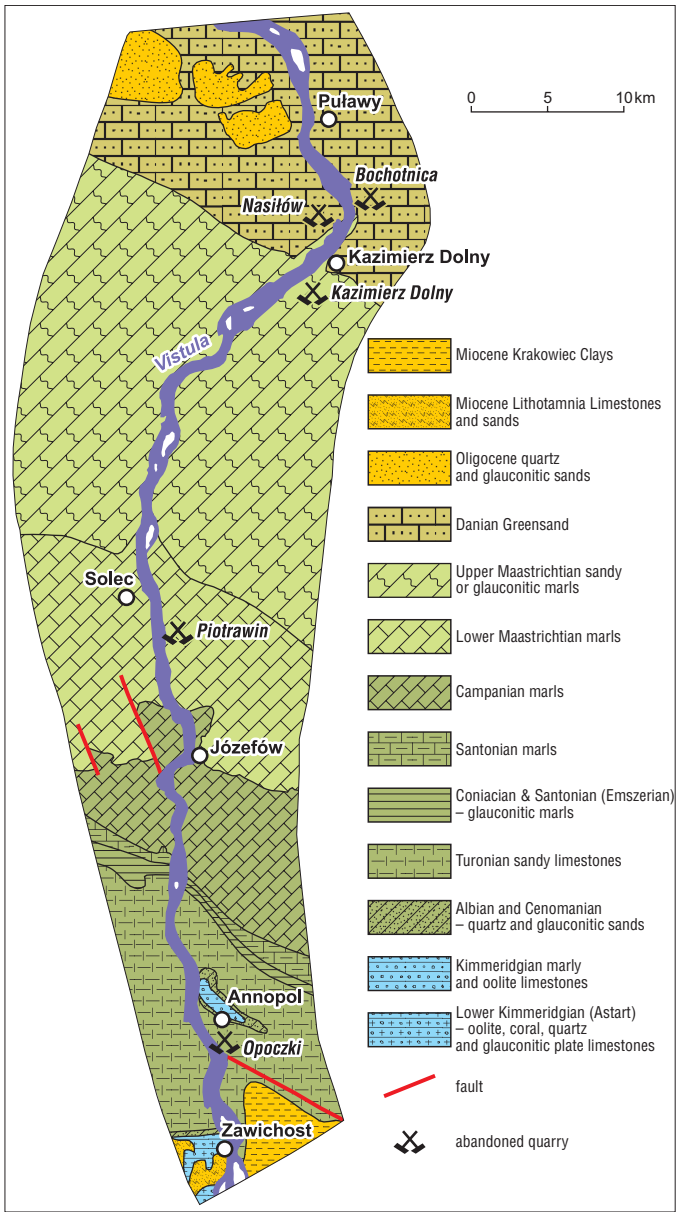

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Fig. 4. Geological outline of the Middle Vistula Valley (after W. Pożaryski, 1951a)

Maastrichtian) bedrock intercalated with gaizes is exposed (Fig. 5). In the lower part of the wall carbonate layers crop out. Their age was defined on the basis of fossil fauna (ammonites, including inocerams, and belemnites) as the Upper Campanian. It is one of the very few places in Europe, where this rich fauna-bearing formation is easily accessible. The most typical species are: *Hoploscaphites constrictus, Pachydiscus egertoni, P. colligatus*, and *Hamites cylindricus* (Pożaryski, 1951 b).

Farther to the north, along a short section of the river, fragile Santonian marls, and farther up to the vicinity of Józefów compact and harder Campanian marls are exposed. At the section between Józefów and Solec the Vistula River cuts through the soft marls of Lower Maastrichtian age. It is reflected in the morphology of the area. North of Solec character of the Vistula River Valley changes significantly. Steep edges are getting lower and their distance to the valley line is rising. Soft marls of the lower part of the Upper Maastrichtian occur here. Their durability is very low and they are easily a subject to the karstification processes. Karst phenomena are common here. The marls are covered with the low Holocene terraces up to 7 km wide. In the east, the Vistula Valley borders with the adjoining Chodelska Kettle. In this place well developed Pleistocene and Holocene Vistula River terraces occur. Higher terraces are mainly built of sands, therefore, large groupings of dunes and wind-blown sands are common here. The largest dunes are located in the neighborhood of Opole Lubelskie and Karczmiska.

The Vistula is getting more capricious and unstable (shifting bed) between Solec and Zastów Polanowski. The riverbed, which is up to 500–600 m wide, is diverse in terms of numerous holms which are the parts of the low Holocene terraces. The area is transforming very fast. During the last 120 years the river in this part destroyed three villages almost totally. Simultaneously, a new terrace came into being. It is 1.5 km wide and big enough to let the Brześce village develop.

The Vistula recovers its ravine character from Zastów Polanowski. High scarps with geological and natural values become more visible. There are many exposures with Upper Cretaceous and Tertiary rocks. Specific thermal conditions and high insolation favors the growth of thermophilous and steppe vegetation. Because of these values one of the scarps — Skarpa Dobrska — a wildlife reserve on area of 39.7 ha in 1991 came into a being. It is situated on the right bank of the Vistula, south of Kazimierz Dolny, between villages Dobre and Podgórz. In the lower parts of the scarp marls and chalk liable to erosion are exposed. Its terraces are covered with thin layer of calcareous soil greened with xerothermic sward (Pawłowski, 2007). Higher, steep, sometimes vertical parts of the slope are built of Upper Maastrichtian opokas. Cretaceous deposits reach the height of 60 m and are overlain by loess of several meters thick. A little more northward, on the left riverside,

Fig. 5. Abandoned quarry of Upper Cretaceous marls in Piortrawin. Photo by B. Bąk

Fig. 6. A view from the 16th-century Janowiec castle over the middle Vistula Valley and river terraces. The castle walls were built of opoka — a traditional, regional building material. Photo by B. Radwanek-Bąk

there is a scarp in Janowiec. On its edge are picturesque ruins of the 17th century Firley's castle with an extensive view over the valley and Radomska Plain (Fig. 6). The edge of the valley is in this point 4 km far away from the river, containing few levels of terraces. The scarp is built of Upper Cretaceous opokas. Their exposures, with relative heights up to 50 m are well exposed especially north of Janowiec. They stand out owing to the contrast between white opokas and green scarp vegetation. The best way to discover the Vistula gorge is to go there by boat. This kind of trip guaranties the most beautiful sights.

Compared to previously described parts, this section of the valley is characterized by freshness of its form. Current research indicates a possibility of its tectonic origin related to the Laramian phase. It was discovered by the boreholes which shown that north of Janowiec and west of Puławy there was an old Vistula paleovalley filled with fluvial deposits. It is not visible in the terrain morphology. Its estimated age is preglacial. The axis of paleovalley is not in accordance with the present Vistula direction. Nearby Kazimierz Dolny, it elongates SW-NE and about 3 or 4 km west from Janowiec and east from Puławy it crosses the current riverbed. It was also about 30–40 m more incised into the ground than the present valley filled with alluvial deposits of 30 m thick.

There are some interesting exposures located in abandoned quarries in the described part of the Vistula gorge. There is a possibility to monitor the lithological and stratigraphic profiles of Cretaceous and early Tertiary rocks (Peryt & Walaszczyk, 1993).

Upper Cretaceous bedrocks (so called "Kazimierz opokas") were exploited at a large scale at the town quarry. This several hundred meters long, 40 m high and multilevel excavation is located on a Vistula River scarp in the southern suburbs of Kazimierz Dolny (Fig. 7). There are present two types of bedrocks which are varying in porosity, compactness, and contents of calcium carbonate. They were mainly used for regulation of the riverbed. In the upper part of the profile there are two characteristic layers of soft marls each 1.5 m thick. A rich fauna of snails (Turitella plana, T. quadricinata), bivalves (*Nucula, Cucullaea undulata, Lima hoperi, Pecten acutplicatus, P. nilssoni, Ostrea canaliculata*), cephalopods (*Nautilus patens, Belemnitella mucronata*), and brachiopods (*Terebratula spp.*) in the exposed rocks is present.

Fig. 7. A view over abandoned old town quarry in Kazimierz Dolny. Photo by B. Radwanek-Bąk

Fig. 8. The outcrop of the Cretaceous/Tertiary boundary in the old quarry at Bochotnica. Photo by B. Bąk

In Bochotnica, around 4 km north of Kazimierz Dolny, on a Vistula Basin slope beside the blue tourist trail, there is a small abandoned quarry (Fig. 8). Two factors decide about attractiveness of this place. The first one is a possibility of observing a documentary profile with a boundary of the youngest Cretaceous (Upper Maastrichtian) beds with those of the base Paleogen system (Danian). In the lower portion of the quarry two bedrocks with different porosities are exposed. They are intercalated with marls and comprise rich fauna (spiculae, fragments of ammonites, bivalves, brachiopods, belemnites, and snails). Above the bedrock occur about 0.6 m thick layer of almost pure, compact, and locally silicified, hard light-grey or rusty limestones. This layer for many years has been considered as the hardground (Pożaryska, 1952). In the light of new paleontological and sedimentological studies origin of this stratum seems to be more complicated (Machalski, 1998). This layer contains numerous fossils characteristic of the Upper Maastrichtian like sponges, bivalves, snails, and ammonites (Machalski & Walaszczyk, 1987; Radwański, 1996). The top surface is uneven, with channels filled with material derived from the overlaying light-green fine-grained quartz-glauconitic sandstones (Machalski & Walaszczyk, 1987). This about 0.5 m thick bed is commonly called a phosphate one due to the presence of phosphate concretions. These concretions are pseudomorphs after sponges or rarer after bivalves and brachiopods. The layer is overlain by a rocky series of Danian age. It is built of grayish-light-green porous and breakable lens-shaped gaizes and 0.3–0.4 m thick intercalations of more solid marly limestones. Owing to the grey color this series is locally named "siwak" and is about 40 m thick.

Fig. 9. The chamber exploitation of opokas in the Bochotnica quarry. Photo by B. Bąk

The second reason of the attractiveness of the Bochotnica quarry is the way of exploitation. It is one of the unique examples of chamber exploitation (Fig. 9). Here the bedrock was excavated for construction purposes. Some of the chambers together with natural pillars survived until now, however, before opening to the public some recon-

Fig. 10. The outcrop of the Cretaceous/Tertiary boundary section in the Nasiłów quarry. Photo by B. Radwanek-Bąk

structions mainly due to safety reasons are required. Since 1992 the quarry is under protection as a "documentary geosite of inanimate nature". To honor two eminent Polish geologists it is called Krystyna and Władysław Pożaryski's wall.

North of Kazimierz Dolny, on the opposite bank of the river, in Nasiłów, there is a similar geological locality of European significance (Fig. 10). It is 350 m long and 30 m high, abandoned, partially grown over the ruderal vegetation bedrock, quarry. In the lower part of the quarry occur Upper Cretaceous (Maastrichtian) gaizes. The upper visible part consists of Paleocene (Danian) light-grey limestones locally called "siwaks" (Marcinowski & Radwański, 1996). The transition between these two beds is marked by the 0.5–0.7 m thick layer of compact and hard limestones. They are overlain by 0.4 m thick layer of glauconitic light-green sandstones with phosphate concretions.

Rocks occurring in this excavation are rich in many fossils documenting the boundary between the Cretaceous and Tertiary (Radwański, 1989).

The gorge section of the Vistula River Valley ends in Puławy. On the left bank of the river there is the Puławy Mountain (Góra Puławska) with Upper Cretaceous, Tertiary and Pleistocene rock exposures. Of note, among them, there is a several meters thick layer of decalcified gaizes from the turn of the Cretaceous and Tertiary (Danian). Its top is a denudation surface and is overlain by the Lower Oligocene loam. The decalcified gaizes, which are also present in many other exposures in this region point to intensive chemical weathering processes under warm and wet climate conditions during the Early Paleogene. At Góra Puławska village an outcrop of Pleistocene sediments close to the Adamówka gulch mouth occurs. In these sediments artifacts of the Paleolithic man were found. The cultural layer occurs in a paleosol separating two loess horizons.

The quarries described above are important geosites and because of that reason they are placed on the European list of geological heritage. They are also interesting geotouristic attractions. The accessibility during the walks or bike trips is perfect; they are well marked and described in intelligible way for wide public. They are also parts of education paths created in borders of the Kazimierz Landscape Park. The quarries in Piotrawin, Nasiłów and Kazimierz were reclamated mainly by flattening the slopes. This type of reclamation favors not regulated plants' growth, which disables these places from its proper usage as geosites.

Loess covers the main part of the Lublin Upland. The most interesting region of their occurrence is Nałęczów Plateau, extending to the east of Kazimierz Dolny. Thickness of the loess cover (North Poland Glaciations) reaches up to 30 m here (average thickness is 10–15 m). It is also the area with diversified terrain morphology. Intensive deforestation until the end of the 19th century caused fierce water erosion and piping phenomenon development. The effect of this process is unique at the European scale network of gaps and gorges with density up to 11 km/km^2, mostly 5 km/km^2. Processes are active also nowadays. In the Kazimierz surroundings there is an access to many picturesque ravines, both natural and anthropogenic. The latest is called "Głębocznice" (road gully). Walking down on them gives an opportunity to observe the whole formation processes of this morphologic form. The gorge development begins with shallow piping forms and erosion furrows, which develop in "gills" what means V-shape valley inci-

Fig. 11. Korzeniowy Dół near Kazimierz Dolny — an example of anthropogenic gorge named "road gully". Photo by B. Radwanek-Bąk

sions with big bottom fall. Next, they can transform into ravines or typical, long and deep gorges. "Głębocznice" are effects of erosion caused by human activity, in this case frequent usage of roads by horse-driven carts. Characteristic attributes are vertical walls and small width (Fig. 11).

Rich geological heritage and great landscape values of this region should be protected on a higher level. There have been made many efforts to establish the geopark here for a few years. In the future this should allow for wider accessibility and appropriate preparation for specialist interdisciplinary research purposes as well as geotourism.

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