Cultural Geomorphological Landscapes of the East Sudetes

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Abstract

The chapter focuses on anthropogenic transformation of relief in two subregions of the East Sudetes—the Śnieżnik Massif and the Złote Mountains. They can be considered as representative for the Sudetes, which exemplify a mid-latitude, medium-altitude mountain range distinguished by a high degree of human impact on the geomorphological system due to a great variety of economic activities carried out in the past and now. Human impact on topography is both direct (anthropogenic landforms and features) and indirect (enhancement and then reduction of soil erosion, channel pattern change, and modification of fluvial processes). The recent human-induced landscape changes related to the current economic activities such as forestry and tourism co-occur with relic landforms in the depopulated and abandoned areas, which are the legacy of more intense human impact in the past. The chapter presents the diversity of anthropic landforms of various age according to their origin related to various economic activities such as agriculture, forestry, settlement, mining, quarrying, industry, and water management. The section on indirect human impact includes a discussion on anthropogenic modification of morphological processes and their record in hillslope and alluvial sediments. Finally, the persistence, values, and promotion of cultural geomorphological landscapes are highlighted.

Keywords

Cultural landscape · Human impact · Anthropogenic landforms · Śnieżnik Massif · Złote Mountains

11.1 Introduction

The Sudetes—in comparison with other *Mittelgebirge* (medium-altitude mountains) ranges in Poland—are distinguished not only by a high degree of anthropogenic transformation of the topography, but above all by a great variety of economic activities carried out here in the past and now. This is mainly due to their great diversity in terms of lithology and related mineral resources and relief. The first factor supported mining and exploitation activity, which had strongly developed in this area since the Middle Ages (thirteenth–fourteenth centuries), while the second factor substantially contributed to the development of tourism. Tourism development is one of the oldest in the present-day Poland—it was carried out in an organized and planned form from the end of the eighteenth century (Mazurski 2012). In addition, mineral and thermal water resources contributed to the creation of numerous health resorts, vast forest areas favoured forest management and timber industry, and arable lands reached a height of up to 1000 m above sea level. A characteristic feature of the development of the Sudetes was also strong industrialization, not limited to towns, but also involving rural areas. Numerous and various industrial and craft plants based on local raw materials were found even in villages located high in the mountains. This is a feature that clearly distinguishes the Sudetes from other mountainous areas in Poland.

All the above-mentioned economic activities have left their tangible evidence in the landscape, both direct, as anthropogenic landforms and features, and indirect, in the form of anthropogenic modification of morphological processes and their records in hillslope and alluvial sediments. The uniqueness of the Sudetes in terms of the possibility of tracing changes in the topography under human impact also results from the changing intensity of anthropogenic activity over time. Especially the period of the last 150 years allows us to trace the landscape effects of first increasing human impact (until 1945), and then its significant weakening, with the cessation of many economic activities, including

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P. Migoń and K. Jancewicz (eds.), *Landscapes and Landforms of Poland*,
World Geomorphological Landscapes, https://doi.org/10.1007/978-3-031-45762-3_11

land abandonment, especially in the 1980s and 1990s. In the last 20 years, a successive, though generally local, intensification of human intervention in the environment and landscape is observed, leading to new transformations. Fluctuations in the human–environment relationships are directly related to socio-economic changes that have taken place in this area. The most important among them include: (1) depopulation, commonly observed throughout the area from the end of the nineteenth century and lasting until today; (2) the change of the state border after World War II, the displacement of the German population and the influx of new settlers, often from areas with different environmental conditions (lowlands, fertile soils); (3) political and economic changes in Poland after 1989 related to the fall of communism and the development of free market economy; (4) Poland's accession to the European Union (2004) and the Schengen area (2007), which allowed, *inter alia*, for access to funds for new investments and the development of the near-border areas in which the Sudetes are located.

The changing political and socio-economic conditions translate into clear changes in the landscape. Their effect is a unique palimpsest of anthropogenic landforms and, more broadly, of a geomorphological cultural landscape. They represent forms of different ages and origins, and a characteristic feature is the coexistence in close proximity or even overlapping of various anthropogenic landforms: relict and contemporary, newly created and undergoing gradual degradation. For this reason, the Sudetes can be treated as an open-air research laboratory, both for tracing the way in which diversified human activity was recorded in the relief and sediments, and for assessing the degree of persistence of anthropogenic landscape changes in areas where human impact weakened. It also makes it possible to identify processes that contribute to the degradation or consolidation of elements of past cultural landscapes in the relief.

The chapter focuses on the presentation of direct and indirect anthropogenic transformation of the topography in two subregions of the East Sudetes—the Śnieżnik Massif and the Złote Mountains (Fig. 11.1). This choice arises, on the one hand, from the high concentration of various anthropogenic landforms and constructions in this area and, on the other hand, from high dynamics of the observed socio-economic changes, both depopulation and the revival noted in recent years. In addition, it is also dictated by the availability of literature and detailed evaluation of both areas in terms of human impact.

11.2 Setting and Location

The East Sudetes constitute the northern part of the Bohemian Massif and are mostly located in the Czech Republic. The highest culmination is Mt. Praděd on the Czech side (1492 m asl) in the Hrubý Jeseník range. The chapter focuses on two physiographic mesoregions, which form the westernmost part of the East Sudetes: the Śnieżnik Massif and the Złote Mountains, which are both cross-border mountain ranges (Fig. 11.1). Their total area is 471 km^2. The highest culmination in the analysed area is Mt. Śnieżnik (1424 m asl) situated at the state border, and the maximum height difference is 822 m. The European watershed runs through the Śnieżnik Massif. Most of the area is drained to the Baltic Sea—via the Nysa Kłodzka River (left-bank tributary of the Odra River) and its numerous mountain tributaries. The southern end of the region belongs to the North Sea basin, and the eastern slopes of the massif—to the Black Sea basin. Due to the mountainous nature of the watercourses, there is a high hazard of flooding.

The permanent settlement network developed in the thirteenth–fourteenth century. However, human penetration of the region, including trading routes, commenced much earlier (Herzig and Ruchniewicz 2008; Felcman et al. 2012). Due to its borderland location, the statehood of the region often changed (Czech, Austrian-Hungarian, Prussian/German, Polish), and thus numerous wars and diverse cultural and economic influences affected its development. The shift in state borders after the World War II, together with the almost total exchange of population, was one of the most influential transformations in the history of the region, and its socio-economic effects are observed until nowadays.

The analysed area is protected under the Śnieżnik Landscape Park and its buffer zone and is also covered by several Natura 2000 habitat areas. There are also several nature reserves, including the Niedźwiedzia Cave (*Bear Cave*) and Wilczka Waterfall. The areas directly related to the former mining activities are also protected, both as the ecological sites (Rogóżka, Biała Marianna, Orchids' heap) and the documentation site (Adit No. 18 in the Underground Tourist and Educational Route in the Old Uranium Mine in Kletno).

11.3 Geology and Main Features of Relief

Geologically, the Śnieżnik Massif and most of the Złote Mountains are located within the Orlica–Śnieżnik dome, dominated by various types of Lower Palaeozoic gneisses and schists (Don et al. 1990, 2003) (Fig. 11.1). Within them there are, among others, amphibolites and crystalline limestones (marbles). On the other hand, the northern part of the Złote Mountains belongs geologically to the metamorphic Złoty Stok–Skrzynka zone and the Carboniferous granitoid massif of the Kłodzko–Złoty Stok (Mazur et al. 2007). Moreover, in the area of Lądek-Zdrój basalts occur, which are a remnant of late Neogene volcanism (Badura

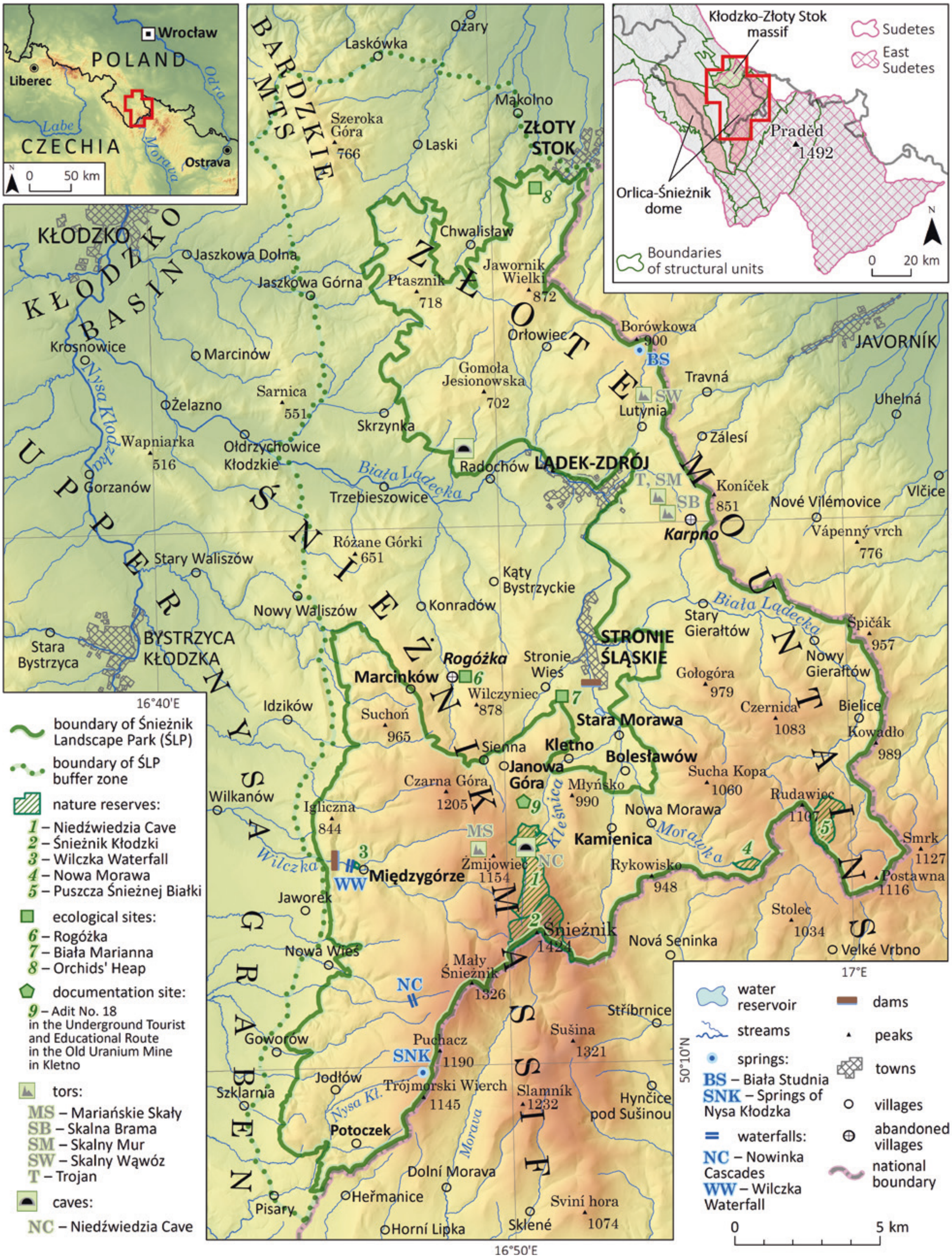

Fig. 11.1 Study area, with localities mentioned in the text and simplified geological background in the inset (map courtesy of Kacper Jancewicz)

et al. 2005). The boundaries of both regions are tectonically conditioned and are legible in the landscape. The mountain ranges represent tectonic horsts associated with the Neogene orogenic movements, which lifted the older denudation surfaces to various heights (Migoń 1996; Sobczyk and Kasprzak 2014).

The highest summit of the Śnieżnik Massif (Mt. Śnieżnik) has the shape of a massive dome raised 100–200 m above the adjacent summit levels, and there are six ridges of various lengths radiating out of the summit, with rounded and gentle summit surfaces interspersed with domed peaks (Figs. 11.1 and 11.2a, b). Characteristic for the western part of the Śnieżnik Massif is the presence of extensive flattenings at an altitude of 700–850 m asl, which create the lower morphological level within the massif (Migoń 1996). The western morphological boundary of the massif is very pronounced due to its tectonic origin (Ranoszek 1999; Badura and Rauch 2014). The mountain ranges are dissected by deep, V-shaped valleys with steep slopes, often following fault lines (Fig. 11.2c). The streams locally form waterfalls (i.e. Wilczka Waterfall and Nowinka cascades). The Wilczka Waterfall is the largest and highest waterfall in the Śnieżnik Massif, and one of the highest in the entire Sudetes. The step of the waterfall, 22 m high, was created on a tectonic fault and at the same time on the lithological boundary of more resistant gneisses above and more rapidly degraded metamorphic schists downstream. In the latter, a deep gorge developed below the waterfall, with almost vertical rock walls reaching up to 25 m in height. Due to the exceptionally picturesque nature of this place, the area around the waterfall was intensively developed for tourists in the mid-nineteenth century, although it was a popular tourist attraction even much earlier (see Sect. 11.4.3).

The Złote Mountains have the form of a long mountain ridge, with varied topography (Fig. 11.2d). The northern and southern parts are more compact, with a few branching ridges, while the central part is a narrow, winding ridge with short arms extending on either side. The sharp north-eastern boundary of the range is tectonic in origin, and numerous tectonically-controlled landforms can be distinguished on the Czech side of the mountains (Štěpančíková et al. 2008; Štěpančíková and Stemberk 2016). The main river of this area is Biała Lądecka, which forms two polygenetic gorges below and above the spa town of Lądek-Zdrój. A characteristic feature of the valley, which in this area is 200–350 m wide, is the presence of several terraces of different ages.

The relief of both regions is also strongly determined by lithology and rock resistance. Therefore, characteristic features of relief are numerous rock outcrops forming tors and mid-slope crags (Fig. 11.2e, f). They developed mainly in gneiss and quartzite and less commonly also in mica schists (with less spectacular sizes). Tors occur in the upper parts of the slopes, in the zones of convex slope breaks, as well as on the plateaus and around the peaks. They take various forms: rock walls, pulpits, rock spurs, and towers. Their shapes follow the pattern of cracks and fissures or cleavage and their common feature is morphological asymmetry (Migoń 1996). In the Śnieżnik Massif, the highest tors are 15 m high (Mariańskie Skały), and the length of the outcrop can reach up to 50–60 m (the rock group at the top of Mt. Młyńsko, the rock wall on Mt. Żmijowiec). In the Złote Mountains, tors are up to 30 m high (Trojan, Skalna Brama/*Rock Gate*) and 100 m long (Skalny Mur/*Rock Wall*). They are most common around the town of Lądek-Zdrój, where they serve as climbing routes and viewpoints (Sobczyk 2005).

Tors within the slopes are found in many deeply incised valleys, where the slope is up to 30°. Rock outcrops are often accompanied by block fields, with single boulders up to 2–3 m long. Blocky-debris and debris-sandy-silty covers are also common, testifying to the intensity of denudation processes in periglacial conditions. Locally, they form tongues and block streams, and the structure of the covers indicates their origin by solifluction processes (Martini 1979; Traczyk 1996). The thickness of slope covers is 1–1.5 m on average, reaching higher values in the lower parts of the slopes, for example, up to 4–6 m in the Kleśnica valley bottom (Traczyk 1996). In the lower slope sections, colluvial sandy loam covers predominate, which may be associated with later anthropogenic activity (see Sect. 11.5). Particular periglacial landforms include frost cliffs and steps several metres high, and cryoplanation terraces up to 50 m long, covered with angular boulders. These forms are closely related to lithology, appearing along the contact of more resistant rocks (gneisses, quartzites) and less resistant schists (Martini 1979). Landforms of periglacial origin within the Śnieżnik dome also include nivation hollows (Martini 1979), patterned grounds, and earth hummocks (Klementowski 1998).

The Śnieżnik Massif and the Złote Mountains combined are also one of two main areas of carbonate rocks occurrence in the Sudetes. Various forms of surface and underground karst have developed, including numerous caves (Pulina 1977). One of the most spectacular—not only at the scale of the Sudetes, but throughout Poland—is the Niedźwiedzia Cave, which is open to the public and characterized by very rich and varied dripstone forms (speleothems) (Jahn et al. 1989). As a result of recent discoveries, the karst system turned out to be much more extensive than originally assumed (Sobczyk et al. 2016; Kasprzak and Sobczyk 2017). The total length of the currently explored corridors is approximately 4.5 km, the height difference is 118 m, and the largest chamber, the Mastodon Hall, is 115 m long, 20 m wide, and 20 m high (Haczek et al. 2014). Furthermore, the best developed examples of surface karst are found in the vicinity of the Niedźwiedzia Cave, in the Kleśnica valley. These are karst springs, ponors, sinkholes, and dry valleys (Pulina 1977; Jahn et al. 1989).

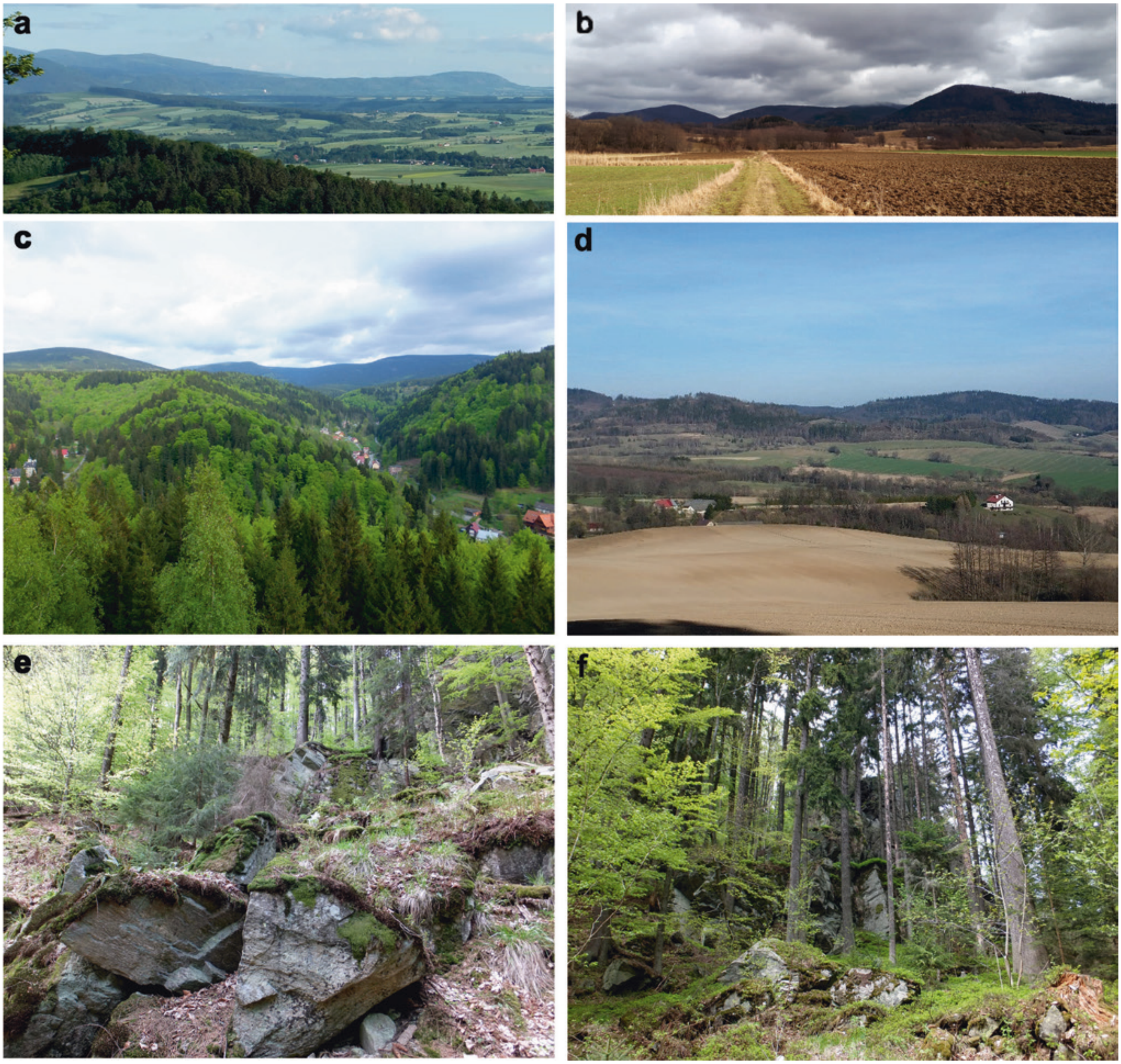

Fig. 11.2 Main features of the relief in the study area. **a, b** Tectonic boundary of the Śnieżnik Massif. **c** V-shaped valleys dissect the Śnieżnik Massif (vicinity of the village of Międzygórze). **d** Undulating relief of the Złote Mountains. **e, f** Gneissic tors in the Złote Mountains (Skalny Wąwóz) (photographs by A. Latocha-Wites)

11.4 Diversity of Anthropogenic Landforms and Features

11.4.1 Landforms Related to Mining and Industry

The topography of the East Sudetes has been modified by mining activities dating back to medieval times, with the peak in the sixteenth century, followed by episodes of local intensification of prospection and extraction in the eighteenth and nineteenth century. The Złote Mountains and the Śnieżnik Massif were important local centres of mining, based mainly on polymetallic ores, including silver, iron, zinc, as well as gold and arsenium in the northern part of the Złote Mountains (i.e. Ciężkowski et al. 1996; Stysz and Mączka 2009). In the 1940s and 1950s, many old adits and mines were re-opened for exploitation of uranium ores (Klementowski 2010). Although it was only a brief episode, intensive works “refreshed” the former mining areas, contributing to the visual enhancement of past mining-related landforms, which can still be recognized in the contemporary topography. The impact of mining and ore prospection is rather spatially limited, but nevertheless it may be locally spectacular. Numerous new landforms result from direct or indirect ground surface transformation, such as open cast pits, adits, shafts, trenches, spoil heaps, heaps of gang stones, disturbed ground, linear surface excavations, trial pits in former mining and prospecting areas, and subsidence hollows. The inventory of mining legacy in the vicinity of the former mining town of Bolesławów (now a village) revealed 40 adits and associated spoil heaps, 1270 exploratory pits, and 8 shafts. And the most recent excavation of underground galleries in this area (47.5 km in total) was related to the exploitation of uranium in 1948–1953 (Ciężkowski et al. 1996). Field mapping and analysis of LiDAR data in three former mining areas in the Śnieżnik Massif (Marcinków, Janowa Góra and Potoczek) revealed ca. 210 stone heaps and ca. 190 mining pits within an area of a mere 0.7 km^2. Hollows related to former adits and shafts are 5–15 m deep and 8–20 m in diameter, trial pits are represented in the contemporary topography by holes 1–2 m deep and 2–5 m in diameter, and prospecting trenches are 1–1.5 m deep. The associated heaps of stones are 1.5–5 m high, with the length up to 30 m (Fig. 11.3) (Migoń and Latocha 2018).

The original topography of the region has also been highly modified by numerous quarries of various age and size. In the study area, the most important and largest quarries were related to the exploitation of marble and basalt, although exploitation of gneiss, schist, and granite was also locally important. In the nineteenth century stone quarrying industry reached its peak, with as many as 118 quarries in the study area (according to the topographic maps Messtischblatt 1:25,000 from the 1880s) with the total surface of ca. 0.3 km^2. Nowadays only two larger quarries are still in operation. In spite of the abandonment of most quarries, usually due to depletion of resources, they provide a long-lasting evidence of past human activities and are

Fig. 11.3 Landforms related to mining in the vicinity of the village of Janowa Góra. **a, b** Stone heaps. **c** Entrance to an adit, now collapsed. **d** Trial pit (photographs by A. Latocha-Wites)

still well visible in the landscape in spite of being usually overgrown by vegetation (Fig. 11.4). Geomorphic legacy of quarrying is diverse and includes both concave (former quarries themselves) and convex features (heaps of unused material), as well as various types of disturbed and man-made ground in the vicinity of former quarries.

Mining and quarrying were often associated with on-site processing of raw materials, and thus, numerous remains of former ironworks, ore processing plants, and lime kilns are still visible. Similarly, glass-making industry, which was among branches very typical for the Sudetes since medieval times and was present in the Śnieżnik Massif up to 2010s (in the town of Stronie Śląskie), has required quarrying of necessary resources (quartz, feldspar). The impact of former industrial sites can also be traced in sedimentological record through the presence of slag or by-product deposits. In addition, many technological processes required the use of timber, and hence, widespread forest clearances followed, enhancing the potential for soil erosion.

11.4.2 Landforms Related to Agriculture, Settlements, and Forestry

Agricultural activity has encroached onto the mountainous areas in the thirteen–fourteenth century, initially following forest clearances for mining and ore processing (Valde-Nowak 1999). However, due to increasing population, which in most locations reached its peak in the nineteenth century, even the less favourable areas were turned into agricultural lands, including steep slopes (more than 15°) up to 1000 m asl. The increased agricultural pressure, along with harsh mountainous climate and shallow and stony soils, resulted in severe soil erosion from arable fields. In order to prevent the undesirable surface wash, new ploughing techniques were used since the nineteenth century (Inglot 1979). They included ploughing parallel to the contour lines and a new type of plough turning soil downslope. As a result, slope profiles were modified from smooth to the stepped ones. The terraced slopes are the most evident manifestation of

Fig. 11.4 Landforms related to quarrying—abandoned marble quarry in the village of Rogóżka (photograph by A. Latocha-Wites)

human impact on the geomorphic slope domain until today, although agricultural activity has long ceased in all more elevated areas in the region (Latocha 2009b). The relic agricultural terraces are currently found both within permanent grasslands and forests, and they are very persistent anthropogenic landforms (Fig. 11.5a, b, f). In some areas, assemblages of several or up to a dozen or so terraces may be found within the slope, with the series of alternating benches and risers. Morphometric characteristics of agricultural terraces vary from site to site, depending on local slope properties. Their length ranges from 50 up to 400 m, and the height of the risers varies from 0.2 to 5.5 m. The usual distance between the risers is 20–100 m, and the inclination of risers ranges from 20° to 60°. Usually, the steeper and the longer is the slope, the higher is the terrace and the steeper is its riser (Latocha 2009a, b). The densities of anthropogenic escarpments, mostly agricultural terraces, calculated for selected catchments in the study area, range from 0.6 to 13.1 km/km^2.

Some terrace risers are reinforced with stone walls or numerous heaps of stones are located along the escarpments. The slope covers in the study area are very abundant in rock debris due to shallow soil and the proximity to crystalline bedrock. Therefore, local farmers were forced to regularly clear their arable lands, gathering and removing the stones, which were constantly appearing on the surface due to ploughing, erosional wash (soil erosion), and frost upheaval. The collected stones were piled up not only along the terraces but also along the field and ownership divisions. They were collected in the form of dry stone walls, or as isolated stone piles within the arable lands (Fig. 11.5c–e). Although ploughing has completely ceased at higher elevations, these landforms are still a very spectacular landmark of many former agricultural areas, even though they are nowadays located in the forest. The height of stone piles can reach up to 4 m, their length up to 15 m, and width up to 10 m. The stone embankments are usually up to 1.5–2 m high and can be several hundred metres long. Also, the density of these landforms is locally impressive. There might be more than 100 stone piles per 1 km^2 in villages located higher up in the mountains. For example, within the areas of two abandoned villages—Karpno (Złote Mountains) and Rogóżka (Śnieżnik Massif)—there are ca. 140 and 130 piles of stones per 1 km^2, respectively.

Slope terracing was also necessary in settlements, where steep slopes had to be levelled for building purposes. Settlement terraces are another very persistent landscape feature, and they last much longer than the buildings themselves, once erected upon them. In some depopulated areas, these terraces are the only traces of the location of former farmsteads. Although most of these relic landforms are now located within forest, they can still be easily identified in the relief as unnatural flats within a slope. Their surface usually reach up to 100 m^2.

Terracing has led not only to changes of topography and slope longitudinal profiles, but it also influenced the dynamics of morphological processes by dividing slopes into separate units with erosion dominating in their upper parts and accumulation in the lower parts, behind the upper edge of each terrace (see Sect. 11.5).

In addition to agriculture, forestry and timber industry were among important economic activities, not only in the past but also nowadays. In the pre-industrial era, timber was used as an important building material and the main source of fuel for most technological processes—in mining, ore processing, glass-making, weaving, and spinning (Fogger 1952). With the advent of coal-based industry at the turn of the nineteenth century, the role of forestry changed but on no account it became less important. The Sudetes became an important supplier of raw timber and processed timber products. Paper industry flourished, with paper mills, manufactures, and factories common across the Sudetes (Szymczyk 2005). The huge demand for timber resulted in widespread clearances of slopes up to the water divides. However, the economic crisis in the nineteen/twentieth century, depopulation, land abandonment, and collapse of handicraft and timber industry resulted in both intentional and spontaneous afforestation. The shifts in forest cover have affected the geomorphic system by alteration of slope-channel coupling and especially by an increase/decrease of sediment wash and transfer. The forest cover is nowadays much more extensive than ca. 150 years ago (the increase in forest area is by ca. 35%, as calculated for the entire Kłodzko region, which includes the analysed area), but the forestry still exerts vital impact on geomorphic systems, mainly causing linear erosion due to logging.

Both in the agricultural lands and in the forested areas, an extensive network of roads has developed over centuries. Most of them are not in use any longer, but nevertheless they can still be recognized in the landscape. On the one hand, roads parallel to the contour lines have substantially changed slope profiles, and in some areas, they form spectacular cuts and escarpments, often reinforced by retaining walls which allow for their better preservation. On the other hand, roads perpendicular to the contour lines have evolved in some places into gullies (sunken lanes) (Fig. 11.6). The gullies within crystalline bedrock (gneiss, schists) usually occur only in the lower or middle parts of slopes, where there is a thick layer of fine-grained weathering mantle or colluvial deposits. Road gullies within agricultural lands may be as deep as 4 m, with an average depth of 1–2 m. Their length does not exceed several hundred metres. Road gullies within forested areas are up to 1.2 m deep, while the depth of logging tracks ranges from 0.1 up to 0.7 m, and their width is 0.3–1.7 m. Most gullies in the study area are relic landforms, with the exception of areas, where intense timber harvesting, involving

Fig. 11.5 Relic features related to agriculture. **a, b** Slopes with agricultural terraces. **c, d** Stone walls. **e** Stone piles, built of materials collected from an agricultural slope. **f** Terrace riser (photographs by A. Latocha-Wites)

the use of heavy machinery, contributes substantially to the deepening of forest roads and logging tracks, transforming them into gullies. They are usually very irregular in both their longitudinal and cross-sectional profiles, which is in opposition to much more regular gully profiles related to agriculture. Within some roads, former cobbling has been preserved, which usually—but not always—prevents further incision.

Fig. 11.6 Old road gullies (sunken lanes). **a** Sunken lane overgrown with vegetation, with evidence of soil creep along the sides. **b** Road gully filled with mineral and organic material (photographs by A. Latocha-Wites)

11.4.3 Landforms and Constructions Related to Water Management

Alterations of channel patterns have a history going back to at least medieval times and were forced by demands of various types (Fig. 11.7). To ensure adequate water supply to mills, parallel channels (leats) maintaining minimal gradient were built to connect with mills and to provide sufficient drop. At the end of the nineteenth century, there were 121 water mills in the study area, as presented in the topographic maps Mestischblatt 1:25,000. Although the leats are no longer in use and most of them are dry, they are still well recognizable in the relief, as are the ruins of the mills. Networks of artificial channels were also built in mineral exploitation areas, to facilitate ore processing or mineral extraction. Widespread dam and reservoir construction started in the beginning of the twentieth century as one among the means to reduce flood hazard. There are two dry reservoirs in the study area, on the Morawka and Wilczka rivers. The latter one is famous by its spectacular stone dam, which is 29 m high and 102 m wide (Fig. 11.7d). Particularly common were engineering works along rivers, which included channel and bank straightening, often using stone armouring, bed grading, building of steps, and check dams to limit bedload transport. They were mainly constructed using local stones as building material.

Two main rivers in the study area, Wilczka and Biała Lądecka, have been channelized along 49% and 26% of their length, respectively (Latocha and Witek 2013). Special engineering works were also necessary to protect road surfaces and disturbed slopes against water erosion. Numerous stone bridges, road culverts, and other underground passages and pipes are the testimony of the extent of the road construction works. The diverse hydrotechnical constructions are very common; they occur even in the upper reaches of the streams, and some of them are very spectacular in size (Fig. 11.7c). In the nineteenth century, special attention was also paid to the springs, many of which became tourist attractions. Water outflows were often enclosed with ornamental stone walls and bas-reliefs, and their surroundings were adopted for tourists needs, with new infrastructure, such as benches, tables, and footpaths. Most of these features have been neglected or destroyed in the post-World War II period; however, some of them have been recently restored, for example, the springs of Nysa Kłodzka in Śnieżnik Massifs and Biała Studnia (*White Well*) in the Złote Mountains. Similarly, unique in-channel features such as waterfalls were also adopted for the tourist needs in the nineteenth century. This is the case of the Wilczka waterfall in the Śnieżnik Massif. Not only a proper tourist infrastructure was built at the site, but also the waterfall itself was modified and made higher through an artificial step, which was destroyed during the flood in 1997 (the pre-WWII height was 27 m and it is 22 m nowadays). Access to the site with improved tourist facilities has been recently restored (Fig. 11.8). Additionally, there is a new recreational water reservoir in the village of Stara Morawa and numerous fishing ponds.

All hydrotechnical constructions, both the old and neglected ones, and the currently used and maintained, have the potential to locally modify fluvial processes. They can influence the intensity and spatial distribution of erosion and accumulation within the channels, which is crucial during extreme hydrometeorological events (Latocha and Parzóch 2010; Kasprzak 2011; Latocha and Witek 2013; Kasprzak and Migoń 2015). Additionally, clogged or destroyed underground drainage systems can substantially alter hydrological properties of soil, which results in the

Fig. 11.7 Diversity of water management constructions; examples. **a** Stone bridge. **b** River bank reinforcement. **c** Check dam (all examples from the upper reach of the Nysa Kłodzka river). **d** Dry flood control reservoir with the dam on the Wilczka river, in the village of Międzygórze (photographs by A. Latocha-Wites)

development of wetlands and marshes within the abandoned settlements.

11.4.4 Other Features of the Cultural Geomorphological Landscape

Anthropogenic landforms related to mining, quarrying, agriculture, forestry, and water management are the most spectacular features of the cultural landscape directly related to geomorphology. However, there are also numerous other elements, which contribute to the richness and diversity of the cultural geomorphological landscape in the study area. First of all, the settlement network and the rural layouts highly depend on the topography, with villages stretching along the valley floors, forming typical mountain settlements (Germ. *Waldhufendorf*). Most of them date back to medieval times and their general layout has been well preserved until the present-day. Local stones were used to construct many buildings, including the representative ones, like churches or manors, as well as smaller architectural features such as commemorative plates and monuments, road-side chapels, crosses, and figures of the saints, which are especially abundant in the study area, forming its specific cultural landscape (Fig. 11.9).

An increasing popularity of tourism since the second half of the nineteenth century has also added to the cultural geomorphological landscape. Local tourist organizations took effort to allow or improve access to various attractive places, such as viewing points, picturesque or unusual rock formations, caves or springs (Dziedzic 2013). Adaptations of natural landforms for tourist purposes were especially widespread around the spa town of Lądek-Zdrój in the Złote Mountains and the mountain resort of Międzygórze in the Śnieżnik Massif. However, minor alterations related to tourist facilities were also common in other areas. They

Fig. 11.8 Tourist facilities at the Wilczka Waterfall (photograph by A. Latocha-Wites)

included the construction of footpaths, rock-hewn staircases, metal or stone barriers, rock-cut viewing platforms or viewing towers, as exemplified by the most recognizable construction on the summit of Mt. Śnieżnik which was built from the local gneiss. Tourism has continued to grow almost without interruptions (save the World War II period), and the infrastructure is being constantly enlarged. In particular, rapid development of ski-resorts (Czarna Góra, Kamienica) and dedicated bike trails (single tracks) has contributed to further anthropogenic transformation of slopes in the past several years.

11.5 Indirect Human Impact on Relief and Sediments

The development of settlements, agriculture, mining, and industry in the historical times resulted in large-scale deforestation of the Sudetes, which triggered intense soil erosion. The severity of past soil erosion emerges from documentary sources, modelled values, specific landforms (stone piles and stone embankments), and slope wash deposits (Latocha et al. 2016; Migoń and Latocha 2018). For the pre-World War II period, there is evidence for episodes of intense rainfalls able to remove the entire soil cover from the slopes, so that the local peasants were forced to carry it back upslope to sustain land productivity (Bac 1950). Calculations of slope material stored within agricultural terraces in three small catchments in the Śnieżnik Massif and the Złote Mountains allowed for an estimation of the annual denudation from arable lands, which was 0.15–2.67 mm year^{-1} depending on topographic location and lithology (Latocha 2009a).

Sediments, which can be linked with past human activities, are widespread both within the slopes and in the valley floors, and they have also modified the local topography. They form a distinct sandy-silty topmost layer in colluvial and alluvial sedimentary successions, which is the result of selective surface wash (Jahn 1968). Fine charcoal particles commonly occur within this layer and thus can be dated

Fig. 11.9 Minor elements of cultural geomorphological landscape, with local stones used in old and modern vernacular architecture. **a** Old lime kiln. **b** New road-side chapel. **c** Ruins of a church in depopulated village. **d** Modern tourist infrastructure (photographs by A. Latocha-Wites)

and related to past soil erosion resulting from forest clearance and agricultural activities. This fine-grained layer differs substantially from the underlying layer of more coarse grained sediments, representing mostly periglacial environments. The human-induced colluvial deposits are found not only at footslopes, but are also common within any flattenings within the slopes higher up. Their thickness on the former arable lands is between 10 and 55 cm, depending on bedrock lithology and topographical position, with the thickest layers developed on schists. The thickness of colluvial sediments increases within agricultural terraces, where the sandy-silty layer is usually ca. 1 m deep, reaching up to 1.6 m in the extreme examples, which proves the effective role of terraces as sediment traps and efficient anti-erosion protection. The thickness of the agricultural sandy-silty layer, which originated from slope wash and ploughing, and accumulated over the terrace riser, increases along with the increase of slope inclination and slope length (Latocha 2009a).

The sandy-silty alluvia with high organic content, including charcoal particles, are also related to surface wash from slopes (e.g. Klimek et al. 2003; Klimek and Latocha 2007). After temporal fluvial transport, they were eventually deposited within the floodplains during the episodes of overbank flow. Sedimentological analysis of alluvial deposits within three small catchments in the study area revealed a high variability of their thickness, ranging from a few centimetres up to over 1.2 m. The variability was evidently dependent on the local variations in the valley morphology, and the alternations of the thickness of alluvial deposits were observed even within short distances (Latocha 2009a). The fine-grained alluvia were found up to 780 m asl, which is much higher than previously reported from other parts of the Sudetes (Teisseyre 1985).

Surface wash from deforested slopes and linear erosion along field access and forest roads, as well as the subsequent deposition of alluvial sediments within the valley floors, have transformed the entire geomorphic system. The floodplains have been built-up, and the original braided-river fluvial system inherited from periglacial environments has evolved into single-channel rivers which are typical for the region until nowadays (Latocha 2009a). The human-induced soil erosion and floodplain accretion were confirmed by the radiocarbon datings of fine charcoal particles found at the base of the sandy-silty colluvial and alluvial deposits. In all investigated catchments, they can be correlated with the advent of human occupation and forest clearances for agriculture or glass industry, which was also confirmed by the historical documents (Latocha 2009a).

Depopulation, abandonment of arable land, decline of industry, and afforestation of upper slopes, which have been observed since the end of the nineteenth century and intensified in the post-War War II period, altered the geomorphic system again. Especially, in many areas, the slope-channel coupling was disrupted. Reduced surface wash and material delivery from the slopes have resulted in an increase of downcutting and lateral erosion of streams and rivers. Additionally, the multi-thread flow during the flood events has been observed in several rivers in the study area, e.g. in the Biała Lądecka and Wilczka channels (Czerwiński and Żurawek 1999; Latocha and Parzóch 2010).

By contrast to the sedimentological record of past agriculture, the indirect legacy of past metallurgy and glass-making is very limited and only site-specific, although the enrichment of local colluvia or alluvia with slag or waste/by-product deposits can be easily detected during field surveys.

11.6 Persistence, Values, and Promotion of Cultural Geomorphological Landscapes

The relic anthropogenic landforms are surprisingly persistent in the landscape, adding to its geodiversity and, indirectly, to the diversity of habitats and wildlife (Latocha et al. 2019). Some former anthropogenic landforms have even been protected as ecological sites due to their unique habitats and species, such as old marble quarries in Rogóżka and Stronie Śląskie (Biała Marianna) and post-mining heap in the town of Złoty Stok overgrown with orchids. The old mines in Złoty Stok and an abandoned basalt quarry near Lądek-Zdrój have also been included into the European Ecological Network Natura 2000 due to their unique habitats. The relic anthropogenic landforms are also able to modify current morphological processes, which is well visible in the fluvial system impacted by diverse water management modifications, especially during the extreme events. Some relic landforms (agricultural terraces, road gullies, prospection pits, embankments, and channel reinforcements) may become obliterated with time due to natural processes such as denudation, erosion, accumulation, impact of vegetation (e.g. tree uprooting), or animals (e.g. burrowing). Observations in former mining areas in the Śnieżnik Massif show that afforestation proceeds quickly and after 20–30 years former exploitation pits, spoil heaps and access roads become completely overgrown (Ciężkowski et al. 1996). Nevertheless, they can still be recognized in the landscape, especially outside the growing season, or on the detailed terrain models based on LiDAR data (Fig. 11.10). Actually, only landforms which were deliberately removed by human action (e.g. stones from buildings or agricultural heaps of stones) have completely disappeared from the landscape.

It is worth to mention that some anthropogenic landforms and features have received new functions nowadays. Especially the former mining and industrial sites have become important tourist attractions. This is the case of Złoty Stok and Kletno where former gold/arsenium and fluorite/uranium mines have been adapted for tourist purposes. There is an art gallery in the old lime kiln in Stara Morawa and a rope park in the former quarry in Złoty Stok. The most known karst cave in the Sudetes, the Niedźwiedzia Cave, was discovered in 1966 due to limestone quarrying. The recent restoration of some springs can be perceived as both the reconstruction of tourist infrastructure reviving the pre-World War II tradition, an enhancement of tourist offer, and promotion of interesting geosites. Nevertheless, there are many other areas, which are not promoted as tourist attractions, but where the diversity and abundance of anthropogenic landforms would be of interest to any

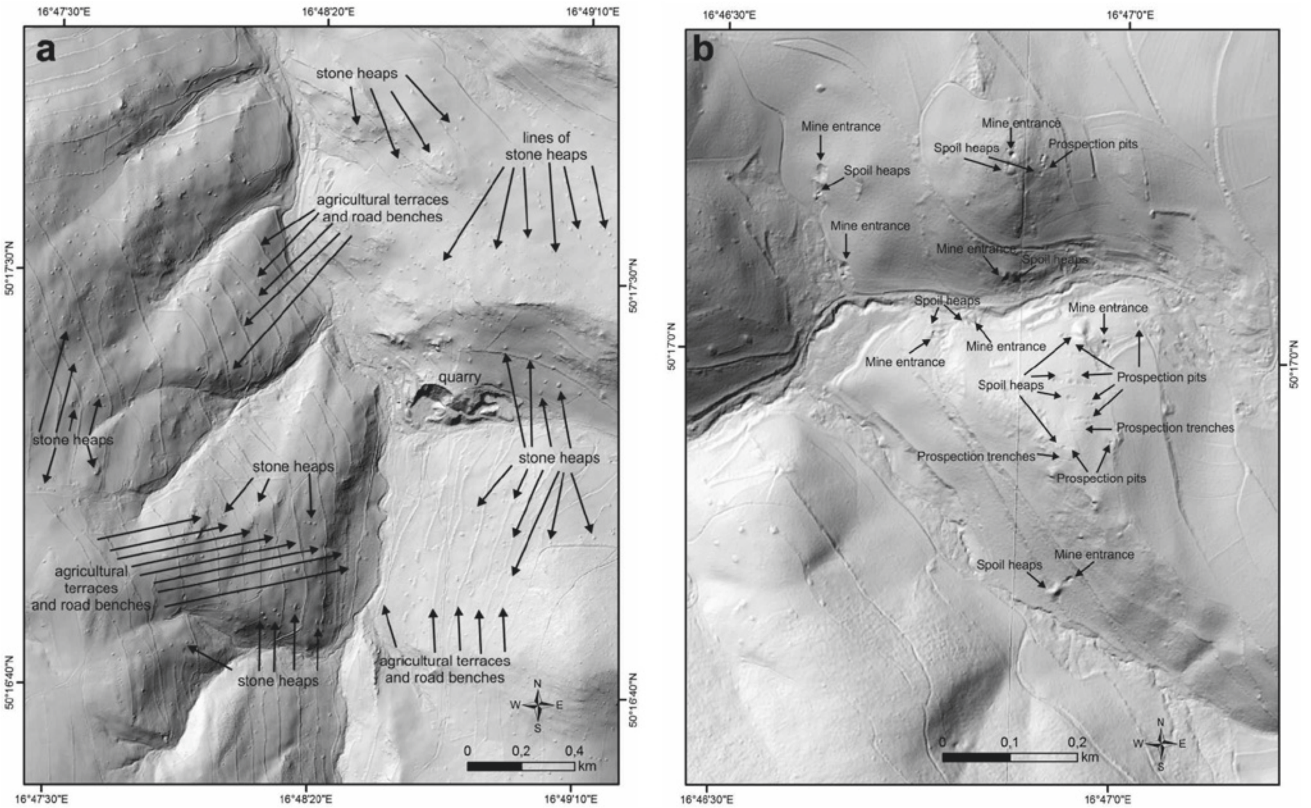

Fig. 11.10 Abundance of relic anthropogenic landforms in the Śnieżnik Massif is still well visible on the LiDAR terrain model. **a** Relic agricultural features. **b** Landforms related to old mining. Source: Migoń and Latocha (2018)

visitors interested in discovering traces of past human activities, which are still detectable in the present-day cultural geomorphic landscape of the East Sudetes.

11.7 Conclusions

The discussed subregions of the Śnieżnik Massif and the Złote Mountains in the East Sudetes can be considered as representative for the Sudetes, which exemplify a mid-latitude, medium-altitude mountain range highly modified by long-term and diverse human activities. Human impact on topography was both direct (anthropogenic landforms) and indirect (enhancement and then reduction of soil erosion, channel pattern change, and modification of fluvial processes). The abundance of anthropogenic landforms of various age and origin is the characteristic feature of the cultural geomorphic landscape of the region. The recent human-induced landscape changes related to current economic activities, such as forestry and tourism, co-occur with relic landforms in the depopulated and abandoned areas, which are "witnesses" of more intense human impact in the past, involving more widespread agriculture, mining, quarrying, and industry.

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