■ Landslides in Bulgaria**Boyko BEROV**

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Key words : landslide, Bulgaria, conditions, distribution, causes**1. Introduction**

Bulgaria, a Southeast European country, is situated in the central part of the Balkan Peninsula and lies at northern latitude of 42-44 degrees. Neighbouring countries are Romania to the north, Greece to the south, Turkey to the southeast, Yugoslavia and Macedonia to the west. The Black Sea is the eastern frontier of Bulgaria. Various types of destructive geological processes assail Bulgarian territory as a result of complex geological, tectonic and topographical features. More than 60 types of natural and man-made processes and phenomena are registered on the Map of Geological Hazards in Bulgaria (Iliev-Broutchev, ed. 1994).

The landslide hazard is one of the most important in the country. Landslides are widely spread with uneven territorial distribution. The number of slope movements in Bulgaria is not as great as in Japan, but almost all of the types recognized by Varnes (1978) are manifested. Cases of complex landslide movements occur very often. The variety in kinds of mechanism, rate of movement, different size and shape in landslide manifestation is due to the diversity of the geological, geomorphologic, hydrogeological and engineering geological conditions in Bulgaria. The main natural factors that contribute to landslide activity in the country are endogenic: slow tectonic movements and earthquakes; and exogenic: erosion, sea erosion, precipitation, melting snow and variations in the ground water tables. Nowadays, the part played by and the variety of man-made works or human factors is considered to be as strong as natural ones. The reason is that construction and mining activities in Bulgaria have given

rise to man-provoked slope movements, the numbers of which are on a big increase.

2. Engineering-geological conditions for landslides

Engineering-geological conditions in Bulgaria are various and complex due to the variety of geological units in the country's territory, the presence of many different tectonic structures and the genetic and lithological abundance of rocks. From the geotechnical point of view, the lithological variety of rocks has been organized into 4 main groups of engineering-geological types of rocks and soils (Fig. 1). The types of solid rocks include hard and dense magmatic, metamorphic and sediment rocks with strong structural bonds and high strength parameters (such as granites, diorites, gneisses etc.) When these kinds of rocks are tectonically disturbed, broken, weathered or somehow changed, their strength parameters are lower, which characterize types of soft rock. Clayey and cohesionless soils are the youngest lithological formations (Neogene and Quaternary). Considering mainly geological, tectonical, morphological and geotechnical criteria, five large regions and some inside zones have been distinguished in the territory of Bulgaria (Kamenov & Iliev, 1963). The names of these engineering-geological regions and zones as well as the main geological processes are given in Fig. 1.

Of the geological conditions, which contribute to the landslide manifestations, the presence of clayey and sandy-clayey material in the structure of slopes is the most important, as well as some weak interbeds and surfaces. These kinds of geological conditions are espe-

Fig. 1 Engineering geological regions in Bulgaria (according to Kamenov & Iliev, 1963)

cially characteristic for the structures formed by Tertiary and Quaternary sediments. About 90% of the Bulgarian population lives in such sediment terrains. The hilly parts of these basins, the basin boundaries and the river slopes inside the basins are the areas vulnerable to landslides. There are many places in Bulgaria where the inversion geomechanical model (heavy and brittle rocks situated over soft and plastic ones) creates the possibility for continuous and complex landslides. The thickness of weathering materials, the large tectonic zones with intensively cracked rocks and the influence of ground and surface water all provide favourable landslide conditions that also exist in the country's territory. There have been many investigations on the conditions and factors for landslide activity in the country (Kamenov & Iliev 1963; Kamenov et al. 1973; Iliev 1973; Kamenov et al. 1977; Frangov et al. 1996; Brouchev 1996). The general conclusion is that in 2/3 of the territory of Bulgaria, the geologic, geomorphologic and geotechnic conditions create the possibility for the existence and reactivation of landslide processes. But it is difficult and perhaps incorrect to generalize the engineering-geological conditions as every landslide manifestation has its own specific particularities that are discussed in more detail in "Landslide distribution".

3. Topography

Considering its small size - approximately 111,000 square kilometers, Bulgaria has a large variety of topographical features. The relief is characterized by diversity including high and low mountains, plateaus, elevated lands, hilly regions, vast low lands, valleys, Quaternary river basins, gorges and deep cut defiles. More than half of Bulgarian land is hilly and mountainous. The average altitude of the country is about 480 m. Plains (up to 200 m) make up 30% of the territory, plateaus, elevated lands and hills (200-600 m) - 40%, low mountains (600-1000 m) - 16%, medium high mountains (1000-1500 m) - 10%, and high mountains (over 1500 m) - 4%. The highest peak in the country and also in the Balkan Peninsula is Mussala - 2925 m in the Rila Mountains. The main characteristics of the topography are alternating bands of low and high terrains that extend in an east-west direction across the country. From north to south, these bands are the Danube Plain, the Fore Balkan, the Balkan Range (or Stara Planina), the Southern Balkan Valleys, the Sredna Gora Range, the Upper-Thracian Plain and the Rila-Rhodope Massif Mountains (Fig.2). The contact zones between high and low terrains are prone to landslide movements.

The border between Bulgaria and Romania is the Danube River. The riverbank on Bulgarian territory is

Fig. 2 Situation and main characteristics of the topography of Bulgaria (according to Rekacewicz, 1997 with supplements)

high while on the opposite side on Romanian territory there is vast lowland. This topographical feature creates the possibility for the permanent action of river erosion and slow cutting of the high Bulgarian coastline. The result is periodically activated landslides due to erosion of the Danube River. The river coastline on Bulgarian territory is about 470 km long and many landslides have been observed along it. To the south of the Danube River lies the Danube Plain - the largest hilly plane region, covered by loess formation in Bulgaria. The Shoumen Plateau (about 500 m) is the highest inner region of the Danube Plain. The rivers (Iskar, Vit, Osum, Yantra etc.) passing through the Plain from the south to the north, cut the elevated lands of loess and create favourable zones for landslide manifestation. Other landslide prone zones are the peripheries of the plateaus.

To the south of the Danube Plain lies the Fore Balkan - one of the fore mountain ranges of the Balkan Range. The Fore Balkan's medium altitude is about 370 m and its highest elevation about 1500 m. Many valleys and defiles divide the longitudinal mountains of the Fore Balkan. Landslides occur in river slope zones.

The Balkan Range (Stara Planina) is situated approximately in the middle of the country and forms the main watershed from which rivers drain north to the Danube River and Black Sea or south to the Aegean Sea (as a part of the Mediterranean Sea). Only the Iskar River (368 km long) - the longest river in Bulgarian territory, provides an exception. Originating from the Rila Mountains, the Iskar River runs across the Balkan Range creating a long defile. The defile of the Iskar River is a zone where many different kinds of slope movement are manifested. The Balkan Range is about 600 km long and 30 to 50 km wide. Its aver-

age altitude is more than 700 m and the highest point is Botev Peak (2376 m) in the central part of the Range. The Balkans then continues at a lower altitude to the cliffs of the Black Sea.

The Southern Balkan Valleys are a relatively narrow band of lowlands that lie to the south of the Balkan Range. In fact, the Southern Balkan Valleys represent a number of relatively small or bigger valleys separated from each other by hilly areas. The Sofia Valley (or Sofia basin) is the biggest amongst these valleys. Debris fans cover the zones at the foot of the Balkans. These areas are prone to slow creeping and construction works must be conducted very carefully, otherwise active landslide movement may be provoked.

To the south of the Southern Balkan Valleys lies the Sredna Gora Range. This range is about 300 km long. Its medium altitude is about 600 m and its highest elevation is more than 2000 m. The contact zones between the Southern Balkan Valleys and the Sredna Gora Range are also the territories prone to creeping and potential landslides.

The Upper-Thracian Plain lies to the south of the Sredna Gora Range. The plain includes the Maritsa River valley and the lowlands that extend to the east from the river to the Black Sea. Situated approximately in the central part of the Upper-Thracian Plain is the East Maritsa coal basin - the biggest coal basin in the country's territory. As a result of open pit mining exploitation in this basin, many cases of man-made landslides have been manifested.

The Rila-Rhodope Massif Mountains occupy the Southern and South-western Bulgarian areas. The massif includes the mountains Rila, Pirin, Rhodopes and the mountain group of Osogovo-Belasitsa. Many valleys have been developed between and inside the mountains. The Rila and Pirin Mountains are the most outstanding topographical features in Bulgaria and the Balkan Peninsula. The average altitude of the mountains is more than 1000 m. More than 25 peaks exceed 2600 m. Mount Musala (2925 m) is the highest peak in the Rila Mountains as well as in the Balkan Peninsula. Mount Vihren (2915 m) in the Pirin Mountains is the second highest peak in Bulgaria. The Struma River valley and Mesta River valley are the longest inner lowland topographical features. The Rila-Rhodope Massif Mountains are marked by faulting zones, the areas of which are characterized by the manifestation of different kinds of slope movements.

A special investigation on the occurrence of large landslides with a slip surface of more than 20 m deep

Fig. 3 Distribution of the large landslides according to the altitude (Frangov et al., 1996)

Fig. 4 Distribution of the large landslides according to the slope angle (Frangov et al., 1996)

and a volume of more than 1million cubic meters was performed by Frangov et al., 1996. Information on 160 large landslides in Bulgaria was collected. Two important results from those kinds of landslides, considering the topographical conditions - altitude and degree of the slope, are shown in Fig. 3 and Fig. 4.

The conclusions of the authors are that two basic groups of large landslides can be differentiated considering the altitude: the first group - from 0 to 200 m and the second - from 500 to 900 m (Frangov et al., 1996). The first group includes the large landslides along the Danube River, the Black Sea coast and in the East-Maritsa coal basin (48%) and the second - the landslides in the Tertiary basins of Southwest Bulgaria, the defile of the Iskar River and the Rhodopes (Frangov et al., 1996). Another important conclusion considering the degree of the slope is that more than 95% of the large landslides are developed on slopes, ranging from 3° to 30° with a peak of 9° to 12°. However, many other landslides smaller in volume occur in the country's territory and cause a lot of damage; but there are no statistics on the relation between the altitude and degree of the slope.

4. Climate and Precipitation

The Balkan Peninsula is subjected to the influence of two major climates: the Continental in the north and the Mediterranean in the south. Bulgaria is the territory of transition of those two climates. There are four seasons in Bulgaria. The climate in the northern part of the country is characterized as moderate conti-

nental. To the south of the Balkan Range, in the Upper-Thracian Plain the climate is on a transition between Mediterranean and continental influences. The Rila-Rhodope Mountains mark the northern border of domination by the Mediterranean climatic zone. The influence of the Black Sea is limited only to a narrow belt (about 60 km large) along the seacoast in Eastern Bulgaria. A mountainous climatic zone with relatively low temperature, heavy precipitation and continuous snow retention, can be differentiated at an altitude above 1000 m. Due to the variety of relief, contrasts in weather over a relatively short distance are often observed. The average annual temperature in Bulgaria is about 10-11°C. The average winter temperature in January is about minus 2°C, and average summer temperature in July-August is about 21°C. However, the lowest winter temperatures can surpass the limit of minus 30°C, and the highest summer temperatures can be more than 40°C. Compared to the lower-lying areas, the mountain regions show lower temperatures and snow can persist for 6-7 months in a year. The snow-cover lasts about 10 days in mild lowland areas and more than 200 days in the high mountainous areas. Average precipitation in Bulgaria is about 650 millimeters per year. Depending on the region, it can vary between 450-1300 mm/a. Higher mountains receive most of the rainfall - about 2500 mm/a. The heaviest rains fall during the spring, usually in May and June. Autumn is a season of light but continuous rainfalls. The average temperatures and precipitation may vary widely from year to year. The spring, starting from March, is a season when the ground water table in slopes is at its highest. This is due to the combination of snow melting and atmospheric rains. There is no rule but most of the landslides occur during the spring and autumn.

5. Seismicity and slow tectonic movements

The factors of slope instability, earthquakes and slow tectonic movements exert influence all over the country's territory. As part of the Alpine-Himalayas seismic belt, Bulgaria is subjected to local seismicity as well as to the seismic influence of neighboring countries - Romania (Vrancea epicentral area), Macedonia, Yugoslavia, Northern Greece and North-western Turkey. The epicenter of the strongest local earthquake (1904) with a magnitude of 7.8 was located in the Struma River Valley in South-western Bulgaria. The Upper Thracian Plain, the Veliko Turnovo region, the Sofia basin and the Northern Black Sea coast (near Ka-

liakra Cape) are also local territories with comparatively intensive seismic activity. In these regions earthquakes with a magnitude of more than 7 have been registered.

Seismic activity has induced different kinds of slope movements, mainly rock falls and topples, on the steep slopes in mountainous regions in the country. Some data were established after the Vrancea Earthquakes on 4 March, 1997 and 30 May, 1990 and the Turkish Earthquake on 17 August, 1999 (Frangov et al., 1998; Kostak et al., 1998; Matova et al., 2001). Two big areas in Bulgaria - the high Danube River Bank and the Northern Black Sea coast are subjected to strong seismic influence that could provoke large landslide activation. In these regions a number of ancient and dormant landslides have been recognized, and slopes in many places are very close to critical equilibrium. The observations of the last 30 years along the Danube River bank show that during strong earthquakes ($M > 6.0$), small landslides have been activated (Brouchev & Frangov, 2000). Comparatively no large mudflows occur in the loess sediments when they are moistened. The direct relation with the larger, typical slide movements is not so evident. The landslide activations are registered one or two years later. Deformations are observed in the slopes right after the seismic influence. But the real rapid landslide activation is delayed. One of the reasons of this delayed after-effect is the change in the direction and quantity of the ground water in the slopes (Iliev, 1996). Along the Northern Black Sea coast, seismic triggered landslides have been occurring throughout history. The most recent was registered in 1901. However, the engineering-geological conditions in this area create the vulnerability for large landslides that could be triggered from local seismic epicenters. After a catastrophic earthquake (1977) with the epicenter in the Vrancea area - Romania, considerable movements that would normally occur after 25 years (Iliev, 1996) were registered in the Taukliman landslide on the Northern Black Sea coast.

The slow tectonic movements (uplift) are the main factors for the presence of high and steep slopes. Almost all the territory of Bulgaria is in the process of recent uplift; with a maximum 6 mm/a (mm/year). Along the Danube River bank, slow tectonic movements show some differences. In the region of the towns of Touttrakan, Svishtov and Vidin, there is uplift of about +2.0 mm/a; in the region of the town of Lom, it is 0.0 mm/a; and in the region of the towns of Oryahovo and Kozloduy it is -1.0 mm/a (Hristov et al.,

Table 1 Some representative landslides that have occurred since 1940 in Bulgaria

No.	Locality	Occurrence, month year	Volume, 10 ⁶ m ³
1	Gorni Tsibar Village, Danube River bank	November 1940	2.0
2	Touttrakan town, Danube River bank	November 1940	0.4
3	Touttrakan town, Danube River bank	1942	0.4
4	Railway Sofia-Kulata, near v. Kroupnik	1942	2.5
5	Open pit "7 September"- Pernik Coal basin	December 1950	2.0
6	Open pit "Republika"- Pernik Coal basin	1955	3.0
7	Zlatni Pyassatzki-Kranevo, Black Sea coast	September 1963	15
8	Open pit "Trojanovo-2," Maritza-Iztok Coal basin	August 1964	30
9	Open pit "Trojanovo-1," Maritza-Iztok Coal basin	June 1965	16
10	Open pit "Trojanovo-2," Maritza-Iztok Coal basin	January 1966	27
11	Open pit "Alexander Milenov," Pernik Coal basin	April 1968	2.0
12	Open pit "Trojanovo-2," Maritza-Iztok Coal basin	December 1968	55
13	Dragovishitza Village, Sofia District	January 1969	4.0
14	Ruse, Lyulyaka Pumping Station	March 1969	0.01
15	Touttrakan town, Danube River bank	March 1969	0.2
16	Smolyan town, Cherna River, Eastern Rhodope	April 1971	0.57
17	Kranevo Village, Black Sea coast	April 1971	5.0
18	Moesia Town, near Danube River	April 1972	1.2
19	Touttrakan town, Danube River bank	1972	1.5
20	Oryahovo town, Danube River bank, many cases	March 1973	0.1
21	Nicopol town, Danube River bank, many cases	March 1973	0.3
22	Cherven Bryag Village, Kyustendil Distr.	April 1976	0.82
23	Kokalyane Village, near Sofia City	April 1976	41
24	Oranovo Village, Blagoevgrad District	1976	>30
25	Oryahovo town, near the railway station	April 1977	0.15
26	Panorama resort, Zlatni Pyassatzki, Black Sea coast	June 1978	2.75
27	Orsoya Village, Danube River bank	December 1978	19.0
28	Lom town, Boruna area, Danube River bank	February 1979	30.4
29	Doupnitza town	August 1979	1.4
30	Gorni Tsibar Village, Danube River bank	February 1980	2.5
31	Ostrov Village, Vratza District,	April 1980	0.09
32	Dounavtzi, Vidin District, near Danube River	May 1980	4.8
33	Oryahovo town, Danube River bank	1981	0.3
34	New Bothanic Garden, Sofia City	April 1983	1.5
35	Varna town, Galata, Black Sea coast	April 1984	0.75
36	Sofia-Bistritza	May 1984	0.28
37	Vladaya, along railway Sofia-Pernik	May 1985	0.05
38	Balchik town, Black Sea coast	October 1985	0.62
39	Nicopol town, Danube River bank	October 1985	0.02
40	Touttrakan town, Danube River bank	1985	0.4
41	Open pit "Trojanovo-North," Maritza-Iztok Coal basin	August 1987	13
42	Orsoya Village, West part, Danube River bank	October 1988	16
43	Slivata Village, Danube River bank	October 1991	9.0
44	Provadia town	December 1991	0.03
45	Sofia-Zemlyane	March 1992	0.2
46	Varna-Zlatni Pyassatzki, Black Sea coast	March 1997	0.05
47	Zlatni Pyassatzki-Journalist, Black Sea coast	April 1997	1.4
48	Zlatni Pyassatzki-Panorama, Black Sea coast	April 1997	0.9
49	Balchik-Albena, Black Sea coast	April 1997	5.0
50	Dzhebel municipality, Eastern Rhodope	January 2001	>150

1973). Although it has low velocity, these differentiated tectonic movements are factors for slope instability in the regions.

6. Landslide distribution

The distribution of landslides in Bulgaria is irregular in the country's territory. However in some areas, the landslides are more numerous, bigger and more frequent than in other areas. Thus, these areas qualify as landslide regions. Such large regions are the high Danube River Bank, the Northern Black Sea coast, the Tertiary basins in Southern Bulgaria - East-Maritsa coal basin, Sofia and the Pernik valleys. Many landslides are manifested also on the river slopes in the Fore Balkan and the Balkans, in the Rila-Rhodopes fault zones and the periphery of the lava flows in the Rhodopes. The largest and most destructive landslides that have occurred over the last 60 years are distributed in these regions of the country (Table 1). The variety of landslide profiles is too big to be presented in detail but the most characteristic and frequent cases are shown in Table 2.

The high Danube River Bank is a region where the

Table 2 Representative profiles of landslides in the territory of Bulgaria

Representative profile	Geological structure	Regions
1. Loess, Q 2. Clays, N ₂	West Danube River bank
1. Loess, Q 2. Sandstones and marls, K	Central Danube River bank
1. Limestones, N ₁ 2. Clays, N ₁	Black Sea Shore Line	Taukliman
1. Limy marls, N ₂ 2. Clays, N ₁		Balchik Town
1. Limestones 2. Sands 3. Clays		Varna City
1. Flysch, K ₂		Emine Cape
1. Limestones, K ₂ 2. Marls, K ₁		Plateaus in NE Bulgaria and the Fore- Balkan
1. Clays, Pg or N ₂	Graben's border strips
1. Rhyolites, Pg 2. Clays, soft sandstones, Pg	Rhodope Mts.
1. Clays, N ₂	Maritza-Iztok open-pit coal mine
1. Clays, N ₂ or Q	Slopes in the country	

landslides are ancient and the slip surfaces are situated deeply, usually more than 20 m below the terrain level. There are many urban areas affected by landslides and erosion. Tectonically, the Danube Plain coincides with the Moesian Platform. Its geological profile from bottom to top is as follows: bedrock made by magmatic and metamorphic rocks; thick cover of sedimentary rocks - sandstones, limestones and marls; surface zone made by gravels, sands, clays and loess. Loess formation is widely spread on the high Danube River Bank. Ordinarily, its thickness varies from 15 to 80 m. The sediments under the loess are different as is seen in Fig. 5 and Fig. 6.

The geomorphologic evolution of the Danube River Bank is connected with the fluctuations of the Black Sea erosional basis. Seven terraces were formed during the Quaternary. The general inclination of the sediment strata is in the north, northeast direction. This fact contributes to landslide manifestation in the same direction. The low physical-mechanical properties of the Tertiary sediments, which are revealed along the river coast, are a very important condition for landslide occurrence. Some formations are 60-80 m thick. Due to this reason, many landslides have a deep-seated

Fig. 5 Types of geological structure along the Danube riverside of Bulgaria

1-loess formation - eQ, gravels and sands - aQ, clays - N₂; 2-loess formation - eQ, marls - N₁; 3-loess formation - eQ, sands - N₂; 4-loess formation - eQ, clays, sands, coals - N₂; 5-loess formation - eQ, clays - N₂, sands, organic limestones - N₁; 6-loess formation - eQ, clays - N₂, organic limestones, clays and sandstones - N₁; 7-loess formation - eQ, limestones, marls, sandstones - K₂; 8-loess formation - eQ, marls, sandstones - K₁; 9-loess formation - eQ, clays, sandstones, limestones - N₂; 10-sandy clays, gravels and sands - aQ.

Fig. 6 Schematic geologo-geomorphologic cross-section along the Danube riverside of Bulgaria

1-loess formation - eQ; 2-gravels, sands and clays - aQ; 3-clays with sandy interbeds - N₂; 4-limestones - N₁, K₁; 5-calcareous clays and marls - N₁, K₁; 6-sandy limestones and calcareous sandstones - N₁, K₁; 7-fault

slip surface. The main instability factors for landslides along the Danube riverside are erosion, contemporary earth crust movements, earthquakes, precipitation, fluctuation of the ground water table, as well as human activity. The riverbank between the town of Dunavtsi and the point of flow of the Iskar River represents an almost continuous landslide section, more than 120 km along the Danube River. The most frequent cause of landslide manifestation is that the slip surface is predetermined and lies in weak Pliocene clays. The loess formation situated above acts as a static load. Due to the river erosion, the weak clay layers outcrop on the river slope. The present landslide activation is connected with variation in the ground water table in slopes. The permanent erosion of the Danube River and seasonal fluctuation of the river water level are the main factors for slope instability. The landslides have a volume of more than 15 million cubic meters. A continuous preparatory period has

Fig. 7 Landslide distribution on the Bulgarian Black Sea coast: 1 - landslide zone; 2 - separate landslide; 3 - landslides triggered in 1996; 4 - landslides triggered in 1997 (according to Kamenov et al. 1973 and Evstatiev et al. 1997)

been observed during which an active prism of compression is formed a few years before the active landslide. Five big landslides have occurred in this region over the last 30 years. These landslides caused damage in populated areas - in parts of the town and villages of Mizia, Orsoia, Tsibar and Slivata, where several family houses were destroyed. Other landslide sections along the Danube River are located around the towns of Nikopol, Svishtov and Toutraikan. A high degree of landslide hazard is established in the Toutraikan region where the landslides are characterized by slip surfaces ranging from 10 to 25 m under the terrain level, a volume of about 1 million cubic meters and a frequency of occurrence of 15-20 years (Frangov et al., 1996).

There is frequent landslide activity along the Bulgarian Black Sea coast. The seashore line is about 400 km long. It crosses the large morphological-tectonic structures of the Strandja anticlinorium, the Balkanide structures and the Moesian platform (Fig. 7) in a south-north direction.

Historical evidence shows that disastrous landslides destroyed ancient towns within the boundary of the Moesian Platform - the Northern Black Sea coast (Iliev

Fig. 8 Taukliman Landslide - April 1994 (photo N. Dobrev)

1973; Stakev et al. 1994; Koleva-Rekalova et al. 1996). Miocene and Quaternary sediments form the coast slope of the Moesian Platform. The Miocene sediments include mainly marls, sands, clays and limestones. The Balchik deep-seated landslides were formed into unconsolidated aragonite sediments of the Miocene (Sarmatian) age (Koleva-Rekalova, 1994; Koleva-Rekalova et al. 1996). The Quaternary deposits are represented mainly by loess formation, the thickness of which is about 10-15 m. In the southern part of the Moesian Platform, a steep slope is raised up to 250 m above sea level (Kamenov et al. 1973). This part of the seacoast is the most vulnerable in terms of landslide occurrence.

The Northern Black Sea coast is the region where landslide activity causes the most destruction because the coastline is densely urbanized. In 1997, after heavy rainfalls in a short period, 4 big landslide activations provoked a lot of material damage, destroying a number of houses and cutting in several places the main road to the biggest seaside resort in Bulgaria - Zlatni Pyassatsi. The landslides along the Northern Black Sea coast have been triggered several times during the last 50 years but the landslides in 1997 were the most significant ones, causing considerable damage and material losses (Varbanov et al. 1997; Evstatiev et al. 1997).

The coastline between the towns of Varna and Kavarna represents an almost uninterrupted landslide section that is about 30 km long and up to 2-3 km wide. The most dangerous areas for slope instability are those in the towns of Balchik and Kavarna, the village of Kranevo and the Zlatni Pyassatsi resort. The landslides along the Northern Black Sea coast are represented mainly by the following types: rotational earth slump, translational block slide and are more often complex. They have one deeply situated slip surface and 1 or 2 more shallow ones. The present activations usually occur in shallow levels. Many of the landslides

are ancient and are temporarily stabilized. However, there are coastal slopes that are very close to critical equilibrium and can be easily destabilized (Fig. 8).

The main factors for slope instability are sea erosion and the variations in ground water regime. The seismic impact from a short or more remote distance (epi-centers in Shabla and Vrancea areas) can also start landslide activations along the Northern Black Sea coast (Iliev, 1973; Konstantinov & Konstantinov, 1989).

The East-Maritsa coal basin and the Pernik valley are two regions where landslide manifestations are mainly connected with open pit mining exploitation. The landslides in the East-Maritsa coal basin are the largest ones in Bulgaria arising from man-made technogenic impacts. During mining works on the borders of the open pit mines landslides of different sizes, 300-500 m in length, 500-700 m in width, 90-100 m in depth occurred. The landslide volume is of the order of dozens of millions of cubic meters. The rate of movement during the active stage reached about 3-4 m/min. The geometry and the profile of the slope movements are typical for the development of landslides in horizontal sequences of clay and coal caused by relaxation of the horizontal stresses resulting from a reduction in the thickness of the overlying strata (Varnes, 1978). A prism of active pressure, a central body and a prism of passive pressure have been observed. The slip surfaces are sub-horizontal and develop in weak clay seams situated above or inside the coal strata.

The Sofia valley is a region where geological and tectonic conditions predetermine landslide occurrence mainly in the periphery of the valley and along the bank slopes of the rivers crossing the valley. As a geological structure, the Sofia valley is a graben filled with Neogene and Quaternary sediments - gravels, sands, clays and coal strata of limnic origin, irregular thickness and continuity. The main trends of the present tectonic movements are the uplifting of the northern and southern parts of near mountains (up to 2 mm/a) and the sinking of the central parts of the graben (approx. 1 mm/a). In this way, the vertical tectonic movements slowly change the geodynamic equilibrium and the slopes along the northern and southern borders of the Sofia valley are prone to creep and landslide manifestations. The delluvial and debris fan deposits containing sands and clays are favorable media for the development of these processes. The creep usually precedes the active sliding phase and it is observed mainly along the southern periphery. The ancient landslides are situated along the northern and southern

Fig. 9 Landslide "Schupenata Planina" ("The Broken Mountain") in 1963 (Photo G. Simeonova)

Fig. 10 Landslide in Djebel municipality - Eastern Rhodope 2001 (Photo A. Benderev)

borders of the Sofia valley. They are characterized by deep sliding surfaces and have been stabilized. Consequently, erosion processes reactivate local shallow landslides inside the ancient ones. These landslides have 1 or 2 benches up to 40-50 m long, 80-100 m wide and slip surfaces up to 10 m deep. The ancient slide terrains can be easily activated during digging work for construction. Because the Sofia valley is densely built up, creep and landslide processes affect a number of villages, towns and quarters of Sofia City - the capital of Bulgaria.

Landslides in the Rila-Rhodope region are numerous with ancient and recent activity. The biggest ones are situated in the eastern part of Rhodope around the towns of Smolyan, Peshtera and Djebel. The landslide "Schupenata planina" ("The Broken mountain") (Fig. 9) near the town of Djebel is the most remarkable natural phenomenon, formed about 100 years ago. Depending on the lithological composition, the morphological conditions and the properties of the rocks and soils, three groups of terrain can be distinguished in the Rila-Rhodope region - mountain massifs (horsts), valleys (grabens) and contact zones (Brouchev et al. 2001). All three types of terrain are prone to landslide occurrence. Amongst the large variety of rocks and soils in the region, the volcanic rocks represented by rhyolites,

andesites and pyroclastites are the most favorable media for landslide activity. Pyroclastites, tuffs, tuffbreccias and conglomerates are present mainly in the Eastern Rhodope. They are typically weak rocks quickly attacked by water and weathering processes.

Large landslide activation occurred at the beginning of 2001 in the Djebel municipality and in the region around the villages of Ustren, Chakartsi, General Geshchevo and Benkovtsi (Fig. 10).

This region is a depression filled with Paleogene sediments - sandstones, clays and a transition between them. Lava flows; lava sheets and other forms of rhyolite, andesite, latite and their pyroclastites were formed during Paleogene volcanic activity in the depression (Brouchev et al. 2001). The contemporary relief was formed during the following uplift. The dense river-gully network cuts the volcano-sedimentary rocks. The processes of erosion, landslides and rock falls occur. The dimensions of the different landslides vary from 0.5 km to 2.0 km in length and from 1.0 km to 2.5 km in width. The sliding surface depth of recent activation has not been estimated exactly. It is supposed to be more than 100 m under the terrain surface (Brouchev et al. 2001). Landslides have significantly transformed the previous relief. So, former maps have lost their reliability.

1000 landslides have occurred in urban areas and more have occurred on the roads, railways and in others territories. Their number is still unknown.

Conclusions

The consequences of catastrophic landslide occurrences in Bulgaria within the last 20 years can be summarized in terms of few human lives, properties, economic activities and traffic troubles in rural areas. Many populated, urbanized and rural areas, historical and cultural sites and transport connections are at risk of landslides. Landslides often make the ecological environment worse. Some cases of landslide damage show that the losses can sometimes be severe. For example, the permanent interruption of the Sofia-Thessaloniki road by debris flows is very costly for Bulgaria because this road is the only transport connection between Bulgaria and Greece at present (Dobrev 1999). The cases of people being moved from areas affected by or at risk of landslides are frequent. Many historical and cultural sites with world importance have been irreparably damaged. These examples show that landslide mitigation and control measurements are essential.

In Bulgaria, three national companies of Geozashtita ("Geoprotection") cover the country territory on a regional basis - in the town of Pernik, this company is responsible for Southern Bulgaria, in Pleven - for Northern Bulgaria and in Varna - for the Black Sea region. New consideration to the landslide hazard in Bulgaria was given after the landslides in 1996 and 1997 along the Black Sea coast. A strategy of landslide mitigation was made in 1999. A complete landslide information system has been started by the three-geoprotection companies, and others that aim to collect information on all landslides in Bulgaria. Useful information on landslide conditions, factors, sizes, known activations and damages was input. A map of the landslides in the Republic of Bulgaria (in scale 1 : 500,000) was drawn up due to the successful collaboration between the Ministry of Construction of Bulgaria and the Bulgarian Academy of Sciences (Varbanov, ed., 1999). Initially, all available landslide data in urban areas were included, but forthcoming data for road and railway networks and rural areas are to be added.

It is planned for this information to be digitalized and finished through GIS techniques that are now available in Bulgaria. It is essential because landslide activity has been increasing noticeably for a few years, according to an increase in man-made influences. This tendency will continue to increase, taking into account the industrialization and urbanization in resort areas and the forthcoming construction of Trans-European expressways through Bulgaria.

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