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Danube Region Environmental Geology Programme DANREG — Explanatory Notes | Editor: G. Császár

Environmental Geohazards

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Introduction

Compilation of the environmental hazard maps has become an ordinary practice all over the world during the past ten years. Nevertheless, these maps are prepared according to various methodologies which reflect different approaches concerning their make-up and content (Aleotti & Chowdhury 1999). There is still a lack of uniform guidelines defining their compilation. The Map of Environmental Geohazards (MEG) of the DANREG region at a scale of 1:100 000 represents one type of geohazard map which has been elaborated by a trilateral team of the DANREG programme (Slovakia, Hungary and Austria). The original map name "Environmental Risks Map" has been changed with agreement of the national project leaders in order to respect the definition of concepts like hazard and risk (Dearman 1991).

MEG is a complex and multi-purpose map supplemented by a legend and an explanatory text. Coloured planar, linear and point symbols are used to display relevant geological hazards of the Danube region:

Natural hazards:

- pollution sensitivity,
- hydrological and hydrogeological phenomena,
- mass movements,
- tectonics,
- seismicity,
- erosion and accumulation,
- karst and hydrocompaction.

Anthropogenic hazards:

- deposition (replenishment, waste),
- mines,
- subsidence.

The philosophy of the MEG, *e.g.* the means of hazard delineation and evaluation integrate the opinions of specialists from each country engaged in the project. Differences in the assessment of some hazards (pollution sensitivity of rock environment, waste) resulted from using unbalanced parameters or to inaccessibility of important data. The selection of hazards, the manner of their assessment and display reflect the geological setting of the region and its hydrogeological and engineering geological conditions. The accuracy of geological hazard depiction is limited by the scale of the map (1:100 000).

All available information about the selected hazards, either in the form of various maps at different scales (ranking from 1:25 000 to 1:200 000) and databases, or aerial and satellite images, have been used as a background. The following maps, prepared in the framework of the DANREG programme, have also been used for the construction of the MEG: Surface Geological Map scale 1:100 000, Lithogenetic and thickness Map of the Quaternary scale 1:200 000, Neotectonic Map scale 1:200 000 and Engineering Geological Maps scale 1:200 000. The results of field mapping, particularly of slope deformations and erosional features, were an important source of information, too.

The editors deeply regret that because of a long and serious illness Gerhard Schäffer was not able to correct the final version of the Map of Environmental Geohazards and to complete the text of the Austrian part of the Explanatory Note. Therefore there are some differences in the accuracy of the map and some gaps in the text, both concerning the Austrian part.

Natural hazards

Pollution sensitivity

General aspects

The sensitivity of the environment (rocks and groundwater) to pollution is delineated in the MEG by the five danger categories:

1. very high (permeable rocks on the surface),
2. high (permeable rocks on the surface covered by thin aquiclude or less permeable rocks),
3. moderate (permeable rocks covered by thick aquiclude or less permeable rocks covered by thin aquiclude or rocks of medium permeability),
4. low (rocks of medium permeability covered by thick aquiclude or low permeable rocks covered by thin aquiclude or without cover),
5. very low (low permeable rocks covered by thick aquiclude or aquiclude on the surface).

Each category is represented by different colour in the MEG. The borders of main lithologies (karstic, volcanic, granitic and metamorphic rocks) are also depicted in coloured areas.

Two different methods were used for the evaluation of hydraulic parameters of rocks in the DANREG region. In spite of this fact the results of the assessment of environmental pollution sensitivity are very similar for the territory of each country. It means that to the similar or the same rocks the same degree of sensitivity has been attributed on the territory of each country.

Pollution sensitivity assessment in the Slovak territory is based on the 4–5 degree semi-quantitative classification of parameters like uppermost aquifer transmissivity, aquiclude thickness and depth as well as on the qualitative classification of permeability type of rock body down to 20 m depth. The aquiclude is defined by its hydraulic conductivity being k £ 10–7 m/s$^{–1}$. Different types of the structural arrangement of the aquifers and aquicludes have been classified to the five categories of pollution sensitivity (Tab. 1).

Between 1992 and 1994 this principle of rock body evaluation was used for the preparation of the Map of the suitability for waste disposal at a scale of 50 000 concerning nearly the entire territory of Slovakia (36 former districts except for the cities of Bratislava and Koπice) (Kováèiková & Segíò 1995). The suitability map for each district consists of the land valorisation map, 2 documentation maps, waste disposal sites inventory at a scale of 1:10 000, legend and a brief commentary. The methodology for their preparation was regulated by a Guidebook of the Ministry of the Environment of the Slovak Republic (M≥P SR 1993). These maps, financed from the State budget, were digitised and printed.

For the MEG purposes the corresponding Suitability maps for waste disposal (scale 1:50 000) were used in sim-

Assessment of pollution sensitivity in the Slovak part of the Danube region

Transmissivity of the aquifer	Thickness (depth to the surface) of aquiclude	Structural arrangement
$A \geq 10^{-3}\ m^2s^{-1}$	1 = 0 – 2 m	/ thickness of the aquiclude 2A3 aquifer expressed by transmissivity \ depth to the underlying aquiclude surface
$B = 10^{-4}\ m^2s^{-1}$	2 = 2 – 5 m	
$C = 10^{-5}\ m^2s^{-1}$	3 = 5 – 10 m	
$D = 10^{-6}\ m^2s^{-1}$	4 > 10 m	
$E < 10^{-6}\ m^2s^{-1}$		
Pollution sensitivity category	**Structural arrangement of aquicludes and aquifers**	
1 — very high	1A4	
2 — high	1A3, 2A3, 2A4, 1B3, 1B4	
3 — moderate	1A2, 2A2, 3A3, 3A4, 1B2, 2B2, 2B3, 2B4, 1C3, 1C4, 2C3, 2C4	
4 — low	1A1, 4A4, 1B1, 3B3, 3B4, 1C2, 2C2, 3C3, 3C4, 1D3, 1D4, 2D3, 2D4	
5 — very low	4B4, 1C1, 4C4, 1D1, 1D2, 2D2, 3D3, 3D4, 4D4, E	

plified form. The hydraulic parameters of rocks in the Bratislava district have been taken from the special (scale 1:25 000) suitability map for waste disposal of the area at a (VOJTAŠKO *et al.* 1991) and also from the existing boreholes or determined by the qualified assessment. Information about the Quaternary rock thickness are extracted from the Lithogenetic and thickness Map of the Quaternary (PRISTAŠ *et al.* 1996a, b) and/or Engineering Geological Map (KOVÁČIK *et al.* 1996) prepared for the Slovak part of the DANREG programme.

In Hungarian territory the pollution sensitivity reflects the degree of uppermost aquifer protection against the impact of all surface anthropogenic sources of pollution. In the western part of the Hungarian territory (from the Austrian border approximately to the surroundings of Bábolna village) the assessment of pollution sensitivity is based on the modified classification scheme applied in the (scale 1:100 000) map sheets of the Little Hungarian Plain (Kisalföld) by BOLDIZSÁR [in SCHAREK (ed.) 1990, 1991a, 1991b, 1993 and 1995].

Pollution sensitivity of the superficial formations was evaluated by using the combination of parameters like permeability, highest groundwater level and thickness of the impermeable cover, if there is any (considering the uppermost sedimentary series with a coefficient of permeability $k < 10^{-3}$ cms^{-1}), using the following scheme (Tab. 2):

Because of the vertical and/or horizontal variability of the parameters considered, both methods (Tab. 1 and 2) have to be regarded as fundamental guidelines for the preparation of MEG.

Due to the lack of basic data from boreholes and laboratory tests in the eastern part of the territory (east of Bábolna village) the assessment of the surface pollution sensitivity is based on a less strict scheme though based essentially on similar principles taking into consideration the surface geology and the depth of groundwater level. In case of the presence of several different layers above the groundwater table their estimated, weighted average transmissivity was calculated for the purpose of the MEG. That is the reason why a specific sediment (*e.g.* loess) can be assigned to different sensitivity categories in different areas. For the compilation of the MEG the materials of the relevant land management projects (*e.g.* BOLDIZSÁR & POZSGAI 1982; KÉRI 1982; PRAKFALVI *et al.* 1983, OROSZNÉ *et al.* 1982, Faculty... 1985) and engineering geological studies (RAINCSÁK-KOSÁRI 1993) were also used as background materials.

Table 2

Assessment of pollution sensitivity in the Hungarian part of the Danube region

k — coefficient of permeability	t — highest groundwater level below the surface	f — cover thickness
$k_0 > 10^{-4}\ cms^{-1}$	$t_0 < 1$ m	$f_0 < 1$ m
$k_1 = 10^{-4} - 10^{-5}\ cms^{-1}$	$t_1 = 1 - 2$ m	$f_1 = 1 - 2$ m
$k_2 = 10^{-5} - 10^{-6}\ cms^{-1}$	$t_2 = 2 - 5$ m	$f_2 = 2 - 5$ m
$k_3 < 10^{-6}\ cms^{-1}$	$t_3 > 5$ m	$f_3 > 5$ m
Pollution sensitivity category	Parameter combinations	
1 — very high	$k_0t_0f_0$	
2 — high	$k_1t_1f_1$	
3 — moderate	$k_1t_{2\text{-}3}f_2$, $k_{2\text{-}3}t_2f_1$	
4 — low	$k_1t_{2\text{-}3}f_{2\text{-}3}$, $k_{2\text{-}3}t_2f_2$, $k_{2\text{-}3}t_3f_1$	
5 — very low	$k_{2\text{-}3}t_3f_{2\text{-}3}$	

The Austrian approach to the assessment of pollution sensitivity is mainly based on the qualified assessment of relevant parameters like rock permeability or transmissivity, groundwater level depth, structural arrangement of the aquifers and aquicludes considering the results of classification of similar lithologies in the Slovak and Hungarian territories. This is due to a lack of data from boreholes and laboratories or their inaccessibility. In the Austrian part of the Danube region the rocks and soils have also been classified according to five categories of pollution sensitivity.

Regional overview of surface pollution sensitivity

With regard to surface pollution sensitivity we can distinguish areas with typical and clearly defined geological, tectonic and geomorphological conditions in the Danube region.

Podunajská níΩina Lowland. The area is bordered by Danube River to the south, eastern margin (Bratislava–Pezinok) of the Malé Karpaty Mts on the west and Ipefl/Ipoly River on the east. A characteristic feature of this area is its lowland and hilly relief. The occurrence of persistently wet places, ox-bow lakes and abandoned flood channels is typical for the ≥itn″ ostrov (territory between the Danube and Little Danube rivers) and for the flood-plains of the Váh, Nitra, ≥itava, Hron and Ipefl/Ipoly rivers. A dominant part of this area has a very high and high sensitivity to pollution. It is caused by the common occurrence of permeable Quaternary sediments (fluvial, alluvial fan and terrace) and Neogene (lacustrine and brackish) sandy and gravelly ones. The pollution sensitivity of loess and loess-like soils varied between moderate and very low degrees. The deluvial clayey sediments on the slopes of hilly land have also very low and low sensitivity.

Záhorská níΩina Lowland. This area is situated between the Morava River (border between Slovakia and Austria) and the western margin of the Malé Karpaty Mts (Devínska Nová Ves–Stupava–Lozorno). The relief is mostly lowland and hilly and is built up by Quaternary (fluvial, eolian, alluvial fan and terrace) clayey, sandy and gravelly soils as well as Neogene (marine and brackish) sediments (clay, marl and sand). The prevailing pollution sensitivity categories are high, moderate and very high.

Juhoslovenská kotlina Basin. This is a very small area situated in the easternmost part of the Danube region north of the Ipefl/Ipoly River (surroundings of the Vinica and Veflká Èalomija villages). It is built up by Neogene (marine, brackish and lacustrine) sediments of varied lithological types (clay, sand, gravel, marl, conglomerate and sandstone). Fluvial sediments (clay, sand and gravel) and deluvial (loamy-stony) of Quaternary age also occur. The area is of high, moderate and also low sensitivity to pollution.

Krupinská planina Upland and Burda Mts. The area is situated north of the Ipefl/Ipoly River among the villages Slatina–Ïurkovce–ˇahy and north of the Hron River estuary. The Neogene volcanics (tuff, tuffit, agglomerate and andesite) are the dominant rocks of the area. These rocks are often fractured in the surface so they were usually classified as having high pollution sensitivity. Deluvial clayey soils with debris of volcanic rocks make up the slopes along the bottom parts of the Krupinská planina and Burda Mts. They have moderate or low sensitivity to pollution.

Malé Karpaty Mts. The Malé Karpaty Mts is the only area where pre-Tertiary rocks occur on the surface. They are considered as a young horst structure and form the western border of the Podunajská níΩina Lowland. The rocks cropping out on the surface are granite, granodiorite and schists of the Palaeozoic–Proterozoic (?) basement as well as Mesozoic and Upper Palaeozoic sediments. Karstic rocks locally occur in the vicinity of Borinka. Deluvial, mostly clayey sediments cover the bottom slopes of mountains. The most part of the area (granitoid and metamorphic rocks) has very low, moderate and low sensitivity to pollution.

Sopron Hills. Considering surface pollution sensitivity, the zone of the Sopron Hills located near Lake Neusiedl/Fertõ is represented by highly varied sedimentary rocks of comparatively small areal extent arranged along NW–SE striking main structural features. The extremely porous Miocene limestones are assigned to the highest category of pollution sensitivity together with the major part of fluvial sediments and flood-plains (*e.g.* the valley of the Ikva stream). The Quaternary clastic sediments creating alluvial deposits of high permeability and the Miocene conglomerates with silty matrix are generally ranked to category 2. The laminar, schistose, fractured, tectonically affected Palaeozoic metamorphic crystalline schist and gneiss series are considered as having moderate sensitivity to pollution.

Layers of the Upper and Lower Pannonian formations with high clay content are assigned to the low and very low categories of pollution sensitivity.

Little Hungarian Plain (Kisalföld). From the Lake Neusiedl/Fertõ through Kapuvár, Csorna, the swamp land of Hanság to Mosonmagyaróvár and Gyõr, a dominant part of the Little Hungarian Plain is covered by thick Quaternary fluvial accumulations consisting of gravel, sand and other flood-plain sediments. It is characterised by the almost complete lack of superficial protecting cover and by high groundwater level. Regarding pollution sensitivity, these features classify it among the most threatened areas. Fluvio-aeolian sediments slightly reworked by wind, as well as peat deposits can equally be characterised by very high permeability. Only the Early Holocene clayey, organic fluvio-lacustrine and paludal sediments form sporadically local protective layers of moderate effect situated just above the prevailing groundwater level. On the basis of laboratory tests of samples taken from mapping boreholes the clastic, ill-sorted, gravel-bearing, sandy, silty sequence of the terrace II/A has occasionally been assigned to the moderate category of pollution sensitivity.

Pannonhalma–Tata Hilly Land. In the area of Pannonhalma, Tárkány, Kocs, Tata and Tatabánya the surface loess cover and the underlying Pannonian sediments ensure far more favourable geological qualification for the Pannonhalma–Tata Hilly Land in view of surface pollution sensitivity, than the unconsolidated, clastic, fluvial sediments of the neighbouring Little Hungarian Plain. Nevertheless, valley floors, flood-plains and the alluvial plain skirting the Danube's bank characterised by swamp and paludal formations, having high groundwater level and featuring high or very high surface pollution sensitivity are also widely extended among the aforementioned series.

Gerecse–Pilis Mts–Buda Hills

These mountain ranges are extending from Tatabánya to Budapest, dismembered by the Dorog, Héreg–Tarján, Gyermely, Zsámbék basins and other smaller Tertiary basin areas. Mesozoic karstified limestones and dolomites with associated Middle and Upper Eocene limestone sequences represent the most typical and the most threatened zone in this region regarding surface pollution, since karst galleries and cavities provide free passage of meteoric water to the main karst aquifer without any screening. In the basin areas clayey, coal-bearing Eocene and gravel to clayey Oligocene formations observed between uplifted Mesozoic structural blocks constitute occasionally effective or moderate protective layers above the main karst aquifer.

In contrast to the above mentioned sequences the Miocene formations, representing the higher cover in the basins of the area, exhibit high lithological diversity. This ranges from porous limestones of excellent transmissivity through moderately permeable clayey-sandy-gravel-bearing mixed series and loose or compact sandstones to impervious clay and clay-marl deposits. Their sensitivity to pollution is widely varied. The Pannonian deposits play a rather subordinate role in this area constituting mostly impervious, aquiclude horizons of the categories 4 and 5. The thick clayey loess cover has also low sensitivity.

Börzsöny and Dunazug Mts. This area is extends along the two sides of a big curve of the River Danube, called the "Danube bend". It is built up essentially by the Tertiary, mostly andesite-dacite stratovolcanic series of very low to moderate surface pollution sensitivity. Accordingly, the related sequences feature a certain degree of diversity ranging from the comparatively higher permeability (category 3) of the pyroclastic series to the very low sensitivity (category 5) of the thick lava and subvolcanic magmatic bodies.

Eastwards from the Börzsöny Mountains the Oligocene Mány and Törökbálint formations crop out from beneath the volcanic series. They make up an area of low or moderate surface pollution sensitivity. These formations are covered by variably thick remnants of a loess sequence. The area is slightly dissected by a network of valleys with high groundwater level and frequently inundated flood plains with notable (category 1) sensitivity to surface pollution.

Pest Plain. Fluvial, fluvio-aeolian or aeolian, unconsolidated clastic, variably thick Quaternary sediments of high surface pollution sensitivity cover virtually the whole area of the Pest Plain from Budapest to Vác. They rest on Oligocene and Miocene sediments (clay, sandy clay, clay-marl, rhyolite tuff, *etc.*) exhibit in most areas low, but slightly variable sensitivity to downward migrating pollutants. Following the replenishment of one-time clay pits in this area they accommodate a series of large waste depositories partially without appropriate protection against groundwater. Without technical protection the area is not suitable for superficial waste disposal as the fairly varying groundwater level is generally near the surface (BKH...1993).

Hydrological and hydrogeological phenomena

Geohazards that could cause the fatalities, injury of persons or animals, damage to property or disruption of economic activities are shown in the MEG. Such are moist areas (persistently, intermittently), former moist areas, moors and swamps as well as flood boundaries. In addition to these hazards, larger water areas (dam, lake, pond), water streams and flood protected embankments are also delineated in the MEG.

The major part of the Danube region has been flooded in the past. Great damages have been caused by frequent floods along the main rivers, first of all the Danube itself (including its Moson and Little Danube branches), Lajta /Leitha, Rába, Rábca, Morava/March, Váh, Hron, Ipefl /Ipoly as well as by stagnant inland water in the surroundings of the Lake Neusiedl/Fertõ. *E.g.* the main part of the Little Hungarian Plain was a swamp region even in the 19th century. Besides a few flat, dry elevations it extended from Gyõr to Lake Neusiedl/Fertõ and included the Szigetköz area. Because of problems in discerning quite clearly the limits between the temporary water covers resulting from floods and inland water, the flood boundaries in this vast area can only be regarded as inferred (theoretical) or historical ones. Flood boundaries in the Slovak part of the Danube region as well as in other areas of Hungary represent those of the maximum floods recorded up to now.

The drainage of most river channels of the Danube region as well as the construction of flood protected embankments have reduced the occurrence of inundations to a minimum. For example the establishment of a great canal network in Hanság (*e.g.* Hanság Canal, Szegedi Canal, Kapuvár–Bõsárkány Canal *etc.*) until the end of the 1960s resulted in substantial drop of the groundwater table. Significant part of the related area became suitable for agricultural cultivation. On the other hand, the dam of Gabèíkovo hydroelectric power plant protects more than one third of the Danube length on the Slovak territory.

In spite of the aforementioned measures some small areas of the DANREG region are still flooded by rivers (*e.g.* Danube near Mosonmagyaróvár, Morava/March, Hron, Ipefl/Ipoly) and larger areas by raising inland water (*e.g.* surroundings of Lake Neusiedl/Fertõ) due to snow thawing during the early spring periods or extreme precipitation.

Besides the Hanság area, moors and swamps of regional extent are concentrated especially in the surroundings of Lake Neusiedl/Fertõ, along the Danube River in the Austrian territory, along the Leitha River up to Bruck an der Leitha, southwest of Marchegg and the March/Morava River, between the Danube and the Little Danube and between the Little Danube and the Nitra River. Besides the Little Hungarian Plain intermittently moist areas occur often in the hilly land between Pannonhalma and Komárom.

Mass movements

According to the classification of slope movements (Varnes 1978) one can range a great majority of slope deformations in the DANREG region into the slide group. The group is represented mostly by potential and stabilized landslides and earth flows. Active deformations are scarce. Only a several slope deformations of small areal extent have a character of block failures (block field and block rift). They can be classified to the creep group.

The landslides and earthflows are of recent age. They are mostly of shallow (< 5 m) and medium (5–15 m) depth. The typical lithologies of sliding slopes of the Danreg region are deluvial clay with variable debris content, eolian loess or loess-like soils of Quaternary age as well as the Neogene (Miocene and Pliocene) clays. The average slope angle ranges from 5° to 10° but locally exceeds 15°. According to the areal extent the slope deformations are depicted in the MEG by point or areal symbols. Due to the scale used most of deformations are marked by point symbols.

Information on landslides and other deformations are derived from interpretation of air photographs, archives (*e.g.* Central landslide register Geofond in the Slovak territory) and also from field mapping.

In the region the following sites of slope deformation occurrence have been recognised:

Eastward to Modra (small landslide), north-eastern from Sereï (two active frontal landslides on the left bank of Váh River), between Dubník and Rúbaò villages, among Èaka–Doln˝ Pial–Radava–Èechy villages, near ⁄ubá village, among Santovka–Veflk˝ Pesek–Lontov villages, Pavlová–Malá nad Hronom–Kamenica nad Hronom villages, near Ipeflské Uflany and Hruπov villages, at the surroundings of the Fertõboz (a number of slides towards north) and Hidegség villages (four smaller landslides), between Pereszteg and Sopronkövesd villages (several small landslides), around Gyõrújbarát, Nyalka and Écs villages (small, northward oriented landslides), at Almásneszmély, Süttõ, Lábatlan, Baj, Nagysáp, Epöl, Gyermely and Máriahalom villages, around the Hont, Drégelypalánk, Nagyoroszi and Rétság villages.

Tectonics

Disjunctive tectonic failures with activity from the Pliocene to Quaternary and/or during Quaternary as well as some significant pre-Pliocene strike-slip and normal faults are the most important for land-use purposes. Some of them have a character of lineaments or seismoactive faults (Hurbanovo–Diósjenõ, Ölved–Dobrá Voda, Mór –Komárom zone and the one along Danube River extending through Budapest towards Vác). Only verified neotectonic faults of significant length are delineated in the MEG. The strike-slip and normal faults shown in the MEG are not distinguished according to their depth extent (subsurficial, surficial). The tectonic failures shown in the MEG have been adopted from the tectonic and neotectonic maps of the DANREG region.

Seismicity

According to the historical records the DANREG region has been affected by earthquakes of variable intensity in the past. Seismic hazard of the area is expressed in the MEG by isoseists with intensity ranging from 6° to 9° MSK as well as by epicentres (more exactly places of maximal observed macroseismic intensity). Due to different sources of geophysical information, their interpretation and the scale of the MEG (too detailed) some isoseists do not correspond altogether in the border areas. The epicentres with information about the degree and year of observation shown in the MEG ranging from 2° to 9° MSK (Mercally-Sieberg).

From the MEG it is clear that the surroundings of Komárno (Komárom) was affected two times (1763 and 1783) by the strongest earthquakes in the past (9° MSK). Their connection with the seismoactive fault crossing the Komárno area is evident. Several other strong earthquakes have been recorded in the region: 6° MSK — Záhorská Bystrica (1890), 7° MSK — Lozorno (1914) and 8° MSK — IΩa near Komárno (1822).

Erosion and accumulation

Water erosion

Within this group of hazards, known to be present in the DANREG region there are mainly gullies, sheet erosion, aggradation and lateral erosion. The gullies are usually concentrated on slopes of hills and uplands built up by Quaternary deluvial (loam, clay with debris content), aeolian (loess) and aeolian–deluvial (clay) soils as well as Tertiary sediments of varied lithology. Their occurrence in mountains built up by hard rocks is rare (*e.g.* Dunazug/Visegrád, Börzsöny, Burda Mts and Krupinská planina Upland) The significant gullies (individual and/or areal occurrence) are concentrated mainly in these parts of the Danube region: Ipeflská pahorkatina Hills (Demandice and Trhyòa eastward from ≥eliezovce, around Dolné Semerovce), Krupinská planina Upland (between Pláπſovce–ˇahy–Hruπov), Juhoslovenská kotlina Basin (surroundings of Dolinka), eastward from Hegyeshalom, around Pannonhalma and Sokorópátka, between Tatabánya and Almásneszmély, eastward from Esztergom, between Kesztölc and Piliscsév, around Nagycsikóvár, on the eastern side of the Hill Urak asztala, between Nagykovácsi and Budakeszi, between Perõcsény and Nagybörzsöny, and around Kóspallag and Felsõpetény.

Sheet erosion occurs usually on slopy areas built up by Quaternary (deluvial, fluvial and alluvial fan) soils as well as Neogene and Palaeogene sediments and can be observed in Sopron Hills and its surroundings (at Ágfalva, around Fertõrákos, near Fertõboz and Hidegség, between Pereszteg and Pinnye, around Várbalog and Pusztasomorja, around Mosonszolnok, near Kimle and Mosonszentmiklós), as well as in other areas (at Budakalász, north–west of Diósjenõ, and south of Ipolyszög.

Aggradation can be observed near Hainburg an der Donau, Purbach am Neusiedler See, in the surroundings of

Rust, in some small areas south of Hegyeshalom and also in several sites along the foreland of the NNE–SSW striking hills around Pannonhalma–Sokorópátka. The material weathered through erosion is spread in fans by small, seasonal rivers, where their kinetic energy suddenly drops.

Lateral erosion of water streams occurs sporadically. It is due to the canalisation of the majority of streams. An example of intensive lateral erosion is the Danube River near Zebegény and Nagymaros, the Váh River near ˇintava (to the NE of Sereï) and the Hron River near Malá nad Hronom. Active landslides in both latter sites have been caused by lateral erosion.

Wind erosion (deflation)

Unfavourable geological, geomorphological and wind conditions causing deflation exist in the eastern part of the Danube region. Deflation has affected slopes in the hills (*e.g.* between Rétalap and Mezõörs villages) and some river valleys (Nitra, Hron, Ipefl/Ipoly) which are mostly built up of aeolian sand, loamy-sandy fluvial and alluvial fan sediments. Morphologically impressive and active aeolian forms like dunes however do not exist in the region.

Karst and hydrocompaction

This group of hazards is represented by surface karstic forms (sinkholes or dolines, uvalas) and subsurface ones (caverns, caves). They are closely interconnected with Mesozoic (Lower Jurassic) limestones of restricted areal occurrence near Borinka situated NW of Bratislava (Malé Karpaty Mts), with the occurrence of Mesozoic and Paleogene (Eocene) limestones in significant areas of the Gerecse, Pilis Mts and the Buda Hills.

Hydrocompaction in loess or loess-like sediments is a very important geohazard concerning foundation subsoils

$$I_{mp} = \frac{\Delta h_p}{h - \Delta_h}]100 [\%]$$

or their bearing capacity. Collapsible soils occur in the DANREG region but they were studied in more detail only in the Slovak part, with sufficient number of laboratory tests. Therefore the hydrocompaction in loess is shown in the Slovak territory only.

The ability to collapse in soils is measured with a value of collapse coefficient $I_{mp} > 1$ (Slovak Technical Standard STN 73 1001. Foundation of structures — subsoil under shallow foundation). This basic characteristic of collapsible soils is defined in ˇAJGALÍK & MODLITBA (1983):
h_p = vertical deformation of the tested sample after saturation by water under certain stress [mm];
h = initial height of the tested soil sample with natural moisture content [mm];
Dh = total vertical deformation of the tested soil sample of natural moisture content from the beginning of the test to the beginning of saturation [mm].

In the Danube region we can distinguish rather collapsible soils (typical loess, sandy loess) with Imp > 3%, medium collapsible soils (eolian sand with fine particle admixture) with I_{mp} = 1.5–3%, and weakly collapsible soils (clayey loess, loess-like sediment) with I_{mp} = 1–1.5 % (KLUKANOVÁ & FRANKOVSKÁ 1995). In the MEG the collapsible soils are distinguished in accordance with the scale used. They are shown only in general form.

Anthropogenic factors of hazard

Deposition

Artificial replenishment of former swampy areas is common around Budapest but it occurs also in several other major urban settlements.

The relevant hazard in this group is represented by dumps of various waste types (communal, agricultural, industrial, mining and dangerous). A great number of waste disposal sites, mainly communal and agricultural, have been registered in the Danube region (only in the Slovak territory more than 1000, KOVÁÈIKOVÁ & SEGÍÒ 1995). The three participating parties in DANREG programme agreed upon showing the repositories with waste volume of more than 2500 m^3.

As concerns the Hungarian territory besides the communal repositories around Budapest and other major cities, the fly ash and cinder dumps of electric power plants and the mining wastes of underground coal mines are prominent (Tatabánya, Dorog, Tokod, Felsõpetény, Kosd *etc.*). Their data were obtained from regional registers (EGERER & SOMFAI 1985; Faculty...1985 *etc.*) and PHARE programme studies.

Mines

A typical feature of the Danube region is the great number of surface and subsurface occurrences of Quaternary and Neogene fluvial, eolian, marine and lacustrine sediments (gravel, sand, clay, loam, clay-marl). These resources were exploited for industrial purposes in numerous pits. Most of them are abandoned now, but others are still being exploited (often as small mining units). Here are some examples — Pannonian clay-marl near Sopron was mainly used for brick production, the same age clays between Pannonhalma, Komárom and Tatabánya have also been exploited for ceramic utilisation, extraction of peat in Hanság proceeds on local level *etc.*

The rocks were quarried in several sites like near Sopron (limestones and metamorphic rocks), Gerecse and Pilis Mts (limestones and dolomites), Börzsöny and Dunazug/Visegrád Mts (andesites), Malé Karpaty Mts (metamorphics), Krupinská planina (Hruπov, Horné Turovce) Upland and Burda (Chflaba) Mts (andesites). Some of the mentioned quarries are still in operation.

The majority of underground mines in the Danube region are abandoned now, only a few active ones are still operated in Hungarian territory (in year 2000 the shaft Mány I/a in the Tatabánya–Nagyegyháza–Mány coal basin and Lencsehegy I near Dorog). These mines impose a serious burden to their environment.

A lot of abandoned pits and/or quarries were designated as waste disposal sites.

Subsidence

Subsidence of the surface caused by mining activities is also represented in the MEG. It can be of considerable extent as a result of underground mining, especially in the Tatabánya–Mány–Nagyegyháza and Dorog basins and at Felsõpetény.

Conclusions

The detailed studies and mapping of the Danube region focussed on the compilation of the Map of Environmental Geohazards have revealed the following facts:

1. Concerning planning and building of engineering structures the most important natural geohazards of the Danube region are:

— sensitivity of the environment to pollution,
— seismicity,
— hydrocompaction in loess (collapsibility),
— inundations and
— erosion.

Sensitivity and seismicity have been assessed in a semi-quantitative manner. Among the anthropogenic hazards waste dumps of various types especially with dangerous contents are the dominant types.

2. The scale of the Map of Environmental Geohazards at 1:100 000 is not detailed enough for the delineation of such geohazards as *e.g.* collapsibility, slope deformations and waste disposal sites. More detailed maps (scales 1:50 000 and 1:25 000) allow more accurate presentation of these hazard types and they are, therefore, more useful to the community of users.

3. The Map of Environmental Geohazards is designed for land use planning applications and for mitigation of the negative effects of geohazards.

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