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Engineering geological maps of geofactors of the environment of the Košická kotlina Basin and Slanské vrchy Mts. (Eastern Slovakia)

ĽUBOMÍR PETRO[1] – ZOLTÁN SPIŠÁK[1] - ERIKA POLAŠČINOVÁ[1]

[1]Dionýz Štúr Institute of Geology, Werferova 1, 040 11 Košice

Abstract: The Košická kotlina Basin and Slanské vrchy Mts. region (1500 km^2) has been recently intensively studied from them viewpoint of relevant factors of the environment (geofactors), i.e. factors affecting significantly the environment. The result of their evaluation is a set of engineering geological maps on the scale 1 : 50 000. The set consist of a engineering geological zoning map, map of relative susceptibility of the area to landsliding and map of significant geofactors. The contribution briefly presents the methodology for their construction and main results of the mapping. The maps should serve as an aid in rational land use planning.

Key words: Košická kotlina Basin and Slanské vrchy Mts., geological factors, set of engineering geological maps.

1. Introduction

Intense development of the town agglomerations Košice and Prešov in the last 15 years brought about the necessity of compilation of suitable geological base materials. At the beginning of the 90-ties, in the framework of the science-technology project "ZP-547-008 - Investigation of Geological Factors of the Environment, co-ordinated by the Dionýz Štúr Institute of Geology (GÚDŠ) in Bratislava, a systematic compilation of a set of geofactor maps started on the scale 1 : 50 000 in 6 regions of Slovakia. It included the design of a methodology for different map types. The set consisted of a geological map, map of deposits and raw material prognosis, hydrogeological, pedological, groundwater quality map, map of geochemical reactivity of rocks, geochemical-environmental map, map of natural rock radioactivity and an engineering geological map. The aim of the investigation was to provide basic idea on relevant geological factors of the environment, i.e. on its abiotic component. They affect in a significant way, positively or negatively, the development of all spheres of the society. The maps should serve as one of basic materials in land use planning and rational use of the territory.

The Košice Basin and Slanské vrchy Mts. (Eastern Slovakia, Fig. 1) are one of the above mentioned regions of Slovakia, where the maps of geofactors were compiled in the years 1992 - 1993. In the presented contribution we are dealing with the mapping of geofactors important from the viewpoint of engineering geology, as well as with the methodology of engineering geological map compilation. It consists of a set of three maps - map of zoning, map of relative susceptibility of the area to landsliding and map of significant geological factors. The compilation of the above maps was based on suitable existing maps from the whole territory (geological map 1 : 25 000 and 1 : 50 000, map of suitability of the area for solid municipal waste disposal 1 : 50 000), of its part (engineering geological map 1 : 10 000) or other map types compiled within the above mentioned project.

2. Geomorphologic-geological setting

The Košická kotlina Basin has a generally hilly relief with an altitude above sea level of 250 - 400 m.

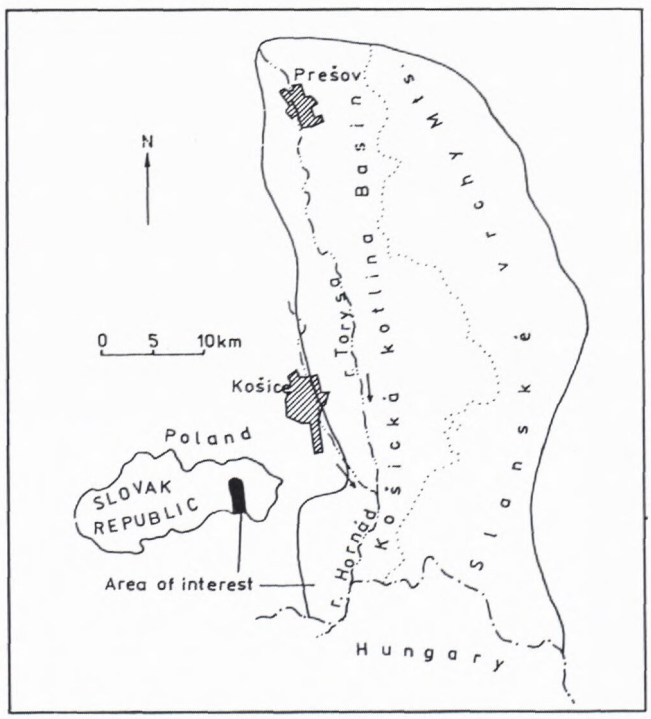

Fig. 1 Geomorphological position of the studied area

Average slope angle is 6° - 14°, less often 14°-24°. The relief is strong, relative altitude differences reaching as much as 550 m. Average annual precipitation in the basin is 600 - 700 mm.

The area under study is situated in the western part of the Eastern Slovak Neogene Basin, which formed due to the pull-apart process (VASS et al., 1988). The filling of the basin consists above all of molasse Neogene sediments of the Main Molasse (Egenburgian-Sarmatian) and partly also sediments of the Pannonian Late Molasse (VASS, 1982). From lithological viewpoint, Neogene sediments are represented by pelitic facies (claystones, clays, siltstones) as well as detritic facies (sandstones, conglomerates, gravels).

An organic part of the Eastern Slovak Neogene Basin are Neogene volcanic rocks (Egenburgian-Pannonian), which are, on one hand, a component of sedimentary formations (layers, lenses as well as extensive horizons of redeposited tuffs), but, on the other hand, they form morphologically conspicuous volcanic structures - andesite stratovolcanos of the Slanské vrchy Mts. (KALIČIAK et al., 1991 and in press). They are composed predominantly of effusive (lava flows) and volcanoclastic facies. To a lesser extent there are tumefaction and dome-shaped forms of extrusive and intrusive andesite and diorite porhyry bodies.

Quaternary rocks are represented significantly on the territory under consideration. This applies to their extent as well as thickness. Areally of greatest extent are fluvial, proluvial, deluvial and eolian-deluvial sediments. Their thickness is in some places reaching 20-25 m.

The oldest tectonic features on the territory, which affected significantly the pre-Tertiary underlier, are faults of NW-SE direction. Younger appear to be NE-SW faults. Faults of N-S direction created in the Neogene and reactivated during the Quaternary are the youngest as far as activity is concerned and the most important ones from the viewpoint of macro-relief formation (JANOČKO, 1989 and 1990). These tectonic faults are responsible for the origin of some landslides. In view of the considerable number (over 400) and area, landslides are an important geomorphologic element of the area under study (PETRO - SPIŠÁK, 1994).

3. Maps of geological factors of the environment

We started to compile maps of geological factors of the area studied from the viewpoint of engineering geology following a request of the Ministry of the Environment of the Slovak Republic in 1992. We used the methodology elaborated by specialists from the Department of Engineering Geology of the Dionýz Štúr Institute of Geology in Bratislava in 1991. At present, a modified version is prepared in the form of an obligatory regulation for the whole territory of Slovakia.

The basic philosophy for the compilation of the engineering geological zoning map, maps of relative susceptibility of the area to landslides and of significant geological factors was the use of all accessible geological, hydrogeological, engineering geological and pedological materials, especially maps. They were complemented by existing data bases of relevant geofactors, by aerial photographs and field mapping. Accessory were drilling and laboratory works.

3.1 Engineering geological zoning map

The map may be characterised as synthetic and multi-purpose. It shows geological environment to the depth of 10 m. Typologic zoning (MATULA - HRAŠNA, 1976) on the level of zone and sub-zone has been applied. Zones are territorial units distinguished on the basis of homogeneity or similarity of one of the principal geological factors - rocks. In this respect, the genetic-lithologic classification of rocks valid on the territory of Slovakia is used (MATULA - PAŠEK, 1986). This means that each zone represents a different genetic-lithologic rock complex. A change in the lithology within the same genetic complex, or a change of thickness of the Quaternary layer is expressed as a sub-zone. Besides rocks and soil, the map shows further significant geofactors, such as hydrogeological phenomena (groundwater level depth, its flow direction, aggresivity of groundwater, springs etc.), geodynamic phenomena (erosion gullies, landslides, block failures, neotectonic failures etc.) and raw material deposits.

The map includes text explanations with a detailed evaluation of physical-mechanical properties of rocks and soils within the distinguished zones (33) and sub-zones (166). The results of laboratory tests of soils, including archived ones (7575) were statistically processed. For the purpose of map compilation, 508 exposures were documented in the field, 44 boreholes were made (689 m) to the depth of maximally 20 m, 18 monoliths were collected (approx. 40x40x40 cm) from solid and semi-solid rocks as well as 16 samples of groundwater. Potential suitability of the zones for shallow foundations, for the construction of transport communications and earth dams was evaluated in the sense of standards valid on the whole territory of Slovakia. The breaking characteristic of rocks was evaluated in a similar way. The obtained results are summarised in a brief characterisation of the distinguished zones in a table.

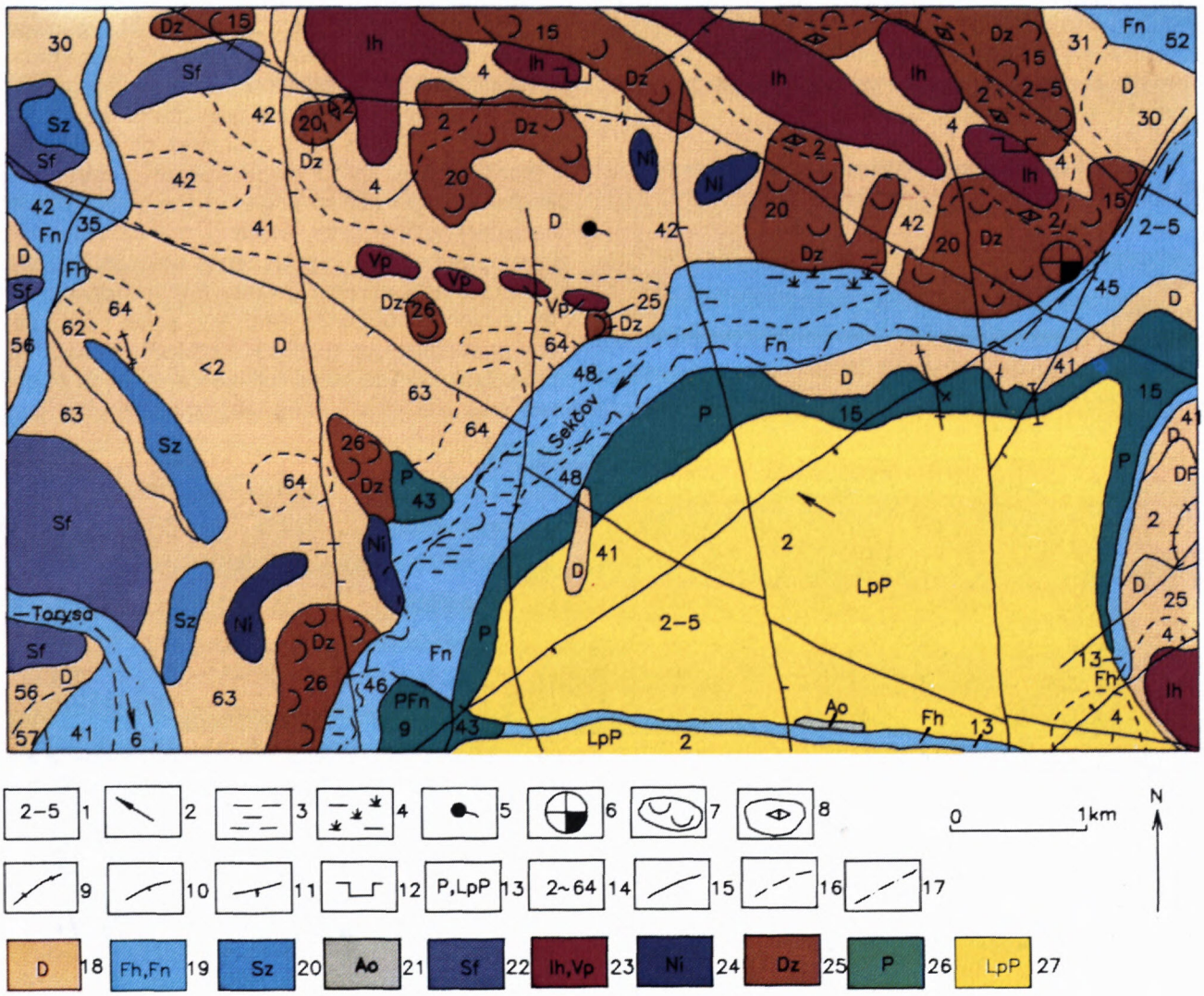

Fig. 2 Engineering geological zoning map (north of Prešov, northern part of the Košická kotlina Basin and Slanské vrchy Mts. region).
Hydrogeological symbols: *1 – groundwater-level depth, 2 – groundwater flow direction, 3 – moist area, 4 – swamp, 5 – significant spring, 6 – corrosivity of groundwater (ph, hardness, content of* SO^{2-}_4 *and* CO_2. Geodynamic phenomena symbols: *7 – landslide area, 8 – block deformations, 9 – erosion gully, 10 – fault active before the Quaternary, 11 – fault active during the Quaternary.* Documentation symbols: *12 – abandoned quarry, 13 – symbols of zones and combined zones, 14 – code number of subzone, 15 – zone contour, 16 – subzone contour, 17 – watch stream*

Zone types: *18 D – zone of deluvial sediments (clayey and clayey-gravelly soils), 19 Fn – zone of lowland stream sediments (gravels with clayey cover), Fh – zone of mountain stream sediments (sandy-clayey gravels), 20 Sz – zone of sandstone-conglomerate rocks (conglomerates with sandstone intercalations), 21 Ao – zone of waste filling, 22 Sf – zone of flysch rocks (sandstones, siltstones and claystones), 23 Ih – zone of intrusive rocks (andesites, diorite porphyres), Vp – zone of pyroclastic rocks (andesites and rhyolite breccias), 24 Ni – zone of clayey-silty sediments (claystones, siltstones), 25 Dz – zone of deluvial sediments of landslides (clayey-gravelly soils), 26 P – zone of alluvial fans (proluvial) sediments (clayey-sandy gravels, sandy clays), 27 Lp – zone of eolian-deluvial sediments (clays).*

From the map it is evident that in the Košice Basin, on the surface there are usually Quaternary rocks. In the Slanské vrchy Mts. predominant are volcanic and volcano-sedimentary rocks, covered in the foothills and in depression mostly by deluvial sediments. Neogene sediments emerge on the surface less frequently, they have usually the character of soils and they are characterised by considerable variability of physical-mechanical properties. This applies especially to lithologically varied formations in which there are alternating fine and coarse soils. High lithologic variability reflected in marked changes of properties is typical also for some types of Quaternary rocks (e.g. deluvial,

proluvial and terrace fluvial sediments). An example of a simplified engineering geological zoning map from the northern part of the territory (the surroundings of Prešov) is on Fig. 2.

3.2 Map of relative susceptibility of the area to landslides

The map has the character of a special, multi-purpose map. The "traffic-light" method indicates territorial units of zone and sub-zone type in which we assume the same or very similar conditions for the origin and development of landslides. Green colour represents stabile areas, orange conditionally stabile and red unstable areas. The principal factors of zoning were the rock environment (lithologic and sedimentation conditions, degree of failure and weathering of the pre-Quaternary underlier rocks, thickness and character of the rocks), hydrogeological (groundwater level depth) and geomorphologic (slope angle of the relief and its character) in the area, existing manifestations of slope deformations (various types of landslides and block failures), erosion gullies. For the division of the territory into zones and sub-zones we used semi-quantitative or qualitative classification of the above factors. The basis for the compilation of this map was the engineering geological zoning map

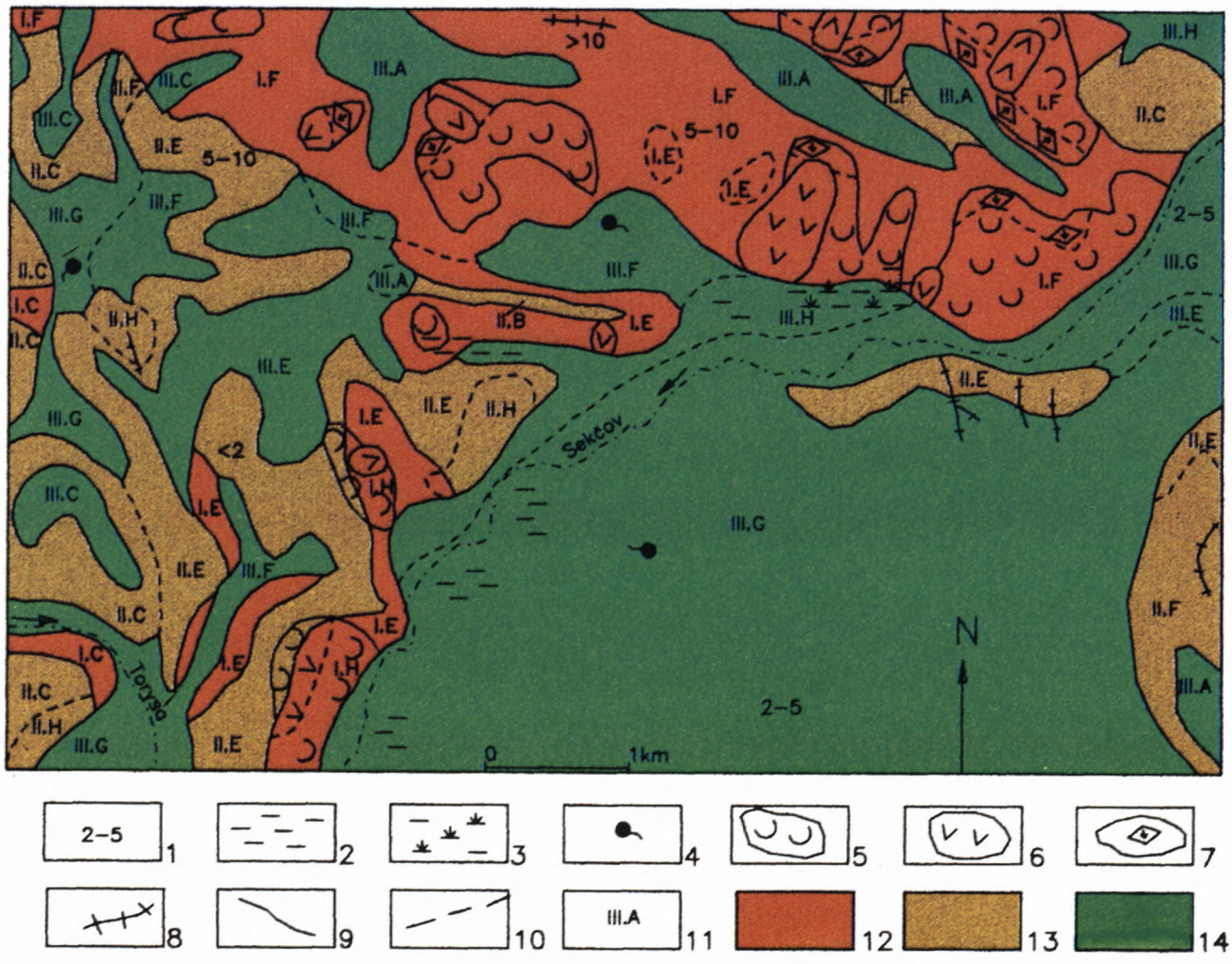

Fig. 3 Map of relatively susceptibility of the area to landsliding (north of Prešov, northern part of the Košická kotlina Basin and Slanské vrchy Mts. region)

Hydrogeological symbols*: 1- groundwater-level depth, 2 - moist area, 3 - swamp, 4 - significant spring.* Geodynamic phenomena symbols: *5 - area of dormant or stabilized landslide occurrence, 6 - area of active landslide occurrence, 7 - area of block deformation occurrence, 8 - erosion gully.* Documentation symbols*: 9 - zone contour, 10 - subzone contour, 11 - symbols of zone and subzone,* Zone symbols: *12 - Zone of unstable areas: I., subzones - I.C solid and semisolid rocks, I.E fine sediments, I.F debris, I.H fine soils; 13 - Zone of relatively stable areas: II., subzones - II.B and II.C solid and semisolid rocks (volcanic, flysh, II.E fine sediments, II.F debris, II.H fine soils; 14 - Zone of stable areas: III., subzones - III.A solid rocks, III.C solid and semisolid rocks, III.E fine sediments, III.F debris, III.G gravelly-sandy soils, III.H fine soils*

(3.1). Besides zones and sub-zones it contains also basic data on slope deformations (surface extent and activity) and hydrogeological condition (moist areas and swamps, springs and groundwater level depth). The map is complemented by a brief explanatory text and a brief table characterising the distinguished sub-zones in each zone, including a typical schematic cross-section.

We distinguished totally 23 sub-zones in the territory under study. The results of the mapping show evidently that unstable areas are concentrated in the Košická kotlina Basin as well as in the Slanské vrchy Mts. They are especially slopes with occurrences of active and potential landslides, block failures, or with favourable geological structure and high probability for destabilisation. The principal cause of the origin of slope deformations are excessive precipitation, slope angle change, its loading or moistening, weathering of the rocks and groundwater buoyancy. From anthropogenic causes predominant are deforestation, undercutting or loading of the slope, or undermining. An example of a map of relative susceptibility of the area to landslides, from the northern part of the territory (the surroundings of Prešov) is in Fig. 3.

3.3 Map of significant geological factors

This synthetic and multi-purpose map provides in a concentrated form a complex picture of relevant geological factors of the environment from the viewpoint of engineering geology. The geofactors have predominantly the character of geobarriers, i.e. they prevent or limit human activities. Only some of the shown geofactors have the character of geopotentials (e.g. mineral deposits or high-quality agricultural soil). It has to be mentioned that the character of a geofactor in relation to various activities of man is variable. This means that one and the same geofactor may have the form of a geopotential (e.g. deposit as a source of raw material), or geobarrier (deposit as a hindrance to construction).

The map of significant geological factors has been compiled with the use of both previously mentioned maps as well as some others (e.g. map of water management, deposits and prognoses of mineral resources, pedologic or seismic maps). It shows, with the help of coloured areal, linear and point indicators the following geofactors - mineral deposits (including groundwater resources), the suitability of the geological underlier for the construction of solid municipal waste depositories (areas suitable for waste disposal), agricultural soil (occurrences of highest-quality soil types), slope stability (by occurrences of landslides), low bearing capacity soils, gully erosion, seismicity (isoseists and seismic focuses), inundation (boundaries of maximum flooding), undermining and neotectonic failures (faults with activity range from the Upper Pliocene).

Dominant among the most frequent geobarriers are especially slope deformations of landslide and block failure types, neotectonic failures of normal fault type, inundation areas and low bearing capacity soils. Among the most important geopotentials of the area under study are fertile soils and groundwater resources. A list of mineral deposits and of most fertile soil types is attached in the explanatory text to the map. Fig. 4 shows an example of a map of significant geological factors, in non-coloured form, from the northern part of the territory (the surroundings of Prešov).

4. Conclusions

1. On the basis of geological, hydrogeological maps, maps of mineral deposits and pedologic maps, as well as complementary survey and mapping, an engineering geological map has been compiled, consisting of : zoning map, map of relative susceptibility of the area to landsliding and map of significant geological factors, on the scale 1 : 50 000.

2. The maps are multi-purpose and, using zones and sub-zones, they indicate or evaluate geological factors of the area under study from the viewpoint of engineering geology. Their legibility also for non-geologists is supported by tabular form of evaluation of the results applicable in practice.

3. In spite of the scale - 1 : 50 000 - the maps are a suitable basis for urban and land-use planners, as well as Bureaux of Environmental Protection, in land use planning and environmental impact assessment. Their application in practice may prevent unsuitable interventions into the geological component of the environment as well as help to eliminate existing negative impacts of such interference in Nature.

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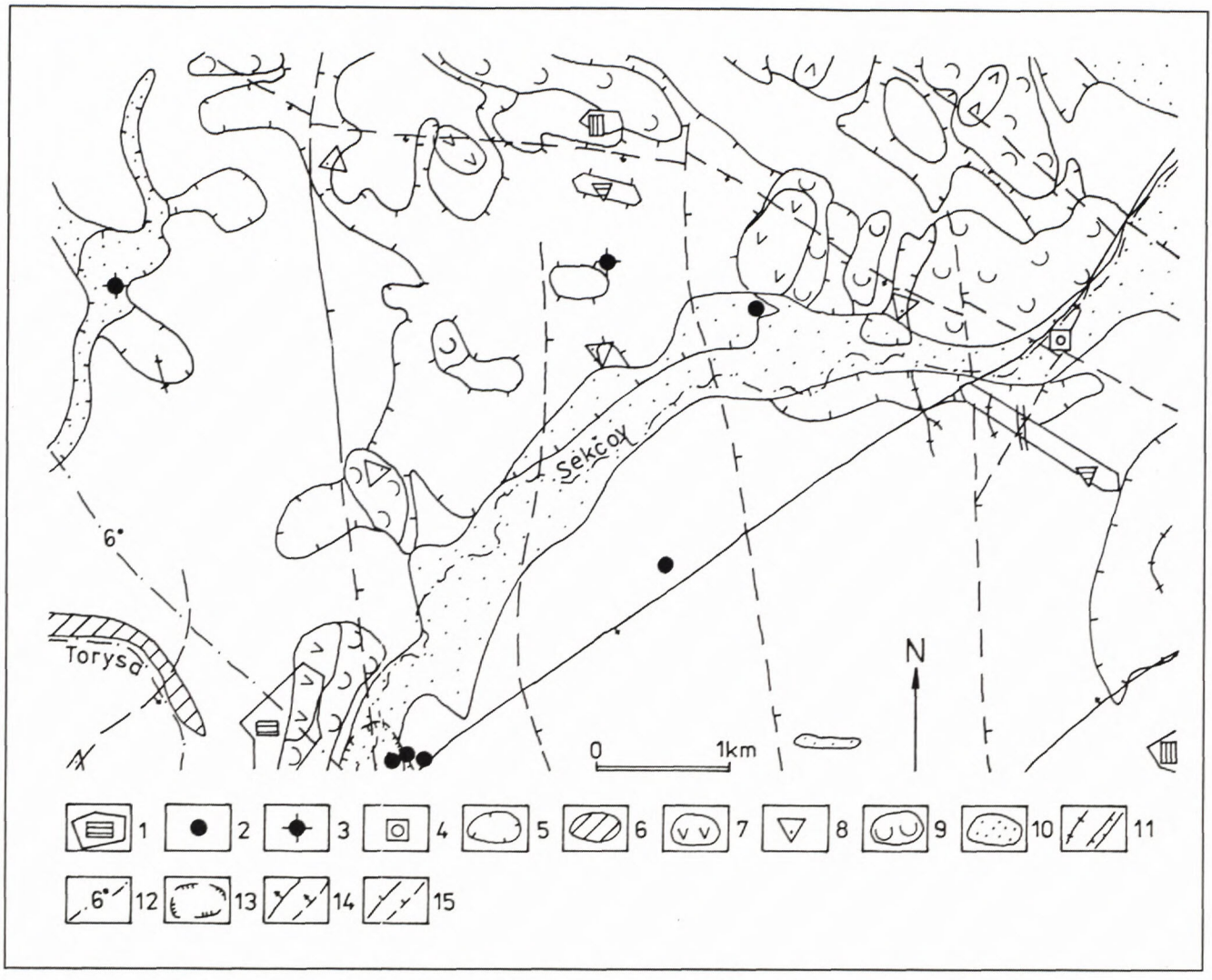

Fig. 4 Map of significant geological factors (north of Prešov, northern part of the Košická kotlina Basin and Slanské vrchy Mts. region).

Raw material deposits: *1 - external contour of deposit with symbol of raw material type, 2 - significant groundwater source in Quaternary sediments, 3 - significant groundwater source in pre- Quaternary rocks, 4 - mineral water source.* Geological basement suitability for municipal waste sites: *5 - suitable area to landfill sites.* Agricultural soil: *6 - area of the most fertile soils occurrence.* Slope stability: *7 - active landslide of large areal extent, 8 - active landslide of small dimensions, 9 - dormant landslide of large areal extent.* Foundation soil bearing capacity: *10 - low bearing capacity foundation soils.* Erosion: *11 - active gully erosion.* Seismicity: *12 - intensity of seizmicity in °MSK.* Inundation: *13 - area flooded by great water.* Tectonic failures: *14 - fault active during the Quaternary (verified, assumed), 15 - fault active from the Late Badenian to the end of Pliocene (verified, assumed)*

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