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Engineering Geological Map

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Introduction

The Engineering Geological Map is based on the genetic and lithological classification of rocks and soils. The map has been constructed on the basis of the Surface Geology Map 1:100 000 of the DANREG area and the basic principles are in accordance with the guidelines given by the International Association of Engineering Geology [Annon. 1976, Matula *et al.* 1979, Matula (ed.) 1981]. The map 1:200 000 displays the engineering geological zones and the important tectonic features. In order to prevent the duplicity of data displayed in other DANREG maps (Tectonic Map, Neotectonic Map, Environmental Geohazards Map, and Hydrogeological Map), only limited data are shown in Engineering Geological Map. The geodynamic phenomena are shown in the Environmental Geohazard Map: the slope deformations, erosional and accumulation features, subsidence manifestations, sagging of loesses and karstic features, also including important major earthquake events. Neotectonic phenomena are shown on the Neotectonic Map. The hydrogeological data on the Environmental Geohazard map show the depth of water level and the chemistry of the groundwater, and partly the hydroisobaths and important springs. Another reason for this concept was to render the map as readable as only possible. Some endogenous and exogenous geodynamic data, the hydrogeological conditions and some environmental features which usually appear in the standard map are described in the text. During the compilation of our map we were collecting and using the earlier geological and engineering geological maps as well of the concerned area. These were:

— Austria: Brix & Pascher 1994; Fuchs 1965, 1984, 1985a, b, c, d; Grill 1968; Hermann *et al.* 1993; Hoch & Hacker 1971; Huber 1978; Jelem 1975; Kapounek & Fink 1978; Kümmel *et al.* 1957; Österreichisches... 1979; Schmid 1970, 1972; Vetters 1910; Wessely 1968.

— Slovakia: Matula *et al.* 1989, Nemèok 1982, ˇajgalík & Modlitba 1983.

— Hungary: OVH 1984; Raincsákné Kosáry (ed.) 1984; Scharek (ed.) 1990, 1991 a, b, 1993; Scharek & Tullner (eds) 1992, 1993.

The engineering geological zones (pre-Quaternary basement, or Quaternary deposits) are regional units with identical or similar genesis and lithology·[Fodorné (ed.) 1971, Fodorné & Kleb 1986]. Rocks and soils down to the depth of 5 metres were taken into account. The boundaries of zones are shown on the map in full black line and marked by using symbols (*e.g.* Vl, or D etc.).

Different colours indicate the characteristic lithological composition of the uppermost 5 m of the section. Altogether 11 colours appear in the map representing the following lithologies: mostly solid rocks (with the uniaxial strength > 50 MPa), mostly semi-solid rocks (with the uniaxial strength < 50 MPa), alternation of hard (solid) and soft rocks, mostly gravelly soils, mostly sandy soils, mostly fine soils, alternation of gravelly and fine soils, alternation of sandy and fine soils, loess (and loess-like sediments), organic soils and peat, and anthropogenic (man-made) deposits.

The zones are described in brief in the following text. Only limited data of the geotechnical issues were available on parameters from the Austrian project area. Slovak technical standards (STN) were used for characterisation of some geotechnical parameters. Sporadic investigations using the Schmidt Hammer Test were carried out, to improve the correlation of the rocks. The fracture zones were partly checked in the field and verified also from the satellite and airborne images.

A brief description of the engineering geological characteristics is given in Tab.1. The following items are described: (1) Symbol of zone, (2) Name of the zone, (3) Lithological content and age of rocks/soils, (4) Hydrogeological conditions, (5) Geomorphological conditions, geodynamic phenomena, (6) Geotechnical classification of rocks/soils, (7) Geotechnical description of rocks/soils, (8) Stability of slopes/cuttings, (9) Usage of rocks/soils, raw materials, (10) Recommendations for constructions, environmental hazard.

Types of rocks and soils

Mostly solid rocks

These are shown in dark-blue colour on the map and include Palaeozoic crystalline (both intrusive and metamorphosed) rocks, Mesozoic limestones, dolomites, sandstones, as well as Miocene carbonate rocks and volcanics essentially consisting of andesite lavas. Although different in their origin, the “mostly solid rocks” feature uniformly favourable uniaxial strength characteristics (> 50 MPa).

The rock types are found in the uplifted areas of the Hundsheim Mts, (including the Braunsberg), the Leitha Hills, and the Rust Upland in Austria. The Malé Karpaty Mts. represent a large occurrence of this type of rocks in Slovakia (mostly igneous, metamorphic and carbonate rocks). The largest area of solid rocks is in the Eastern part of the DANREG area (Krupinská planina in Slovakia, and the Börzsöny Mts and Pilis Mts in Hungary).

Mostly semi-solid rocks

This group includes semi-solid (soft) rocks with uniaxial strength lower than 50 MPa. It comprises sandy sediments and the claystone facies of Palaeogene basin sediments (in the Austrian part of Badenian and Pannonian ages).

Occurrences: West slope of the Hundsheim Mts., in the area surrounding of the Arbestal Upland and their easterly hills, the area of the Leitha Hills, the area between the Leitha River and the Parndorfer Platte (Austria) and the area south of Sopron (Hungary).

Table 1

Engineering geological characteristics of the zones of the Engineering Geological Map

Symbol of zone	Name of zone	Lithological content, age of rocks/soils	Hydrogeological conditions	Geomorphological conditions, geodynamic phenomena	Geotechnical classification of rocks/soils	Geotechnical description of rocks/soils	Stability of slopes/cuttings	Usage of rocks/soils, raw materials	Recommendations for constructions, environmental hazards
Ao	**zone of municipal waste**	communal waste, mixed wastes, mixture of loams, sands, rocks and man-made products	irregular water level, aggressiveness, contaminated groundwater	predominantly flat irregular area, partly moderate elevations	mixture of fine, coarse soils, rocks and man-made products	very variable geotechnical characteristics	varied stability of slopes	no use, some parts may be recycled (metal, glass, plastic etc.)	source of contamination for water, soils and air, unsuitable area for any type of construction
Ai	**zone of industrial waste**	industrial waste, variety of man-made products, contaminated loams, sands etc.	irregular water level, aggressiveness, possible heavily contaminated groundwater	predominantly flat irregular area, partly moderate elevations	fine and coarse soils	very variable geotechnical characteristics	varied stability of slopes	no use, partly dangerous materials	source of contamination for water and soils, unsuitable area for any type of construction
L	**zone of loessy sediments**	loess, loess like sediments (Quaternary – Pleistocene)	mostly dry, water level below 10-15 m, * $Kf=10^{-4}–10^{-6}$ m/s	flat area, collapsibility of loess, partly wind erosion, possible fast gully erosion (deflation)	fine soils	low plasticity consistency: firm	even steep slopes are stable, if high water content – unstable slopes and rapid erosion	production of bricks	danger of collapse of loess due to high water content, damages to constructions
E	**zone of aeolian sands**	aeolian (wind blown) sands Quaternary – Pleistocene)	mostly dry, in general very permeable, $Kf=10^{-4}–10^{-5}$m/s	flat elevations of the terrain, in areas without vegetation – wind erosion	coarse soils	fine to medium grained sands, medium dense to dense	generally stable slopes	high quality material for constructions	good construction grounds, sensitivity to gully erosion, unsuitable for waste disposal due to permeability
P	**zone of proluvial sediments**	gravels, clayey gravels of alluvial fans (Quaternary)	irregular depth of groundwater (0,5–3 m), possible aggressiveness $Kf=10^{-3}–10^{-5}$m/s	mostly moderate inclined area, partly almost flat	predominantly coarse soils with substantial admixture of fine particles	medium dense to dense	generally unstable in cuttings	low quality material for embankments	irregular depth of the groundwater, possible aggressiveness of groundwater
D	**zone of deluvial (slope) sediments**	fine soils, partly with angular gravels and cobbles up to 40% (Quaternary)	water level below 3-5 m, $Kf=10^{-5}–10^{-7}$m/s	mostly moderate inclined area, erosion and landslides on steeper slopes	fine soils	variable plasticity and consistency	generally unstable slopes and cuttings	material for embankments	gully erosion and landslides on slopes, fine soils – suitable for waste disposal sites
F	**zone of alluvial deposits**	sandy to clayey soils, sands, sandy gravels (Quaternary)	water level on the contact of loams and gravels $Kf=10^{-2}–10^{-7}$m/s	flat area, periodic floods, arrable land	fine and coarse soils	fine soils: soft to firm, gravels: medium dense to dense	generally unstable cuttings due to high water content	gravels suitable for constructions, source of groundwater	high water level, inundation area, danger of groundwater pollution

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Ao	**zone of municipal waste**	communal waste, mixed wastes, mixture of loams, sands, rocks and man-made products	irregular water level, aggressiveness, contaminated groundwater	predominantly flat irregular area, partly moderate elevations	mixture of fine, coarse soils, rocks and man-made products	very variable geotechnical characteristics	varied stability of slopes	no use, some parts may be recycled (metal, glass, plastic etc.)	source of contamination for water, soils and air, unsuitable area for any type of construction
Ai	**zone of industrial waste**	industrial waste, variety of man-made products, contaminated loams, sands etc.	irregular water level, aggressiveness, possible heavily contaminated groundwater	predominantly flat irregular area, partly moderate elevations	fine and coarse soils	very variable geotechnical characteristics	varied stability of slopes	no use, partly dangerous materials	source of contamination for water and soils, unsuitable area for any type of construction
L	**zone of loessy sediments**	loess, loess like sediments (Quaternary – Pleistocene)	mostly dry, water level below 10-15 m, * $Kf=10^{-4}–10^{-6}$ m/s	flat area, collapsibility of loess, partly wind erosion, possible fast gully erosion (deflation)	fine soils	low plasticity consistency: firm	even steep slopes are stable, if high water content – unstable slopes and rapid erosion	production of bricks	danger of collapse of loess due to high water content, damages to constructions
E	**zone of aeolian sands**	aeolian (wind blown) sands Quaternary – Pleistocene)	mostly dry, in general very permeable, $Kf=10^{-4}–10^{-5}$m/s	flat elevations of the terrain, in areas without vegetation – wind erosion	coarse soils	fine to medium grained sands, medium dense to dense	generally stable slopes	high quality material for constructions	good construction grounds, sensitivity to gully erosion, unsuitable for waste disposal due to permeability
P	**zone of proluvial sediments**	gravels, clayey gravels of alluvial fans (Quaternary)	irregular depth of groundwater (0,5–3 m), possible aggressiveness $Kf=10^{-3}–10^{-5}$m/s	mostly moderate inclined area, partly almost flat	predominantly coarse soils with substantial admixture of fine particles	medium dense to dense	generally unstable in cuttings	low quality material for embankments	irregular depth of the groundwater, possible aggressiveness of groundwater
D	**zone of deluvial (slope) sediments**	fine soils, partly with angular gravels and cobbles up to 40% (Quaternary)	water level below 3-5 m, $Kf=10^{-5}–10^{-7}$m/s	mostly moderate inclined area, erosion and landslides on steeper slopes	fine soils	variable plasticity and consistency	generally unstable slopes and cuttings	material for embankments	gully erosion and landslides on slopes, fine soils – suitable for waste disposal sites
F	**zone of alluvial deposits**	sandy to clayey soils, sands, sandy gravels (Quaternary)	water level on the contact of loams and gravels $Kf=10^{-2}–10^{-7}$m/s	flat area, periodic floods, arrable land	fine and coarse soils	fine soils: soft to firm, gravels: medium dense to dense	generally unstable cuttings due to high water content	gravels suitable for constructions, source of groundwater	high water level, inundation area, danger of groundwater pollution

continuation Table 1

Symbol of zone	Name of zone	Lithological content, age of rocks/soils	Hydrogeological conditions	Geomorphological conditions, geodynamic phenomena	Geotechnical classification of rocks/soils	Geotechnical description of rocks/soils	Stability of slopes/cuttings	Usage of rocks/soils, raw materials	Recommendations for constructions, environmental hazards
Nk	**zone of alternating clayey to gravelly sediments**	gravelly, sandy, silty and clayey sediments (Neogene)	irregular depth of groundwater, pressure groundwater, $Kf=10^{-3}–10^{-7} m/s$	hilly area, moderate slopes, gully erosion	layers of both fine and coarse soils	fine soils: firm coarse soils: dense, some layers cemented	stable to unstable slopes and cuttings	coarse soils (gravels, sands) suitable for constructions	gully erosion and landslides (in fine soils) on slopes
Vp	**zone of pyroclastic rocks**	tuffs, epiclastic volcanic rocks (Neogene)	irregular pore or fracture permeability, CO_2 and SO_4 aggressiveness	gentle and steep slopes on the margins of volcanic highlands susceptibility of rocks to weathering and gully erosion	generally semisolid rocks	low strength of rocks (< 50 MPa)	slopes with rocks prone to weathering – possibility slope movements	building materials	suitable for waste disposal
Vl	**zone of effusive rocks**	andesites, rhyolites, basalts (Neogene)	fracture permeability, hydrocarbonate aggressiveness	steep slopes, dissected relief, tops, hydrothermal alteration	solid rocks	generally high strength of rocks (> 50 MPa), dense rock breaking	stable slopes	building stone, ore resources	good conditions for constructions
Si	**zone of claystone – siltstone rocks**	claystone and siltstone rocks (Mesozoic, Neogene)	almost impermeable rocks – aquiclude	flat ridges, gentle to mild slopes, susceptibility of rocks to weathering and landsliding	semisolid rocks	low strength of rocks (< 50 MPa), plastic rocks	possible activation of slope failures in cuttings and also on natural slopes	marlstones – production of cement, claystones – production of bricks	landslides, erosion good conditions for waste disposal
Sf	**zone of flyschoid rocks**	flyschoid rocks (sandstones, mudstones, shales) (Mesozoic)	fracture and pore permeability of sandstones, other rocks – aquiclude	moderate slopes, susceptibility of mudstones and shales to weathering	solid rocks, partly also semisolid rocks (mudstones, shales)	variable characteristics, dense rock breaking	possible instability of slopes in shales and mudstones	generally no practical use	limited suitability to construction due to variable properties, limited suitability to waste disposal sites
Sz	**zone of conglomerat e rocks**	conglomerates and breccias (Mesozoic)	fracture permeability	morphologically active forms, steep slopes, dissected relief	solid rocks (clayey members semisolid)	strength of rocks over 50 MPa, rocks with clayey matrix below 50 MPa	prone to slope failures in cuttings	building stone – conglomerates cemented by sand or lime	danger of groundwater pollution, not suitable for waste disposal
Sp	**zone of sandstone rocks**	sandstones, arcoses, grauwackes and quartzites (Mesozoic)	fracture permeability CO_2 aggressiveness	steep slopes and walls, quests (mainly quartzites)	solid rocks (those cemented by clay semisolid)	strength of rocks over 50 MPa, rocks with clayey and marly cement below 50 MPa	prone to slope failures in cuttings	quarzites, arcoses and sandstones – building stone, construction material	danger of groundwater pollution, not suitable for waste disposal

Sd	**dolomitic rocks**	dolomites (Mesozoic)	fracture and karst-fracture permeability	morphologically active forms, steep slopes, dissected relief strong tectonic deterioration	solid rocks	strength of rocks far over 50 MPa, fragile rock, dense rock breaking	stable slopes	material for concrete, chemistry	danger of groundwater pollution, not suitable for waste disposal
Sv	**limestone rocks**	limestones, dolomitic limestones (Mesozoic)	karst and fracture permeability	steep slopes up to cliffs karst relief (canyons, caves, dolines) karst phenomena	solid rocks	strength of rocks far over 50 MPa, soluble rock	stable slopes	production of lime and cement, building stone, groundwater resources	danger of groundwater pollution, good for constructions, not suitable for waste disposal
Sk	**zone of carbonate and clastic rocks**	marls, sandstones, chertstones (Mesozoic)	fracture and fracture-karst permeability	variable relief according the type of rocks	solid and semisolid rocks	varied characteristics, strength of rocks over 50 MPa, but also below	generally stable slopes, marls less stable	low quality material for earthworks	danger of groundwater pollution, not suitable for waste disposal due to karst permeability
Ih	**zone of intrusive rocks**	tonalites, granites, granodiorites, diorites etc. (Palaeozoic)	fracture permeability, CO_2 aggressiveness	flattened relief of highlands	solid rocks	strength of rocks far over 50 MPa	stable slopes and cuttings	building stone of different quality gravel, stone for concretes	good conditions for constructions, not suitable for waste disposal
Mn	**zone of epimetamor-phosed rocks**	phyllites, phyllonites, weakly metamorphosed schists (Palaeozoic)	low fracture permeability, CO_2 aggressiveness	gentle and mild slopes, dense net of gullies	solid rocks (phyllites, phyllonites may be semisolid ones)	varied characteristics, anisotropy of properties	stable slopes, cuttings are not very stable due to quick weathering	phyllites, metacarbonates appropriate for building stones	variable conditions for constructions, clayey schists are suitable for waste disposal
Mv	**zone of highly metamor-phosed rocks**	mica schists, gneisses, amphibolites, migmatites (Palaeozoic)	low to middle fracture permeability, CO_2 aggressiveness	mild to steep slopes	mostly solid rocks	strength of rocks far over 50 MPa, anisotropy of properties	stable slopes, rocks in cuttings prone to weathering	amphibolites, gneisses and migmatites – good building stones	area suitable for waste disposal
R	**zone of residual sediments**	weathering zone of basement (mica schists) (Quaternary)	irregular depth of groundwater, $Kf=10^{-3}–10^{-7}$ m/s	moderate slopes	soil with preserved structure of the basement rock, coarse soil	low plasticity, consistency: firm to hard	stable slopes, prone to gully erosion	–	area not suitable for waste disposal

* Kf = hydraulic conductivity

Alternation of hard and soft rocks

Non-uniform formations of variable lithological and stratification pattern are assigned to this group. The uniaxial strength of this type of rock is lower than 50 MPa. They incorporate Palaeozoic low-grade metamorphic rocks — gneiss and micaschist series, Lower Miocene and Pannonian sediments bearing sandstone banks, as well as Badenian and Lower Pannonian marls and sandstones.

Rocks crop out in the Leitha Hills in Austria and along the northern periphery of the Bakony Mts, Quaternary freshwater limestones in the Gerecse Mts and in Sopron Hills in Hungary.

Mostly gravelly soils

They are depicted by dark-green colour. They represent terrace formations of the Danube River and its tributaries uplifted to different altitudes. Lithologically, sandy gravel occurs most commonly with lenticular and cross-bedded intercalations of medium- and coarse-grained sand, including layers of organic clay along the Danube River. Sometimes the gravel is covered by loamy sediments up to several metres (*e.g.* the Gänserndorf terrace in the North of the Marchfeld including the Schlosshofer Platte).

Mostly sandy soils

Typical occurrences of sandy soils are shown in yellow colour. This group consists essentially of fine-grained aeolian and fluvial sands. The deluvial slope deposits, which were derived from Pannonian sediments also belong into this category.

Larger occurrences are know from Marchfeld, from the Hundsheim Mts, from Seewinkel, from the northern and western part of the Braunsberg Mt and from spots along the Danube (mostly its right bank in Hungary) and Little Danube rivers throughout the whole DANREG area. There are essential occurrences of aeolian sands in the ≥itavská and Pohronská pahorkatina uplands in Slovakia.

Mostly fine soils

Apart from unconsolidated Upper Pannonian formations which consist of sandy silt and aleuritic loess, sandy loess and loess and fine sand assemblages belong to this group. Undivided fluvial sediments (NW of Sopron in the region of the border) contain mostly fine soils. Due to its specific textural features, loess is quite different from silts which are deposited in water with the same grain-size distribution pattern. Loess and loess/like sediments are therefore distinguished by a specific code sign.

Fine soils occur along the rivers Leitha and Fischa, in the surroundings of Lake Neusiedl in Austria, they cover the very most part of the Podunajská níΩina Lowland in Slovakia, occurring along the River Hron and also cover large parts of the Kisalföld (Little Hungarian Plain) in Hungary.

Alternation of gravelly and fine soils

Holocene alluvial deposits in basins and intramountain valleys (Danube, March, Wulka), are assigned into this category. Gravels are quite common at the base of their typical section overlain by sand and flood-laid silt, rich in organic matter. Consequently, the thickness of this unit is mostly intermediate and varies from site to site.

This type of deposit occurs mostly along the rivers Danube and March. The gravels are overlain in the flood plain of the tributaries of the River Danube by up to 5 m offlood plain clay and silt and along the River March by up to 3 m of loam.

Alternation of sandy and fine soils

Fine-fraction members of loose, slightly reworked proluvial fills (without matrix) of dry valleys are combined in this group. Also included are deluvial clay, silt and sand, and lacustrine-paludal sediments. By their specific lithology they can easily be distinguished from the basement.

The occurrence of this lithological type is rare. It was documented on local faint morphologic highs in the Seewinkel area in Austria.

Loess and loess-like sediments

Loess and loess-like sediments are always distinguished from fine (aleuritic/silty soils) due to their specific engineering geological properties. They are mostly of aeolian and also polygenetic genesis. Typical loess is relatively homogeneous, bedded soil with high content of silt fraction (0.05–0.005 mm), calcareous and porous. The sediment is shown in yellow-brown colour in the map.

Loess and loess-like sediments cover large parts is Slovakia and Hungary mostly along the Danube River.

Organic soils and peat

The typical locality for organic clay, as well as peat and muck assigned to this category occurs around the Lake Neusiedl/Fertõ and the Hanság. The maximum thickness is in the Austrian part between 1 and 2 m. They are commonly underlain by sand and gravel. The whole assemblage is highly irregular in extent and thickness and has low and very low bearing capacity. This assemblage occurs locally in some small, abandoned river channels in the Szigetköz area and in a number of intramountain basins without an outlet.

Organic soils are common in ox-bows along the Little Danube and Hron rivers in Slovakia and along the whole main course of the Danube River. There is a relatively large occurrence of peat east of the Malé Karpaty Mountains as well.

Anthropogenic (man-made) deposits, replenishment

These occur commonly in the vicinity of large cities (Wien, Bratislava, Budapest, Gyõr) and industrial areas

(Tatabánya, Esztergom), as well as in operating or abandoned pits. Owing to their alternating composition they have generally irregular low to very low load-bearing capacity. In open pits and central districts of capitals their thickness can exceed even 10 m.

Engineering geological zones

29 zones have been delineated in the map: 13 zones of Quaternary deposits and 16 zones of pre-Quaternary basement. When the knowledge of the study area allowed to detach two zones in superposition, combined zones were marked in the map (OF and EF).

The zones as the following: zone of municipal wastes (Ao), zone of industrial wastes (Ai), zone of loessy sediments (L), zone of aeolian sands (E), zone of proluvial sediments (P), zone of deluvial (slope) sediments (D), zone of alluvial deposits (F), zone of river terrace sediments (T), zone of oxbow deposits (Fs), zone of organic sediments (O), zone of organic sediments on alluvial deposits (OF), zone of eolian sands on alluvial deposits (EF), zone of clayey-silty sediments (Ni), zone of sandy sediments (Np), zone of gravelly sediments (Ng), zone of alternating clayey-silty and gravelly sediments (Nk), zone of pyroclastic rocks (Vp), zone of effusive rocks (Vl), zone of claystone-siltstone rocks (Si), zone of flyschoid rocks (Sf), zone of conglomerate rocks (Sz), zone of sandstone rocks (Sp), zone of dolomitic rocks (Sd), zone of limestone rocks (Sv), zone of carbonate and clastic rocks (Sk), zone of magmatic and intrusive rocks (Ih), zone of low-grade metamorphic rocks (Mn) and zone of highly metamorphosed rocks (Mv), zone of residual soils (R).

Zone of municipal (communal) wastes (Ao)

This zone is composed of isolated areas in the vicinity of large settlements. The landfill material consists mainly of: household wastes, ash, clinker, local industry wastes, redundant soils and construction debris. Although, the thickness of wastes varies, it is generally less than 10 m. The landscape depressions (such as pits, ox-bows, etc.) have been used generally to dispose of local wastes. Even grading and recultivation of the surface render the area within this zone hardly suitable for construction works. Its unsuitability is due to high compressibility, irregular sagging, low bearing capacity and health hazard, or even danger (methane).

Zone of industrial wastes (Ai)

It incorporates technological wastes of industrial estates (frequently involving dangerous elements) and overburden of the mining branch. The material is very variable, mostly inert rocks of various granulometric composition. The thickness of these accumulations reaches 10 metres, locally even more. Specific cases are the wastes from the chemical industry, with special physical and mechanical properties and chemical composition. These require special care because of their possible ecological harmfulness. The zone is not suitable for any type of construction.

Zone of loessy sediments (L)

The loess is widely distributed in a thickness of several tens of metres. In the Austrian part of the project it is mostly less then 5 m. The thickness of the loess sediments in Slovakia vary between 5 and 15 m (greatest thickness in Slovakia occur in the surroundings of Svodín (up to 40 m). Lithologically variable, the zone is a sequence of aeolian and fluvio-lacustric-aeolian deposits, as well as fossil soil horizons.

The age, genesis, thickness as well as the fossil soil horizons are partially varied, while the age, genesis, thickness, character and properties of loessy sediments are varied. The loess and loam was formed mainly during the Middle and Late Pleistocene, with the greatest representation during the Mindel, Riss and Würm glacials. Typical loess is a relatively homogeneous bedded soil with a high content of silt fraction (0.05–0.005 mm). The loess is calcareous and very porous. The porosity and the bearing capacity decrease with age of the sediments. Sagging depends on the thickness of this zone. The colour is mostly yellow to pale-brown.

Loess is the most common of all Quaternary sediments in the DANREG region. Larger amounts of loess cover the area in the N of Gänserndorf terrace (Oberweiden, Strasshof ad. Nordbahn), near the airport Vienna (Schwechat), Schwadorf and S of Sopron. Loess sediments (typical loesses and loessy loams) occur often along the Danube River on both riverbanks in Slovakia and in Hungary. Extensive deposits occur in the Trnavská, Nitrianska, ≥itavská, Pohronská and Ipeflská pahorkatina uplands. They are subordinately present over the Záhorská níΩina Lowland, together with fluvial sediments.

From the hydrogeological point of view the zone is important to protect groundwater horizons. Hydrocompaction occurs sometimes while the scour erosion (on slopes), or lateral erosion occurs to a limited extent only.

The loess is suitable for brick-making and pottery. The zone is suitable, or limitedly suitable (sagging, furrow/gully erosion) for building construction.

Zone of aeolian sands (E)

The deposit is fine-grained sand (fraction 0.5–0.25 mm prevails), well sorted, with predominance of quartz (more than 90%). The thickness of the zone varies from a few metres up to 25 m (Marcelová). In Austria it is mostly less than 5 m. The sediment has medium bearing capacity. The morphology depends on the preservation of sand dunes. When preserved, sand dunes are suitable for building construction especially in inundation areas.

The zone of aeolian sands occupies the southern part of the Záhorská níΩina Lowland and isolated areas in ≥itn˝

ostrov, in Rábaköz in the proximity of the Danube River. The aeolian sand is well permeable.

Due to the predominantly low thickness and limited extent of the sands, pore water is usually absent. Accumulations of water can be expected to occur in thicker sand beds, within depressions of the Záhorská níΩina Lowland.

Wind erosion (deflation) is increasingly active due to the removal of vegetation (exploitation of wood or agriculture in the Záhorská níΩina Lowland).

Aeolian sands can be used for building construction (cement), for casting, or for the glass industry. The zone comprises mostly dryer, inferior site index soils. The zone is unsuitable for landfills.

Zone of proluvial sediments (P)

This zone includes sediments with poorly rounded components deposited in dry valleys with seasonal flooding. The sediment consists of coarse-grained gravels alternating with sandy and loamy beds. They may be seldom boulder-size, like at the foothills of the Malé Karpaty Mts The gravels are generally unsorted, the pebbles are semirounded to angular. The thickness of the sediments varies between 2 and 10 m. The slope inclination has a range of 1.5–5 degrees. Scour erosion and landsliding affect the slopes dipping 4–5°.

The zone occurs in the Parndorfer Platte in Austria, W and E of the foothills of the Malé Karpaty Mts and in the smaller Pleistocene and Holocene accumulations from side valleys along the Little Danube River, at the foothills of Krupinská vrchovina Highland in Slovakia.

Significant water-bearing can be expected only in thicker gravelly horizons. In general, proluvial sediments are more favourable for the concentration of groundwater than the deluvial ones.

The zone is only limitedly suitable for building constructions. One can expect an uneven compressibility within the zone. The contained clastic fraction will increase the strength after compaction. The zone is suitable for landfills. Flat slopes are suitable, or conditionally suitable for any kind of building construction.

Zone of deluvial (slope) sediments (D)

Slope deposits of mountainous and hilly regions belong to this zone. The composition of slope loams reflects the lithology of the basement rocks. If the basement is made up of solid or semisolid rocks, the loam has a variable content of fragments.

The deluvial sediments overlying Neogene gravels usually contain pebbles. The thickness of loams ranges between 2 and 10 m. Higher thickness is rare. The thickness of loams increases downhill. Hard rocks (limestones, dolomites, and granodiorites) are overlain by thin deluvial loams. In case of semisolid rocks (such as claystones, tuffs *etc.*) the loamy cover is thicker. Depending on the underground, the inclination of slopes rarely exceeds 20–25 degrees. The deluvial sediments related to volcanic rocks contain a higher percentage of clay particles. The deluvial sediments in the Malé Karpaty Mts more often contain clastic components. Scour erosion and also landsliding occur locally. Owing to their lithological variability, the compressibility in the zone is irregular. Most of the sediments of this zone are highly congelative (frost susceptible).

Only small occurrences of deluvial deposits were identified in Austria (*e.g.* in the depression south of the Leitha Hills in the N of Winden). Deluvial slope loams occur at the foothill of the Malé Karpaty Mts and in the Krupinská vrchovina Highland and at foothills of the Börzsöny and Pilis Mts.

The deluvial loams are highly water-bearing. Springs at the base of the slopes stop in most cases during the dry seasons.

This zone is used mostly as pasture or arable land.

Zone of alluvial (fluvial) deposits (F)

The zone of fluvial deposits is the dominant zone in the region. It covers at least 40% of the total DANREG area (estimation). It is present over the whole braided river-system (Danube, Váh, Hron, Ipefl/Ipoly, ≥itava *etc.*). The zone incorporates alluvial deposits of fluvial plains and intramountain valleys. These have a mixed lithological composition (gravel, sand, fine particles). The total thickness of the deposits ranges between 5–10 m. The flood deposits are clayey to loamy. The gravels are coarse and loamy. The river deposits show a wide range of grain size categories. The plasticity ranges from low to high. The fine sediments are of variable consistency. The morphology is completely flat (in most cases does not reach even one degree).

Logically the zone covers areas along main rivers of the region: Danube, Leitha, Fischa, Little Danube, Nitra, Hron, Ipefl/Ipoly *etc.*

The alluvial gravel is an important aquifer. The maximum and minimum of groundwater level is depicted on the Environmental Geohazard Map. Due to the occurrence of aquifers this zone is used for exploitation of groundwater and is often protected from any other activities except agriculture.

Mixed sand and gravel are suitable as infillings, or for road construction. Pure gravels are suitable for stabilising of gravity banquettes. The alluvial gravels are used for local building construction.

Zone of river terrace sediments (T)

The terrace sediments along the main rivers and their tributaries are composed of Pleistocene gravels and sandy gravels. The younger terraces have the largest areal extent and are dated as Würm and later. Most of the older terrace sediments have been eroded. The sediments contain coarse gravels and sands. The main fraction of the terrace gravels is medium- to coarse-grained. The older terrace sediments are highly weathered. The surface of terraces is flat. The boundaries towards the surrounding zones are morphological visible.

Terrace sediments cover the majority of the Austrian part of the map. Along the main water courses (Danube, Váh, Hron, Ipefl/Ipoly, ≥itava, *etc.*) the terrace steps at various levels are preserved.

The groundwater is usually bound to the proximity of the gravel base (some 5 m below the surface). The permeability of the gravels varies, depending on loam and clay admixtures. The zone offers a good quality for concrete addition.

The area is almost unsuitable to dispose waste (due to local high permeability). The reality is adverse. There are a lot of illegal local dumps there, mostly with household waste.

Zone of oxbow deposits (Fs)

The oxbow fill is composed of sediments of variable consistence (solid clay to slurry) with a high content of organic matter. The thickness of the sediments exceeds often 5 m. The oxbow zone represents morphologic lows in the lowlands. The peat deposits occur locally in this zone. The fill in the remnants of dead channels in the Szigetköz area is characterised by silts with high organic content. This zone is delineated by the Danube River and the Mal″ Dunaj River (Little Danube) and the Leitha River. This zone includes isolated lake areas as well.

The groundwater level is seasonally fluctuating, in pace with the rate of flow in the rivers and their inundated areas.

Certain areas are used for agricultural purposes in order to preserve the fertile soils. The groundwater is close to the surface. Therefore this places are not suitable to store waste (as it was done in the past).

Zone of organic sediments (O)

Isolated areas in the Podunajská níΩina Lowland, adjacent to the main course of the Danube and Mal″ Dunaj rivers, belong to this zone. The occurrences of organic silt, clay and peat (5–10 m thick) are typical for this zone. They are present mainly in the Hanság and Rába Valley and around the Lake Neusiedl/Fertõ. Minor deposits of organic sediments occur in the zone of oxbow lakes. In Austria the maximum thickness is 2 m. The top of the groundwater sometimes rises above the surface (swamps). Because of their fauna and flora, the areas with peat and bogs are often protected due to the rare flora and fauna associations. The peat has been used as a fertiliser in the agriculture.

Zone of organic sediments on alluvial (deposits above flood-plain) deposits (OF)

This zone includes young, uncompacted sediments with variable amounts of organic matter occurring above flood-plains, and at the periphery of flat areas, that are filled with peat. In the Podunajská níΩina Lowland, there is an isolated zone adjacent to the Danube and Mal″ Dunaj river valleys. Minor zones of organic sediments occur also in the zone of oxbow lakes. Occurrences: in the Hanság area and around Lake Neusiedl/Fertõ.

Zone of aeolian sands on alluvial deposits (EF)

This zone has several small occurrences in Záhorská níΩina Lowland in Slovakia. There are wind-blown sands lying over alluvial deposits of the Morava River. The thickness of sands is up to 5 m. The other characteristics are identical with those of zones 3.4 and 3.7.

Zone of clayey-silty sediments (Ni)

The zone is represented by fine-grained Pannonian compact rocks with variable content of clayey, silty and sandy (in the eastern part often tuff) sedimentary rocks. Sporadically, they include beds with carbonate matrix. Gravel beds occur occasionally. Occurrences in Austria are concentrated especially in the N between Parndorf and Potzneusiedl.

The rocks of this zone have varied consistency. The Pliocene clays are soft while the oldest Badenian sediments are compact to hard. The plasticity index is generally high to very high and increases with the distance from the mountains margins. In compliance with the Standard STN 73 1001 the compacted soils in this zone can be assigned to classes F6 to F8. According to the Standard STN 73 3050 we rank the mentioned rocks in the 3rd exploitability class. The most unfavourable engineering geological property of the rocks in the zone is their generally risky congealing capacity and their overall increased susceptibility in contact with water.

With regard to the permeability of the soils, we rank them as aquicludes with a very low permeability coefficient.

The weathering susceptibility is high. If a slope is undercut, either by river erosion or due to human activity slope movement might be triggered. Such geodynamic phenomena can be observed, *e.g.* in the area between Sered and Hlohovec. At this location the Váh River has undercut the adjoining slope, which is covered by compacted Neogene sediments. The slope movement disrupts the road body and jeopardises the buildings. Similarly, the landslide near Viπtuk was caused by the action of the Viπtuck″ potok brook. In this case, the road surface has been damaged and the dam of the Viπtuk water works has been threatened. In both cases the landslide bodies were more or less drained by means of dewatering boreholes. In the area north of Sered a monitoring system has been established.

The rocks of the zone can be used for building constructions and for brick-making (Devínska Nová Ves, Pezinok *etc.*) as well as for blending clays in for the cement production (in RohoΩník). The thickness of clays and absence of sandy intercalations is generally sufficient to assure safe waste disposal.

Zone of sandy sediments (Np)

The sand beds of the Pannonian are unconsolidated. They are mainly well-stratified and bear intercalations of sandstone with carbonate matrix at the bottom. This zone also includes unconsolidated or slightly consolidated Neogene sediments. Occurrences in Austria are of only minor importance. The Pliocene sands are moderately compacted to compacted. The Miocene sands are always compacted. The sands are often cemented by carbonate or clayey matrix. The bearing capacity of Neogene sands increases in accordance with the distance from the mountains and with the higher clay content.

According to the Standard STN 73 1001 the rocks of the mentioned zone belong to the classes S1 to S3 and the sands with clayey admixture to classes S4 up to S5. In compliance with the Standard STN 73 3050 we rank them into 2nd a 3rd mineability classes.

The permeability coefficient of the sands in this zone ranges from 10^{-7} to 10^{-4} m/s[1]. It decreases in function of the increasing compactness of sands (porosity drop) and with the increase of clay content, or silty fraction. The groundwaters in Neogene sands from the margin of the Malé Karpaty Mts are slightly mineralised. The groundwaters of the Podunajská níΩina Lowland are often characterised by sulphate aggressiveness. The sulphates derive from agricultural activities.

The area covered by Neogene sands is characterised by a very smoothly modelled morphology. Only river erosion causes steep slopes with landslide scars. The stability of the slopes is threatened during technical works (cuts and excavations).

The area of the Záhorská níΩina Lowland is generally afforested, while the Podunajská níΩina Lowland is cultivated by agriculture. If the sands are less compacted and the groundwater is close to the surface, the zone offers foundation soils unsuitable or conditionally suitable for building constructions. The congelation (frost sensitivity) of Neogene sands with higher content of clay has to be investigated with respect to road construction. The rocks of this zone are unsuitable for waste dumping.

Zone of gravelly sediments (Ng)

Neogene gravels are more compacted than the younger terrace gravels. The material is mostly strongly weathered. In comparison to Quaternary gravels, they contain minor part of loamy admixture and are coarser.

This zone is areally rather restricted. It occurs locally at the base of the Pannonian deposits with gravels west of Fertõrákos and in minor occurrences in Austrian part.

Rill and gully erosion is relatively intense on the slopes.

Usually coarse, sandy gravels are sources of groundwater.

Material is suitable for infillings, gravity banquettes and for road construction. Due to the weathered material, their use for making concrete is only limited.

Zone of alternating clayey-silty and gravelly sediments (Nk)

The zone includes mainly terrestrial Oligocene–Miocene sediments of varied composition, as well as formations underlying the volcanic complex of the Börzsöny Mountains, at the margins of the Malé Karpaty Mts, and in the area of the Krupinská planina Plain. The Volkovce, Beladice, Ivanky, Záhorie, Vráble and Studienka formations are part of this zone. In Austria this zone is present in the southern part of the Leitha Mts. (Auwaldschotter).

The rocks of this zone are characterised by almost chaotic alternations of beds and lenses of clays, sands and gravels with various ratio and grain size fraction. From the engineering geological point of view, the thickness and the areal extents are too small to allow differentiation among the lithological types on the small scale map. The individual lithological types are in compliance with the soils in the zones Ni and Np.

Although the gravelly and sandy beds have the highest permeability, the largest yields can be expected in the zone that is in contact with permeable underground or surroundings.

The zone is characterised by smooth slopes, locally disturbed by out-wash erosion. The slopes might be disrupted by erosional impact or by inappropriate building constructions.

The utilisation of the zone depends on the lithological type corresponding to zones of sandy or fine-grained sediments.

Zone of pyroclastic rocks (Vp)

It occupies eastern part of the area under study. Various types of pyroclastic rocks are represented — sandy and aleuritic tuffs and tuffites, tuffitic sandstones and pyroclastic breccias.

The rocks are almost exclusively semi-solid, with uniaxial compressive strength values between 2 and 40 MPa.

Quite distinct is the susceptibility of the mentioned rocks, mainly of syngenetically, or postgenetically altered ones, to weathering. The intensity of weathering causes in several cases that the rock breakdown to form sand. Fresh rocks we assign, according to the Standard STN 73 1001, into classes R3 and R4, and in case of intense weathering into R5 and R6.

The water-bearing of the pyroclastic rocks is conditioned by their genesis and grain size. Pore permeability predominates, but the fissure permeability is also important. Mineral springs also occur. The aggressiveness is usually of the hydrocarbonate type.

Despite the fact that the relief is characterised by smooth slopes, the dissection is relatively high. A decisive factor, responsible for the breakdown of the Krupinská planina Plain into discrete blocks, is the outwash, generally selective erosion. The andesite pyroclastics in the Burda area are being quarried as construction materials. The zone is predominantly afforested, the site index of soils ranges between 3 and 7. It offers good conditions to found buildings, a limiting factor may be the outwash erosion. If sufficiently large and thick, the silty and pelitic tuffs and tuffites provide good environment for waste disposal.

Zone of effusive rocks (VI)

The rocks of this zone occur mainly in the eastern part of the area under study, in the Krupinská planina plain, Burda Mts in the Slovak part, in Börzsöny and Pilis Mts. The main types of rocks are extrusive and intrusive andesites of the Mátra, Vinica and Burda Formations.

Depending on the genesis, mineral composition and postgenetic alterations the rocks of the zone show distinct variations in physical and mechanical properties. The compressive strength of "sound" andesites reaches up to 200 MPa. According to the Standard STN 73 1001 we rank such rocks into R1 class, the mineability class according to the Standard STN 73 3050 is 7. Altered rocks of the zone are of semisolid rocks character in some places.

The relief is relatively intensely dissected and the exposed lava flows create usually positive relief.

Among geodynamic phenomena, the weathering of hydrothermally altered rocks occurs.

The water-bearing of the zone depends on tectonic jointing. Shallow circulation of groundwaters is typical for the weathering zone, the springs have relatively low yield due to the small areal extent of the zone.

The andesites at the Vinica and Hruπov sites are mined for local purposes and for road maintenance. The area of the zone is afforested. Due to jointing the rocks of the zone are unsuitable for waste disposal. The conditions for constructions are limited because of the dissected relief.

Zone of claystone-siltstone rocks (Si)

The zone includes the Eocene and Oligocene marine marl and sandstone sequence. Also Miocene formations with varied lithological composition contain some sequences belonging to this category. Mesozoic rock types of this zone belong to the Marianka formation (also including sandstones, marls and limestones). They occur at the western margin of the Malé Karpaty Mts, between Marianka and Tureck″ vrch Mts. The rocks are black shales with sandstone and crinoidal limestone intercalations, known as the Mariánka shales. Occurrences in Austria are known from the slopes of the Leitha Hills, in the surrounding of the Arbestal Hills and in the area of Neckenmarkt.

The uniaxial compressive strength reaches up to 60 MPa. Therefore they belong to the category of solid rocks. According to the Standard 73 1001 the rocks of this zone belong into class R2 and according to the Standard STN 73 3050 into the classes 4 and 5. The shaly beds are less resistant against weathering.

The clayey shales are practically impermeable. The clastic limestone intercalations with fracture permeability are negligible, due to their limited distribution.

At the W margin of the Malé Karpaty Mts the zone has a smooth morphology. Erosion occurs due to the effect of water and weathering. Most of the zone is afforested. The zone offers suitable conditions for building constructions. The conditions for waste disposal are to some degree favourable.

Zone of flyschoid rocks (Sf)

To this zone we have assigned tiny occurrences of the flyschoid series of the Borinka sequence in the Slovak part of the DANREG area, represented by alternation of sandy limestones and sandstones and silicites. The properties of individual engineering geological types are described in zone of sandstone rocks and zone of limestone rocks.

Zone of conglomerate rocks (Sz)

This zone includes the conglomerates and volcanic tuffs of the Krupinská planina plain, the breccias and conglomerates of the Devínska Nová Ves Member (Badenian) and the feldspathic greywackes, arkoses and polymictic Permian conglomerates of the Devín Formation as well as several minor occurrences in Austria and Hungary.

In compliance with the Standard STN 73 1001 they are ranked into class R2, and in compliance with Standard STN 73 3050 into classes 5 and 6. The technical properties of the zone are similar to those of the zone of sandstone rocks (Sp).

Zone of sandstone rocks (Sp)

We include into this zone Neogene sandstones with carbonate matrix between Sopron and Fertõrákos, the quartzites and arkoses (hard rocks) of the Lower Triassic, the lower terrigenous envelope unit of the Malé Karpaty Mts (LúΩna Formation), which occurs in isolated outcrops in the area of Devínska Kobyla and W and NW of Pezinok. Furthermore, the Jurassic siliceous sandstones and bioclastic limestones at the W margin of the Malé Karpaty Mts are also included. In Austrian part of the area under study only minor occurrences are known.

The Middle Triassic quartzites and arkoses for example are characterised by a very high uniaxial compressive strength reaching as much as 200 MPa. According to the Standard STN 73 1001 the rocks of this zone are assigned into class 1 and according to the Standard STN 73 3050 into the classes 6 and 7. The permeability of the mentioned rocks is relatively high, but due to the limited distribution of the zone the yield of springs is low. A highly uneven morphology is typical (Traja jazdci in the Malé Karpaty Mts).

The zone is afforested. It provides good conditions for building constructions, but it is unsuitable for waste disposal.

Zone of dolomitic rocks (Sd)

The Triassic dolomites in Austria and Slovakia are comprised in this zone. The dolomites have usually thick banks. The exposed surfaces are strongly affected by weathering. Other characteristics are similar to those of the zone of limestone rocks.

Zone of limestone rocks (Sv)

Several lithological rock types belong to this category: In Austria the Dachstein Limestone, the Lower Jurassic limestones, the Miocene reef limestones and the Pliocene–Pleistocene freshwater limestones. Miocene limestones occur mainly in the surroundings of the Leitha Hills and in the Rust Hills. Minor occurrences are found on the NW margin of the Hundsheim Mts limestones on the Braunsberg Mt, the hill with the castle of Hainburg and the western part of the Hundsheim Mts. In the Mesozoic carbonate rocks of the Slovak part of the DANREG area the limestones prevail over dolomites. The zone has a minor occurrence in the Malé Karpaty Mts, east of Borinka Lower Jurassic limestones occur in the Borinka sequence, of the Malé Karpaty envelope unit. Dolomite intercalations occur locally in limestones.

We rank the limestones among the hard rocks: uniaxial compressive strength reaching approximately from 90 to 150 MPa. According to the Standard STN 73 1001 they belong to the classes R1 and R2, while the Standard STN 73 3050 ranks them into class 6.

Permeability is connected with jointing or karst phenomena.

The limestones in the quarry East of Borinka are resistant to weathering. They contain tectonically affected zones and karstic features. They are used as underground material for roads and railways. The zone is afforested. It provides a suitable foundation soils for massive building constructions, but it is not suitable for waste disposal.

Zone of carbonate and clastic rocks (Sk)

The rock complexes in this zone, floored by a variegated sandstone-marl-limestone formation, occur in the Malé Karpaty Mts, in the area between Borinka and Tureck″ vrch. There are marls, sandy-crinoidal to calcareous sandstones, locally chertstones of Early Jurassic age, of the Malé Karpaty envelope unit. The rocks in this zone are characterised by slab-like jointing, and for marls a shaly breakdown is typical.

The greatest weathering resistance have the chertstones with a tendency to form positive features in the relief. The marly limestones are less resistant to weathering. The limestones and chertstones are ranked, in compliance with the Standard STN 73 1001 with the classes R1 and R2, and have the uniaxial compressive strength exceeding 100 MPa, while the marly rocks are characterised by smaller resistance (some 60 MPa) and belong to classes R2 to R4. According to the Standard STN 73 3050 we assign the rocks of this zone into the classes 5 and 6.

The permeability of the mentioned rocks is of fissure type, or fissure-karstic, respectively. The springs occur mainly where the limestones contact marls.

Several quarries are in operation in this zone. The stone from them is being used in road and railway construction. Large parts of the zone are afforested, the meadows occur to a lesser extent. The zone offers suitable conditions to found common types of constructions. To dispose wastes, the zone is mostly unsuitable, excepting the areas floored by sufficiently large marl bodies.

Zone of magmatic and intrusive igneous rocks (Ih)

This zone is characterised by granites and granodiorites, to a lesser extent by diorites in the Malé Karpaty Mts which form an important part of the crystalline basement. The two-mica granite to granodiorite of the Bratislava type (often intersected by abundant pegmatite and aplite dikes) is the most common lithology. The biotitic, mostly fine-grained granodiorite occurs especially in the surroundings of Bratislava.

This type of rock is also outcropping in the Hundsheim Mts. A system of galleries was established for dumping waste. An area of approximately 10 km^2 is without springs. At present the rock is not used in the industry.

The amphibole — and biotite-amphibole diorites are known from the Horsk″ park area in Bratislava.

The rocks of this zone belong to the hardest of the whole Slovak part of the DANREG region. The uniaxial compressive strength reaches 120 to 180 MPa. According to the Standard STN 73 1001 we assign the rocks of this zone into classes R1 and R2 and according to the Standard STN 73 3050 into the classes 6 and 7.

The geomorphology in the zone is high to rolling. Water erosion occurs distinctively in tectonically affected areas.

Fracture permeability is predominant, but the springs have small yields only. The groundwater is only weakly mineralised, but chemical effects can be recognised.

In tectonically affected areas outwash erosion and weathering is effective. For instance, in the area of the Devínska Kobyla Mt clayey fracture fills are known down to a depth of several tens of metres.

Several quarries located in the granodiorites and granites were operated in the past. Presently only the quarry at the southern foothill of Devínska Kobyla near Bratislava, is in operation. The rock, formerly used for building constructions, is nowadays used for roads and railways, irrigation and drainage purposes and river embankments. The zone is suitable for building construction, and conditionally suitable in the tectonically disrupted and weathered zones. The zone is to some extent suitable for dumping waste. Tectonically disturbed areas are unsuitable in all respects.

Zone of low metamorphosed rocks (Mn)

In Hungary, the gneiss and mica schist complexes of the Sopron Hills belong to the zone of low-epimetamorphic rocks. Another small patch can be observed north of Fertõrákos at the state boundary. In Austria, small occurrences of the zone are known in the Leitha Mts and S of Sopron. In Slovakia, the rocks of this zone have only limited distribution in the area of the Malé Karpaty Mts. The rocks are regionally metamorphosed and their contact is epimetamorphic. They occur predominantly in the Harmónia series, NW of Pezinok. The bulk of them consist of sericitic-chloritic phyllites, sericitic-biotitic and biotitic phyllites, the green schists of Marianka and Harmónia successions and graphitic schists and metaquartzites and metapelites. Also the schists and schistose gneisses from the Dúbravka area belong to this zone. A small occurrence of the zone of low-metamorphic rocks is also located north of the Ipel'ské Predmostie. The rocks cropping out here are phyllites, quartzites and metadiabases of the Hron Complex of Young Palaeozoic age.

The rocks of this zone are characterised by schistose decomposition. The uniaxial compressive strength reaches 20 to 70 MPa, therefore we assign these rocks into classes R3 and R4 according to the Standard STN 73 1001 and according to the Standard STN 73 3050 into the mineability classes 5 and 6.

The permeability is of fracture type and the springs have a low capacity.

The weathering and the outwash erosion are the dominant geodynamic features in the area. The weathering takes place mainly in cuts and excavations. Due to the low resistance to weathering the use of these rocks as construction material is limited.

The zone is predominantly afforested, but meadows do also occur. The zone has suitable conditions to set up buildings, but it is only conditionally suitable to dispose waste.

Zone of high metamorphosed rocks (Mv)

The zone of highly metamorphic rocks is represented by meso- and catazonally metamorphosed rocks in the Malé Karpaty area. NW of Pezinok and in the S of Bratislava the fine- to coarse-grained amphibolites and biotitic schistose gneisses to paragneisses has the greatest areal extent. They belong mainly to Harmónia series of the Malé Karpaty Mts. The migmatites occur at a small scale west of Svät″ Jur. In contrast to the schistose gneisses, which are characterised by schistose structure, the amphibolites are massive. Minor occurrences in Austria are in the vicinity of the villages of Berg and Jois.

The tectonical decomposition of rocks is responsible for the engineering geological characteristics, such as the uniaxial compressive strength and weathering resistance. The uniaxial compressive strength of amphibolite reaches 200 MPa. According to the Standard STN 73 1001 we assign these rocks into class R1, the schists and schistose gneisses into the classes R1 and R2, and according to the Standard STN 73 3050 into the mineability classes 6 and 7.

The schistose rocks have a limited resistance to weathering. The morphology of the zone is characterised by medium to high-angle slopes, and by local rock walls.

There is fracture permeability. The springs have low capacity. The water has carbonate type aggressiveness.

The amphibolites were considered a good quality construction stone in the past. Ores occur in the area of Pezinok. The zone is predominantly afforested. It offers suitable conditions to set up building constructions. The high tectonically disrupted zones have to be taken into account while designing tunnel constructions. In this zone only restricted areas are suitable for waste disposal.

Zone of residual sediments (R)

This zone was shown in one locality — in the Leitha Hills. The weathering zone on top of the micaschists reaches up to 15 m there. It contains sporadical quartz veins.

The geotechnical characteristics are similar to the zone of deluvial —slope— sediments. The material has a character of fine soils. The plasticity is high. The textural prints of the mother rock are partly preserved.

It is suitable for waste disposal.

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