Assessing the Geological Environment Constituents of the Neogenous Sediments Related to Various Geotechnical Applications

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Abstract. The paper aims to assess the geological environment constituents of the Neogene sediments related to different geotechnical applications. The environment of Neogene sediments is a very important geological environment for the Czech Republic as it may be found, for example, below the Quaternary geological structure of the Ostrava Basin. This environment appears as unfavourable from many points of view, but there are also interactions with engineering structures that may also have a positive character.

1. Introduction

The paper aims to describe a special engineering-geological and geotechnical environment that is rather abundant both in the Czech Republic and Slovakia. These are Neogene (Miocene) sediments of clays and claystone that are very characteristic geological environments to be found below Quaternary sediments. In practice, it means that if the Quaternary sediments are not very thick, this environment becomes significant and may be exploited in different manners. At the same time, there are examples where caution is necessary because of its presence as it may complicate certain implementations.

2. Characteristics

Neogene is a typical geological environment in the Czech Republic (CR) and Slovakia (SR). Its spatial distribution is larger than in other geological units. The reason why engineering geologists are interested in Neogene is the fact that it is often situated under the Quaternary. Three types of occurrences are distinguished:

- Option 1 – if the thickness of the Quaternary structure is low, certain constructions may penetrate all the way to the Neogene.
- Option 2 – if the thickness of the Quaternary structure is high, Neogene remains untouched.
- Option 3 – the Neogene naturally outcrops onto the surface. This mostly happens by river or stream downcuts, or it may get revealed due to a landslide. An example of the Neogene

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outcropping onto the surface due to a slope deformation is the Televizní Street in Ostrava-Lhotka, CR.

Neogene is made up by grey-blue crumbly claystone. It has the character of a fine-grained soil of class F4 - F6. In the building practice, the advantage of Neogene lies in the fact that the layers lying below cannot get contaminated. At the same time, the Neogene layer may serve as the top insulator and prevent, for example, the leak of methane onto the surface. If constructions are founded directly on the Neogene, related problems must be considered and dealt with, such as freezing. If clay minerals contained in the Neogene absorb water that subsequently freezes, the soil or rock structure gets broken. This phenomenon may be prevented by piling a dike above the Neogene layer. In the conditions of the CR and SR, the dike must have at least 1 m as freezing reaches there in the local climatic conditions. Filtration failures are other problems of the Neogene. They may occur during excavation works (suffusion is responsible for the loss of fine particles by erosion due to which a depression may form). An example of the phenomenon may be an accident in the mine shaft Doubrava IV. Other problems may be caused by loess sediments on the slopes due to their susceptibility to swelling and softening. As a result, landslides may form on the slopes [1, 2].

As opposed to other environments, e.g. alluvial environments, the Neogene is less homogeneous. Its parameters differ in dependence on the changes in temperature and moisture. Differential settlement may occur due to the changes in temperature or moisture and in combination with uneven thickness of the overlying layer (Quaternary).

3. Neogene in the Czech Republic

In the Paleogene and Neogene different regional geological units formed in the CR, among which there are ***Krkonoše Piedmont Basin*** that is a group of Limnic Tertiary basins bound onto the Ohře rift south-east of the Krušné hory Mountains. From the WSW to ENE the unit 1 includes the Cheb Basin, Sokolov Basin, North-Bohemian (Most) Basin and Žitava Basin. The ***Cheb Basin*** is the most western Tertiary basin of the Krkonoše Piedmont Basins and lies on the crossing of the Tachov gully and Ohře rift. The sedimentation continued from the Eocene to Pliocene (brown coal, clays, kaolin, diatomites, glass and foundry sands – frequent conflicts of interest) – unit 1a. The ***Sokolov Basin*** is the smallest Tertiary basin in the Ohře rift west-southwestwards from Doupovské hory Mountains with significant deposits of energy raw materials (uranium, brown coal, bentonite, clays) – unit 1b. The ***North-Bohemian Basin*** is the largest Tertiary basin in the Ohře rift between the Doupovské hory Mountains and the České středohoří Upland (brown coal, diatomites, clays, quartz rock, bentonite) – unit 1c. The ***Žitava Basin*** is the Tertiary basin linking onto the Ohře rift. Within the CR it appears as a negligible south-eastern offspur (brown coal, clays, lignite) – unit 1d. The ***Doupovské hory Mountains*** are a complex bedded volcano of the Tertiary age between Kadaň and Karlovy Vary, on the crossing of the Jáchymov Fault and Ohře rift. Alkali volcanites are represented mainly by olivinic basalts, leucitic tephrites and abundant tuffs. Phonolites (aggregates, bentonites) are missing – unit 2a. The ***České středohoří Upland*** is s classical area of the Tertiary alkali volcanites (olivinic basalts to phonolites) stretching in the Ohře rift between Nový Bor and Chomutov, with the main volcanic centre near Roztoky n. Labem (diatomites, pyropes, aggregates, feldspar substitutes) – unit 2b. The ***South-Bohemian Basin*** is a fresh-water sedimentation area of the Upper Cretaceous and Tertiary Age, where the Lišov rock bar of the crystalline complex separates the eastern *Třeboň Basin* from the smaller western *České Budějovice Basin* – unit 3. The ***České Budějovice Basin*** is a smaller basin in the west, belongs to the system of South-Bohemian basins, is filled with fresh-water sediments of the Upper Cretaceous, and to a smaller extent with the Neogene and Quaternary. There are rare sea ingressions from the Alpine foredeep (tectites, lignite, gravel-sands, diatomites) – unit 3a. The ***Třeboň Basin*** is a larger eastern basin from the system of South-Bohemian basins, filled with continental Cretaceous and Tertiary sediments (clays, kaolin, diatomites, bentonite) – unit 3b. The ***Outer Klippen Belt of the Western Carpathians*** is made up by extensive fragments of Jurassic and Cretaceous sediments carried from the depth, in the face of the flysch belt nappes – Štramberk, Pavlovské vrchy (limestone) – unit 4c. The ***Carpathian Foredeep*** is an external part of the Carpathian Range in the eastern Moravia, which formed in front of the face of the Outer

Carpathians nappes and lies on the south-eastern slope of the Bohemian Massif. It is filled with the Miocene sediments of the Egerian to Badenian (natural gas, natural oil, bentonite, clays and gypsum in the Opava Basin) – unit 4a. The ***Vienna Basin*** is an extensive Tertiary Neogene basin with sea and gradually fresh-water sedimentary filling that is over 5 000 m thick (natural gas, natural oil, lignite) – unit 4b. The ***Carpathian Flysch*** is a part of the Outer Carpathians in eastern Moravia, made up by clayey and sandy sediments of the Cretaceous and Paleogene, with prominent nappe structure of pre-Miocene Age. It builds the Ždánický les, Chřiby and mountain ranges on the border with Slovakia – Javorníky Mountains, Beskydy Mountains, and White Carpathians – unit 4c [3].

4. Selected properties of Neogene foundation soils in the Czech Republic – Engineering-geological conditions of the Ostrava interest area

The zone of alternating fine, sandy and gravel sediments and the zone of Miocene sediments are the zones of the Neogene geological structure in the map sheets of the engineering-geological zones in the Ostrava Region. Marine calcareous clay and claystone with layers of fine sands of the Outer Carpathian Foredeep of the Miocene age are classified in classes F4, F6, F8, S3 – S5 [4, 5, 6, 7]. They are susceptible to changes in the volume, such as swelling and softening, and they are low permeable. The soils are suitable for undemanding engineering structures.

The prevailing foundation soils are made up by 60.5 % of clays of class F8 (CH, CV), clay of class F6 (CL, CI) with 31.4 %, and clay of F4 (CS) with 5 % proportion. The classes F3 (MS), F7 (MH, MV, ME), S4 (SM) and S5 (SC) hardly reach 3.1 %.

Table 1 compares the arithmetic means of the properties of Neogene clays of class F8 (CV) in the interest area, and of the Neogene Brno clay of class F8 (CV) [8]. As the properties differ, it is not possible to produce a uniform typology of foundation soils without overestimated parameters for any locality, but only for a particular area.

Table 1. Comparison of Neogene clay in the area of interest and the Neogene Brno clay [8] as foundation soil of F8 (CV) class

Properties	Neogene Brno clay F8 CV	Neogene clay in the area of interest F8 CV
water content (%)	33	23.8
apparent density of solid particles ($g\cdot cm^{-3}$)	2.698	2.75
bulk density ($g\cdot cm^{-3}$)	1.883	1.97
liquid limit (%)	76.6	72
plasticity index (%)	46.7	26.8
consistency index (-)	1.1	1.02
porosity n (%)	48	42.35
degree of saturation (-)	0.91	0.92
effective cohesion (kPa)	40	24
angle of internal friction (º)	19º	20.26º
total cohesion (kPa)	180	200
angle of internal friction (º)	8º	6.4º
oedometric modulus (MPa)	15	16.7

5. Neogene in the Slovak Republic

The Neogene sediments within the Western Carpathians fill the young depression structures: basins and intra-montane depressions (valleys). Their formation and development is connected with Alpine orogenic processes and the period of Cenozoic, i.e. time frame of 24 – 1.8 million years. The mechanism of their formation and development is very complex and depends on their location within the current Alpine-Carpathian arc. The sediments filling the depression structures settled in the marine-continental conditions, while the conditions often altered in the geological timing. The result of the subsidence of the sedimentary depocentres, upheaval of the surrounding mountain ranges and continuous volcanic action, producing various types of materials, is often thick (as much as 8 000 m) accumulations of sediments. In the fillings of the basins and valleys prevail the detritic sediments – sands/sandstone, gravel/agglomerates, clay/claystone, silt/siltstone – accompanied by the seams of coal and lignite, evaporites and carbonates (organogenic or fresh-water limestone). The sediments are the parent rocks but also suitable reservoir rock for the deposits of natural oil and gas. The different lithological types of rocks, in dependence on the sedimentary marine-freshwater conditions, contain fauna and flora. Their study and classification (biostratigraphy) with the help of their radiometric dating permitted the determination of the sediment age. The outcome is the classification of the different stages of the Neogene and Budin Paleogene (chronostratigraphy). For the practical comparison of the sediments it was necessary to introduce lithostratigraphic units (formations and layers). The basic division of the Neogene basins and valleys of the Western Carpathians in Slovakia respects their spatial distribution and structural style. In Slovakia we classify the following basins: 1. Vienna Basin (Slovak part), 2. East-Slovak Basin, 3. Danube Basin (Slovak part) with foredeeps 3a. Blatniany, 3b. Rišňov, 3c. Komjatice, 3d. Želiezov and 3e. Gabčíkovo, 14. South-Slovak Basin with the valleys 14a. Ipeľ, 14b. Lučno, 14c. Rimava and 14d. Cerová vrchovina. Among the valleys there are: 4. Bánov, 5. Upper-Tatry, 6. Turčiany, 7. Ilava, 8. Trenčin, 9. Upper-Hron Region, 10. Rožňava, 11. Orava, 12. Žiar and 13. Zvolen-Slatina Valley.

Looking closer at the ***Vienna Basin,*** it is a complex intra-montane basin. As a whole, it spreads on the divide of the Eastern Alps and Western Carpathians, whose units form its bedrock. It opened in the vicinity of a subduction zone (overthurst zone) of the Western Carpathians in a pull-apart system on shallow crust faults. Two levels are distinguished in its structure. The Early Miocene level is made up by sedimentation in shear cuts or depressions carried on the back of flysch nappes (piggy-back type). The Medium and Upper Miocene level is related to the opening of the basin in its faults in NE-SW direction. This younger level may be characterised as a pre-arc basin when related to the volcanic arc. By the end of the Miocene and Pliocene the basin became parts of the Pannonian Basin and faded. The Neogene sediments are as much as 5 500 m thick. Another basin in Slovakia, the ***Danube Basin*** divides into Blatniany, Rišňov, Komjatice and Želiezov deeps. They are separated by heart ranges of the Small Carpathians, Považský Inovec and Tribeč. The central part is represented by the Gabčíkovo depression. The pre-Neogene bedrock is made up by the units of the Central Western Carpathians and Zadunajské středohoří Upland (Pelsó Unit). The Danube Basin has undergone a complicated geological development as well as it has a complex geological structure. The Lower Miocene sediments in the north part of the Blatniany and Rišnov deep developed in the zone of the horizontal shifts. At the end of the Lower Miocene the basin began to open as an extensive basin due to asymmetrical pulling-apart of the earth crust. The initial subsidence (sedimentation in big troughs) controlled by faults occurred in the Medium Miocene and was more intense on the northern edge of the basin (in the sinks) than in the Gabčíkovo depression. The maximum thickness of the sediments of this stage exceeds 3 000 m on the north and on the south it has only around hundreds of metres. This was caused by the upthurst of the crust in the south because of overheating. The spread of the sediments of the next stage (Pannonian – Pliocene) was reverse. The thickness of the sediments in the southern part reaches the thickness of 5 000 m, while in the outer zones it is in the order of tens of metres. Since the Upper Miocene it became part of the Pannonian Basin. The ***South-Slovak Basin*** is a separate basin in the geological sense. Within Slovakia there are sediments in the northern border area of three overlying basins – Budín (Hungarian Paleogene Basin), Fiľakovo (Filakovo–Petervasara) and Nové hrady. The sediments of the basins fill three partial valleys – Ipeľ, Lučno and Rimava – and participate in the structure of Cerová vrchovina

Upland. The basins are in the behind-arc position. They formed in the area of mobility that was predetermined by the tectonic leak of lithosphere fragments from the Alps and Dinarides. In the sedimentary Tertiary filling there are also the Miocene and Pliocene to Quaternary vulcanite's. The thickness of the sediments in such depressions in Slovakia reaches as much as 1 500 m. The last basin is the ***East-Slovak Basin*** and it makes part of an extensive Trans-Carpathian Basin. Its dominant part spreads on the interface of the Western and Eastern Carpathians. The Neogene sediments and vulcanite's lie in the overburden of varying structural-geological units and reach the thickness of about 8.5 km. It is a complex intra-montane pre-arc basin, intra-arc from the Sarmatian. Its formation was conditioned by pulling crust apart and subsequent opening on the transformation faults. Since the Upper Miocene it has become parts of the Pannonian Basin. Some valleys have a two-level structure. The lower level is marine and the upper is lacustrine or fluvial (Bánov, Upper-Nitra, Turčiany, Ilava and Trenčín. The Orava and Rožňava valley only has a lacustrine level. [9,10]

6. Conclusions

The environment of Neogene sediments must be perceived as an important type of pre-Quaternary geological environment. With regard to its abundant spatial distribution in the Czech Republic and Slovakia, Neogene sediments play an important role, particularly in terms of geotechnical applications. As for the engineering geology, it is an environment prone to freezing, in which we may expect problems with swelling, softening and landslides at natural or artificial interventions and under the excess of water. Therefore, relevant measures need always be taken, such as insulation of the environment by another type of non-freezing material in a layer corresponding to the non-freezing depth based on the climatic conditions. On the other hand, a great advantage of Neogene sediments is their impermeability (hydrogeological insulator), which may be used to prevent the spread of pollutants/ contaminants into lower geological layers.

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