Evolution of Sofia Basin during the Neogene

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Lithostratigraphic notes

The sedimentary fill of Sofia Basin represents a large variety of sedimentary rocks grouped into four lithostratigraphic units — variegated terrigenous formation, Gniljane, Novi Iskar and Lozenec Formations (Kamenov, Kojumdgieva, 1983) that represent the distinct stages of the basin evolution — alluvial, marshy-lacustrine and lacustrine.

The variegated terrigenous formation is presented by irregular alternation of clayshales, siltshales, sands and sandstones, varying in color. Gniljane Formation comprises conglomerates, sands and sandstones, siltstones and silty clayshales with lignite interbeds in the upper part (Balsha Member). Novi Iskar Formation comprises gray to gray-bluish clays, diatomaceous clays, silty clays and siltshales as well as varves, composed of alternation of carbonaceous and clayey siltshales. Lozenec Formation consists of irregular alternation of clays, siltshales, sands, and conglomerates with lignite interbeds (Novi Han Member) in the lowermost part of the formation and with micrite limestones (Bogioveci Member) in the upper part of the formation (Yaneva, 1998). The thickness of Neogene sediments in Sofia basin varies from 10 m in the borders up to 1400 m in the central parts.

Sedimentological and geotechnical characteristic

From geotechnical point of view the soils can be subdivided in two groups — cohesive, which include clayey sands, sandy and silty clays and cohesionless sands and gravels. Sands were deposited during the alluvial periods and also as shoreline sediments during the lacustrine stage of the Sofia Basin development. Cross bedding and ripple marks are common structures. Massive sand beds or discontinuous wavy parallel stratification are rarely observed. Quartz and feldspars are principal minerals in sands. Biotite, muscovite and rock fragments are in insignificant amount. According to mineralogical classification proposed by Pettijohn et al. (1972), sands from Gniljane Formation belong to the group of arkoze and subarkoze, whereas quartz sands and subarkoze are characteristic for Lozenec Formation. Monomineral quartz sand is well to medium sorted. Subarkoze and arkoze are poor and medium sorted. Grains from all sand are subrounded to subangular (0,3-0,5 according to Power's scale of roundness). These features reflect on the geotechnical parameters and will be of great importance for the future microseismic zonation of the Sofia Basin (Berov, Ivanov, 1995). The sands and the clayey sands of the Upper (yellow-brown) complex of the Lozenec Formation (Petrov, Ilieva, 1960; Dancheva, 1969) are compacted and their strength and deformation properties are similar to those of the sands from the Lower complex (Ivanov, 1996). The fine sandy or silty fraction prevails in the sands of the Lower (gray-green) complex of the Lozenec Formation. Some of the coarse-grained sands, from lower parts of the section possess relatively high strength parameters. The density of the sands increases with the increased variety of their grain-size. According to their void ratio sands are classified as medium compacted to compacted. Under conditions of compression they behaves as soils of slight settlement. (Tabl. 1)
Table 1
Physical and mechanical properties of Neogene soils from the region of Sofia

<table>
<thead>
<tr>
<th>Lithological varieties</th>
<th>Bulk density $\rho_b$ (g/cm$^3$)</th>
<th>Dry density $\rho_d$ (g/cm$^3$)</th>
<th>Water content $W_w$ (%)</th>
<th>Void ratio $e$</th>
<th>Compressibility modulus $\mu$ (MPa)</th>
<th>Cohesion $c$ (kPa)</th>
<th>Angle of int. friction (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow and gray-yellow fine silty sand</td>
<td>1.72</td>
<td>1.36</td>
<td>26.9</td>
<td>0.98</td>
<td>5.5 - 14</td>
<td>10-30</td>
<td>20-29</td>
</tr>
<tr>
<td>Yellow medium to coarse sand</td>
<td>1.85</td>
<td>1.76</td>
<td>9.5</td>
<td>0.52</td>
<td>9 - 25</td>
<td>-</td>
<td>28-36</td>
</tr>
<tr>
<td>Yellow-brown clays and sandy clays</td>
<td>1.99</td>
<td>1.2 -1.8</td>
<td>13 - 50</td>
<td>0.5-1.4</td>
<td>5 - 11</td>
<td>12-55</td>
<td>22-34</td>
</tr>
<tr>
<td>Grayish-green silty clays and sandy clays</td>
<td>1.84</td>
<td>0.8-1.7</td>
<td>21-51</td>
<td>0.6-1.5</td>
<td>7 - 20</td>
<td>30-128</td>
<td>16-30</td>
</tr>
</tbody>
</table>

All sedimentological features as texture, structure, mineralogical composition, grain-size, roundness and sorting indicate a short distance transport of the clastic material. The abundance of feldspars in arkozes and subarkozes is evidence for relatively cold climate combined with rough relief in the source area where mechanical weathering prevails over the chemical one.

Smectite, illite and kaolinite are the principal clay minerals in clays. In the lower part of the section (Gniljane Formation) kaolinite prevails over smectite and illite, whereas its amount decreases upwards and smectite becomes the most abundant clay mineral in the youngest Lozenec Formation. The behavior of clay strata depends on the mineral composition, water content, type of structural bonds, etc. In the yellow-brown clays and sandy clays smectite predominates, but illite prevails in the grayish-green silty clays. Yellow-brown clays are more susceptible to swelling — up to 48 %, whereas gray clays swell 5-8 %. There are significant differences in their strength parameters, too. Yellow-brown clays possesses average cohesion 22 kPa, which is 3 times less than the cohesion of gray clays (Tabl.1). Smectite domination in the upper part of the section must be taken into consideration during the construction works (Berov, 1996). The prevalence of smectite and illite over kaolinite in the upper parts of the sequence indicates that climate become cooler during the Late Pontian and Dacian. The assumption about colder and dry climate is supported by data obtained after diatom analysis (Oggnjanova-Rumenova, Popova, 1996). The simultaneous presence of smectite, kaolinite and illite indicate a typical association of clay minerals for hydrological open freshwater lake (Allen, Collinson, 1986).

Evolution of Sofia Basin

The geological evolution of Sofia Basin determines behavior and mechanical properties of the sediments deposited there. Geotectonic evolution of Sofia Basin proceeds under block disintegration tectonics of the basement and the basin frame. It started at the Early Meotian, when the sediments of the variegated terrigenous formation had been deposited in the central and northern parts of the basin.

During the Early Pontian a well-developed river net occurred in the region (fig.1A) and alluvial sediments of Gniljane Formation had been deposited there. Sediments from the northern part of the basin show textural and structural features, typical for facies of braided river systems. It is most likely that these streams had run down the northern slopes of the basin borders. Alluvial sediments deposited in the central and southeastern parts of the basin are more fine-grained fine sands and clays. Such sediments are characteristic for streams with lower water dynamics and well developed flood plain like meandering rivers.

The continuing subsidence of the basin and partial or full separation of some meanders had created favorable to coal formation conditions (Balsha Member). Thus, during the Early Pontian, alluvial and lacustrine-marshy environment existed contemporaneously.

Fast subsidence of the central and northern parts of the basin, accompanied with faulting, had initiated the formation of the large eutrophic lake with well-developed littoral zone. Sediments of Novi Iskar Formation had been deposited there (fig. 1B). Abundance of the photosynthesizing flora and carbonate rich coasts had favored precipitation of calcite. The formation of varves is due to the seasonal char-
character of the flora in the basin. The temperature regime was quite similar to those in recent lakes at temperate latitudes (Ognjanova-Rumenova, Popova, 1996). During the Late Pontian sedimentation of clays of Novi Iskar Formation occurred contemporaneously with deposition of littoral lacustrine sediments (limestones) of Lozenec Formation (Yaneva, 1998).

At the end of the Pontian and in the beginning of the Dacian, a shallowing of the basin started. Gradually lacustrine conditions changed into lacustrine-marshy with deposition of coal-bearing sediments (Novi Han Member of Lozenec Formation). Lacustrine conditions prolonged until the Early Dacian in the northeastern and northwestern parts of the Sofia Basin. Development of the alluvial system with braided systems in the borders and meandering rivers in the central parts had continued during the Dacian and Romanian time (fig. 1C). The subsidence had been most active in the central and southeastern parts of the basin during the Dacian and Romanian where it was compensated by accumulation of a thick alluvial sequence.
Conclusion

Three stages of the basin evolution were determined in Sofia Basin on the basis of sedimentological and engineering-geological studies — an alluvial stage when braided and meandering river systems with local swamping developed (Late Meotian-Early Pontian); a lacustrine stage characteristic with the development of a large hydrologically opened lake (Middle and Late Pontian); and the last alluvial stage with the development of braided and meandering river systems with local swamping, again (Dacian-Romanian). The lateral and temporal distribution of the sediments deposited during distinct stages reflects on the engineering-geological zonation of the treated area. The physical-mechanical properties of the deposits of the subsurface zone vary in wide ranges due to their mineralogical, grain-size composition, water content, type of structural bonds and degree of compaction. The results of the present study could be useful for the urban planning and development of the Sofia City as well as for antiseismic construction in all over the basin.

References

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