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Review paper

Geological Characteristics of the Oil Fields in the Slovenian Part of the Pannonian Basin

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PROCEEDINGS

Key words: Geological structure, Potential source rocks, Reservoir rocks, Structure traps, Oil-gas fields.

Ključne riječi: geološka struktura, potencijalne matične stijene, kolektorske stijene, strukturne zamke, naftno-plinska polja.

Abstract

In the Slovenian part of the Pannonian basin the oil-gas field Petišovci, the gas fields Dolina and Gančani, and the oil fields Filovci, Bakovci and Bukovci were discovered. With the exception of Petišovci, the mentioned fields are currently non productive. On this basis, and as a consequence of recent results of oil geological investigations, the lithostratigraphic description of the Neogene beds of this part of the Pannonian basin is presented, together with occurrences of source rocks in the given stratigraphic horizons, as well as the structural characteristics of the territory. The results highlight the somewhat higher potential of certain areas, which is also of importance economically.

Sažetak

U slovenskom dijelu Panonskog bazena u proteklom je razdoblju otkriveno naftno-plinsko polje Petišovci, plinska polja Dolina i Gančani, te naftna polja Filovci, Bakovci i Bukovci. Od spomenutih nalazišta danas je u proizvodnji samo polje Petišovci. Na temelju prije spomenutog i s obzirom na rezultate novijih istraživanja, prikazan je litostratigrafski sastav neogenskih naslaga ovoga dijela Panonskog bazena, te pojave matičnih stijena i strukturna grada područja. Iznijeto je i mišljenje o nešto većoj perspektivnosti istraživanja na nekim područjima, što bi bilo i ekonomski najvažnije.

1. INTRODUCTION

The Slovenian part of the Pannonian basin is known as the Mura depression (AKSIN et al., 1981). This represents one of the deep depressions in the marginal area of the southern and southwestern parts of the Pannonian basin.

The Mura depression is bounded in the west by the massifs of the Eastern Alps, Pohorje and Kobansko with Kozjak, and along the southwestern side by the extensions of the Eastern Karavanke Mountains (Fig. 1). The eastern extensions of these mountain chains were submerged during the Neogene when the basin was formed and in which the Neogene beds were deposited. The total area of the Slovenian part of the Mura depression is approximately 2,640 km^2.

At the end of the 19th century oil was discovered at Selnica in the neighbouring Croatian part of the Mura depression. In the Slovenian part of the depression during the Second World War two fields were discovered: the Petišovci oil-gas field and the Dolina gas field. After the war, the gas field Gančani was discovered, as well as the three oil fields, Filovci, Bakovci and Bukovci (Fig. 1).

In the past, geological and geophysical investigations over a wider region were performed, and a number of deep boreholes were drilled. The results of these investigations included the lithological and stratigraphical study of Neogene deposits, determination of the lithological composition of Pre-Tertiary basement, and tectonic subdivision of the Mura depression into individual units. In terms of petroleum geology the source rocks were identified from which the hydrocarbons migrated into favourable reservoir rocks and pools. A number of structural problems were solved, and also the general structures and tectonic units of the known oil and gas fields were determined.

This lithostratigraphical and tectonical framework is presented, together with the petroleum geological characteristics, and the economically optimal areas for future investigations are highlighted.

2. LITHOSTRATIGRAPHY

The geology of the Mura depression can be separated into three distinct units: the Pre-Neogene basement, the Tertiary sediments (mostly Miocene-Pliocene), and the Quaternary cover.

The Pre-Neogene basement consists of metamorphic rocks and Mesozoic sedimentary rocks. Among the metamorphics gneisses prevail, with mica schists, amphibolites and lenses of eclogite, marble and quartzite (Middle Austroalpine). These rocks are overlain by phyllites (Ordovician) and Silurian-Devonian

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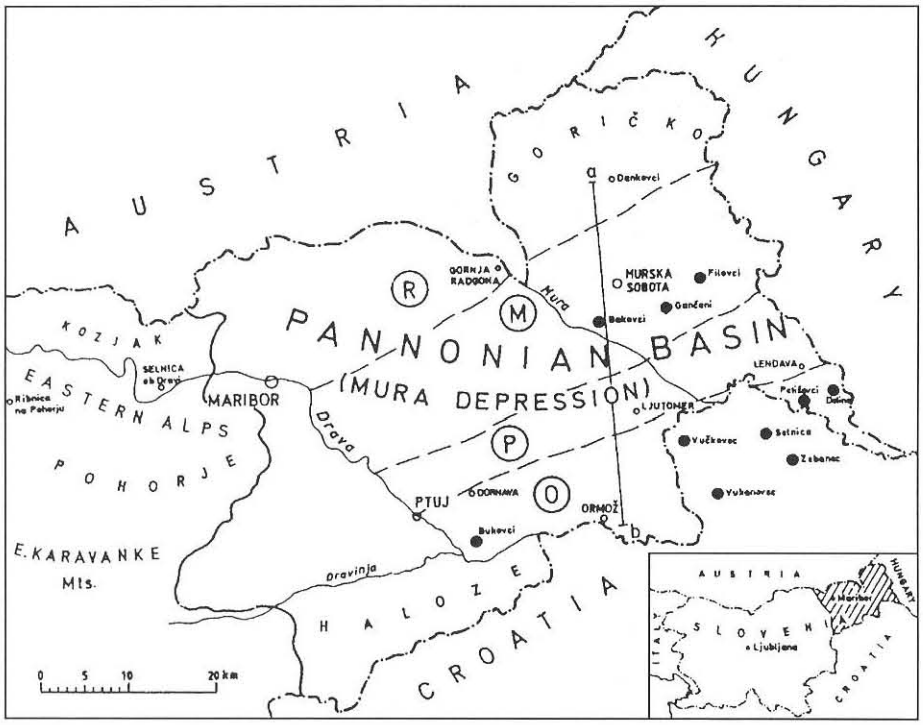

Fig. 1 Sketch-map of the tectonic units of the Mura depression. Legend:
R - Radgona depression;
M - Murska Sobota massif;
P - Ptuj-Ljutomer Depression;
O - Ormož-Selnica antiform;
a—b - trace of the profile;
- - - - supposed border between tectonic units;
• - oil-gas fields.

dark and greenish schists. These beds were overlain by Permo-Triassic red sandstones (Upper Austroalpine). The Triassic is represented by limestones and dolomites, and the youngest Mesozoic member is represented by Senonian limestones, breccias and marls (PLENIČAR, 1954, 1979; FLÜGEL, 1988; MIOČ et al., 1993).

The Tertiary sedimentary rocks consist of Neogene beds from Ottnangian - Pontian age (RIJAVEC, 1976). The Ottnangian-Carpathian deposits include conglomerate, sandstone and siltite. In the lower part of these beds individual layers occur (2-10 m thick) of bituminous black marl that was identified as the source rock of the hydrocarbons. In the upper part dacitic-andesitic tuff occurs between marls and sandstones. The Badenian beds are represented in their lower part by poorly consolidated coarse grained breccia and conglomerate with sand, overlain by marl and lithothamnian limestone. During the Sarmatian clastic deposition continued, and the marine environment became gradually brackish. Marls, sands and conglomerates are the characteristic lithological members (RIJAVEC, 1978). This clastic deposition persisted throughout the Pannonian and Pontian.

Lithostratigraphically the Neogene beds can be subdivided into three formations: the Murska Sobota formation, from Lower Miocene to Lower Pannonian, the Lendava formation, from Upper Pannonian to Lower Pontian, and the Mura formation, from Dacian to Romanian.

South of the Drava River, in the area of Haloze and westerly, in the Southern Karavanke, older, Upper Oligocene (Egerian) beds also occur in which the andesitic tuffs of the Smrekovec series are especially characteristic (ANIČIČ & JURIŠA, 1985; MIOČ, 1978).

3. OVERVIEW OF THE GEOLOGICAL STRUCTURE

The wider region of the Mura depression lies, in the geotectonic sense, in the eastern extension of the Eastern and Southern Alps that represent the Pre-Tertiary basement of this territory. After intensive tangential movements and overthrusts the basement disintegrated into individual blocks (tectonic units) before the Miocene. In the areas of subsided units basins formed in which rapid deposition took place. Tectonic activity of various degrees also continued during deposition of the Neogene beds, as evidenced by the variable thickness of the Neogene sediments. Vertical and horizontal movements and weak overthrustings at reverse faults (e.g. the Ljutomer fault) are characteristic. In this manner units were formed in the shape of depressions (e.g. the Radgona depression) and uplifted blocks - horsts (e.g. the Murska Sobota massif that passes into Pohorje in the west).

During prospecting for oil and gas, special attention was paid to solving the stratigraphic-tectonic and structural problems of the wider region. These problems were studied by numerous authors, among them PLENIČAR (1954), ŠIMON (1973), KISOVAR (1977), MIOČ & ŽNIDARČIČ (1989), ĐURASEK & HARI (1992), and others. After geophysical investigation and deep drilling the following, more important units were distinguished from north to south: the Radgona depression, the Murska Sobota massif, the Ptuj-

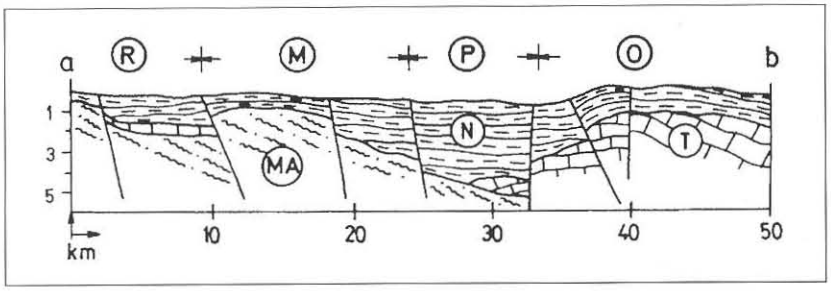

Fig. 2 Schematic cross-section of the territory between the Radgona depression and the Ormož-Selnica antiform. Legend: N) Neogene (mostly sand, sandstone, marl and clay); T) Triassic (limestones, dolomites and dolomite breccia); MA) Middle and Upper Austroalpine (gneiss, amphibolite, phylite); —) Fault.

Ljutomer depression and the Ormož-Selnica antiform (Figs. 1 and 2).

The geological structures of the Pre-Tertiary basement that extend in the NE-SW direction are not laterally equivalent, and deposition of the Neogene beds did not commence at the same time in all localities.

In the Pre-Tertiary basement of the Radgona depression Older Palaeozoic shales, Permo-Triassic sandstone, and limestone with dolomite, as well as Cretaceous beds occur. This basement was overlain by Neogene sediments. Their thickness increases towards the northeast where it exceeds 4,500 m. The extension of this unit towards the southwest is represented by the Ribnica-Selnica graben (MIOČ, 1977).

The Murska Sobota massif lies to the south of the Radgona depression. In the geological structure of the Pre-Tertiary basement gneisses, mica schists, amphibolites (CIGIT, 1958) and even eclogites were determined. The massif was totally submerged during the Badenian after which the first Neogene sediments were deposited (in the apical part), and they exceed 2,000 m in thickness. The southwestern extension of this unit is the Pohorje massif. The geological structure of the wider surroundings indicates the possibility of erosional remnants of carbonate beds (Upper Triassic) in the southern margin of this unit.

The Ptuj-Ljutomer depression lies to the south of the Murska Sobota massif and it represents the submerged part of the territory between this massif in the north and the Ormož-Selnica antiform in the south. The Pre-Tertiary basement predominantly consists of metamorphic rocks, gneisses, amphibolites, and possibly also phyllites. Individual "patches" of crushed to mylonitized dolomite (Upper Triassic) are preserved on the metamorphics. The thickness of the Neogene beds attains 4,000 m in the borehole near Ljutomer. The crushed dolomite, approximately 40 m thick, beneath these beds, represents a tectonic remnant of the overthrust on gneiss. The Ptuj-Ljutomer tectonic unit continues towards the southwest, and its extension is probably the Mežica-Vitanje graben which lies between Pohorje in the north and Northern Karavanke in the south (MIOČ et al., 1993).

The Ormož-Selnica antiform is the most southerly of the described units. The northern limit with the Ptuj-Ljutomer depression is of tectonic character, represented by the Ljutomer reverse fault that dips to the south. The Pre-Tertiary basement of the Ormož-Selnica antiform, as suggested by the regional analysis of the geological structure, consists of Mesozoic, predominantly Triassic beds of the Northern Karavanke. These beds are overthrusted on the metamorphic basement in the Northern Karavanke Mountains. In the course of forming of the Pannonian basin these structures subsided. The Neogene sediments that were deposited on them were deformed already partly during their deposition, and to a larger degree later, during reactivation of the Pre-Tertiary basement. This is indicated by reverse faults in the northern rim of the Ormož-Selnica antiform, and in part by overthrusting on the neighbouring Ptuj-Ljutomer depression.

The Ormož-Selnica antiform is widest in its northwest part, and substantially narrower towards the southeast, in the area of the Dravinja vineyards and Haloze. The major part of this unit, approximately between Ptuj and Dornava in the southwest, and west of Petišovci and Selnica in the northeast, is somewhat uplifted. Furthermore the surface structure of the southeast area dips relatively gently, and only in the southwestern part, in the area of the Dravinja vineyards, are the dip angles steep, vertical or even overturned. It is important to note that the Ormož-Selnica antiform exists at present disintegrated into a number of smaller anticlinal units that are in places several square kilometres in size. Based on the geological relations in the wider area, the Triassic carbonate rocks may be expected in the cores of these units.

4. OIL GEOLOGY

In the wider region of the Slovenian part of the Mura depression the potential source rocks were established among the Neogene sediments. Favourable reservoirs and traps also occur together with favourable structural conditions.

The potential source rocks outcrop in the northeastern part of the area, in the region of Kozjak, and on the southern margin they outcrop in the Haloze area. They are represented by dark bituminous marls to siltites that occur in the lower part of the Ottnangian-Carpathian beds, and appear at several horizons, varying in thickness at individual levels from a few to more then ten metres. Similar marls have also been found in the Badenian deposits. These beds extend from the margins to the central part of the Mura depression where they

were probably the main source of hydrocarbons which migrated into the favourable structures of the reservoir, and formed oil-gas fields.

5. POTENTIAL RESERVOIR ROCKS

The potential reservoirs were found among the rocks of the Pre-Tertiary basement, as well as in the Neogene beds.

In the sequence of beds of the Pre-Tertiary basement rocks occur that are bad reservoirs in certain circumstances, and others with the best reservoir properties. With respect to the older tectonic history and formation of the Pre-Tertiary basement parts or entire units of the tectonically deformed Pre-Tertiary basement may be of interest for accumulation of oil and gas, particularly phyllonites (crushed gneisses), mylonites (crushed dolomites, limestones, Permian-Triassic sandstone), breccias (dolomite and limestone).

The phyllonite zone can appear along the tectonic contact between phyllonites overthrusting gneisses. In this process the gneisses were crushed into fine fragments, and they can have bad reservoir properties. They may be expected in the area of the Murska Sobota massif and the footwall of the Radgona depression.

Mylonites, tectonic breccias and fractured carbonates are more favourable as reservoir rocks, particularly the deformed Triassic dolomites and limestones. The thickness varies from several tens to several hundred metres. They may be expected in the footwall of the Radgona depression between the Neogene beds and the underlying metamorphic complex. Especially favourable carbonate reservoirs are expected below the Neogene deposits in the area of the Ormož-Selnica antiform. These reservoir rocks are part of the fissured and deformed Northern Karavanke carbonate overthrust which consists of Triassic, massive and in part layered limestones, and of Upper Triassic dolomite.

Of potential reservoir value in the Neogene beds are the crushed breccias, conglomerates and sandstones of Ottnangian-Carpathian age. In Badenian the lithothamnian limestone and sandstone that is often fissured is also favourable. It attains a thickness of several metres to several tens of metres. Reservoir horizons can also be found in the Sarmatian beds (sandstones, conglomerates), as well as in the Pannonian and Pontian.

The structural traps could be found in the Ottnangian-Carpathian, Badenian and Pannonian, as well as in Pontian deposits. Beds of marls, clayey marls and clays occur in individual parts of these stratigraphic units, and they can form favourable traps. Their thicknesses vary from several tens metres to a hundred metres.

Structures potentially favourable for oil appear in the region of the Ormož-Selnica antiform and the Radgona depression. In both areas carbonate rocks that are the most favourable potential reservoir rocks occur in the Pre-Tertiary basement. Some also appear in Neogene beds.

The region of the Radgona depression disintegrated and individual smaller antiform features were formed. There were possibilities for the migration of hydrocarbons from the lower parts and their accumulation in the mentioned structures (e.g. Dankovci). In the area of the Murska Sobota massif smaller anticlines occur in which hydrocarbons accumulated in Neogene reservoir rocks.

It is estimated that the Ormož-Selnica unit represents the most favourable area for occurrence of deposits according to its geological structure and oil geology characteristics. Along its strike occur a number of smaller anticlinal structures of several kilometers extension. In the northeastern part of this unit oil-gas fields were discovered in the vicinity of Petišovci, and in the Croatian part at Selnica, Zebanec and the latest gas-fields Vukanovec and Vučkovec (RUNJIĆ et al., 1995; SELJAN & PARLOV, 1995).

In the southwestern extension of the Ormož-Selnica unit oil and gas were drilled at Bukovci, however without any important economic results. From the standpoint of more recent investigations it was estimated that at Bukovci the boreholes were drilled almost parallel to the vertical Neogene beds, where they did not find favourable structures (MIOČ & ŽNIDARČIČ, 1989).

6. CONCLUSIONS AND RECOMMENDATIONS

In conclusion of this short analysis of geological and oil geological information of the Mura depression, it may be stated:

a) the Ormož-Selnica structural unit appears as the most favourable for new petroleum discoveries,
b) the next potentially important structural unit is the Radgona depression, followed by
c) individual areas of the Murska Sobota massif, in which the possibilities of smaller occurrences of oil and gas exist, and of even more favourable geothermal water sources.

Prior to planning further prospecting for petroleum, analysis and interpretation of existing data are necessary. From this, geophysical measurements and further interpretation of the surface structural data are required in order to facilitate a deep drilling programme. In this manner the location of boreholes will be economically better established.

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