Paleotectonic reconstruction of the western edge of Moslavačka gora - draft

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REVIEW

The western edge of Moslavačka Gora is located in the southern part of Bjelovar subdepression. Exploration drilling and seismic survey were conducted in this part of Drava Depression. This paper gives an overview of exploration of Moslavačka Gora western edge made on the basis of exploration drilling, seismic profiles and previously published papers. The intention of this paper is an incentive for the detailed approach in reviewing the basin marginal areas and exploration results analysis. These areas may also represent places of new discoveries of hydrocarbons, which is especially significant due to their prices increase.

Key words: Moslavačka Gora, Drava depression, Paleotectonic reconstruction

1. INTRODUCTION

Bjelovar subdepression represents the southwestern branch of the Drava depression, an area of approximately 2 900 km^2, bordering with Sava depression. That area has already been graded as poor for the discovery of significant hydrocarbon quantities, because this part of Drava depression is separated from the central depression zone, and assumed thickness of Neogene-Quater-

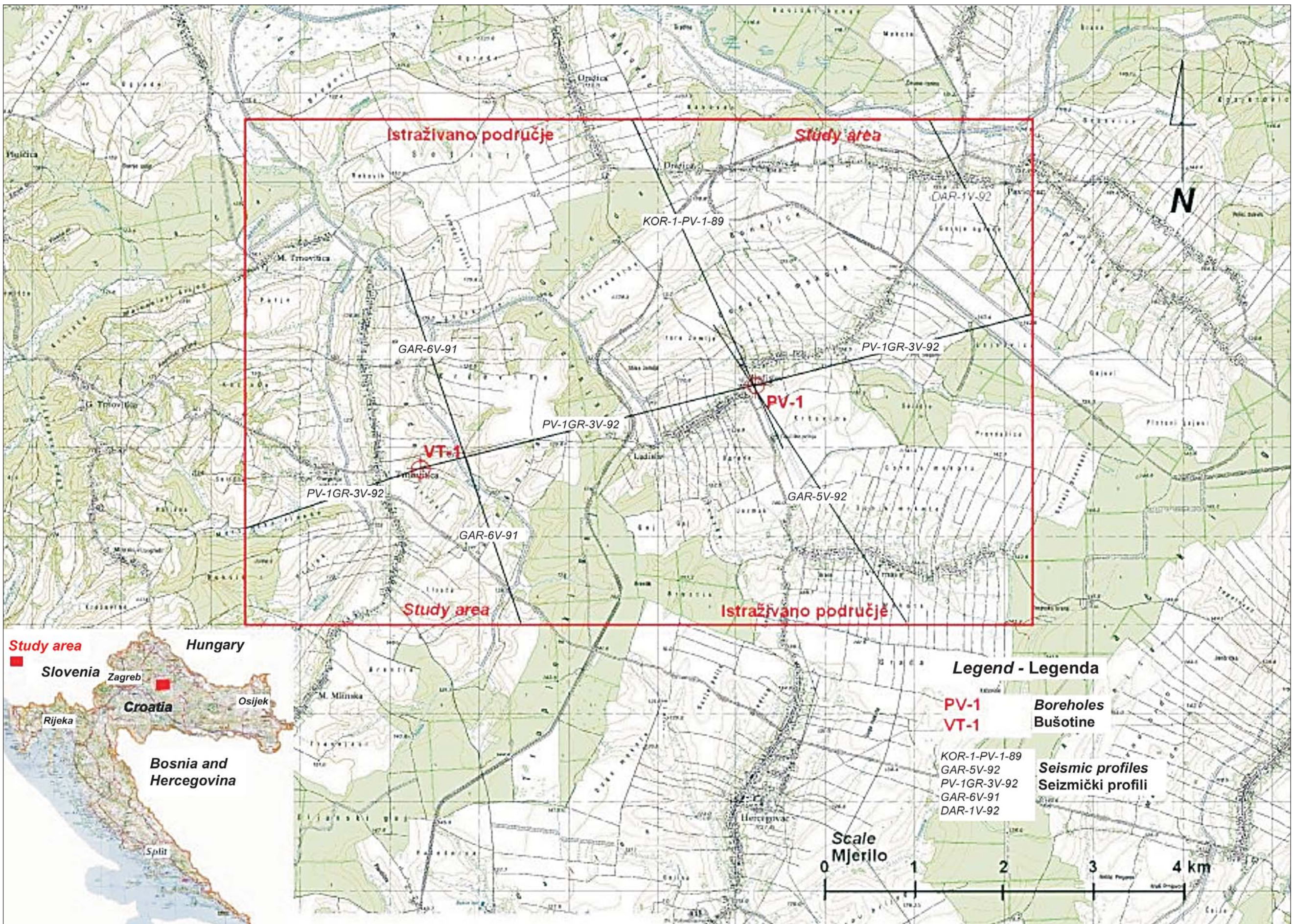


Fig. 1. The studied area
Sl. 1. Područje istraživanja

nary sediments in the deepest parts is over 3 000 m, unlike the central part, where their thickness is often doubled.[2]

Considering the Bjelovar subdepression as essentially non perspective area has resulted in drilling less number of wells, so the quantity of data per unit is much smaller in this area than in the rest of the Drava depression.

Paleotectonic reconstruction of the western margin of Moslavačka Gora was made on the basis of exploration drilling, seismic profiles and previously published papers.[4,9,13] Paleotectonic reconstruction is based on structural maps of the surfaces Tg, Rs7, Z', D_2, Δ and D(α') and paleotectonic profiles. Lithostratigraphic units (formations) are presented under paleotectonic conditions along with the activities of certain faults in space and time. The intention of this paper is an incentive for the detailed approach in reviewing the basin marginal areas, and analysis of exploration results. And these areas may also represent places of new hydrocarbon discoveries which are significant due to the increase in their prices, like the discovery in Grubišno Polje area in 1990 or in Galovac-Pavljani area in 1992.

2. GEOGRAPHIC POSITION

The studied area is placed in the southern part of Bjelovar subdepression and on northern margin of Moslavačka Gora (Figure 1). It is situated aproximatelly 20 km north-east of Garešnica and 20 km north-west of Daruvar covering the area of aproximatelly 40 km^2. Two wells Pv-1 and VT-1 are located in the exploration area. Pv-1 well is situated around 200 m southeast of the church in the Ladislav village, on southern side of V. Ladislavica creek. Aproximate elevation of the well head is 125 m above the sea level. VT-1 well is located 4.2 km from Pv-1 well in the west direction, and 15 km north of Garešnica, well is situated at 140.5 m above the sea level.

Velika Trnovitica is placed on the northern margin of Moslavačka Gora belonging to the southern part of Bjelovar subdepression. The nearest cities are Bjelovar (aproximatelly 20 km to the northwest), Garešnica (aproximatelly 12 km to the south) and Grubišno Polje (aproximatelly 25 km to the east).

3. EXPLORATION HISTORY

Although geological exploration in this area was carried out much earlier, unrelated to hydrocarbon exploration, the exploration in the area of Bjelovar subdepression shall be limited to petroleum-geological exploration. The first exploration operations for discovering hydrocarbon reservoirs have been performed in Sedlarica and Marinovac area in 1922 and 1923.[2] The first significant exploration before World War II was performed by Austrian company "Petrolej", and during the war it was continued by German entrepreneurs, who defined Ludbreg and Subotica structures and Lepavina anticline in 1940-42. In 1949, drilling of Lepavina-1 deep well (937.4 m) discovered oil reservoir in Badenian sandstones and Paleozoic serpentines that was active until 1987. In 1956 the drilling of deep exploration wells started to obtain insight into oil bearing potential of the whole Drava depression, and in the central depression zone and in Bilogora zone. The following oil and gas fields were discovered: Cabuna, Ferdinandovac, Jagnjedovac and Šandrovac. Two more exploration wells Ciglenica-1 and Pavlovac-1 were drilled in the mid sixties in southeastern part. The regional interpretation of Moslovačka Gora northeastern margin was performed by comparing these data with the data from Korenovo-1 well; however the hydrocarbons were not discovered. Rich oil reservoir Jagnjedovac was discovered in 1961.[2] The oil field is situated on southern Bilogora slopes between two other known petroleum-geological structures – Lepavina and Mosti. In 1963, southeastern of Sedlarica structure, another small gas field – Gakovo was discovered making it the great success. Oil – gas field Šandrovac was discovered the same year. Based on geology mapping results and along with already known oil and gas fields, in the area of Drava depression, the total of ten oil and gas bearing zones was defined. They were individually defined by geographical integrity, approximately equal sediment thickness, reservoir rocks depth and trap types. Those are: west Bilogora zone (34% potential reserves), Papuk – Krndija zone (27%), Moslavina zone (22.5%), east Bilogora zone (6,5%), Podkalnik zone (4%), Villany – Mecsek zone (3%), south Gorgeteg zone (1.5%), below Bilogora zone (1%), Central Depression zone (0.25%) and Legrad ridge (0.25%).[4] Areas with discovered oil fields got higher possibility of new discoveries, as for example in west Bilogora zone. Relatively high value was added to Moslavina zone, but it has not been proved yet.

Potential hydrocarbon reserves are distributed within the whole depression in the following way; 56% are in reservoirs with stratigraphic traps, 31% are in fault reservoirs, 8% are in reservoirs with anticlines and 5% are in reservoirs with combined traps.[4] 90% of potential reserves are forecasted to be at the depths less than 1 750 meters. The 1990s were the most significant years for studying and confirming the oil and gas bearing properties in the Bjelovar subdepression. One small oil field, two gas fields and one geothermal field were discovered while other exploration operations works reviewed reservoir and source potential of depression parts which were not drilled before. In 1989 Velika Ciglena-1 (VC-1) well was drilled, located on slightly expressed structural nose near the deepest part on southeastern part of the Bjelovar subdepression. Well data were gathered on Neogene rocks and basement in deep southeastern part of the Bjelovar subdepression. Velika Ciglena geothermal field was also discovered and directional well (VC-1α) was drilled for exploitation of geothermal energy. A series of wells was drilled on Galovac-Pavljani (Pav-1 – Pav-6) location during 1991 – 1994 while in the basement of Tertiary base rocks, Badenian breccias and breccia-conglomerates, oil field was discovered. In Grubišno Polje area in 1993 a well was drilled, which discovered the same gas reservoir Badenian clastic rocks and in Paleozoic schists. In 1997 nearby Bačkovica village in the eastern part of depression, approximately 25 km south of Bjelovar, Bac-1 exploration well was drilled. Except for few shows, there were no hydrocarbons. Similar negative results were obtained by Bac-2 well too, although the seismic survey showed "bright spot» which was reason enough for drilling new Bac-1z well which discovered small gas field Bačkovica.[2]

4. STRATIGRAPHIC RELATIONS

The rocks are generaly divided into two groups. First group is formed of Neogene basement rocks that belong to Paleozoic and Mesozoic and second group of Neogene and Neogene – Quaternary sediment complex. The Neogene basement is composed of carbonates and magmatic and metamorphous rocks. Neogene is presented by clastic sedimens, mostly marl, marly limestone, breccia and sandstone (Figure 2).

4.1. Paleozoic and Mesozoic Rocks

In Tertiary basement, Paleozoic and Mesozoic rocks are present. Paleozoic rocks were dominantly represented by granite gabbros, schist and gneiss. Mesozoic rocks consist of different types of limestone and dolomites, mostly of proved Middle Triassic age.

4.2. Miocene Rocks and Sedimentation Envoronment

Sediments of Lower and Middle Miocene (Moslavačka Gora formation) mark the beginning of comprehensive transgression in the whole subdepression area. They are sedimented discordantly on Paleozoic and Mesozoic rocks and sediments in the basement. They litostratigraphicaly correspond to Moslavačka Gora formation divided to older Mosti member of approximately Lower Miocene to Sarmatian age and younger Križevci member of approximately Lower Pannonian age. The border toward Paleozoic and Mesozoic rocks in the basement is marked by well log (EL-border) "Tg" (Figure 3a) or "Pt", while toward Ivanić-Grad formation (Upper Pannonian) in the top part, is marked by well log marker Rs5. Those sediments have high geological significance. Coarse grain clastics of Moslavačka Gora formation generally have good reservoir properties, maybe locally the best among all the explored Neogene reservoir members, defined in the Croatian part of Pannonian Basin.[2] Pelite sediments belonging to this formation are the best ones that could be considered in some parts as source rocks.

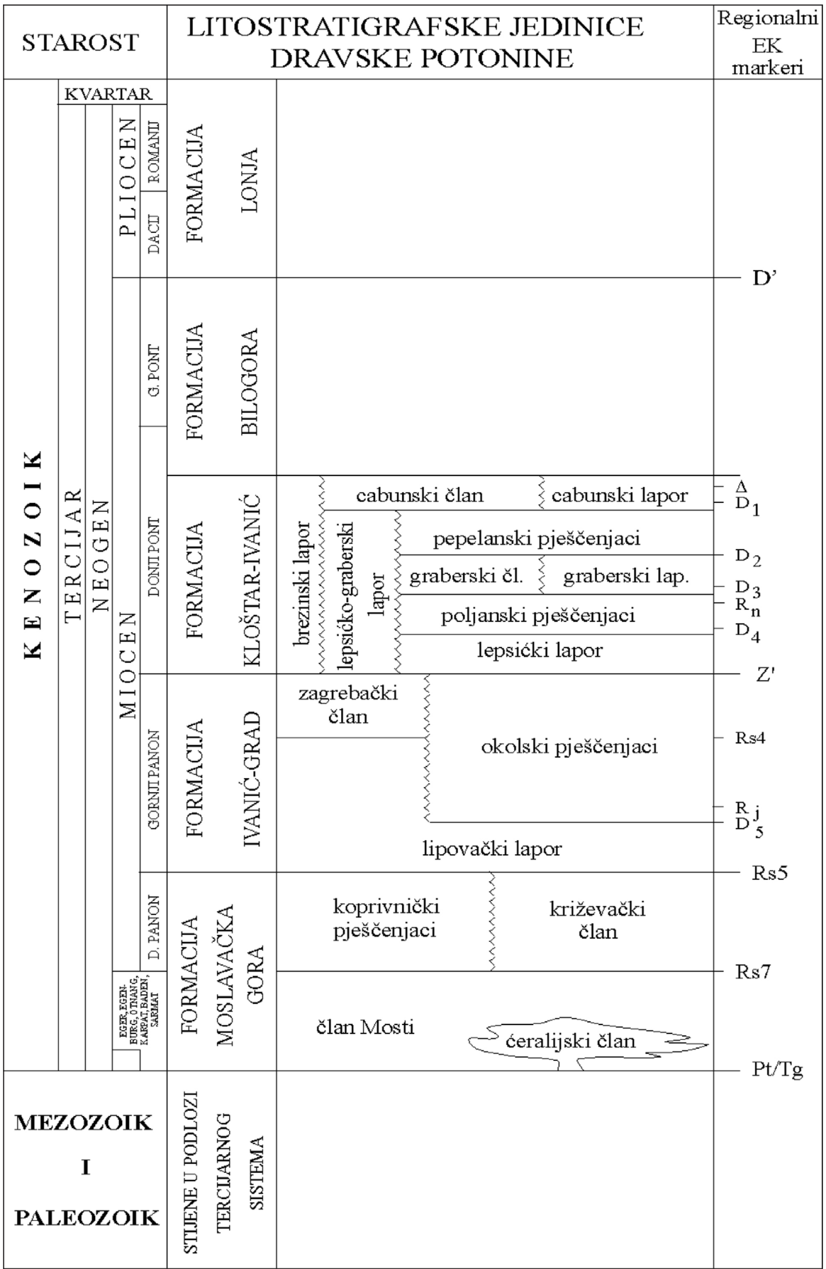


Fig. 2. Litostratigraphic units of Drava depression after Šimon, 1968[2,3]
Sl. 2. Litostratigrafske jedinice Dravske depresije prema Šimon, 1968.[2,3]

The beginning of Lower Miocene extension tectonics is assumed in Ottnangian and Karpatian period, mainly based on analogy with parallel occurrences in the most part of Pannonian Basin system.[5] At the beginning of Neogene extension, sedimentation area with marine sediments affected parts of Medvednica, Sava depression, Slavonia and possibly the edges of Psunj in north Croatia.[13] Other sources also[6,7] describe that period in a similar way, only marine areas are placed toward western part of Croatia – Hrvatsko Zagorje area and Mura depression, moving freshwater areas toward east. The same sources[6,7] quote the list of authors who wrote about continuous sedimentation on the transition from Lower to Middle Miocene with sedimentation of river delta sediments on the edge of Moslavačka Gora and western part of Psunj, although there are other opinions which place the beginning of Neogene sedimentation in Badenian classifying it as marine type.[1] Badenian follows when extension movements are stronger and registered throughout the whole depression area. Several rhomboidal basins[2] (were developed ("*pull-apart*") where sediments of considerable thickness were deposited.[2] At that time, marine sedimentation occurred throughout the whole depression as well as in the most part of northern Croatia.[6,7] Only the biggest mountains like Moslavačka Gora, Kalnik, Papuk and Psunj, remained partly above the sea level and became islands. At the end of Badenian, extension movements weakened, sedimentary environment related to the energy of water became calmer, grain size decreased and fine grained sandstone, marl and limestone were deposited. Breccia and conglomerate are according to their origin mostly cataclastic sediments, and in some cases rockfall sediments. Partial absence of carbonate clasts indicates that in some places bigger reef communities were not developed that could produce such material by weathering. They are greenish with traces of mica and chlorite, that indicates a mixed or hybrid type of green (glauconite) sandstone.[11] Pelitic, marly and marly-limestone sequences which represent the end of Badenian indicate shallowing and calming of sedimentary environment and in such sedimentary conditions the Sarmatian begins. Due to lithologic identity and relatively small thickness it was not possible to separate the upper part of Badenian sediments from Sarmatian sediments, so they represent a unit that is even difficult to distinguish from the top sediments of the Lower Pannonian. However, in the exploration area, this border is visible (EL marker Rs7) as well as in wells and in geophysical profiles (Figure 3b). Sedimentary environment remained shallow and its filling continued in Lower Pannonian. Mostly protected shallow, brackish areas[6,7] remain where sedimentation of thin layers of argillaceous limestone, calcitic, silty or sandy shale, shale, and sometimes sandstone alternate. Carbonate material dominates, originated from algal reefs. The elements of paleorelief protrude above the water surface and they are a source of siliciclastic material, although poorer than in Badenian.[2,3]

Upper Pannonian sediments, Ivanic-Grad formation. In older wells these sediments were often labelled as Banatica sediments according to the characteristic shell fossil *Congeria banatica*. Time of sedimentation roughly corresponds to the Upper Pannonian. The boundary toward Moslavačka Gora formation, in base is represented by well log marker RS5, which in this case was not evident, indicating a possible emersion in marginal areas, and toward the border in top of Kloštar-Ivanic formation, is marked by well log marker Z '(Figure 3c). Formation begins with Lipovac marl member, continues with Zagreb member or its lateral equivalent Okoli sandstone.[9,2,3] At the time of Upper Pannonian, the Pannonian Basin system, where sedimentation occurred, was covered by fresh water of variable depth. The discovered fossil remains were scarce, poorly preserved and mostly free of vascular shape, and in many places it was difficult to separate the individual members and determine the boundary of the particular formation, especially toward Moslavačka Gora formation, i.e. Križevci member, poor by fossil content too.

Sediments of the Lower Pontian, Kloštar-Ivanic formation, are often labelled as "Abichi" layers according to the characteristic fossil mollusc *Paradacna abichi*. The oldest sediments belong to Lepsić marl, followed by Poljana sandstones, Graberje marl, Pepelana sandstone and Cabuna marl. Due to significant domination of impermeable sediments, all of these members were transferred into one Kloštar-Ivanić marl.[9] The lower boundary toward Ivanic Grad is indicated by well log marker Z ' (Figure 3c), While well log marker Δ in the peak of Cabuna marl represents the approximate border with the Bilogora formation (Figure 3e), lithological content is represented by different types of *sandstone* and *shale*. Marly members are mostly lithologically homogeneous, and the exception is the increase of sand component at the top of Lepsić marl.

Argillaceous component prevails in the youngest member, Cabuna marl. Sandstone members are not homogenous and often contain intercalations, sometimes with significant thickness. This is particularly evident in Poljana sandstones. Sandstone almost completely disappeared toward the southern and south-eastern part of the depression. A significant portion of permeable sediments is located in the deepest parts. Almost everywhere, all members of the formations were recorded, showing that the whole area during the Lower Pontian was covered by water.[2] Wells and cross sections of Kloštar - Ivanić formation, registered the border (EK marker D_2) to be between Graberje member and Pepelana sandstone (Figure 3d).

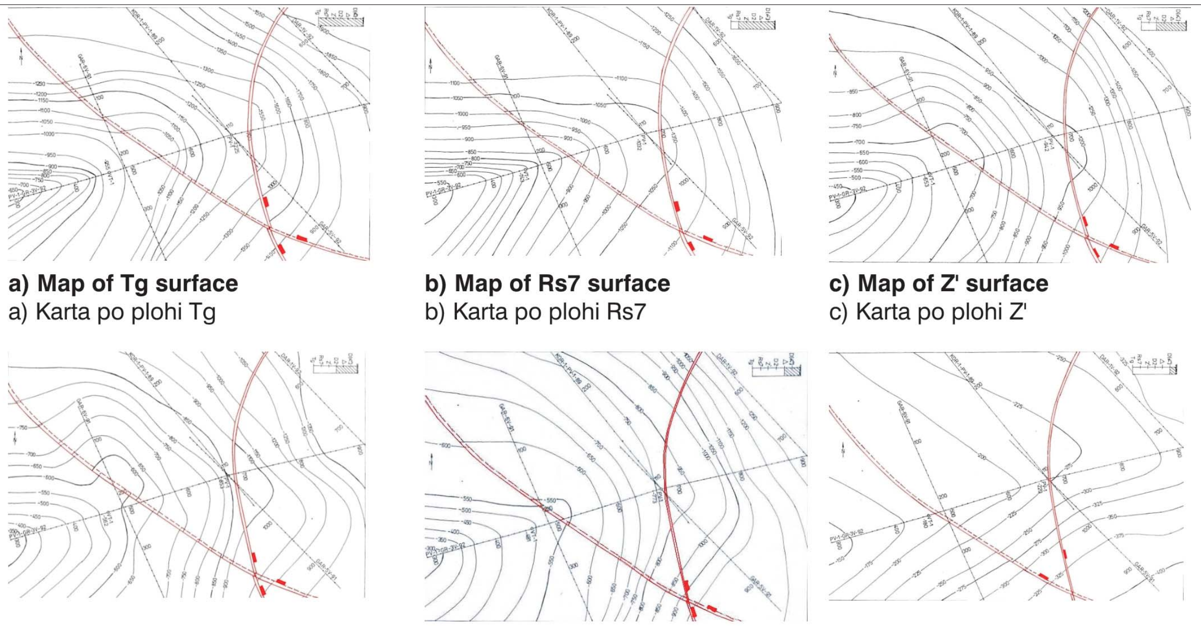
The sediments of the Upper Pontian, ie Bilogora formation, are also called "Rhomboidea" layers, according to the fossil shell *Congeria rhomboidea*. Formation is divided into smaller units (members) due to much lower possibility of discovering hydrocarbons and thus the need for more sediments analysis in the older formations. Well log marker Δ separates it in the basement from the Kloštar-Ivanić formation (Figure 3e), while marker D (figure 3f) separates it from Lonja formation in the top '(figure 3f).

The sedimentation with similar mechanisms as in the Lower Pontian continues, i.e. freshwater, lake and in deltaic environment[2,3] Thicknesses are mostly higher than in the previous formation, particularly in the area of Bilogora indicating that uplift of this massif has not yet begun at that time. Younger sediments in formation are represented by marly clay, clay, sandstone and sand along with domination of impermeable sediments.[2]

Sediments of Dacian, Romanian and Quaternary (Lonja formation) are the youngest part of sediments. Bilogora formation is in the basement, separated by well log marker D '(Figure 3f), while its upper boundary is the present surface area. Its age roughly corresponds to Pliocene (Dacian and Romanian) and Quaternary. Pliocene was a period when the area of the entire Pannonian Basin systems and Bjelovar subdepression, was already divided into a series of freshwater lakes[2,3] which were mainly filled by continuation of the Pleistocene sedimentation in fluvial environments. Material was brought by prograding rivers and streams. Sand and clay were sedimented, and within the deeper lakes the siltstone, marl and even carbonate.

5. TECTONIC HISTORY OF BJELOVAR SUBDEPRESSION

Bjelovar subdepression area represents a separate geotectonic unit in petroleum geological division of the Croatian part of the Pannonian Basin. Geographically



a) Map of Tg surface
a) Karta po plohi Tg

b) Map of Rs7 surface
b) Karta po plohi Rs7

c) Map of Z' surface
c) Karta po plohi Z'

d) Map of D_2 surface
d) Karta po plohi D_2

e) Map of Δ surface
e) Karta po plohi Δ

f) Map of D' surface
f) Karta po plohi D'

Fig. 3. Structure maps[12]
Sl. 3. Strukturne karte[12]

and geologically, this region is now separated from the rest of Drava depression, which is mostly the result of Bilogora uplifting during the Pliocene and Quaternary. Bjelovar subdepression area covers an approximate area of 2 900 km^2 with all major types of structures defined and the tectonic movements that are typical for the Croatian part of the Pannonian Basin.[2]

Pannonian Basin system is the largest regional unit. Its development has begun in Ottnangian, a period of about 18.3 to 17.2 million years ago. Development of Pannonian Basin system began by subduction of Apulian plate under the Dinarides, which created the southern border, represented by Peri-Adriatic-Vardar lineaments and the northern boundary, represented further by the External Carpathians. Certain basins, depressions and subdepressions located within the Pannonian Basin system were developed by extensions along transcurrent fault systems. The beginning of tectonic activity in Ottnangian was accompanied by the beginning of marine transgression in this area.[8] The first transgression did not cover the entire area, and especially not at the same time, so the lower Miocene sediments, in the whole area of the Pannonian Basin system were only partially deposited, and the first Miocene sediments in different areas are of different age.

Extensional movements have intensified during Karpatian age, around 17.2 to 16.4 million years ago[7] when lake-river sediments were deposited in the marginal areas of the basin.[9] In north-eastern Hungary, on the edge of the Paratethys, evaporites were deposited, while the sea surface with normal salinity covered the western part of the central Paratethys (parts of Poland, Hungary, Slovenia, Croatia). There was a certain link with the neighbouring Mediterranean large marine area, and possibly with Indo-Pacific.

At that time, in most of north Croatia, marine sediments were deposited. The extension continued in Badenian, 16.4 to 13.0 million years ago, and Sarmatian, 13.0 - 11.5 million years ago.[6,7] By the Middle Badenian, transgression covered the areas from Austria to Transylvania in Romania and the area around the Carpathian mountains.[9] At that time, all three major areas; the Mediterranean, Central Paratethys (Pannonian Basin) and Indo-Pacific, were connected as proved by the existence of a numerous common fossil types. In the upper part of the Middle Badenian changes in facies occurred[9], the tie with the Mediterranean was interrupted, and during the Sarmatian with the Indo-Pacific too.

The result was the sedimentation of evaporites which spread even more on the whole area of Pannonian Basin system.[2] Completion of the main extensional phase in most parts of Pannonian Basin system was defined by Lower Pannonian, from 11.5 to 9.3 million years ago, followed by appearance of post extension period when the cooling of the lithosphere, became the main cause of this space dynamics.[8] In the Upper Pannonian, between 9.3 to 7.1 million years ago and Pontian, between 7.1 to 5.6 million years ago, sedimentation mainly occurred in brackish and freshwater lake area, a transfer mechanism is deltaic or turbid in the northwest- southeast direction at a distance of several hundred kilometres. The youngest periods of Pliocene, 5.6 to 1.8 million years ago, and Quaternary 1.8 to 0.0 million years ago[6,7], are marked with the fluvial and lakustrine sedimentation. Tectonically, compression forces became stronger by forming reverse and overthrust relations, often by reactivation along older fault planes, and even with strike-slip inversion on the same fault.[2]

6. PALEOSTRUCTURAL RELATIONS

Different types of geological maps of certain exploration area tend to present underground structure as real as possible relating it to the image of current state. Description of structures discovered in a certain field, represents the currently existing shapes and their distribution within space, but it also posts the question of development during the geological history. It is impossible to obtain completely accurate result, but credibility depends on the number and accuracy of data acquired during development.

Examination of formation and decomposition of structures for each marker horizon were performed by gradual adding of the thickness of found formations. This means that the observed surface of horizons will be expressed as relief, and the thickness of formation will be reduced to a horizontal surface, of the final sedimentation levels of the corresponding lithostratigraphic units. The final result is a series of different maps (Figure 4.). Their number can be calculated from the following expressions, depending solely on the number of marker horizons:

$$N=(2n+n)/2 \quad (1)$$

where:

n number of markers

N total number of maps

Horizontal rows of paleostructural triangle represent the maps of observed markers in various sedimentation stages. The last map in this series (structural map) shows current deep relief of related markers. Formation thickness maps and paleostructural maps are part of paleostructural maps system. All maps from paleostructural triangle together represent the course of development and degradation of the structure. The uplifting and lowering of sedimentary area are also clearly visible.

7. PALEOTECTONIC RECONSTRUCTION OF WEST EDGE OF MOSLAVAČKA GORA

Paleotectonic reconstruction enables monitoring of the development of structures and their thicknesses and obtaining images of faults and their different stages of sedimentation process. Changes in thicknesses are related to the existence of niches in the paleorelief and tectonic activity of that time. Further below, a general introduction to the development of exploration area is presented. The oldest registered member of the study area is Mosti member that belongs to the older part of the Moslavačka Gora formation. During the sedimentation of Mosti member, after the emersion phase, lowering of the whole area occurred, so there was a filling of niche in the old paleorelief. Synsedimentary fault structure was definitely expressed, but it is not clearly visible because of small throws and small differences in thickness which might be a result of compression. During the sedimentation of Ivanić Grad formation the activation of faults in the eastern has part begun. Increase of sediments thickness is visible in this area.

Sedimentation of Kloštar Ivanic formation suggests a stronger subsidence of the eastern part. The greatest sediments thickness is still related to the fault zone. Sedimentation of Bilogora formation is accompanied not only by faulting but also by stronger subsidence of the eastern part. Apart from regular faulting and subsiding in the western part of the field, sedimentation of Lonja formation was followed by gradual subsiding along reverse fault in the eastern part.

During the sedimentation of Mosti member, after emersion phase, a subsidence of the whole area occurred resulting with the filling of niches in the old paleorelief (Figure 3b). Synsedimentary fault structure was expressed, however, it is not clearly visible due to small throws and small differences in thickness which may be a result of compression and inversion of slip on normal faults in the eastern part of the study area. After the deposition of Mosti member, faulting in the eastern part took place.

Fault is of a big throw, around 200 meters, but the thicknesses of the Mosti member and Križevci member are very similar. Bed dip is toward east. In the western part there is less pronounced anticline uplift. Surface of Z' marker is significant because it represents the lower margin of Kloštar Ivanic formation (Figure 3c).

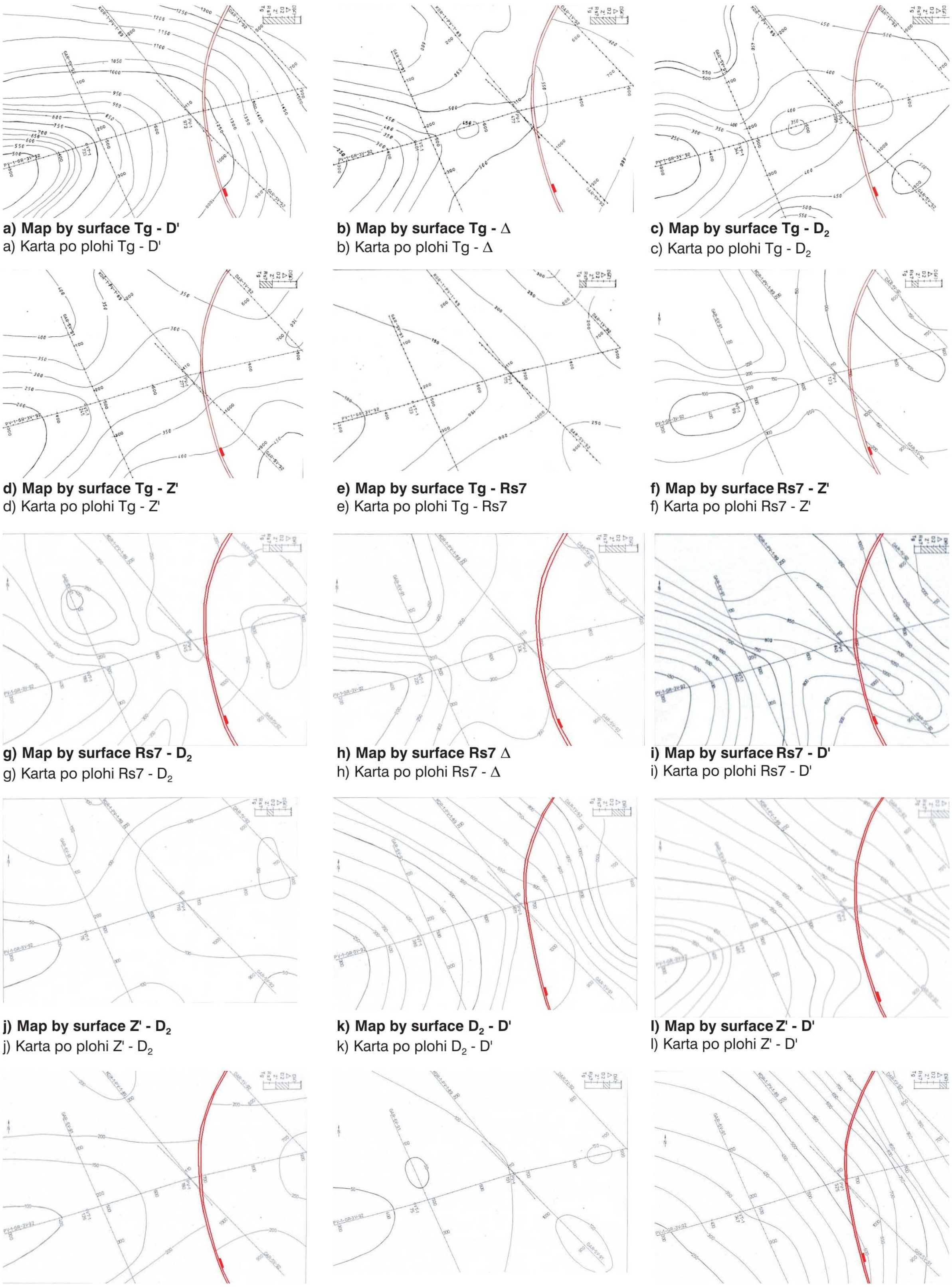
During the sedimentation of Brezine shale, eastern fault was not active, so Brezine marl fills the sediments of Ivanić Grad formation. Due to tectonics, synclinal bending of deposits occurred in the eastern part. Surface of D2 marker represents the border of the Brezine marl inside Kloštar Ivanic formation (Figure 3d).

Fault has remained relatively quiet until the end of sedimentation of Kloštar Ivanic formation. Monocline structure is expressed throughout the entire area. Smaller syncline bending was registered in the eastern and south-eastern part. Surface of marker Δ represents a lower margin of Bilogora formation (Figure 3e).

During the deposition of sediments of Bilogora formation, increased activity of the eastern fault occurred and stronger subsidence of sedimentary basin, especially in the eastern part. Such movements cause thickening of layers of Bilogora formation. Monocline structure is even more emphasized than on previous maps. Great thickness of the Bilogora formation layers, a large fault throw

					D'
				Δ-D'	Δ
			D_2-Δ	D_2-D'	D2
		Z'-D_2	Z'-Δ	Z'-D	Z'
	Rs7-Z'	Rs7-D_2	Rs7-Δ	Rs7'-D'	Rs7'
Tg-Rs7	Tg-Z'	Tg-D_2	Tg-Δ	Tg-D'	Tg

Fig. 4. Possible paleostructural maps
Sl. 4. Moguće paleostrukurne karte



a) Map by surface Tg - D'
a) Karta po plohi Tg - D'

b) Map by surface Tg - Δ
b) Karta po plohi Tg - Δ

c) Map by surface Tg - D_2
c) Karta po plohi Tg - D_2

d) Map by surface Tg - Z'
d) Karta po plohi Tg - Z'

e) Map by surface Tg - Rs7
e) Karta po plohi Tg - Rs7

f) Map by surface Rs7 - Z'
f) Karta po plohi Rs7 - Z'

g) Map by surface Rs7 - D_2
g) Karta po plohi Rs7 - D_2

h) Map by surface Rs7 Δ
h) Karta po plohi Rs7 - Δ

i) Map by surface Rs7 - D'
i) Karta po plohi Rs7 - D'

j) Map by surface Z' - D_2
j) Karta po plohi Z' - D_2

k) Map by surface D_2 - D'
k) Karta po plohi D_2 - D'

l) Map by surface Z' - D'
l) Karta po plohi Z' - D'

m) Map by surface Z' - Δ
m) Karta po plohi Z' - Δ

n) Map by surface D_2 - Δ
n) Karta po plohi D_2 - Δ

o) Map by surface Δ - D'
o) Karta po plohi Δ - D'

Fig. 5. Thickness maps[12]
Sl. 5. Karte debljina[12]

and steeper dip of sediments toward east indicate intensified tectonics. Surface of D '(α) marker, represents the boundary between Bilogora and Lonja formation (Figure 3f). During the deposition of Lonja formation, tectonic regimes remain the same as during sedimentation of Bilogora formation. Expressed monoclinic structure dip on the south and reverse fault indicate a change in tectonic character during the sedimentation of Lonja formation. In the western part the lowering along the newly formed reverse fault occurred. Beds thickness map from surface marker Tg to surface marker Rs7 (Figure 5e) shows the appearance of Tg surface after sedimentation of Mosti member.

Differences in thickness were expressed, ranging from 100 m to the south-east to over 300 m in the north-west. The equidistance of 50 m, chosen regarding the availability of data, has certainly disguised the details in the layout of the ancient paleorelief. Paleostructural map of Tg to Z (Figure 5d), shows small thickening on the eastern side, which indicates the beginning of the eastern fault activation during the deposition of Ivanic-Grad formation.

The same thing can also be seen in paleostructural thickness map between markers Rs7 to Z (Figure 5f). The difference in thickness is even bigger on the paleostructural map D_2-Tg (Figure 5c), which indicates that the fault is still active. The same can be seen on the paleostructural map of markers Rs7 to D_2 (Figure 5g). After sedimentation of Brezine marl, tectonic activity decreased which can be seen from the paleostructural map from Z'marker to D_2 marker (Figure 5j). During the sedimentation of the Kloštar Ivanić formation reactivation of faults took place that can be seen on paleostructural maps Tg-Δ (Figure 5b) i Rs7-Δ (Figure 5h).

After the sedimentation of Kloštar Ivanić formation, the fault activity decreased as seen on the paleostructural map D_2-DΔ (Figure 5n). During the sedimentation of Bilogora formation the fault was again activated and stronger lowering of structures toward east occurred as seen on paleostructural maps Tg-D(α') (Figure 5a), Rs7-D(α') (Figure 5i), D_2- D(α') (Figure 5k), Δ - D(α') (Figure 5o). After sedimentation of Bilogora formation and during the sedimentation of Lonja formation, activity of eastern fault continued with reverse fault show in the western part.

8. CONCLUSION

The area of the western edge of Moslavačka Gora, presented here, covers the area of about 25 km² and situated in the southern part of Bjelovar subdepression. As there are only two wells in the area, interpretation was performed mainly by seismic profiles. Numerous structural and paleostructural maps were prepared for the purpose of this paper. Exploration drilling discovered five formations: Moslavačka Gora, Ivanic Grad, Kloštar Ivanic, Bilogora and Lonja.

Tectonic movements have not been registered in this area during the sedimentation of Moslavačka Gora formation and Ivanić - Grad formation. Normal faulting occurred during the transition from Lower Pannonian to Upper Pannonian in the eastern part of the exploration area due to extension movements. During Lower Pontian, this fault was not active and then during transition to Upper Pontian, it was reactivated.

Basic, anticlinal shape developed after sedimentation of Kloštar Ivanic formation and during sedimentation of Bilogora formation. During sedimentation of the Lonja formation the lowering of the west side of the reverse fault occurred, as a result of stronger compression forces. This was a time when overthrust structures were developing in the entire area of the Pannonian Basin. Results of paleotectonic reconstruction of the western margin of Moslavačka Gora are in accordance with the existing regional tectonics and stratigraphy of Bjelovar subdepression.[2,3]

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