Deterministical Calculation of Probability of Existence of Hydrocarbon Saturated Reservoirs in the Sava Depression, Croatia

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Abstract

The Sava Depression represents southern geotectonical border of the Pannonian Basin toward the sediments of Adriatic Carbonate Platform. It is well-known hydrocarbon province. Analytical target for calculation of hydrocarbon existence probability was the Ivanić-Grad Formation of Upper Pannonian age. Analyzed area was divided in 74 squared cells of size 5x5 km. Probability of hydrocarbon existence had been estimated for each cell (value similar to Probability Of Success – POS), using six geological categories: existence of (1) hydrocarbons, (2) reservoirs, (3) source rocks, (4) traps, (5) quality of reservoirs, and (6) exploration level based on number of wells. Each of categories could be estimated with three values: 3 for clearly proved category from excellent data, 2 for weak or poor evidences for category and 1 in case without evidences. If there was no available data value had not been estimated. The categories 1-5 had been estimated from field files, known published regional papers, relevant doctoral thesis and expert opinions. For exploration level (6) the mark 3 had been used in case with more than 10 wells in cell, mark 2 for 5-10 wells, and mark 1 for 1-5 wells. The further calculation used ponders: 2 for category 1, 1.5 for categories 2, 4, 5 and 1 for categories 3 and 6. The maximal total probability value is 25.5 (existence of hydrocarbons is sure) and minimal 8.5 (no probability of discovering). Result is transformed in POS scale, between 0 (for 8.5) and 1 (25.5) and represented in colored map, using five probability classes (each class comprise 20% of POS). The special emphasis in further exploration needs to be put on existence of anticlines in inter-field areas, especially in northern distributary channel system. The second targets are possible stratigraphic traps along the southern distributary channel system, and sporadically in previous mentioned northern system.

Keywords: Probability of Success (POS), Upper Pannonian, Ivanić-Grad Formation, sandstones, Sava Depression, Pannonian Basin, Croatia.

1. Geological introduction in explored area of the Sava Depression

Sava Depression lies along the SW margin of the Pannonian Basin and has the thickest sequence of the Neogene-Quaternary sediments (over 5000 m) in its western part, i.e. southern from the border with Moslavačka gora Mt. Depression length is about 100 km, and width approx. 25 km (in the widest part; **Fig. 1, fig. 2**)
The reservoirs are widely spread according to the age of individual sedimentary units and laterally so they could be found from basement („buried hill structure") to the Upper Pontian. The reservoirs are practically all types, but structural-stratigraphic and structural types are predominant, while *buried hills* and stratigraphic types are quite significant.

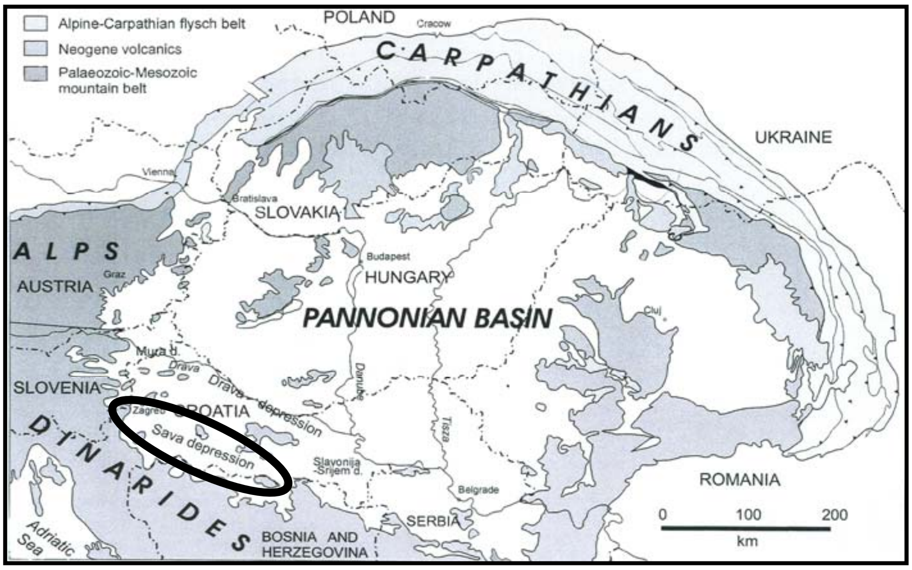

Fig.1. Geographic positions (location map) of the Sava Depression

The most important reservoir rocks are the Pannonian and Pontian sandstones (2nd megacycle) that start with the transgressive sediments of Lower Pannonian age represented by locally derived sandstones (originated from delta front) and interlayered with calcareous marls (deposited in shallow lake). Such deposits are continued by sediments of Upper Pannonian age, and originated from delta front, then the shallow lake continuing sedimentation of basinal deposited in calm environments, and eventually clastics from prodelta and turbiditic environments. Turbidites prevail in the Lower Pontian parts of the sequence, with some sediment originated from prodelta and delta, mostly documented along the NE margin of the Sava Depression. Large masses of deltaic sediments were deposited during the Late Pontian (mostly sandstones), although remains of the basin are still found, especially in the deep part of depression located E of Zagreb and NE of Sisak (SAFTIĆ et al. 2003; **Fig. 2**).
Geological and geochemical investigation of the sediments from 25 exploration wells in the Sava Depression led to identification and separation of the two source rock intervals and enabled the analysis of their characteristics in terms of the total content of organic matter (abbr. TOC), its type, quality, maturity level and generative potential.

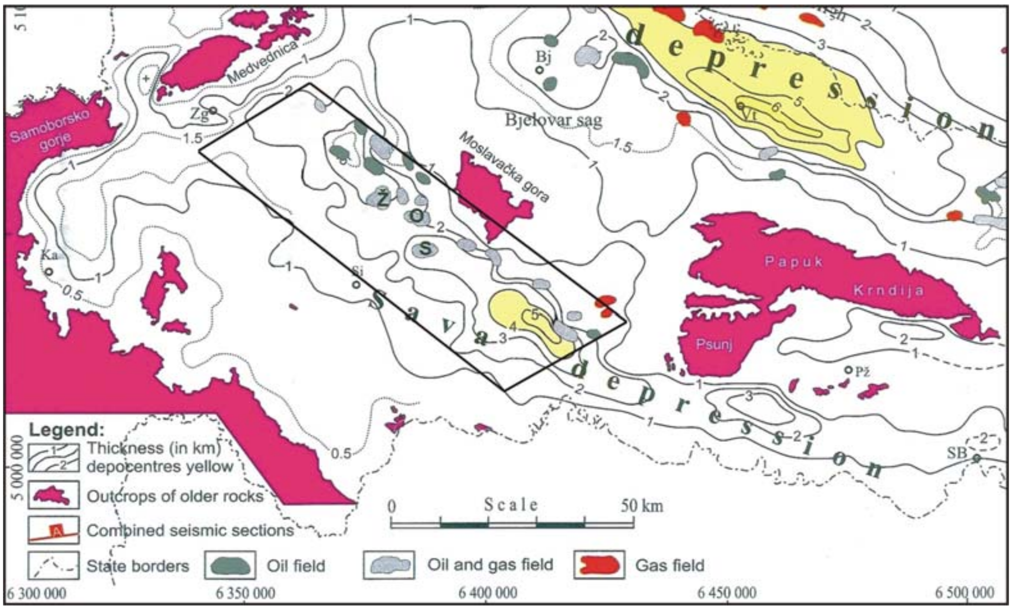

Fig. 2. Isopach map of the entire Neogene to Quaternary sequence with hydrocarbon accumulations (from SAFTIĆ et al., 2003)

High content of organic carbon has been determined in marls, calcitic marls, clayey limestones and shales of the Middle Miocene (Badenian and Sarmatian) and Upper Miocene (Lower Pannonian) age. Average TOC of source rock formations is 1.37 and 1.30%, respectively. Source rock intervals lay at depths of 1200 to 3362 m. Average thickness of the intervals is 100-200 m. Most of the investigated sediments are the petroleum source rocks with good generative potential. Regular linear increase of maturity with depth was determined. Organic matter is in the mature, i.e. in catagenetic stage of thermal alteration that enables the hydrocarbon generation (BARIĆ et al., 2000, 2003; TROSKOT-ČORBIĆ et al., 2009).

The Sava depression is ranked as well explored area, but in spite of that, already in 1994, some authors are pointed out the need for further and oriented explorations (VLAŠIĆ & BAUK, 1994; VELIĆ et al., 2002). In fact, when the volumes of sediments delimited by stratigraphic markers are compared with the number of well that penetrated these horizons, it comes out that some units are not as highly explored as it has originally appeared. More precisely, only 51% of wells (from totally 3700 wells) drilled EL-marker Rs7, which is border between Middle and Lower Miocene. It means that 2nd megacycle of deposition was not everywhere well explored and described.

Previously performed explorations in the Sava Depression led to discovering of totally 20 oil and gas fields. Moreover, 14 of them comprise hydrocarbon reservoirs in the Upper Pannonian sediments. More than 99% of recovered (conditional) oil reserves from these 14 fields had been produced from Upper Pannonian reservoirs. It means that the most quality reservoirs are sandstones of Upper Pannonian age. The second ones are sandstones of Lower Pontian age. Both these stratigraphic units belong to 2nd megacycle of Upper Miocene age (VELIĆ et al., 2002). Moreover, the area of Sava Depression includes the fields with very long period of production. There are located the oldest Croatian fields where hydrocarbon production started in the year 1946, i.e. in 1952.

In the several last decades the production of hydrocarbons continuously was decreased. It is why here is given some kind of calculation model useful for increasing of reserves and selection of new location for potential discovering of additional hydrocarbon reserves.

1.1. Rocks and Depositional Environments in the Sava Depression in Neogene and Quaternary

The rocks in depression subsurface can be divided in two, stratigraphically and lithologically, very different complexes. The older are rocks in **Miocene basement**, and the younger comprises the sediments of Miocene, Pliocene and Quaternary ages. The basement rocks are crystalline magmatic rocks and metamorphic complexes. The age of some sedimentary clastic rocks in basement is not clearly determined, but generally all mentioned basement rocks are of Paleozoic age. The younger sedimentary complex is formed solely of clastics from Miocene to Quaternary ages. It started with sedimentation in extensional tectonic areas, along syn-sedimentational fault zones, with strike NW-SE, on the northern and southern depression margins. Such sedimentation probably started in very restrictive structural depressions in **Ottnangian** with fresh water clastites (sand and gravel). But main event belongs to marine transgression in **Karpatian** and especially **Badenian**. The marine environment rapidly covered entire area. It lasted to **Sarmatian**, when link between Tethys and Paratethys had been broken. It resulted in reducing of marine environment, and salinity decreasing. Consequently, in **Pannonian and Pontian** stages the Sava depression was covered by brackish and fresh water. Depression subsidence is faster and in the deepest part the water depth reached several hundred meters (LUČIĆ et al. 2001).

The target is this researching were the sediment of **Upper Pannonian**. Paleogeographically, in that period the depression had very prominent paleorelief. The water environment had been represented as large lake of the Sava Depression. Very significant tectonic feature had been tectonic graben in the central part of the depression, encircled by sub-water highs. The depression in Upper Pannonian can be observed as some kind of basin open for periodical current flows, of different strength, which generally moved from NW-N toward SE-E. These turbiditic currents transported detritus like clay, and supported sedimentation of basin marls. But, it was dominantly mechanism for transporting silty and sandy detritus (VRBANAC, 1996; VRBANAC, 2002; VRBANAC et al., 2010). On the north of the Sava depression had been located area where large quantities of detritus was deposited, before it was transported in the depression. The origin of this detritus had been located in the Eastern Alps. Such material had been accumulated on tectonic ramp, and after the critical point regarding mass, any tectonic disorder or decreasing of water level in the Sava Lake, detritus started to be transported by turbiditic currents in the deepest part of the depression. In the same time, these deepest parts had been subdued to the highest subsidence. Such mechanism lasted through **Upper Pannonian, Lower Pontian** and weakening in **Upper Pontian**.

During the **Pliocene**, there were several lakes in the SW Pannonian Basin where sedimentation continued in the same environments. Infilling the remnants of the Lake Pannon (again firstly in the Drava and then in the Sava depression) with a variety of clastic sediments mixed with clay and lignite seams was followed by formation of mostly meandering river systems. As climatic change took place coupled with basin inversion and uplift of mountainous areas during the **Quaternary** not only sandstones but also

gravel beds appear as channel fills. The Sava River brought only the carbonate sandy gravels and it didn't happen before **Holocene**.
As the new picture, related to given description of Neogene sedimentation, here is outlined opinion from ĆORIĆ et al. (2009). There surprisingly the presented recent study suggests a distinctly younger age for the Neogene sedimentation in the North Croatian Basins than formerly considered. Probably the complete depositional cycle of its lower basinal infill, comprising the lacustrine and the early marine sediments, belongs to the Middle Miocene, i.e. Badenian stage. This completely changes the paleogeographic picture for the south-western part of the Pannonian Basin System. Instead of Ottnangian freshwater beds and a Karpatian marine transgression, aquatic environments existed solely during the Badenian.
In any case, the thickness of described depositional sequence (which lasted from Lower or Middle Miocene to Quaternary) can reach somewhere more than 5000 meters, but it is also on depression margins reduced to several hundred meters (**Fig. 2**).

1.2. Upper Pannonian Sediments as Researching Target

In the Sava Depression, in the last 60 years of hydrocarbon exploration and production, more than 1750 wells had been drilled. About 75% of wells is located inside contours of oil and gas fields, and rest belongs to inter-field areas. Regarding the paleogeography, the majority of wells drilled the shallowest and the youngest sediments. On contrary, the oldest Miocene sediments and deeper parts had been explored only in about hundred wells, mostly located on depression margins, where Neogene and Quaternary sediments are the thinnest. Eventually, Paleozoic basement rocks are proven with drilling only in few tens wells located along depression borders.
The sediments of Upper Pannonian age belongs to lithostratigraphy unit named as Ivanić-Grad Formation. Lithology is represented by alternation of sandstones, siltites and marls. The sandstones dominate in the central part of depression. On contrary, in marginal parts solely marls had been deposited. Consequently, the thickness of Upper Pannonian sediments is over 800 meters in the deepest part of the Sava Depression, but in marginal areas it is reduced to about 100 meters.
The reservoirs rocks can be sandstones, even thinner of 1 meter, but also thick several tens of meters. Such sandstones can show significant variations in petrophysical properties (porosity and permeability), what depends on their position regarding material source area and lateral distance from the main distributary channels. Generally, values of petrophysical properties decrease from NW toward E as well as away from channels located in the central part of depression.
Sandy detritus had been transported in depression exclusively by turbiditic currents. It means that spatial distribution of sandstone bodies indicates on flow directions of turbidites. The main transport pathways had been located in the deepest parts of depressions. In such areas also the major quantities of sands and silts had been deposited. Clastites had been transported in depression from the north, but very soon the main depositional channel had been divided in two distributary channels. One was located along NE margin of depression and here are discovered the majority of oil and gas fields. The second one is located on the SW margin, and it is poor explored area, where only three oil fields are discovered.

2. Some previous works on deterministical calculation of "POS" in the Croatian part of Pannonian Basin

One of the comprehensive works on probability of new hydrocarbon discoveries in the Bjelovar Subdepression (southern part of the Drava Depression) had been done in Malvić's dissertation (MALVIĆ, 2003). Probability of reservoir's existence has been evaluated. It comprised a selection and quantification of the four main categories of values that are important for hydrocarbon's reservoirs creation. Those were (1) geological and probability evaluation of source rocks and migration pathways, (2) traps and isolators, (3) good reservoirs, together with evaluation of (4) quality and recoverable hydrocarbons. The evaluation is made for three selected units and particular zones inside them. These units are named Mosti Member, Poljana and Pepelana Sandstones Members after valid Croatian lithostratigraphic nomenclature. Zones are named after structures that were mapped and analyzed in mentioned units.

High probability in Mosti Member of 0.57 is calculated (1.0 is probability of 100 %). Unfortunately, hydrocarbon favorable structures are explored almost completely. It is why the new estimation is performed only by the Dežanovec locality. Here, the calculated value is 0.165, and after comparison by risk of the whole unit, a new obtained value is only 0.09. Higher values are obtained for the Poljana and Pepelana Sandstones Members of the Kloštar-Ivanić Formation, mostly because these units are relatively low explored outside the Bilogora zone. Poljana Sandstone Member has probability of 0.57, and three zones are selected. The highest probability of 0.66 is assigned to the Cremušina zone on the northeast. Total probability of Poljana Sandstones Member (probability of the whole unit compared with probability of particular zones) is 0.45. The highest value is calculated in the Šandrovac zone, where probability for new hydrocarbon's discoveries is 1.0 (100 %). It points out that there are certain new reserves within the satellite reservoirs/fields or in recovering of by-passed oil.

The next one paper (MALVIĆ & RUSAN, 2007) encompassed the same area (Bjelovar Subdepression), but with more detailed definitions of regional geological settings as well as petrophysics and production data. Moreover, there are defined the terms "plays" and "prospects" in purpose of calculation of probability of success. Once more time, there are outlined two promising plays in the Bjelovar Subdepression: (1) basement rocks and Miocene breccia and (2) Upper Miocene sandstones.

The last one paper, but the most comprehensive work that include regional geological analysis, geological risk calculation, economical analysis of drilling costs and expected value of potential discovery, and eventually investment risk for now had been published in 2009 (MALVIĆ & RUSAN, 2009). It was modeled to be easily applicable in the Bjelovar Subdepression, but with slight modifications it could be applied in any area of the Croatian part of Pannonian Basin. Only application of these methodology indicated that based on geological settings of the Bjelovar Subdepression it could be expected that there are still relatively small, but economically positive, potential discoveries present.

Moreover, the proposed geological database represents the source of data describing each play or prospect in the Bjelovar Subdepression. The base for database had been methodology applied through decades in INA Oil Company Plc (**Fig. 3**). The five probability classes are selected as follows: 1.00 (proven geological event), 0.75 (highly reliable predicted), 0.50 (fairly reliable predicted), 0.25 (unreliable predicted) and 0.05 (missing geological event).

TRAP		RESERVOIR		SOURCE ROCKS		MIGRATION		HC PRESERVATION	
Structural		**Reservoir type**		**Source facies**		**HC shows**		**Reservoir pressure**	
Anticline and buried hill linked to basement	1.00	Sandstone clean and laterally extended; Basement granite, geiss, gabbro; Dolomites and Algae reefs (secondary porosity)	1.00	Kerogen type I and/or II	1.00	Production of hydrocarbons	1.00	Higher than hydrostatic	1.00
Faulted anticline	0.75	Sabdstones, rich in silt and clay; Basement with secondary porosity, limited extending; Algae reefs, filled with skeletal debris, mud and marine cements	0.75	Kerogen type III	0.75	Hydrocarbons in traces; New gas detected >10 %	0.75	Approximately hydrostatic	0.75
Structural nose closed by fault	0.50	Sandstone including significant portion of silt/clay particles, limited extending;	0.50	Favourable palaeo-facies organic matter sedimentation	0.50	Oil determined in cores (luminescent analysis, core tests)	0.50	Lower than hydrostatic	0.50
Any "positive" faulted structure, margins are not firmly defined	0.25	Basement rocks, including low secondary porosity and limited extending	0.25	Regionally known source rock facies, but not proven at observed locality	0.25	Oil determined in traces (lumin. anal., core tests)	0.25		0.25
Undefined structural framework	0.05	Undefined reservoir type	0.05	Undefined source rock type	0.05	Hydrocarbon are not observed	0.05		0.05
Stratigraphic or combined		**Porosity features**		**Maturity**		**Position of trap**		**Formation water**	
Algae reef form	1.00	Primary porosity >15 %; Secondary porosity >5 %	1.00	Sediments are in catagenesis phase ("oil" or "wet" gas-	1.00	Trap is located in proven migration distance	1.00	Still aquifer of field-waters	1.00
Sandstones, pinched out	0.75	Primary porosity 5-15 %; Secondary porosity 1-5 %	0.75	Sediments are in metagenesis phase	0.75	Trap is located between two source rocks depocentres	0.75	Active aquifer of field-waters	0.75
Sediments changed by diagenesis	0.50	Primary porosity <10 %; Permeability <1x10**(-3) micrometer**2	0.50	Sediments are in early catagenesis phase	0.50	Short migation pathway (<=10 km)	0.50	Infiltrated aquifer from adjacent formations	0.50
Abrupt changes of petrophysical properties (caly, different facies)	0.25	Secondary porosity <1 %	0.25	Sediments are in late diagenesis phase	0.25	Long migration pathway (>10 km)	0.25	Infiltrated aquifer from surface	0.25
Undefined stratigraphic framework	0.05	Undefined porosity values	0.05	Undefined maturity level	0.05	Undefined source rocks	0.05		0.05
Quality of cap rock				**Data sources**		**Timing**			
Regional proven cap rock (seals, isolator)	1.00		1.00	Geochemical analysis on cores and fluids	1.00	Trap is older than matured source rocks	1.00		1.00
Rocks without reservoir properties	0.75		0.75	Analogy with close located geochemical analyses	0.75	Trap is younger than matured source rocks	0.75		0.75
Rocks permeable for gas (gas leakage)	0.50		0.50	Thermal modeling and calculation (e.g. Lopatin, Waples etc.)	0.50	Relation between trap and source rocks is unknown	0.50		0.50
Permeable rocks with locally higher silt/clay content	0.25		0.25	Thermal modeling at just a few locations	0.25		0.25		0.25
Undefined cap rock	0.05		0.05	Undefined data sources	0.05		0.05		0.05

Fig. 3. Geological categories/events classified into five probability classes (from MALVIĆ & RUSAN, 2007, 2009)

Also, there is meaningful connected the way of POS calculation as well as using of utility function and estimation of expected monetary value of potential discovery (in promising play or prospect). Because of the Bjelovar Subdepression is mature petroleum province, such analysis included the risk-averse approach, i.e. exponential utility function. The authors explained that: *"Utility function was applied to calculate risk neutral dollars which hypothetical company would be willing to spend in the exploration of new discoveries (size $2x10^5$ m^3 of oil equivalent and POS 28.48%) within an expected monetary value (EMV) of 2.42 million USD. The amount of 850,000 risk-neutral USD is estimated as the investment limit for a company with a 50 million USD budget, and accompanied by RAV of 35%"* (MALVIĆ & RUSAN, 2009).

3. Calculation Grid and Excel Worksheet

The calculation grid (**Figs 4 and 5**) is presented by cells that covered the explored western part of the Sava depression. It is also part of depression where are deposited the sandstone bodies (members) of Ivanić Grad Formation as target for exploration of hydrocarbon potential.

The analyzed area was divided in squares of size 5x5 km, totally 74 cells (**Figs 4 and 5**). Probability of hydrocarbon existence had been estimated for each cell (value similar to Probability Of Success – POS), using six geological categories: existence of (1)

hydrocarbons (2) reservoirs (3) source rocks (4) traps, and (5) quality of reservoirs (6) exploration level based on number of wells.
Each of categories could be estimated with three values: 3 for clearly proved category from excellent data, 2 for weak or poor evidences for category and 1 in case without evidences. If there was no available data value had not been estimated. The categories 1-5 had been estimated based on (a) field files, (b) a few regional well-known published papers, (c) relevant PhD thesis and (d) expert opinions. In the case of exploration level (category 6) the mark 3 had been used in the case with more than 10 wells in cell, mark 2 for 5-10 wells, and mark 1 for 1-5 wells. The further calculation is based on following ponders (**Fig. 4**): 2 for category 1, 1.5 for categories 2, 4, 5 and 1 for categories 3 and 6. The maximum value of total probability value is 25.5 (existence of hydrocarbons is sure) and minimal 8.5 (there is no probability of discovering hydrocarbons). The calculated value is transformed in POS scale, i.e. between 0 (for 8.5) and 1 (for sum 25.5) and graphically represented in colored map, using five probability classes (<20, 20-40, 40-60, 60-80 and >80% of POS).
In present procedure, each cell (quadrant) in the map received probability percentage of hydrocarbon discovery expressed numerically and in color (**Fig. 5**). As it was expected, the highest value (100%) are calculated in the cell where are already discovered fields with production of hydrocarbons, and field's areas covered the most of the cell. In the case where field covered small part of the cell probability is between 82 and 91%. Almost all fields are located along NE part of the depression, i.e. along the main distributary channels where the major part of detritus had been transported and deposited. The values between 44 and 61% are mostly calculated in the cells that bordered cell covered with hydrocarbon fields.
As the promising cells regarding existence of undiscovered hydrocarbon reserves could be selected quadrants no. 12, 18, 23, 29, 39, 53, 62, 69 and 70. All these cells (except cell no. 53) are located along SW part of the depression. This is also southern margin of lateral changing of sandstone bodies. Regarding the strike of such depositional bodies, existence of system of distributary channels along SW depression part, and regional tilting of the depression toward S in the Middle and Late Pliocene and Quaternary, it can be supposed that still undiscovered hydrocarbon reserves are mostly connected with stratigraphic traps. These traps are mostly linked to lateral thinning of sandstone bodies, and only sporadically for structural traps (anticlines). Moreover, this part of depression is very poor explored by drilling. Rare wells are located on the structural highs, and some of them are even drilled in areas where sandstones of Ivanić Grad Formation are missing. Generally, the lowest values are obtained in marginal parts of the depression where sandstones are missing or are poorly developed as potential reservoir rocks.

Area (cell)	HC shows	Reservoir rocks	Source rocks	Trap	Reservoir quality	Explored by wells	Sum using ponders	Correction if POS<8.5	POS (%)
1	1	2	1	1	1		9	9	2,94
2	1	3	1	1	2	2	14	14	32,35
3	1	2	1		2		9	9	2,94
4	1	2	1	1	1	1	10	10	8,82
5	1	3	1	2	2	2	15,5	15,5	41,18
6	1	2	1	1	2	1	11,5	11,5	17,65
7	1	1	3	1	2	2	13	13	26,47
8	3	3	3	2	2	3	22,5	22,5	82,35
9	3	3	3	2	2	3	22,5	22,5	82,35
10	1	3	2	2	2	2	16,5	16,5	47,06
11	1	1	3	2	1	1	12	12	20,59
12	2	3	3	2	2	2	19,5	19,5	64,71
13	1	3	3	1	2	2	16	16	44,12
14	3	3	3	2	3	3	24	24	91,18
15	3	3	3	2	2	3	22,5	22,5	82,35
16	1			1	1	2	7	8,5	0,00
17	1	3	3	2	2	2	17,5	17,5	52,94
18	1	3	3	2	2	3	18,5	18,5	58,82
19	3	3	3	2	2	3	22,5	22,5	82,35
20	3	3	3	3	3	3	25,5	25,5	100,00
21	3	3	3	2	2	3	22,5	22,5	82,35
22	1	1	1	1	1	2	9,5	9,5	5,88
23	1	3	3	2	2	2	17,5	17,5	52,94
24	3	3	3	2	3	3	24	24	91,18
25	3	3	3	3	2	3	24	24	91,18
26	3	3	3	2	2	3	22,5	22,5	82,35
27		3	3	2		3	13,5	13,5	29,41
28	1	2	3	2	2	2	16	16	44,12
29	1	3	3	3	2	2	19	19	61,76
30	3	3	3	2	3	3	24	24	91,18
31	3	3	3	2	3	3	24	24	91,18
32	1	3	3	1		3	14	14	32,35
33	1	1	2	1	1	1	9,5	9,5	5,88
34	3	3	3	2	3	3	24	24	91,18
35	3	3	3	2	3	3	24	24	91,18
36	3	3	3	2	3	3	24	24	91,18
37	1	1	3	1	1	1	10,5	10,5	11,76
38	1	1	2	1	1	2	10,5	10,5	11,76
39	3	3	3	1	2	1	19	19	61,76
40	3	3	3	3	3	3	25,5	25,5	100,00
41	3	3	3	3	2	2	23	23	85,29
42	3	3	3	3	2	2	23	23	85,29
43	1	1	2	1	1	2	10,5	10,5	11,76
44	3	3	3	3	3	3	25,5	25,5	100,00
45	3	3	3	3	3	3	25,5	25,5	100,00
46	3	3	3	3	3	3	25,5	25,5	100,00
47	3	3	3	3	3	3	25,5	25,5	100,00
48	1	1	1	1	1	2	9,5	9,5	5,88
49	1	2	2	2	1	2	13,5	13,5	29,41
50	1	2	2	2	2	2	15	15	38,24
51	1	1	3	1	1	2	11,5	11,5	17,65
52		1	3	2	2	2	12,5	12,5	23,53
53	1	3	3	1	3	1	16,5	16,5	47,06
54	1	3	2	2	2	3	17,5	17,5	52,94
55	1	1	3	1	1	2	11,5	11,5	17,65
56	1	3	3	1	2	1	15	15	38,24
57	1	3	3		1	2	13	13	26,47
58	3	3	3	3	3	3	25,5	25,5	100,00
59	3	3	3	3	3	3	25,5	25,5	100,00
60	3	3	2	3	2	3	23	23	85,29
61	1	1	2		1	1	8	8,5	0,00
62	1	3	3	2	1	2	16	16	44,12
63	3	3	3	2	2	2	21,5	21,5	76,47
64	3	3	3	3	3	3	25,5	25,5	100,00
65	3	3	3	3	3	3	25,5	25,5	100,00
66	3	3	3	2	2	3	22,5	22,5	82,35
67		1	1	1	1		5,5	8,5	0,00
68	1	3	3	2	1	1	15	15	38,24
69	1	3	3	1	1	2	14,5	14,5	35,29
70	3	2	3	2	1	2	18,5	18,5	58,82
71		1	2	1	1	2	8,5	8,5	0,00
72	1	1	1	1	1		7,5	8,5	0,00
73		2	2	2	1		9,5	9,5	5,88
74		2	2	2	1		9,5	9,5	5,88

Fig. 4. Excel worksheet for calculation of POS in cells

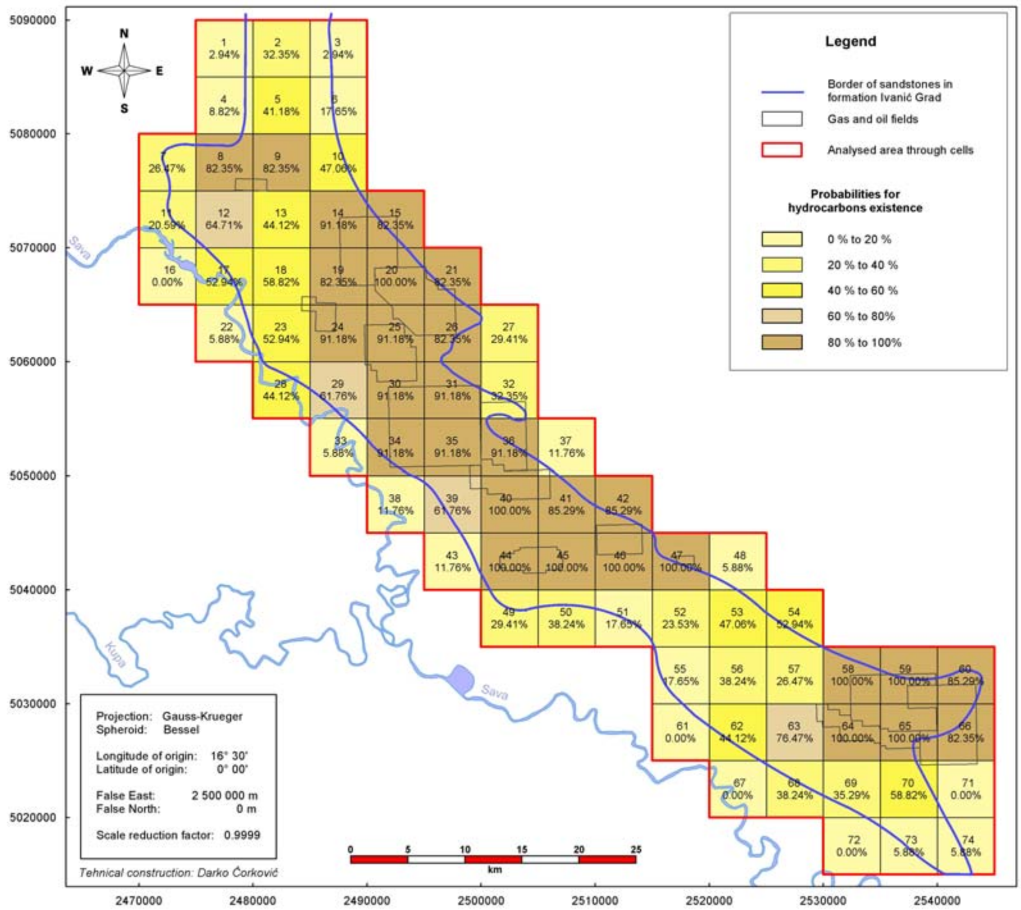

Fig. 5. Location of cells in calculation grid of POS for Ivanić-Grad Formation (western part of the Sava Depression)

4. Review of the Most Important Results

Presented analysis is one practical application of well-known deterministic calculation of POS, modified and used in the western part of the Sava Depression. More precisely, it is applied for new hydrocarbon discoveries estimation in the sandstone members of Ivanić-Grad Formation of Upper Pannonian age. Inside this formation are already discovered the major hydrocarbon reserves in analyzed depression.

Moreover, there are three important statements that could be emphasized in results review:

(a) Statistical analysis of selected geological categories in the Sava Depression indicated on existence of additional parts where can be excepted new, undiscovered hydrocarbon reserves.

(b) The special emphasis in further exploration needs to be put on existence of anticlines in inter-field areas. It is especially valid in area of the northern distributary channel system.

(c) The second targets are possible stratigraphic traps along the southern distributary channel system, and sporadically in previous mentioned northern system.

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