HRVATSKI SAVEZ INOVATORA
10000 Zagreb, Trg žrtava fašizma 14
tel. 01/4612 517, fax 01/4662 680; hsi@inovator.hr

Application of indicators in hydrocarbon reservoir mapping in Croatia

Tomislav MALVIĆ*,**

* INA Plc., Sector for Geology and Reservoir Management, Zagreb, CROATIA, e-mails: tomislav.malvic@ina.hr
** Faculty of Mining, Geology and Petroleum Engineering, Department for Geology and Geological Engineering, Zagreb, CROATIA

ABSTRACT

The mapping of facies is important task in modelling of hydrocarbon reservoirs. One of the most often methods for their description are from the set of indicator ones. Until recently, that set of methods was not used in the mapping of sandstone hydrocarbon reservoirs in the Croatian part of the Pannonian Basin System. Some of such reservoirs properties are: (1) relative small number of point data (<20), (2) irregular spatial distribution, (3) impossibility to determine borders among different lithofacies. The presented innovation included two steps applied for the better reservoir characterisation. The first one (a) was distinguishing of permeable and impermeable parts, applying original technique of indicator variable definition and lately mapping by technique generally applied for original data (Ordinary Kriging). So, it was possible the replace manual interpolation of lateral facies changing line by computer mapping. In the second step (b) indicators had been applied for recognition of even four particular lithofacies, where the characteristic variogram curves are defined, and Indicator Kriging was applied for mapping. The results made possible to follow the directions of each particular lithology (sandstones, marlitic sandstone, sandy marl and marl).

PROBLEM 1: MAPPING OF SANDSTONE AND MARLSTONE BORDER USING INDICATORS

Distribution of sandstone (**Figure 1**) and marlstone (**Figure 2**) in analysed model was matched with manually interpolated line of those lithofacies changing (**Figures 3 and 4**), using available measurements and interpretations. It was assumed that such problem can be interpolated using computer algorithms, as the most of other types of subsurface geological mapping performed in hydrocarbon reservoir analyses.

Those two lithofacies (**Figures 1 and 2**) are marked with indicator variable of values 0 and 1. Transformed data had been analysed by variograms (but no standardized), looking on them as "original measurements". The next analytical step included calculation of variogram surface maps. Eventually, the indicator values (0 and 1) are interpolated by Ordinary Kriging technique, what is original approach in this kind of lithofacies analysis.

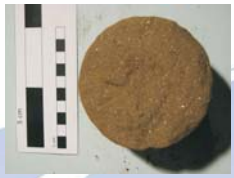

Figure 1: *Sandstone*

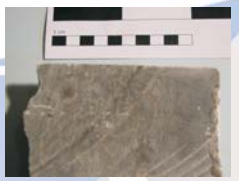

Figure 2: *Marlstone*

Problem 1 solved: recognition of sandstone and marlstone border with high accuracy.

*Colour lithological legend for **Figure 3 and 4**:*
marl = light yellow, sandy marl = yellow, marlitic sandstone = green, sandstone = grey blue.

*Line legend for **Figure 3 and 4**:*
Black line 0.5 = computer interpolated border between sandstone and marlstone;
Red line = manually interpolated border, approx. on the half distance between
0 (marlstone) and 1 (sandstone).

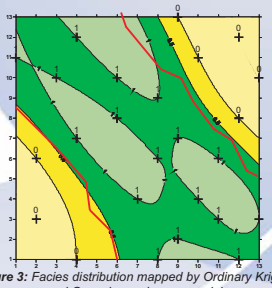

Figure 3: *Facies distribution mapped by Ordinary Kriging and Gaussian variogram model*

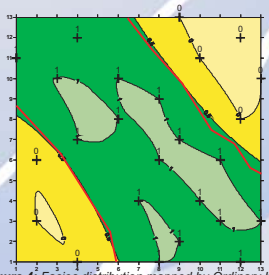

Figure 4: *Facies distribution mapped by Ordinary Kriging and spherical variogram model*

PROBLEM 2: MAPPING OF FOUR LITHOFACIES (SANDSTONE, MARLITIC SANDSTONE, SANDY MARLSTONE, MARLSTONE)

Detailed lithofacies mapping is important tasks in modelling of hydrocarbon reservoirs. Lithofacies type has direct influence on porosity and permeability values, which eventually influence both the migration and accumulation of hydrocarbons. The most numerous reservoirs in the Croatian part of the Pannonian basin major are in the Late Pannonian and Early Pontian sandstones, deposited with turbiditic mechanism in the lake environment (mostly up to 200 meters depth). Sandstones generally form sedimentary bodies that are very elongated in approximately NW-SE direction, with sharp transition toward basin marls in bottom and top. On the contrary, lateral transition is gradual, forming four depositional lithofacies:

(1) Clean, medium-grained sandstones (**Figure 5**),
(2) Silty and marlitic sandstones (**Figure 6**),
(3) Sandy marlstones (**Figure 7**),
(4) Basin marlstones (**Figure 8**).

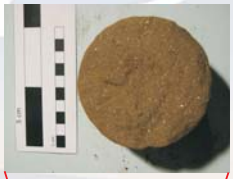

Figure 5: *Sandstone*

Figure 6: *Marlitic sandstone*

Figure 7: *Sandy marlstone*

Figure 8: *Marlstone*

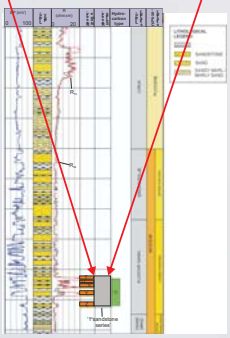

Figure 9: *Schematic composite geological column (including stratigraphy, e-logs and lithology) of the well drilled typical sandstone reservoir of Lower Pontian age.*

Such lateral lithofacies transition was analysed in the several fields in the Croatian part of the Pannonian Basin. Resulting maps of such analysis in the Lower Pontian sediments in the Sava Depression are shown in **Figure 11**. There is applied mapping with Indicator Kriging technique.

This mapping algorithm was applied on porosity data sampled and averaged in one typical Lower Pontian sandstone reservoir. Those values also included marginal parts of sandstone toward basinal marlstone, i.e. some of them were measured in transitional lithofacies (**Figure 11**).

Problem 2 solved: possibility to recognize four lithofacies (in depositional system sand-marl).

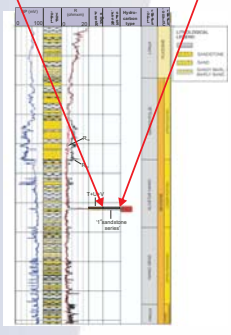

Figure 10: *Schematic composite geological column (including stratigraphy, e-logs and lithology) of the well drilled typical marsltone of Lower Pontian age.*

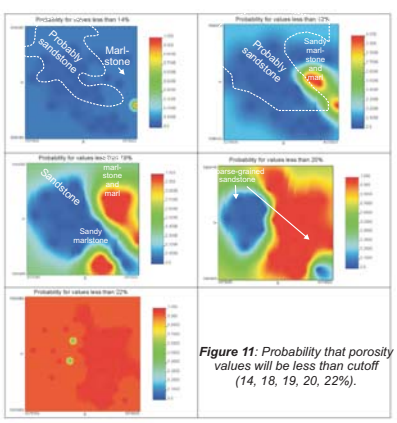

Figure 11*: Probability that porosity values will be less than cutoff (14, 18, 19, 20, 22%).*

ADVANTAGES OF INNOVATION

The innovation made possible the following:
1. Application of computer in more accuracy mapping of lateral lithofacies changing. That was doing mostly manually in the past.
2. Computer mapping of four lithofacies in the depositional environments with sandstones, deposited through Neogene in the Croatian part of the Pannonian Basin System. Earlier only one lithofacies was described in details, i.e. the reservoir lithology with the majority of migrated hydrocarbons.

PURPOSE

Application is in the field of improved mapping of point data, in describing lithofacies borders with computers and geostatistical algorithms. The main application is in the geology of hydrocarbon reservoirs, but can be used in all geosciences that describe rock systems with more lithofacies and common genesis.

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INA d.d. Sektor za geologiju i upravljanje ležištima

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