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Lithofacial Geostatistical Analysis in the Central Part of the Getic Foreland Basin, Romania

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Structural geostatistical analysis of qualitative parameters of reservoirs rocks is suitable for lithofacial correlation by using the geological cross-sections. One of the most classic variables, represented on the maps and geological cross-sections is the lithology of the formations. The study area for the lithofacial structural analysis of this qualitative variable is situated in the north-central part of the Getic Depression, Southern Carpathians, Romania (Fig. 1).

Including an exam by grain size, petrographical and sedimentary structures analysis, the sequence stratigraphic analysis of the siliciclastic deposits exposed in outcrops point out some facies associations, mainly deltaic. Four principal facies associations have been recognized: fluvial associations, fluvial-dominated delta plain associations, fluvial-dominated delta front associations and shoreface association. As a rock reservoir potential, the most important reservoirs in such depositional environments are distributary mouth-bars, shallow marine reservoirs and channel sands.

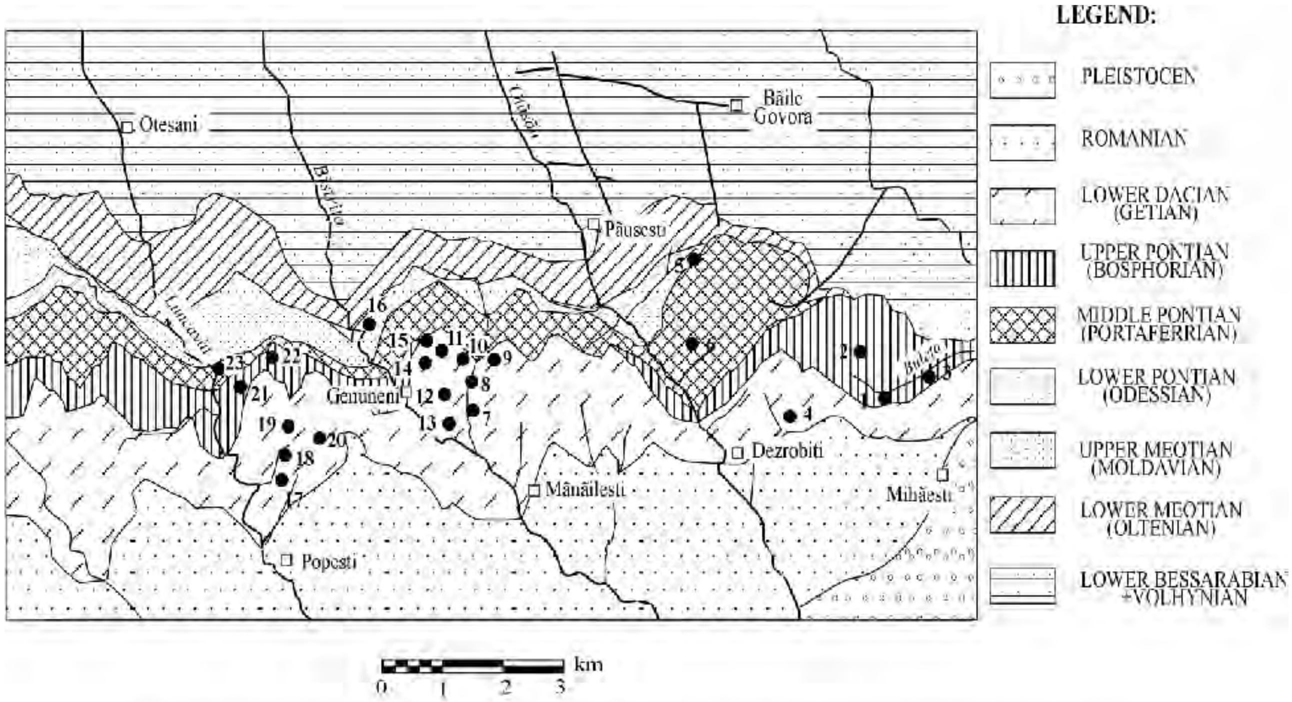


Fig. 1. Sketch map with location of the studied profiles (after Romanian geological map , scale 1 50.000, Govora map, in print).

The locations of the studied profiles are showed in the Figure 1. For all these profiles detailed sedimentological observations have been made. From a lithological point of view, the sedimentary formations in this area are preponderantly constituted from sands and subordinately from shale and gravels. The Meotian formations are characterized by the presence of thin beds of fine and medium sandstones and the presence of some intervals with numerous concretions varying in shape and size (up to 0.5 m in diameter). The relative monotony of the formations is compensated by the numerous sedimentary structures and vertical sequences that can be observed. The most common sedimentary structures are:

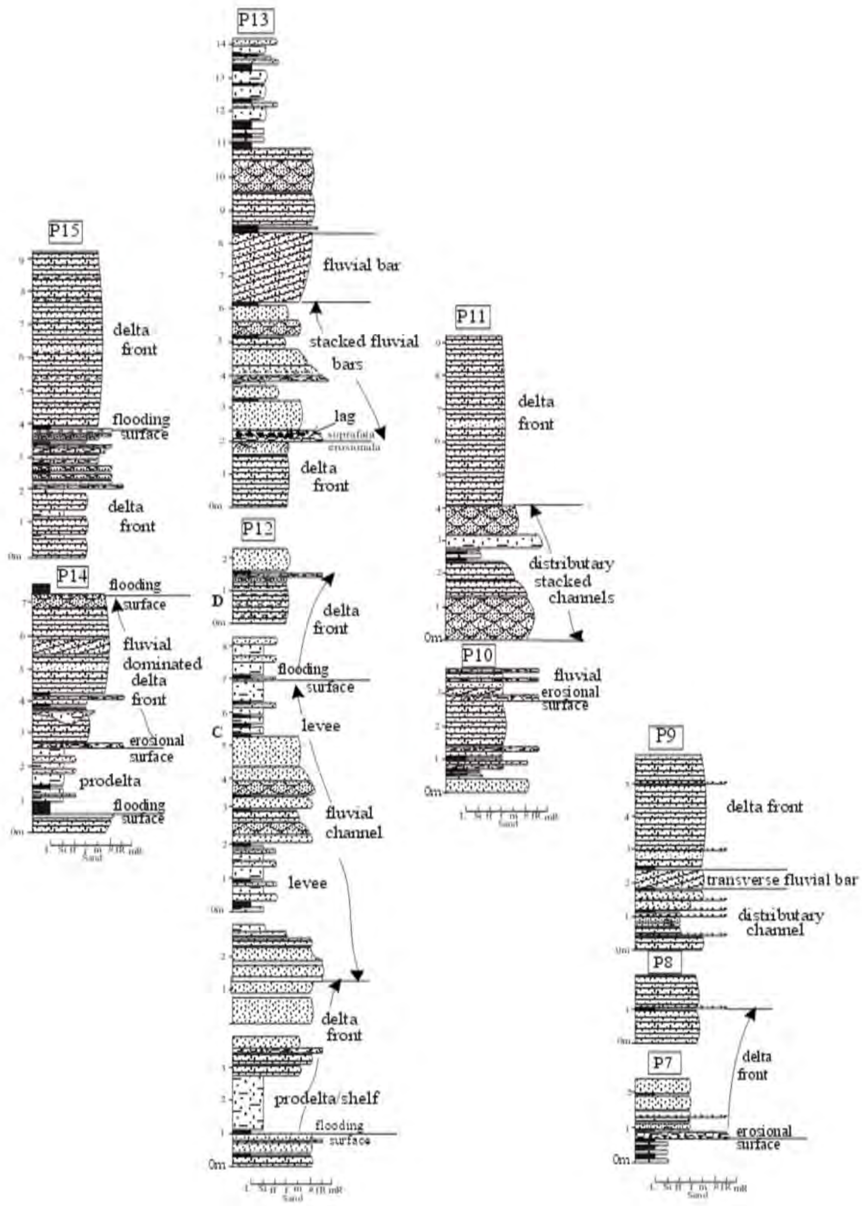


Fig. 2. Granulometrical and sedimentological characteristics of the studied vertical profiles

parallel laminations, trough- and tabular cross lamination (with sets thickness varying from 5cm to 2m, and dip angles between 5^0- 45^0), wave ripples, current ripples, ripple-marks, wavy laminations, flaser structures, mud drapes structures, etc. The vertical sequences are represented both by fining-upward sequences and coarsening-upward sequences, centimeters to meters thick. Some of the sedimentary structures are typically for ones of the depositional environments. The depositional environments in this area are nonmarine environments (alluvial fan deposits) and transitional environments associated with the mouth of large rivers: deltas and seashores. From granulometric point of view, the deposits are various, being represented all the granulometric categories: mud, siltite, very fine sand, fine sand, medium- and coarse sand, fine- and coarse gravel; the contacts between all these granulometric categories are both sharp and transitional.

The Pliocene formations were sedimentologically analyzed for diverse stratigraphic ages. However, for the present stochastic modeling method, only Dacian lithological profiles were chosen (Fig. 2). This chose is motivated by the relative uniform distribution of the profiles within study area. These profiles are: profile P14_15, profile P12_13, profile P10_11 and profile P7_9; they were realized on the basis- and by putting together all the lithological columns with metric dimensions, whom positions are represented in Figure 1.

The Dacian deposits are present on the both sides of the Apa Rosie Valley, the Bistrita Valley, the Buna Valley and the Luncavat Valley (profiles: 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20 - Fig.2). On the Apa Rosie Valley, close to the Genuneni Village, the outcrops are smaller than the others (profiles: 7, 8, 9, 10), and the observations were limited. The sedimentary structures are common to the Neogene deposits in this area: parallel laminations, tabular cross laminations, trough cross laminations, massive structures, and current ripples; the profiles are marked by the presence of thin, tabular- or lens-formed gravel intercalations (0.5-3cm diameter). Regarding the bigger outcrops (profiles: 11, 12, 13), they are less monotonically from granulometric point of view: all the granulometric categories are present, from mud to gravel. The bigger profiles are more varied also from the sedimentary structures point of view, the thickness of the lamina sets varying from 2 cm to 2.20 m; there are present also mud intercalations with convolute lamination and channel structures (profile 12, Fig. 2). The vertical sequences have small dimensions (5-10cm) and are both coarsening- and fining-upward. On the Bistrita Valley was observed two profiles with great thickness, close to the Genuneni Village (profile 14, Fig. 2) and on the northeastern side of the Dughean Hill (profile 15, Fig. 2). There are present many channel fill structures on the predominantly medium sands deposits with parallel lamination. The most common vertical sequences are coarsening-upward sequences with small thicknesses. On the Buna Valley (profiles 17, 18, 19, 20, Fig.2) the outcrops have small thicknesses and the conditions to make observations are less favorable. The predominant granulometric fraction is fine-, and medium sand. The most common sedimentary structures are parallel laminations and channel fill structures. Between these structures there are intercalated massive sand beds and decimeter thick beds of sand with trough cross lamination and heavy mineral concentrations. Are also present (not characteristic for all profiles) microsequences with normal graded bedding.

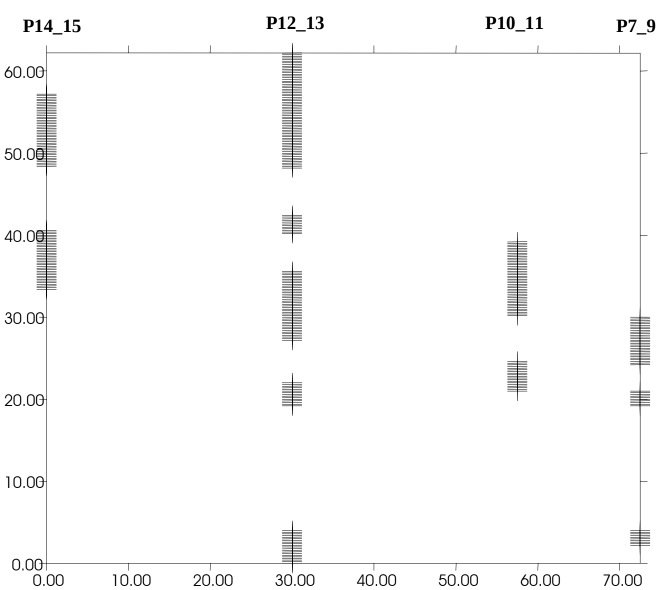
Realization of the geostatistical lithological sections

The geostatistical method used to modeling the lithological distribution is the punctual estimation method (Scradeanu, 1995, 1996; Scradeanu and Mihnea, 1987), based on indicator kriging. The lithological section is considered along an alignment of appreciatively 7250m, trending west to east. The four lithological profiles (Fig. 2), having thicknesses of meters, are crossing a lithological succession made up by mudstones, siltstones, sands and gravels.

Processing of primary data

The main objective of this step is **discretization** ***and*** **codification** ***of primary data – the incontinuous lithological successions (because of the lack of information in outcrops) of the four profiles. The discretization of the information means the transformation of the incontinuous lithological successions of the four profiles into a finite row of qualitative values. Because of the complexity of the lithological succession in the studied case, a discretization interval*** **e=0.2 cm** ***is used. For discretization of the primary data it is necessary to construct a reference system for location of the discretization points. The origin of the reference system (0) has the ordinate at zero and the abscissa at the vertical line of the profile P14_15. The distances between profiles are: 3000m, 2750m and 1500m respectively (Fig. 3). For the graphical representation in this case it was used a 1:100 vertical scale and a 1:1000 horizontal scale. The discretization result of the primary data used for construction of lithological sections are synthesized in tables, and represented by 359 points (82 points for profile P14_15,*** **162** ***points for profile P12_13,*** **65** ***points for profile P10_11, and*** **50** ***points for profile P7_9) of (x, y) coordinates. In these (x, y) coordinates we know the lithology (lutite/siltite/arenite/rudite).***

The codification of the discretizated data means the transformation of the qualitative values "lutite", "siltite", "arenite" and "rudite" in numerical values adapted for geostatistical techniques (kriging indicator). The numerical values used for the codification of the discretized lithological successions are: ***0*** (zero) for *the absence* of the lithological type studied in a specific point of the discretization grid; ***1***(one) for *the presence* of the lithological type.



Following these rules and using the discretization results of primary data, the coded data for construction of the lithological section are obtained (Table 1). In order to be processed by Surfer, the coded data were organized in ASCII files. For each of the lithological type the number of variables is three (*x*, *y*, *lithologic type*).

Structural analysis of coded data

It can be conclude that the lithotype distribution is relatively complex. However, due to lack of data (measurements) along the vertical profiles, as well as in between the

profiles, the variables development is considered compact; therefore, the studied lithological section is considered homogenous from a structural point of view.
Fig.3. Primary data used for construction of the lithological sections

Table 1. ***– Coded data used to construct the geostatistical lithological sections (partial data)***

Nr. crt.	x	y	Lutite	Siltite	Arenite	Rudite
1	0	33.4	0	0	1	0
2	0	33.6	0	0	1	0
3	0	33.8	0	0	1	0
….	….	….	…..	……	……	……
355	72.5	29.2	0	0	0	1
356	72.5	29.4	0	0	1	0
357	72.5	29.6	0	0	1	0
358	72.5	29.8	0	0	1	0
359	72.5	30	0	0	1	0

Because the vertical sampling distance is much smaller than the horizontal one (between 1500-3000 m), the grid geometry is strongly anisotropic (43 horizontal lines and only 4 vertical lines). Therefore, the structural structure is characterized by a strong anisotropy.

Estimation of the spatial distribution of the lithotypes

The spatial distribution of the four lithological types used in this study is obtained by using their numerical values in each point of the primary data discretization grid. Have been chosen at least two network grids: (a) 43 horizontal lines and 50 vertical lines, and (b) 43 horizontal lines and 4 vertical lines. In order to obtain a good correlation between the estimation error variance and the sampling distance, the anisotropy ratio used for the latter network grid is 100. Probabilistic distribution for every lithotype is then obtained by using a probability interval p=0.5-1; moreover, for probabilistic distribution of the rudite, the entire range of apparition was used, p=0-1. As an example, the sections with the arenite appearance isoprobabilities are shown in Fig. 4. In order to visualize the areas where the appearance probability is greater than the absence probability for all the lithotypes, an interval p=0.5-1 of probability and a unitary anisotropy ratio are chosen. The superimposing result of four different sections is presented in Fig. 5., showing that the ordinary kriging has a smoothing effect. The same superimposing result could be made for different probability intervals and different anisotropy ratios. The difference between these realizations reflects an uncertainty of the model because of lacking in data. Distribution of potential reservoirs, as well as facies changes, is shown by isolines of maximum probability sections. In this case the lithological information is directly used in the kriging system especially for the local estimation of sand proportion.

Univariate spatial evaluation could make facies identification possible in inaccessible and/or with lack of information areas and points out the distribution of principal reservoir rocks.

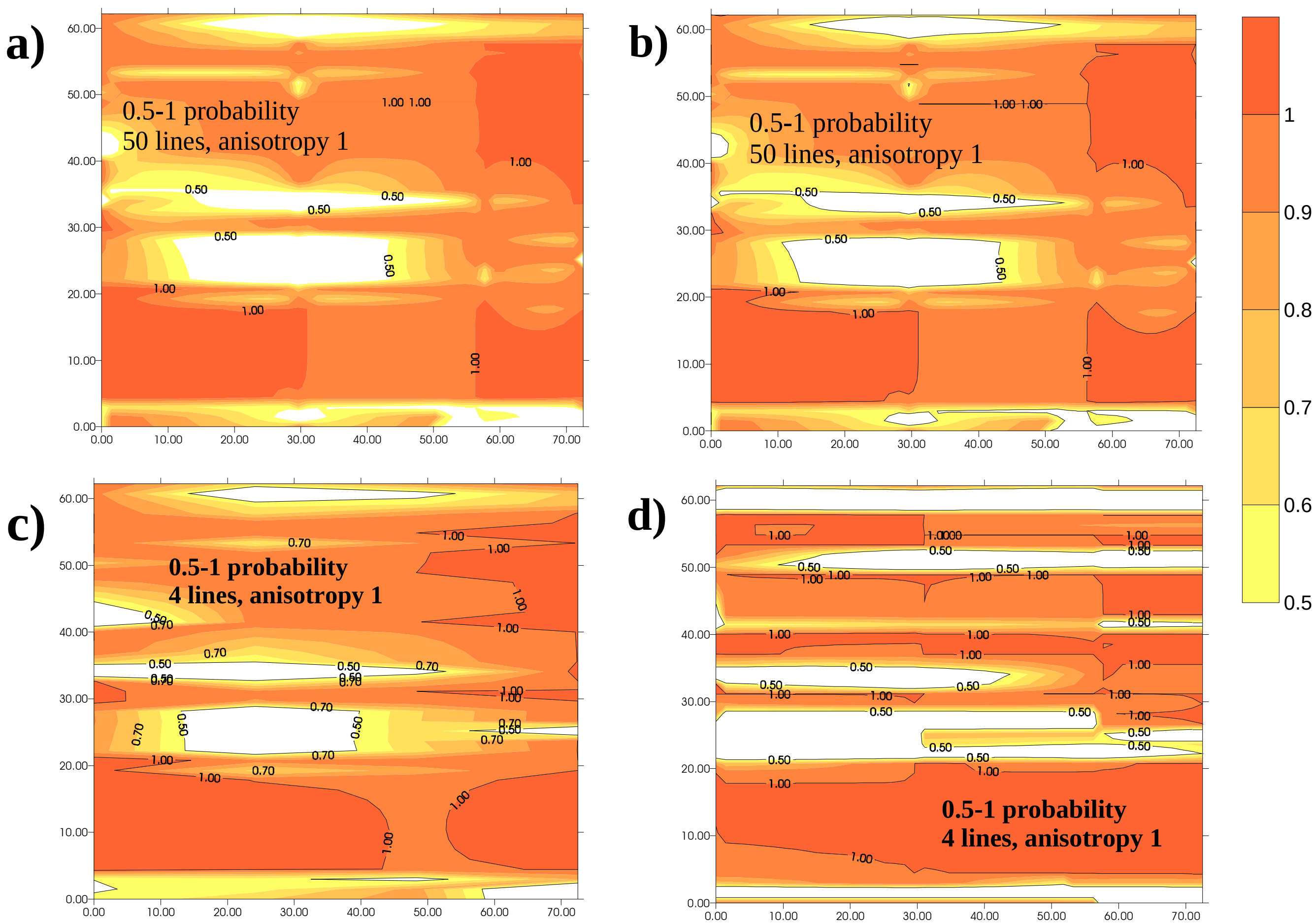


Fig. 4. Sections with arenite appearance isoprobabilities, for 50 lines grid (a,b), respectively 4 lines grid (c) vertically and for an anisotropy ratio with value 1(a, b si c), respectively 100 (d).

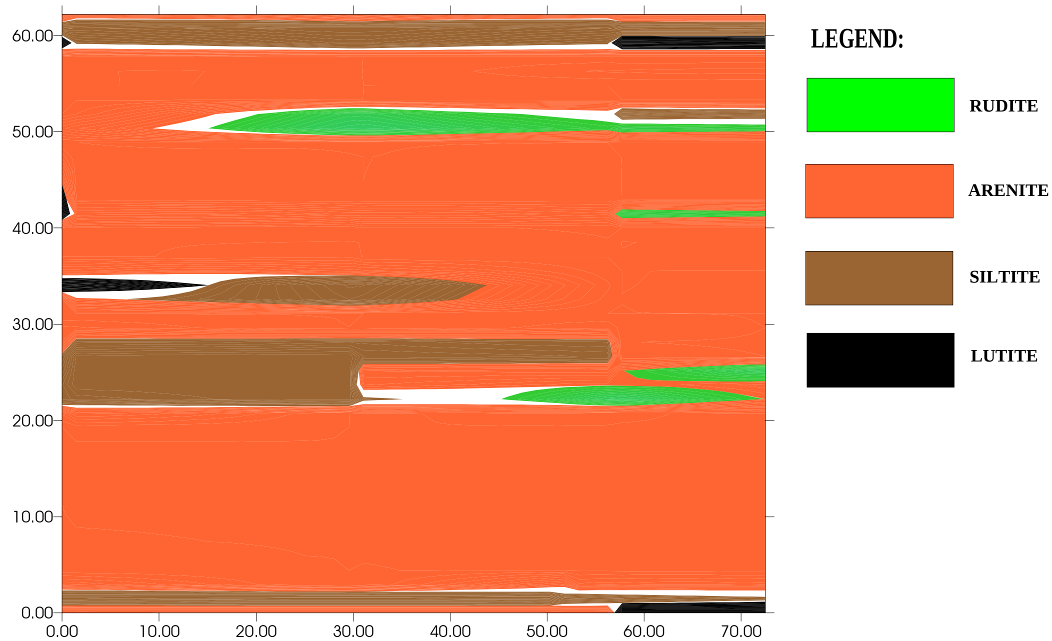


Fig. 5. Geostatistical lithological section for p=0.5-1 probability and for an anisotropy ratio with value 100

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