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COMPLEX FEATURES IN SEDIMENTOLOGY AND TRUNCATED PLURI-GAUSSIAN SIMULATIONS

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Abstract
The importance of simulating representative images of heterogeneities no longer needs proving. The remaining problem is the choice of the appropriate model. The main characteristics of the models can be split in two aspects, the conditional one and its ability to reproduce the studied heterogeneities. This paper focuses on this second aspect.

The truncated pluri-gaussian method makes it possible to obtain a very wide variety of heterogeneities. With very few parameters conditional simulations with complex anisotropies can be obtained. The parameters are classically fitted on well data and seismic attributes [2]. Moreover the sequence stratigraphy analysis constrains the choice of the relationship between the lithofacies, that is defines their arrangement, order, complementarities, correlations…

This paper presents some characteristics of this method insisting on the relationships between the lithofacies. Examples of simulations in different environments are also presented

Introduction:
The fluid movements in the reservoir are guided by the internal heterogeneities of the medium. First at a local scale where the movements depend on the grain sizes and repartition, then at the reservoir scale where the sedimentary arrangement plays an important rule. At both scales, it is important to have representative images to analyze statistically the behavior of the fluids: at the local scale to perform the appropriate permeability up-scaling, and at the reservoir scale to locate the permeabilities barriers or the preferential drains.

In order to solve both problems,it is necessary to construct representative images of the medium. The characteristics to be reproduced are very variable from one environment to another, for instance clay plugs in sand bodies deposits, or diagenetic effect around fracturations…

An efficient tool for reproducing these different shapes is the truncated pluri-gaussian method.

The truncated pluri-gaussian tool:
The truncated pluri-gaussian method is a generalization of the well-known truncated mono-gaussian method [1]. The strength of this approach is that it makes it possible to reproduce very complex relationships between the lithofacies.

The basic idea of this approach is to use several (at least two) gaussian variables (G1 and G2 in figure 1) which condition the spatial structure of the two (or more) different sets of lithotypes. The relationships between the lithotypes are determined by the rock type rule (fig 1-b1) that defines the truncation diagram. The resulting image characteristics then depend on one hand on the spatial structures of the underlying gaussian variables and their correlation and on the other hand on the rock type rule. On this rock type rule diagram, each axis represents the gaussian values, and the rectangular areas correspond to the set of gaussian value couples which define the lithotypes. So, in this example, the red color corresponds to the high values of the second gaussian (G2) and the obtained lithotype (fig1-b1) presents the same anisotropy as G2. This anisotropy can be plotted in a graph giving the values of 90% of the semi-variogram sill for all the directions (fig1-b3). In the same way, the green color corresponds to the lower values of G2 and lower values of G1, the obtained lithotype has the same anisotropy orientation as G1, and the display of the sill presents an ellipsoidal shape orientated west-east. The two other colors (lower values for G2 and higher values for G1) have mainly the same anisotropy orientation as G2 with a smaller influence of G1 anisotropy, the displays of the sills present more rectangular shape.

Using the same gaussian variables as before, different arrangements of four lithofacies can be obtained by only playing on the rock type rule. In the first case (figure 2-a1) the lithofacies are ordered in a strict sequential order using only one gaussian variable (that is a rock type rule depending only on G1 figure 2-b1). The corresponding anisotropy diagram (figure 2-c1) shows the same anisotropy orientation for all the lithofacies with smaller ranges for the two intermediate lithofacies (orange and yellow). On the lithotype semi-variograms for the SW-NE direction, the different sills correspond to the different lithofacies proportions (30% for the green, 15% for the orange, 35% for the yellow and 20% for the red one). To generate the second image (figure 2-a2) a simple lithotype rule cutting the domain in four parts gives a partition of space on which all the lithofacies have the same anisotropy which is a combination of the two gaussian variable anisotropies. In the anisotropy diagram the curves look like "saucers" . In the two following images (figure 2-a3 and a4) the lithofacies are grouped two by two and the resulting anisotropies depend on the gaussian which supports the main truncations.

Applications to different geological features:
It appears that the lithotype rule is the key parameter when using the truncated pluri-gaussian method. This parameter has a direct relationship with the geological features which depend on the sedimentary environment as well as on the posterior events (fracturations or diagenesis).

The use of two (or more) gaussian allows simulating two (or more) sequential geological events which can be correlated or not. These events may have different anisotropies and spatial structures linked to the gaussian. Thus this method is well suited to produce a large range of patterns and to reproduce complicated type of contacts between lithotypes.

In some deltaic systems, the clay plugs fill the spaces left by the meandering channels. In the example on figure 3, the proportion of shales increases towards the east. These characteristics can be simulated using two gaussian variables, one giving the structure of the channel lithofacies and another for the shale adding a non stationarity in its proportion.

Fractured networks are often simulated using object method but they can also be obtained using the pluri-gaussian approach when there is a relationship between fracturation and lithofacies. In the following examples the fracturation is only present in the grey lithofacies while it crosses all the other lithofacies in the second case.

Conclusion:
The truncated pluri-gaussian method makes it possible to simulate very different heterogeneities. All the possibilities have not been thoroughly exploited yet. This paper shows very simple constructions with only two uncorrelated gaussian variables; the addition of correlation between the two gaussian has already been used successfully for simulating algal mounds [3]. Moreover, this tool can be easily improved if the sedimentary process is composed of more than two sets of independent lithofacies. In that case another gaussian variable can be used.

References:
[1] Matheron G., H.Beucher, C.de Fouquet, A.Galli, C.Ravenne, 1987: "Conditional simulation of the geometry of fluvio-deltaic reservoirs". SPE16753.

[2] Doligez B., H.Beucher, F.Geffroy, and R.Eschard, 1999: "Integrated reservoir characterization: improvement in heterogeneous stochastic modeling by integration of additional external constraints". In R.Schatzinger and J.Jordan, eds., Reservoir Characterization-Recent Advances, AAPG Memoir 71, p.333-342.

[3] GALLI, Alain, LE LOC 'H, Gaëlle, ESCHARD, Rémi, GEFFROY, François. Truncated pluri-gaussian method: a case study. AAPG 1998 Salt Lake city

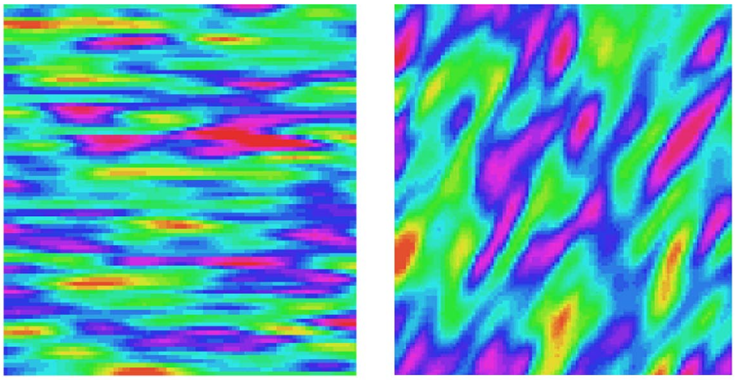

Figure 1-a Two independent gaussian variables

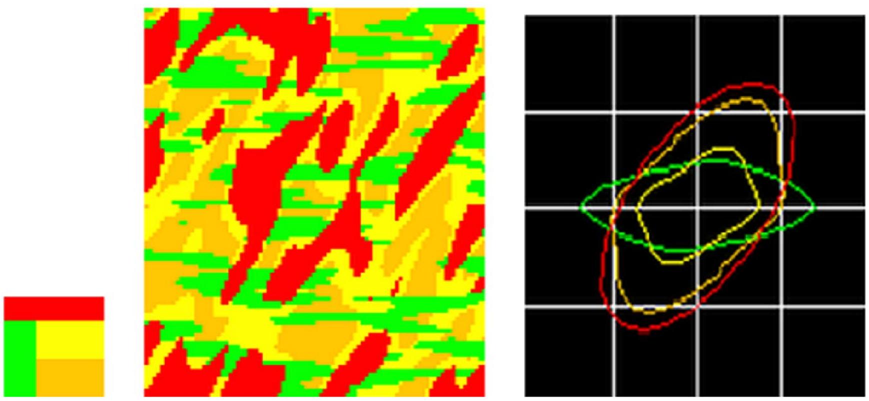

Figure 1-b Rock type rule, obtained lithofacies simulation and the corresponding anisotropy

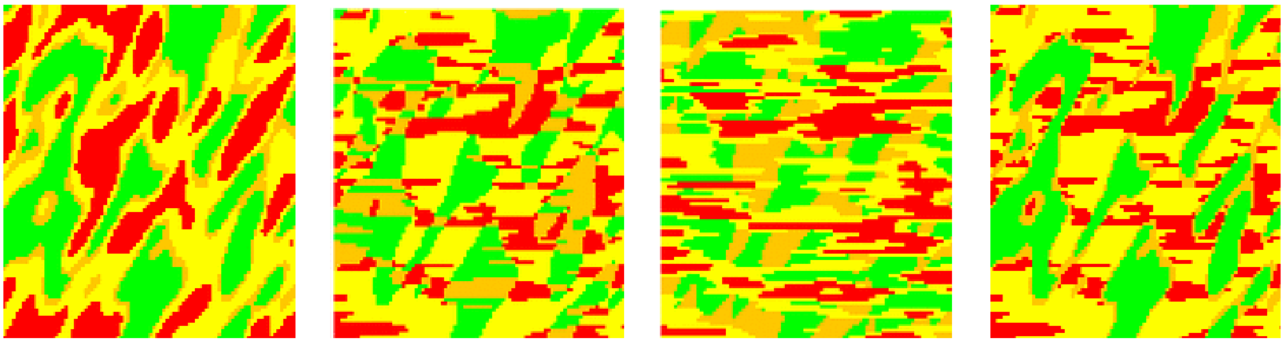

Figure 2-a Lithofacies simulations

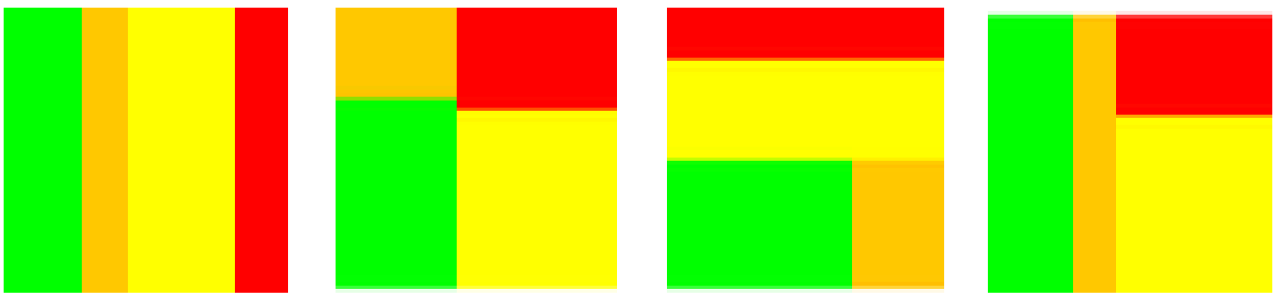

Figure 2-b Rock type rules

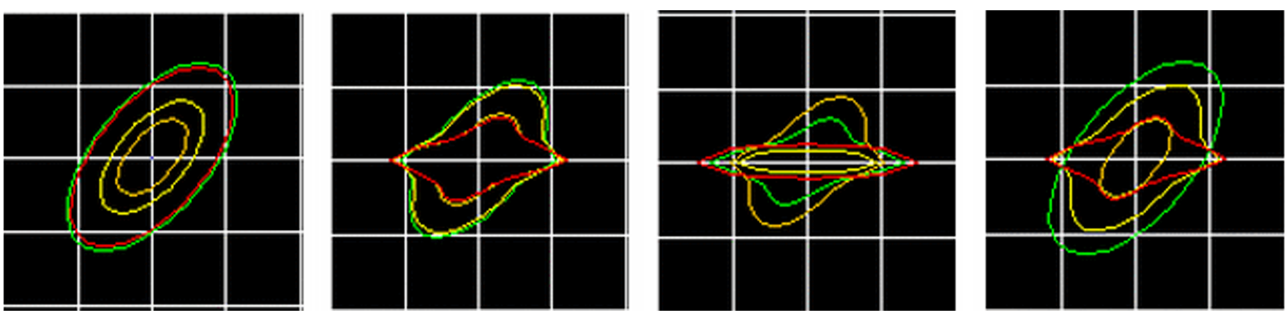

Figure 2-c Corresponding anisotropy diagrams

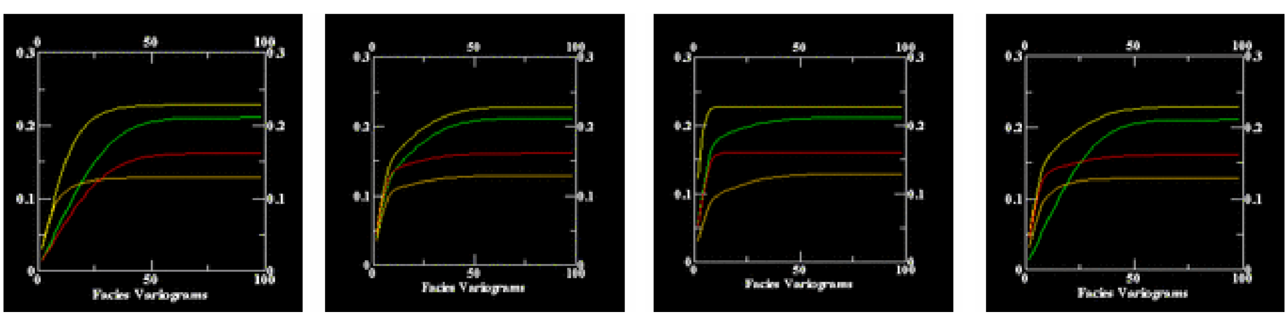

Figure 2-d Lithotype semi-variograms for the direction SW-NE

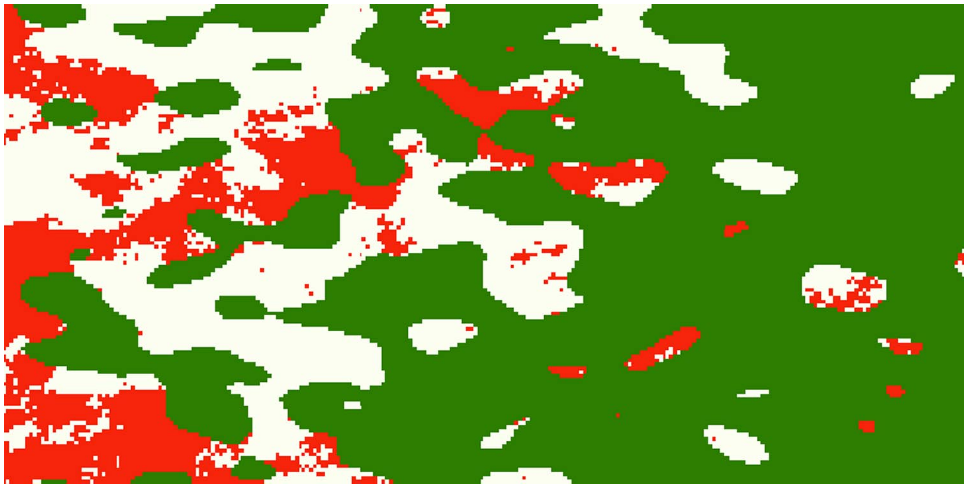

Figure 3 Simulation of clay plugs in a deltaic system

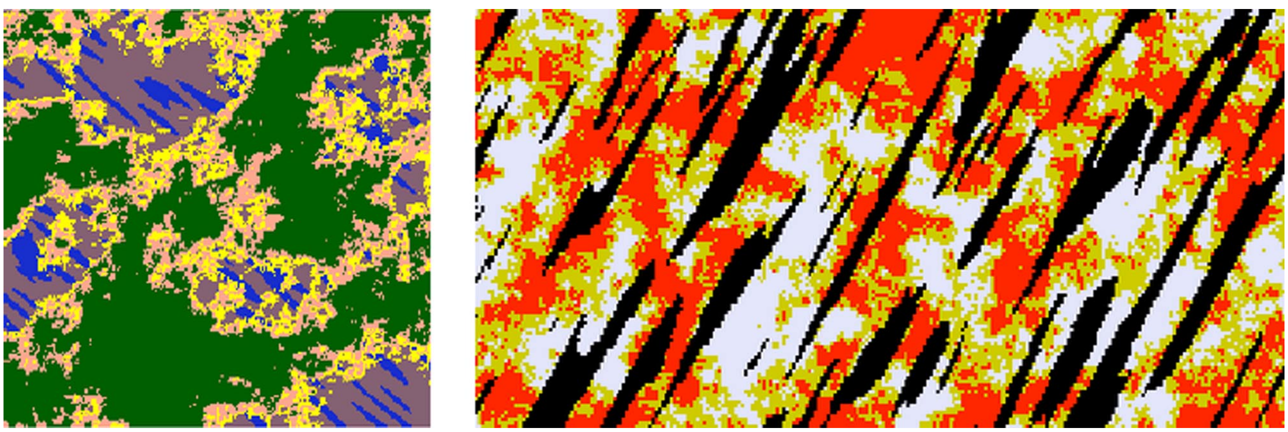

Figure 4 Simulations of fractured medium