Estimation of most likely lithology map in the context of Truncated Gaussian techniques

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Abstract In this paper, we present a technique to estimate a most likely lithofacies map consistently with auxiliary information in the framework of Truncated Gaussian related techniques. It is based on a very simple idea that is to replace the random fields used to perform geostatistical draws by a transformation of the auxiliary variables that are relevant to predict lithology. The different stages of the procedure are depicted. Subsequently two examples are provided to illustrate potential practical applications of the method. Some generalizations are finally discussed: Pluri-Gaussians generalization, utility in the context of uncertainty evaluation.

Introduction

To constrain a lithology model to seismic, a classical approach is to derive soft probabilities from statistical analysis of geophysical properties (inverted acoustic impedances or pseudo Vclay). Usually a relevant analysis can be performed at log scale; but it is not obvious to transfer this information at the scale of a grid cell for geo-modeling prediction. Up-scaling issues lead usually to less contrasted soft probabilities and the direct use of these probabilities in geostatistical processes are often deceiving.

Some transformations are suggested to use these seismic soft probabilities (Pivot 2005) but these transformations are usually subjective and case dependant. Other suggestions are to combine soft probabilities with probabilities interpreted from well data and geological analysis (Deutch 2008, Biver 2008); but there are debates about which combination to use: convex or concave combination? Which probability is the most representative? Is it geological probabilities because they are based on hard data or geophysical probabilities because they are more representative of the entire reservoir?

For all these reasons, we have tried another attempt to conciliate geological and geophysical point of views. It does not mean that other procedures are meaningless but it provides an additional tool which is more focused on estimation

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of lithology instead of classical simulation process. It has to be seen as a complementary approach.

This procedure is using Truncated Gaussian principles and as it is an estimation tool, we decided to name it TGE for Truncated Geophysical Estimation.

TGE technique description

The starting point of this new idea is the observation that geophysical attributes have usually a high frequency content; that is the reason why they are used as co-variables to simulate petrophysical attributes in geomodels.

As a consequence it seems reasonable to guide heterogeneity occurrence with these variables instead of trying to derive a soft probability with all the potential problems described in the introduction.

We remind here the input variables that are available for a lithology model with K facies:

- large scale geobodies that are picked deterministically and in which we want to distribute lithology heterogeneities (they are named AE for Architectural Elements or EOD for Environments Of Deposition);

- lithology hard data to honor (wells data), they can be noted as $Ik(xi);k=1,n$ (indicators for facies k at n different locations xi;

- geological probability trends issued form well data analysis and conceptual geology (vertical proportion curves, low frequency trends), they can be noted $pk(x)$ for facies k and they are summing up to one for each location x in the geo-model, these trends have been established without consideration about geophysical attributes except large scale geobodies;

- one geophysical attribute chosen to guide heterogeneities, note as $Y(x)$;

- variogram or covariance function $C(h)$ of indicators Ik; a proportional model is assumed (same ranges and shape for all indicators k);

The different stages of the proposed technique are the following ones:

- Step 1: anamorphosis of the geophysical attribute; it consists in using experimental distribution of the geophysical attributes in each large scale geobody to perform a uniform transform that is to replace *Y* by its cumulated probability *Fg(Y)* in geobody g; we write *U(Y) = Fg(Y)*.

- Step 2: conditioning step; using the indicator variogram model, we perform a classical simple indicator kriging with geological probability trends as a local mean; this operation provides slightly modified probabilities named *pk mod(x)*, these modified probabilities are equal to *Ik(xi)* for all data locations *xi*; and as a proportional model is used, they are still summing up to one.

  We write: $$p_{k\,\mathrm{mod}}(x) = p_k(x) + \sum_{i=1}^{n} \lambda_i.[I_k(x_i) - p_k(x)] \qquad (1)$$

  where λi are the kriging weights provided by the kriging system:

  $[C_{ij}].(\lambda_j) = (C_{ix})$ with *Cij* the covariance matrix between data points and *Cix* the covariance vector between data points and the point to estimate; available from *C(h)* model.

- Step 3: truncation step; *pk mod(x)* are used to define a stair step function (cumulative distribution of the lithology to estimate) and *U(Y)* is used to define which facies is occurring at location x; this step is illustrated on figure 1 for a case with 3 facies. It is important to notice that the way of ordering the facies has an impact on resulting facies association; we suggest to order the facies regarding average statistics of the geophysical attribute.

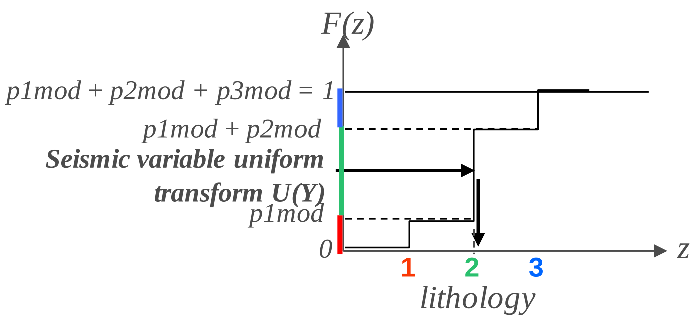

Figure 1: TGE truncation step: the uniform transform of the seismic variable *U(Y)* is used to assign the lithology value regarding the probability of occurrence defined form geological input and data (*pkmod*)

Application on a field case

To test the methodology described in the previous paragraphs, a turbiditic reservoir of western Africa has been chosen. It is sampled with a set of wells reasonably representative (no sampling bias problem); the well data have been interpreted in five different litho-types. The seismic campaign has an intermediate quality but a seismic attribute (pseudo Vclay) seems to be informative for lithology, even inside large scale bodies (AE's) see figure 2.

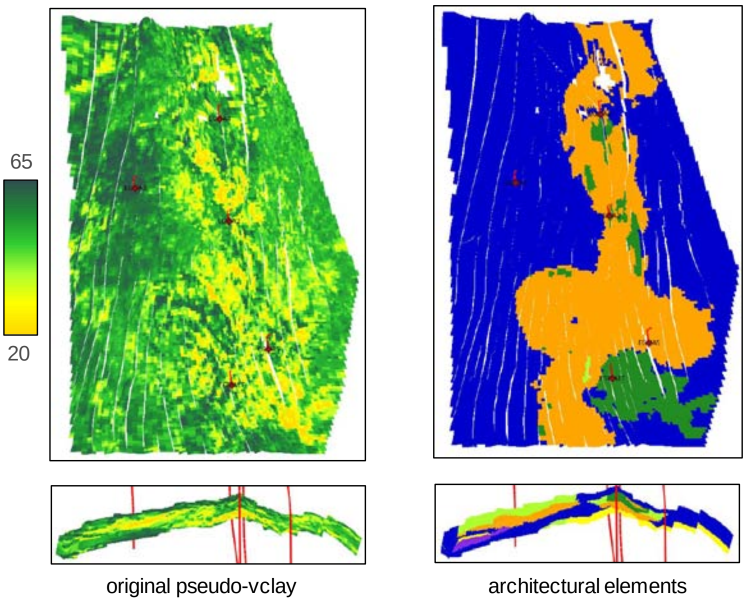

Figure 2: case study, geophysical attribute and interpretation in architectural elements, geophysical attribute is explaining more than these large scale bodies.

The different stages are applied now on the data set.

The anamorphosis step is illustrated on Figure 3. It has been done separately for the different geobodies (AE's); the heterogeneities are still clearly visible inside the geobodies. The conditioning step is illustrated on Figure 4. The geological proportions are only slightly modified in the neighborhood of wells.

The final result after truncation is presented on Figure 5. The TGE facies map is compared with the initial simulated facies map (SIS with variable azimuth); it is obvious that heterogeneities are placed consistently with pseudo-Vclay. The continuity of the facies heterogeneities is also a consequence of pseudo-Vclay continuity.

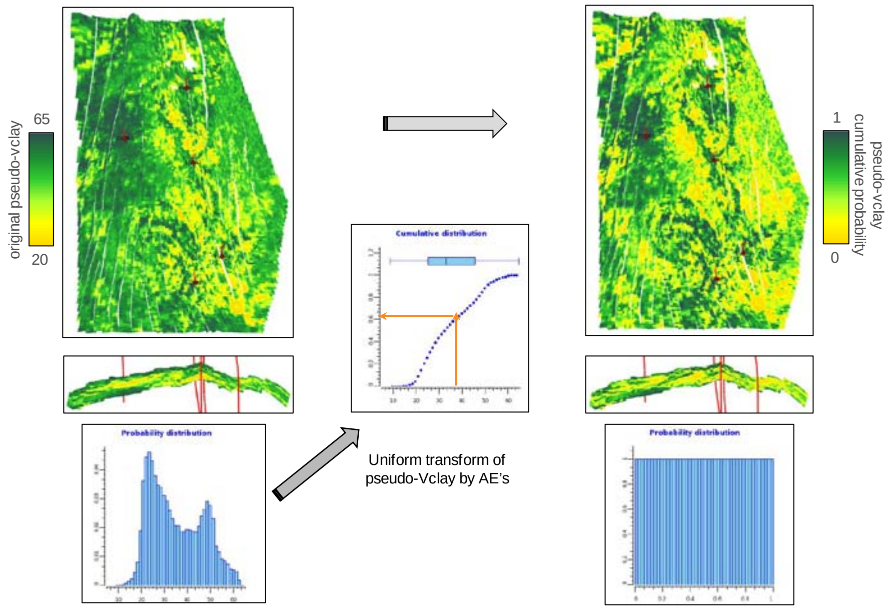

Figure 3: case study, anamorphosis of the geophysical attribute.

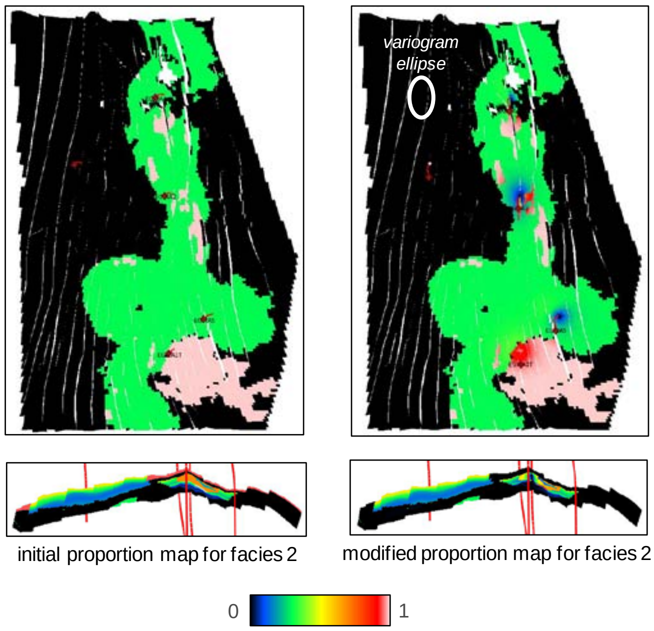

Figure 4: case study, conditioning initial proportion cube to well data

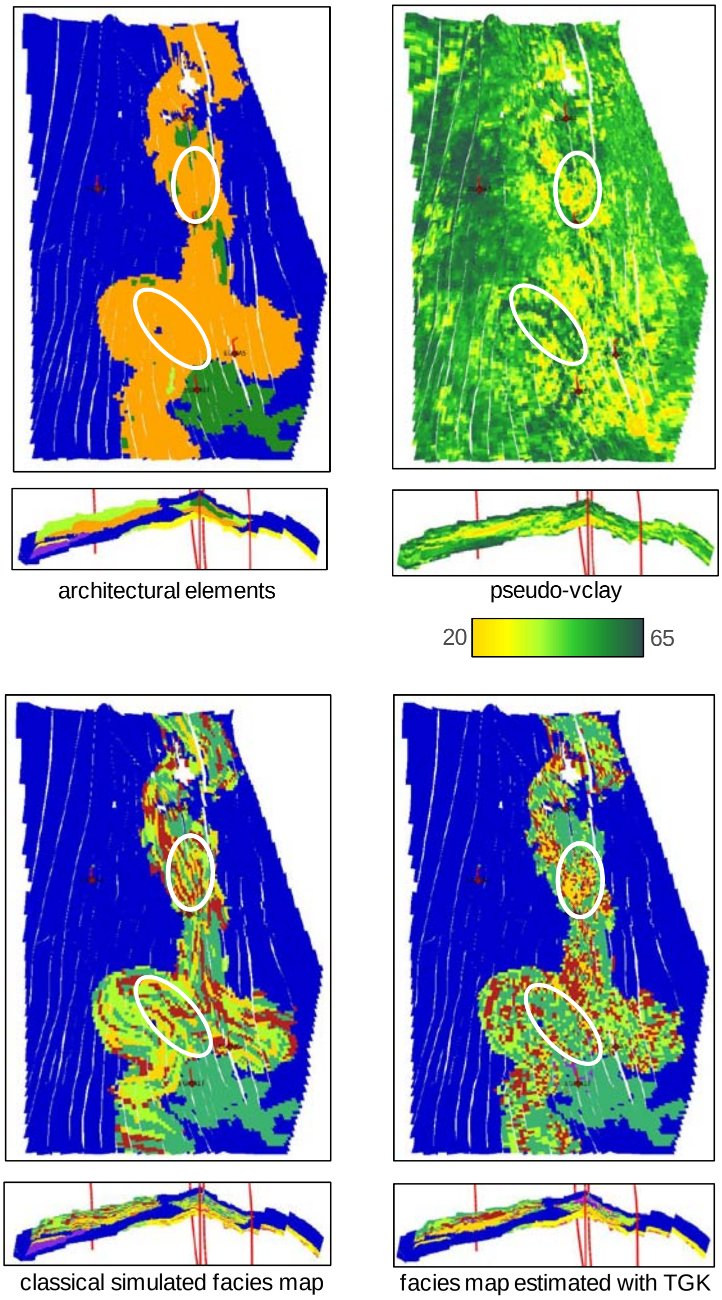

Figure 5: case study, comparison of classical facies model with facies map estimated from TGE procedure; in the new model, heterogeneities are placed according to pseudo-Vclay.

Conclusion and further works

A workflow (named TGE) has been established to build an estimated facies map, merging geological and geophysical information. It has been applied on a real field case. Results are encouraging, heterogeneities are placed consistently with geophysical information, but the amount of each facies is controlled by the geological proportions.

As it has been said in the introduction, TGE is an estimation procedure; and questions may rise if we want to take into account the uncertainties on such a model. Several solutions can be envisioned to handle uncertainties:

- acoustic impedances are obtained from a geophysical inversion process; during this process, it is possible to evaluate uncertainties (geostatistical inversion or sensitivity analysis on inversion parameters);

- geological proportions are built according to hard facies data (VPC) and/or geological concepts; sampling uncertainties can be handled in the formalism of Dirichlet distributions (Hass 2002), alternative concepts can be defined with sensitivity analysis.

As TGE is a derivative of truncated Gaussian formalism, a cyclicity order is imposed between facies. To obtain a better control on facies associations and placement, we could envision to use a second seismic attribute and to use a derivative of Pluri Gaussian formalism (it could be named PGK). This could be done if we manage to modify a bivariate truncation diagram according to local target proportions; this is exactly the subject of Allard and al. contribution presented in this conference.

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