Automatic Determination of Sedimentary Units from Well Data

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Summary

In order to create realistic models of a reservoir with a vertical heterogeneity, it is often better to firstly divide it into several horizontal homogeneous geological units. The Vertical Proportion Curve (VPC) of wells extracted from the reservoir can illustrate the heterogeneity, but the choice of the geological units is usually based on a visual criterion. In the present paper, a new numerical method of wells VPC analysis is proposed. It consists in a geostatistical hierarchical clustering of VPC elementary intervals which results in the division of the reservoir into more homogeneous units that can be further used for modeling. The method is illustrated on two synthetic cases generated by the meandering channelized reservoir model Flumy and a real data case-study.

Introduction

Heterogeneous reservoirs often consist in several horizontal geological units. The determination of these units is important in order to create realistic models of the reservoirs. Of course, the best solution of this problem is a geological expertise, which will provide all the information about reservoir stratigraphy. But if it is impossible to perform such expertise, or if there is no exact conclusion, we propose a new numerical analysis method which is able to describe the vertical heterogeneity of the reservoir and help defining optimally the geological units from the wells data. This method can be useful for modeling heterogeneous reservoirs, using for instance a process-based modeling (e.g., Flumy software for meandering channelized reservoirs) or a stochastic modeling like Truncated or Plurigaussian simulations (M. Armstrong et al., 2011).

One simple tool to visualize the vertical heterogeneity of a reservoir is the Vertical Proportion Curve (VPC), that was first developed for the truncated gaussian simulation of reservoirs. It can be constructed either from wells data or for a whole simulation (Figure 1): this gives the proportion of facies within each elementary interval along the vertical axis. But it is still complicated to make a conclusion about the geological units using only a visual criterion.

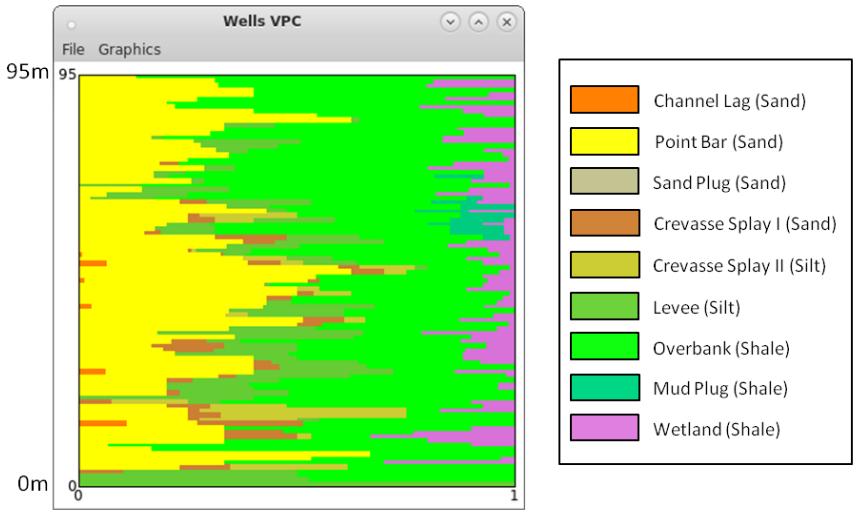


Figure 1 *An example of VPC using real data – 8 pseudo-wells from Loranca sedimentary basin (Spain). VPC elementary interval = 1m, so this VPC contains 95 such intervals.*

Thus, the VPC provides information about sand proportion in each elementary interval. Now we need to group these elements in order to determine homogeneous geological units. Ideally, we are looking for an automatic method that not only divides the VPC into units but also provides a measure of their heterogeneity so that we can choose the most dissimilar units.

Method

To answer this problematic, we have used the Hierarchical Geostatistical Clustering (T. Romary and al., 2015). In general, the clustering is a statistical method of data classification, consisting in sequentially merging most similar data elements into larger subsets or "clusters". Here, we start the algorithm with the number of clusters equal to the number of elements (one element = one VPC interval = one cluster) and at the end, we obtain one cluster including all the elements (there exists an inverse version of this method, here it is not considered). An advantage of this method is that all the clustering hierarchical steps are saved, so we can analyze and determine the optimal number of final clusters by keeping the last and most dissimilar clusters.

A visual representation of the clustering algorithm is the dendrogram – a hierarchical graph showing the order of clustering steps and the dissimilarity level of each clusters merged (Figure 2). In this paper we use a variant of the dendrogram – the graph of Clusters Dissimilarities: each point of this graph represents the ordered clustering step (X-axis) and the merged cluster's dissimilarity (Y-axis). Because at each step of the algorithm the two most similar clusters are merged, this graph is increasing.

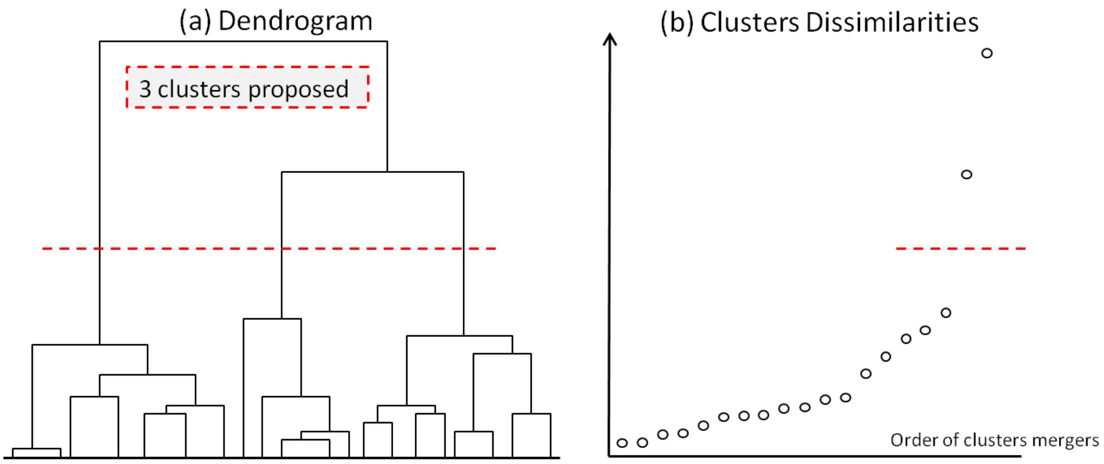


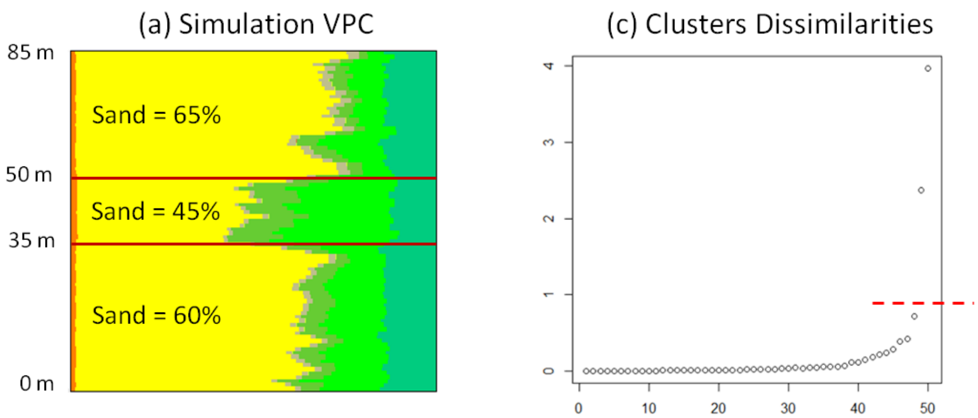
Figure 2 *Visualization of hierarchical clustering algorithm: (a) Dendrogram graph, (b) Clusters Dissimilarities graph. In this example the number of most dissimilar clusters is chosen to be 3 (the highest vertical step after successive homogeneous merges, illustrated by the red dotted lines).*

We have applied this clustering algorithm to the determination of reservoir geological units. The variable used is the sand proportion of each wells VPC elementary interval. Only vertically adjacent intervals can be merged. After several tests, we propose to calculate the initial cluster dissimilarities by using the squared difference of each elementary interval sand proportion. Finally, the last option to be mentioned is the Linkage Criterion. This option determines how dissimilarities between the new cluster and all others must be updated. According to several tests results, the Ward's criterion was chosen among 5 tested criterions: at each step of the algorithm two clusters are merged such that the new formed cluster has the minimal internal variance.

Examples

For determining reservoir geological units by using this method, a number of synthetic tests were performed: firstly, we have created a multiple units block-model using Flumy, then we have extracted some vertical wells from this block, and finally, we have applied the clustering analysis to these wells in order to determine the initial simulation units.

The first synthetic application example is a simulation with contrasted units (three units of different thickness and sand proportion). 20 extracted wells were analyzed. After an examination of Clusters Dissimilarities graph it was decided to visualize the last three most dissimilar clusters (Figure 3):



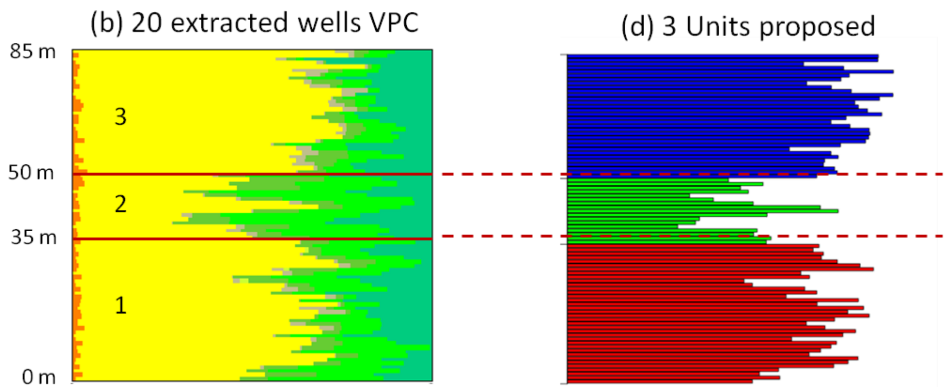


__Figure 3__ Illustration of synthetic test, Flumy simulation with contrasted units. (a) Simulation VPC, red lines represent the limits between the initial units. (b) VPC of 20 extracted wells, the initial units are hardly detectable by a visual criterion. (c) Clusters Dissimilarities graph; the 3 last clusters are the most dissimilar. (d) The sand part of the wells VPC, the colors correspond to the 3 last clusters.

The second synthetic application example is a simulation with less contrasted units. This example is more complicated: there are more units in the model; they are closer in terms of thickness and sand proportion. Only 8 extracted wells were analyzed and the 5 last most dissimilar clusters have been visualized on the Figure 4:

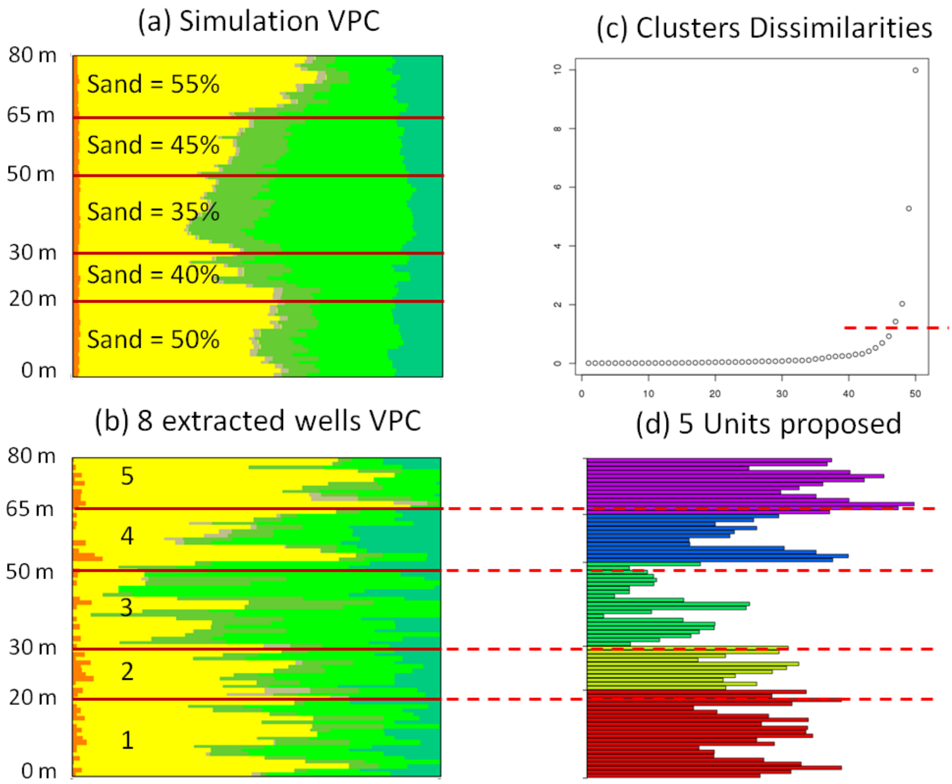


__Figure 4__ Illustration of synthetic test, Flumy simulation with less contrasted units. (a) Simulation VPC, red lines represent the limits between the initial units. (b) VPC of 8 extracted wells. (c) Clusters Dissimilarity graph; the 5 last clusters are the most dissimilar. (d) The sand part of VPC, the colors correspond to 5 last clusters.

The last example illustrates the clustering analysis of the 8 Loranca wells (Figure 1). In this case we do not have an exact geological conclusion, but it was proposed to divide the reservoir into 3 horizontal geological units. The units proposed by geologists and clustering results are presented on the Figure 5.

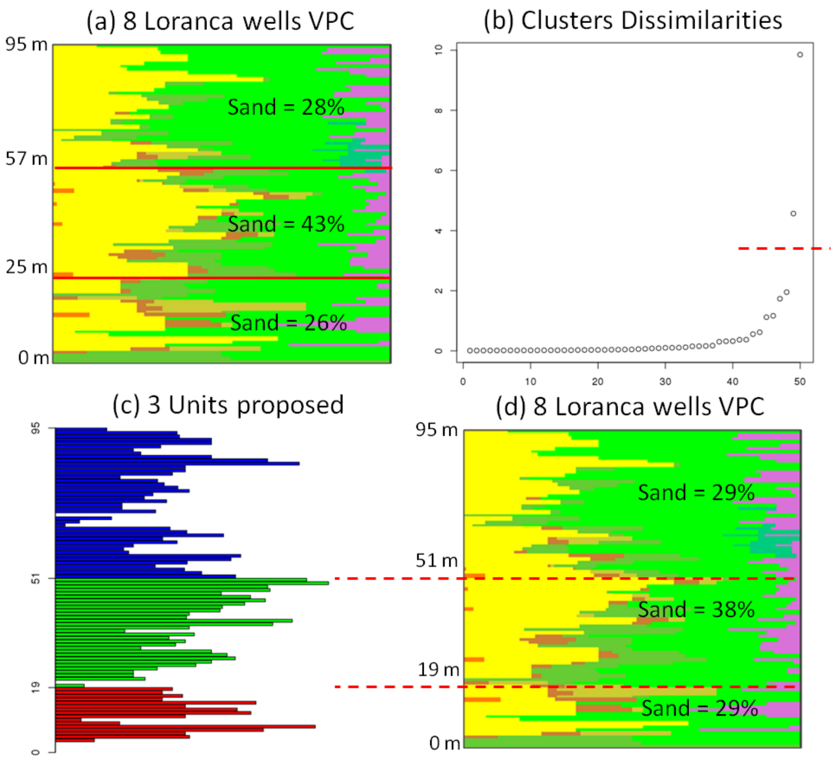


***Figure 5** Illustration of real data test, 8 Loranca wells. (a) VPC of 8 Loranca wells, plain red lines show 3 units proposed by geologists; (b) Clusters Dissimilarities graph, the 3 last clusters considered as the most dissimilar. (c) The sand part of VPC (3 last clusters). (d) VPC of 8 Loranca wells, red dotted lines show the 3 simulation units proposed by clustering.*

Conclusions

The proposed clustering method for analyzing wells VPC shows good results on synthetic tests: it permits to detect the initial simulation units even if the extracted wells VPC are not clearly representative. Results for real data tests (Loranca) are also quite interesting: geological units proposed by geologists are almost similar to the units obtained by clustering. The method can be applied automatically in order to propose a division of a heterogeneous reservoir into more homogeneous horizontal units (with their dissimilarities). Presently, some tests are performed in order to automate the choice of the "optimal" number of horizontal units deduced from the graph of Clusters Dissimilarities.

Acknowledgements

We are grateful to ENGIE and ENI, partners of the Flumy Research Program.

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