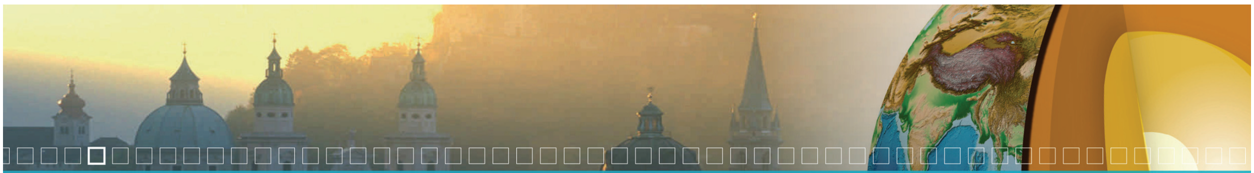

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Geological Variables Fitting in Normal Distribution and Application in Indicator Geostatistical Methods

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Abstract

For geostatistical mapping, normal distribution is the base for matrices operations. Such methods, as the first step, perform normal transformation wherever it is possible. Also, it helps if the original data transformed in indicators and selected in classes approximately follow Gaussian distribution. Examples are presented where (a) classes are of the same size and (b) classes are narrower around median value. In both cases, normal distributed classes of original data (reservoir thickness) are transformed in indicators (0 and 1) and mapped with indicator kriging (IK) and sequential indicator simulations (SIS).

Keywords: geological variables, normal distribution, indicator kriging, sequential indicator simulations, sandstone reservoirs, Upper Pannonian, Lower Pontian.

1 Introduction

There is an assumption that many geological variables follow normal distribution, but often there are no cases with real measurements. Many of such variables have left or right tails or correspond to Poisson or binomial distribution. For many statistical analyses, especially for geostatistical mapping (e.g. de Wijs 1951; Journel and Huijbregts 1978; Hohn 1988; Isaak and Srivastava 1989; Deutsch and Journel 1997), normal distribution is mathematical base for the proper use of descriptive statistics, which includes variance, mean, mod, median etc. Variogram, which is a basis for kriging mapping, is derived from the variance. That means that normal distribution is also condition for a variogram as a representative tool. Many of geostatistical methods, as the first step, perform normal transformation of data wherever it is possible. Normal distribution is also helpful in indicator methods where one more transformation is applied, i.e. indicator transformation based on class values. Although normal distribution of the original dataset before indicator transformation is not necessary, it is very helpful if the frequency of their classes division follows such distribution, because set of those classes also has statistical properties. It is important because in indicator methods only 3rd order stationarity is assumed and any other statistical property is valuable for results reliability.

Examples of indicator data classes selection for some geological variable observed in hydrocarbon reservoirs are presented. Different cases can be observed - (a) when classes are of the same size and (b) when classes are narrower around median value. In both cases, classes that support normal distribution were selected, after which original data was transformed in indicators (0 and 1). Case study for the thickness variable of Upper Pannonian and Lower Pontian sandstone reservoirs is presented. These values were mapped by using Indicator Kriging (IK) and Sequential Indicator Simulation (SIS). In this case, before indicator transformation, original dataset was transformed into classes, so that their frequency approximately follows normal distribution. Similar example, but only with porosity variable can be found in Novak Zelenika et al. 2010.

2 Input data

Input data for mapping was acquired from 23 wells for Upper Pannonian “Beta” reservoir (Table 1) and from 19 wells for Lower Pontian “T” reservoir (Table 2). Input variable was total thickness.

Table 1: Input well data of the "Beta" reservoir

Well	Reservoir	Total thickness (m)
1	Beta	3.0
2		15.5
3		23.0
4		22.5
5		9.0
6		10.0
7		3.5
8		4.0
9		20.5
10		20.0
11		14.5
12		22.0
13		13.5
14		14.0
15		11.5
16		18.5
17		8.5
18		9.0
19		8.5
20		10.0
21		8.0
22		7.0
23		18.0

Table 2: Input well data of the "T" reservoir

Well	Reservoir	Total thickness (m)
1	T	13.0
2	T	12.0
3	T	12.0
4	T	13.0
5	T	11.5
6	T	12.0
7	T	11.0
8	T	9.5
9	T+U	20.0
10	T	17.0
11	T+U	3.0
12	T	13.5
13	T+U+V	25.0
14	T	6.0
15	T	9.0
16	T	10.0
17	T	11.0
18	T	8.0
19	T	6.0

3 Indicator Transformation

Base for Indicator Kriging mapping is indicator transformation of the input data. That means that the thickness values should be transformed into 0 and 1 based on certain cutoff. Sometimes the hardest part is to decide how many cutoffs are enough. The best way for that is to group the data into several classes so that they approximately follow normal distribution pattern. Based on the class's distribution cutoff values were chosen. Figure 1 represent normally distributed classes applied as cutoffs for indicator transformation both for "Beta" and "T" reservoirs.

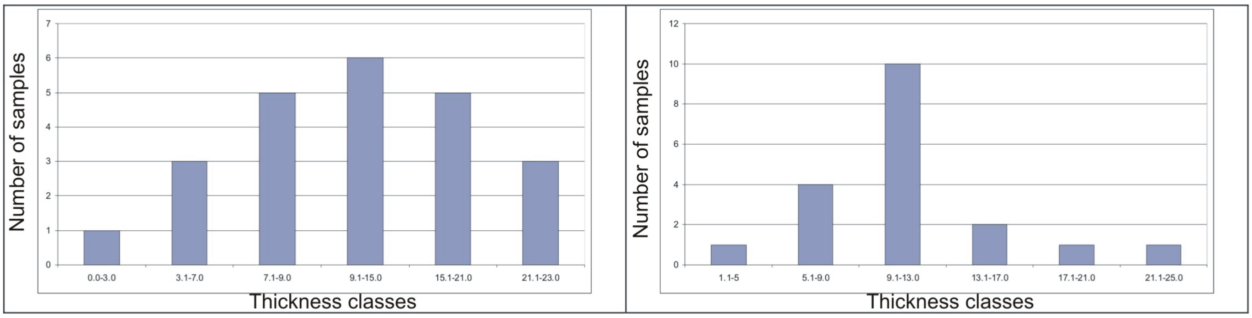
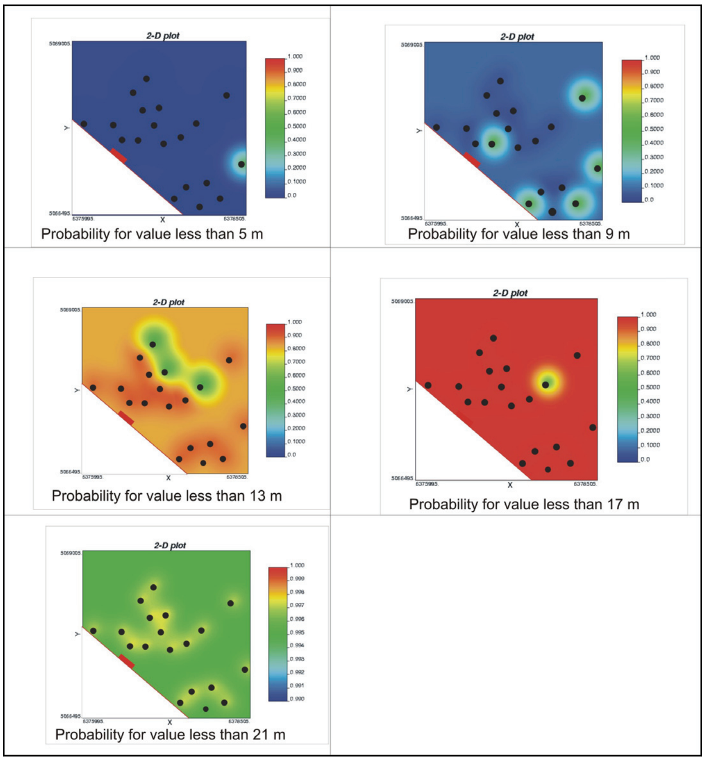


Figure 1: "Beta" (left) and "T" (right) reservoir classes for thickness

There are 6 cutoffs for the indicator transformation of thickness in the “T” and “Beta” reservoirs. Cutoff values for the “T” reservoir were 5, 9, 13, 17, 21 and 25 m and for the “Beta” reservoir 3, 7, 9, 15, 21 and 23 m (Figure 1).

4 Indicator Kriging and Sequential Indicator Simulations mapping

Based on cutoff values, indicator transformation was performed and thickness variable was mapped by Indicator Kriging (IK) and Sequential Indicator Simulations (SIS) techniques. Obtained maps are probability maps. IK shows the probability that the variable is smaller than certain cutoff value (Figures 2 and 3). SIS maps also show probabilities but the mapped variable is higher than certain cutoff (Figures 4 and 5). Mapping was performed in WinGslib software (Deutsch and Journel 1997).



Probability for value less than 5 m

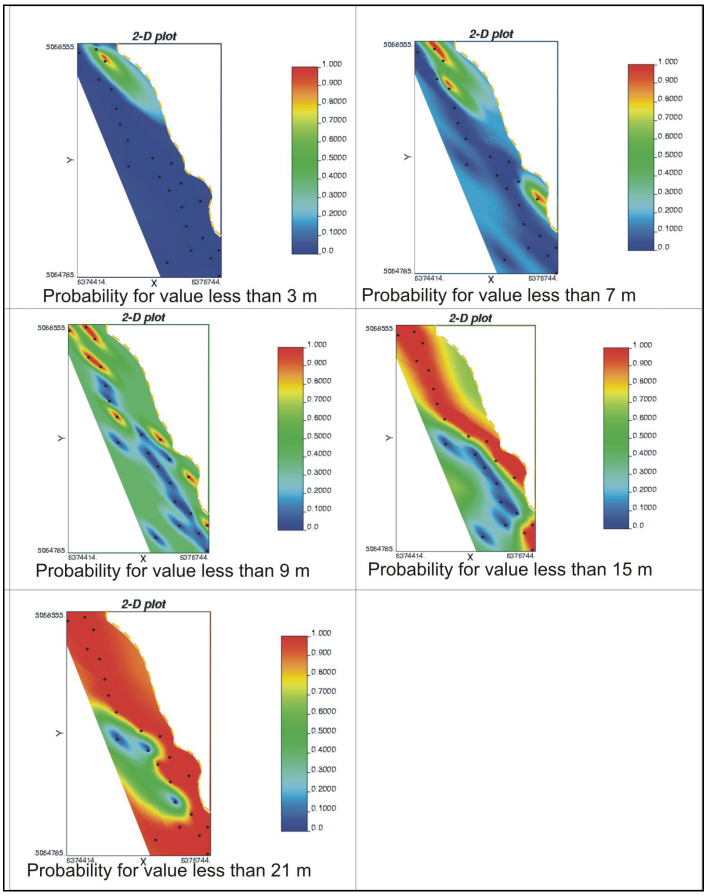
Probability for value less than 9 m

Probability for value less than 13 m

Probability for value less than 17 m

Probability for value less than 21 m

Figure 2: IK maps of the “T” reservoir thickness



Probability for value less than 3 m

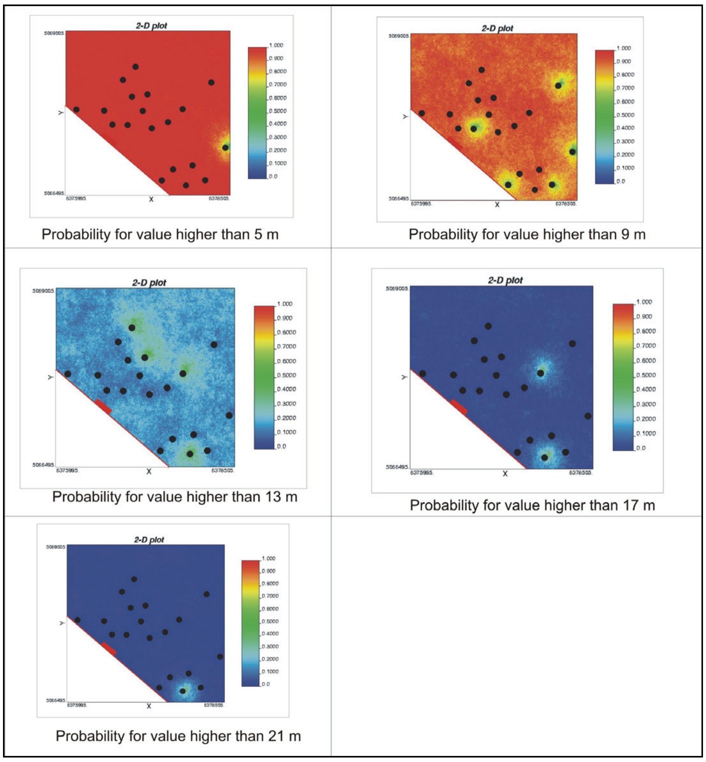
Probability for value less than 7 m

Probability for value less than 9 m

Probability for value less than 15 m

Probability for value less than 21 m

Figure 3: IK maps of the "Beta" reservoir thickness



Probability for value higher than 5 m

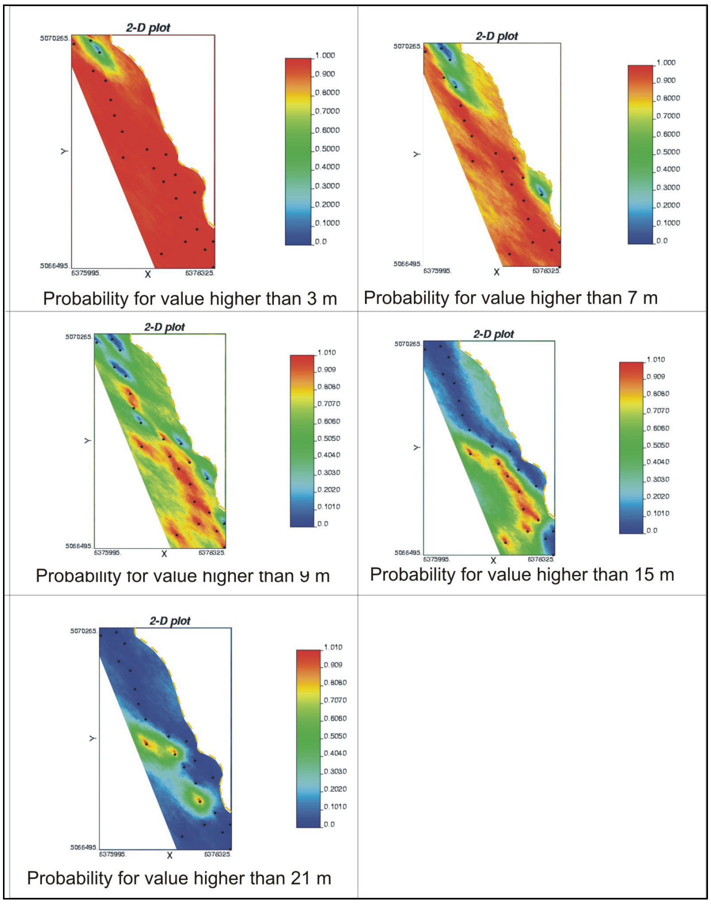
Probability for value higher than 9 m

Probability for value higher than 13 m

Probability for value higher than 17 m

Probability for value higher than 21 m

Figure 4: SIS maps of the "T" reservoir thickness



Probability for value higher than 3 m

Probability for value higher than 7 m

Probability for value higher than 9 m

Probability for value higher than 15 m

Probability for value higher than 21 m

Figure 5: SIS maps of the "Beta" reservoir thickness

5 Conclusion

Most important in mapping by IK and SIS is the definition of the cutoff values. This could be the hardest part because it depends largely on experience. With too many classes of the mapped variable, time needed for mapping drastically increases. Such approach also asks for large number of point data - more than 30. On contrary, employing just a few cutoffs (less than 5) can result in the loss of some important geological features of the mapped variable. In any case, definition of classes that approximately follow normal distribution is useful, because it makes possible to calculate the descriptive statistics of such data and improve interpretation of indicator maps that are based only on 3rd order stationarity (i.e. only statistical feature of the data are variograms. Neither mean nor variance of original dataset are representative. Due to indicator transformation input data are significantly altered as well as their statistics).

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