Geostatistical Estimation of Pay Thickness by Combining the Seismic and Well Data – A Case Study

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Summary

Geo-statistical estimation technique can be applied to quantitatively relate well and seismic data, analyse quantitatively the resulting map and estimate the probability of success directly from the available data. The aim of the present work is to predict the pay thickness of only hydrocarbon bearing layer in the western flank of MH South field.

The seismic attribute of Amplitude x Height of the pay horizon was averaged over a time window corresponding to average reservoir thickness, which showed a good correlation with log derived average effective pay thickness of the producing horizon (correlation coefficient= +.71). Amplitude x height attribute from the seismic was integrated as a secondary constraint with primary well data using kriging with external drift. Detailed pay thickness heterogeneity is brought out with reduced uncertainty.

Twenty five realization maps of effective pay thickness were generated using Sequential Gaussian simulation method. A histogram generated from the various values of effective thickness from these 25 renditions along-with normal distribution curve showed the mean thickness of 6.7 m of the producing layer at the proposed location. A risk map was also generated which predicts about 83% probability of encountering pay thickness equal to or more than 5m. at the proposed location.

Introduction

The geo-statistical method can be applied to quantitatively integrate well and seismic data and quantitatively assess the accuracy of the map. The advantage of this method is that it makes geoscientist and engineers think about the data before making a map. Not only does the method yield maps with certain statistically described properties but also gives the user a quantitative measure of the reliability of the map. Seismic information does contribute to the imaging of the petrophysical property of the reservoir like porosity, permeability, effective pay thickness etc. even though the poor vertical resolution of seismic data at times limits its usefulness to 2D applications, especially when the reservoir thickness is small.

Reservoir characterization is the process of mapping a reservoir thickness, net to gross ratio, pore fluid, porosity, permeability and water saturation. Seismic attributes are being used to prepare these petrophysical property maps after calibrating the seismic attributes with well data. The advantage of using well and seismic data instead of just wells alone, is that seismic data can be used to interpolate and extrapolate between and beyond the sparse well control.

This paper through a case study illustrates the methodology of estimating the effective pay thickness of a hydrocarbon bearing layer at a proposed location by quantitatively integrating the seismic and well data.

Description Of The Study Area

The study area falls in the western flank of MHS field. More than 70 wells are drilled in this area, most of them being directional development well and horizontal well from production and water injection platforms. The study covers an area of 225 sq.km. approx. in the western flank of the field (fig.1). The area warranted a detailed integrated interpretation to model the petrophysical heterogeneity for proper identification of the effective thickness of the only

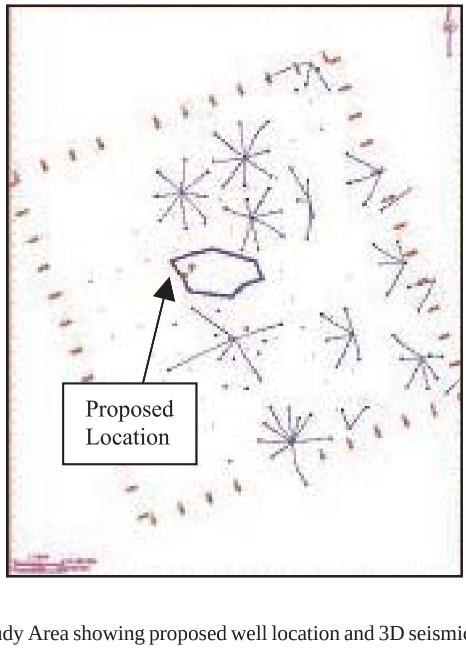

Fig.1 : Study Area showing proposed well location and 3D seismic coverage

hydrocarbon producing layer. Well data being sparse in the western part, the well controlled models were not adequate. It was considered necessary to integrate all available data, especially 3D seismic data and its various attributes. We preferred geostatistical technique because of its capability to integrate diverse data with varied scales.

Analysis of the Input Data

Fig.2 represents the variogram plot derived from wells falling in the study area. The solid line represents the variogram model of the net pay thickness. Geo-statistically it is a good fit. From a practical point of view kriging, KED are all fairly robust to the choice of variogram model, in other words, small changes in variogram parameters leads to small changes on resulting maps because the nugget effect is zero. The well data will be honored in both kriging and KED process. The variogram has quantified an important geologic factor: the spatial continuity of the variable. The variogram model is used in kriging, KED and conditional simulation to control the spatial continuity of the resulting maps.

Bivariate Relationship

Bivariate relationships between various seismic attributes and log derived average pay thickness of the producing layer were studied. The variation in the average thickness of the pay horizon is from 6 m to 10 m in this area, therefore Amplitude x Height attribute of 8 msecs. window below the producing horizon was extracted and found to have a good correlation (corr.coeff. = +.71) with the thickness weighted layered average thickness of producing sub layer derived from log data (Fig.3). Seismic section showing the correlation of layer top horizon along-with other layers in the study area has been shown in Fig.4. Comparing the Amplitude x Height map (Fig.5) with the well based effective pay thickness map (Fig.6) it is observed that wells having high thickness corresponds to the high values of Amplitude x height values.

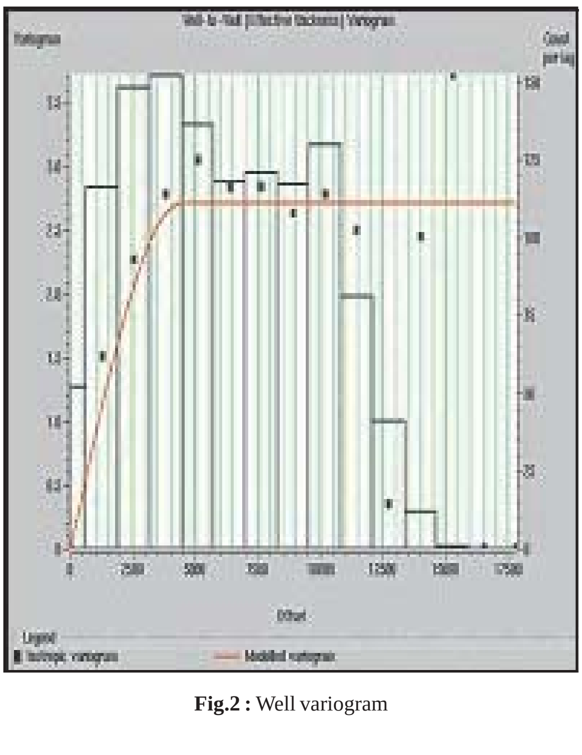

Fig.2 : Well variogram

Integrating Seismic And Well Data

Geostatistical data integration methods are analogous to a regression problem. The objective is to make a prediction at an unsampled location for primary data of effective thickness based on the relationship (linear combination) with secondary variable of Amplitude x Height attribute of seismic. Several geostatistical data integration methods are available. Generally, the choice depends somewhat on the type and amount of the data available. The external drift method has been used for the study.

In this study, a correlation between thickness and Amp. x Height is established and the functions of Amp x Height attribute are used as a drift function, rather than the function of x and y co-ordinates. Thus Amp x Height becomes an external drift or a correlated shaping function that introduces local trends into the kriging system and accounts for spatial variability not sampled by sparse well data. This approach requires that the external drift be known

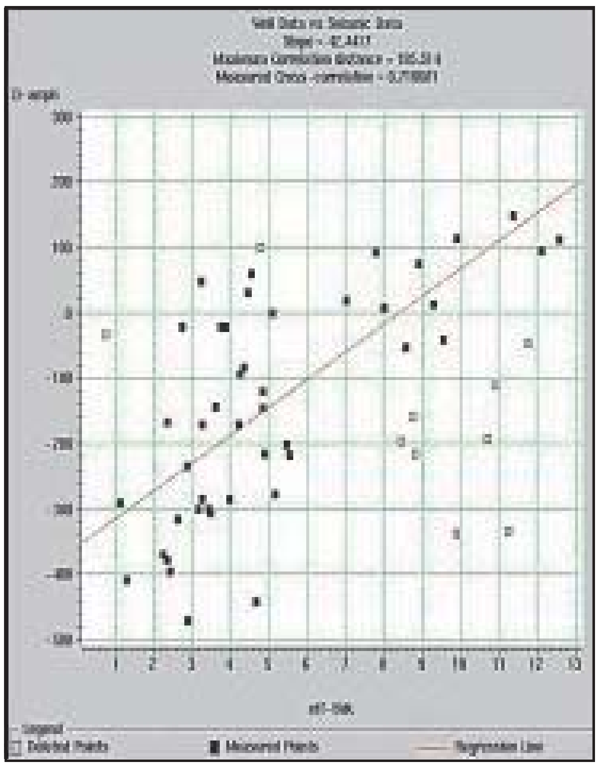

Fig.3 : Cross plot between amplitude height and pay thickness of producing horizon showing correlation coefficient of +0.71.

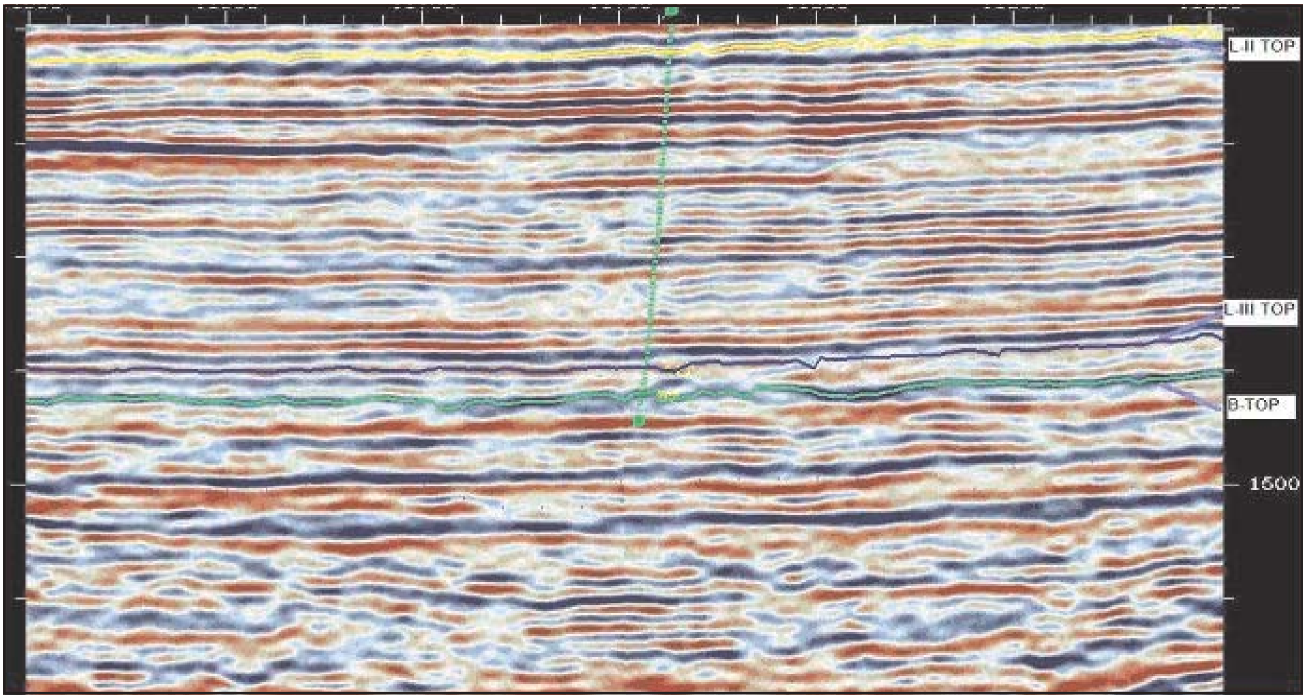

Fig.4 : Seismic section from the study area. The target reflector is L-III top correlated with blue colour.

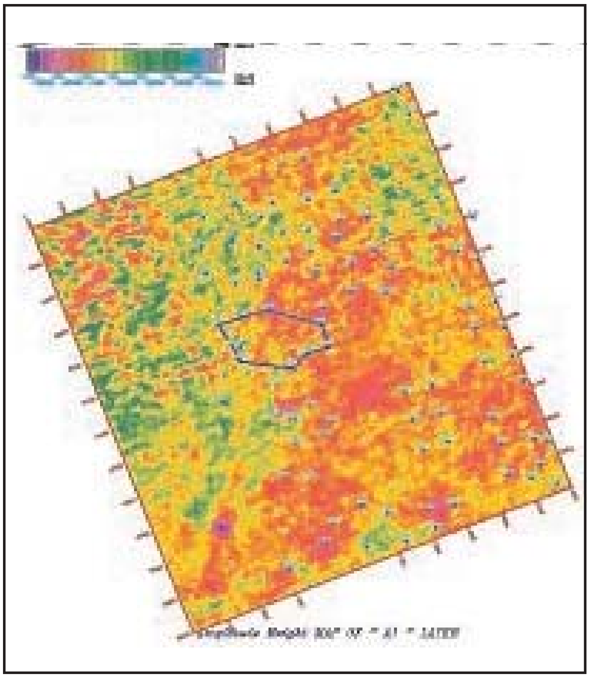

Fig.5. : Average amplitude height map of producing layer + 8 ms window

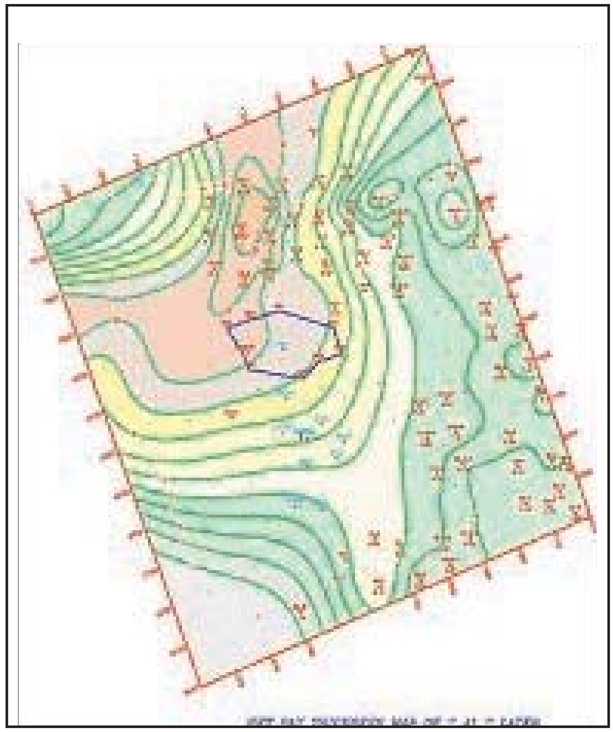

Fig.6 : Well based net pay thickness map

at all estimation points (grid nodes) and at all hard data points.

Well based effective thickness map has been shown in Fig.6. This map yields an estimate of 10.2 m pay thickness at proposed location.

Considering the well variogram model (Fig.2) the kriging operation was performed and the map is shown in fig.7. The kriging solution estimate is approximately 8.62m thickness at the sampled location.

The KED solution is shown in fig 8. KED uses the variogram model derived from well data and amplitude height attribute map as a guide. KED map using the seismic derived amplitude height attribute as a guide indicates approximately 7.9 m pay thickness at the sampled location.

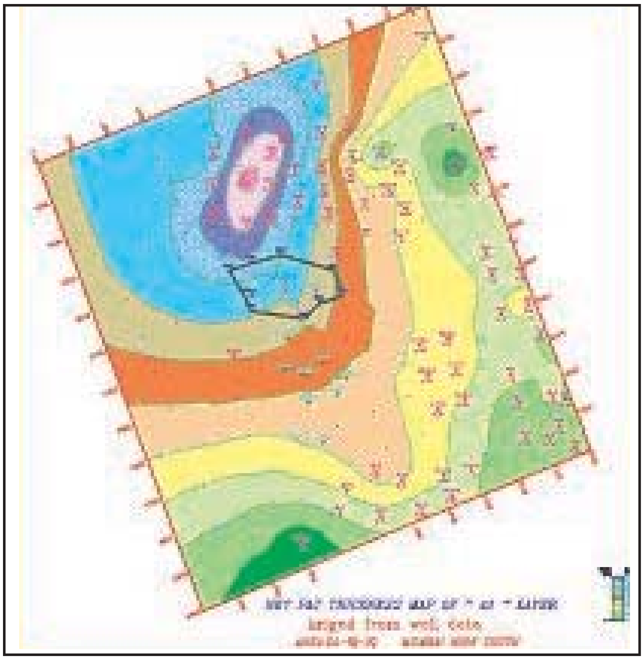

Fig.7 : Kriged solution of effective thickness

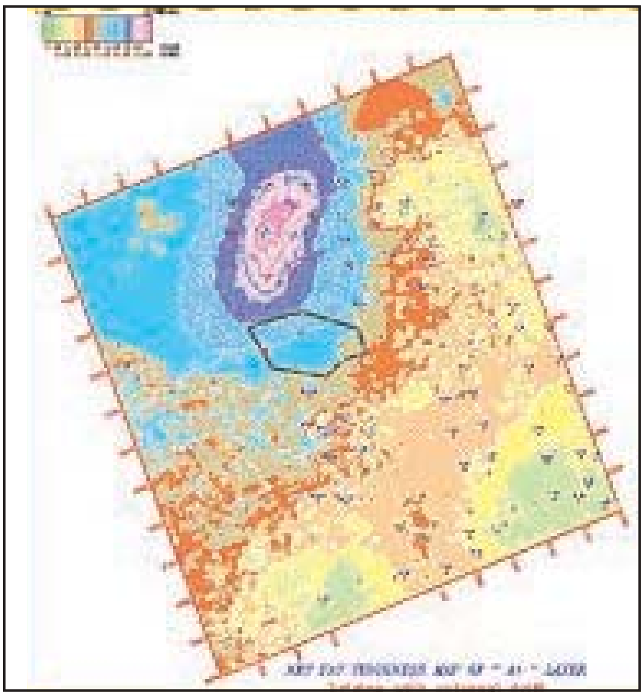

Fig.8 : KED map of effective thickness.

Assessing Accuracy

Method of conditional simulation was used to address the question of accuracy. Twenty five numbers of conditional simulation maps of pay thickness using the seismic attribute of Amp x Height as a guide were prepared. Each map

a) honors the well control within a grid cell
b) honors the variogram model of the well data to control the spatial continuity.
c) Has the same mean and variance as the input well data.
d) Is considered equi-probable.

Fig.9 shows five of the 25 maps. All the maps show more thickness in the northern part of the study area while lesser thickness in south-eastern corner of the area, but differ in detail. Each map is a reasonable way to contour the well data using seismic attribute as a secondary data.

Analysing the value of effective pay thickness from 25 simulated maps at the proposed location, it is observed that this value is ranging from 3.0 m to 9.2 m Fig. 10 represents the histogram of the effective thickness sampled at proposed location out of 25 simulated maps along with normal distribution curve. It is observed that there are only two maps out of 25 maps which shows the thickness less than 5.0 m which states that there is approximately 90% probability of encountering more than 5.0 m thickness at the proposed location.

So far we have analysed only one location. Fig.11 depicts a map showing the probability of encountering effective thickness between 5.0m to 10.0m in the study area. This map defines a risk assessment of the pay thickness in the study area. It is evident that there is about 83% probability of encountering effective pay thickness of more than 5.0m at the proposed location.

Cross Validation

Cross validation was used as a tool to compare the accuracy of the kriging and KED algorithms. Each well was removed, one at a time and remaining wells were used to estimate the value at the location of the removed well. In other words, during each cross validation, we assumed that the specific well had not been drilled. We then used all the other wells to estimate the well data at the missing well location. Cross validation error map of Kriging and KED were prepared (Fig.12 and fig.13) and it was observed that the standard deviation of the kriged cross validation map is 7.4 while the standard deviation of the KED cross validation map is 6.5%, which is less and indicates the less uncertainty after introducing the seismic data. We use the S.D. of the cross validation error as our measure of success.

Conclusion

The geostatistical method was used to first learn about the data, find relationship between seismic and well data, use what had been learned to grid the well data of effective thickness using the seismic attribute of Amp x Height as a secondary data and most important, assess the accuracy of the result. The assessment of the accuracy led to the direct estimation of the probability of success.

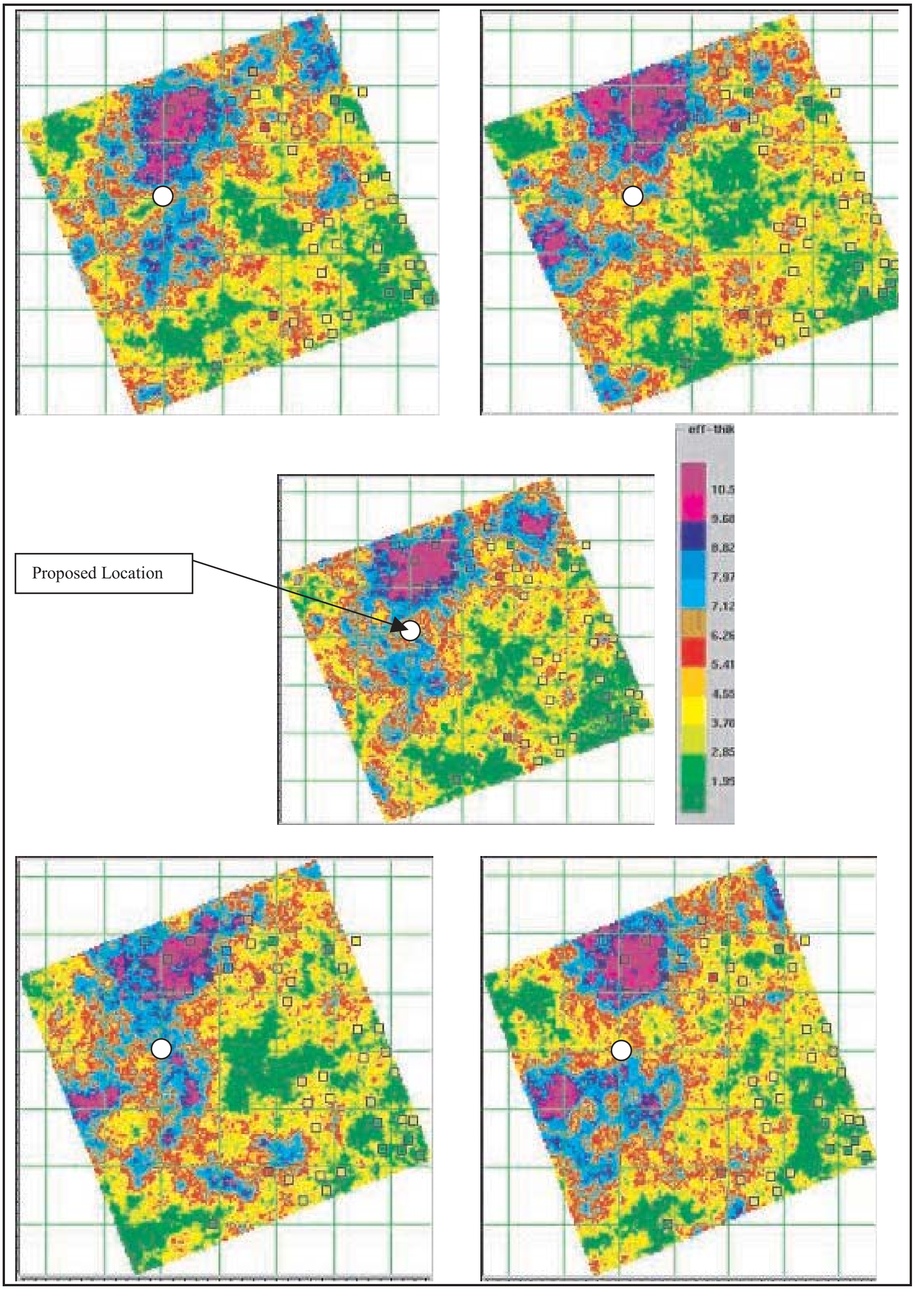

Fig.9 : 5 conditional simulation maps out of 25 realizations showing variation of effective thickness in interval space but honouring the well data everytime.

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