Combining geological surface data and geostatistical model for Enhanced Subsurface geological model

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Abstract

Geostatistics is a branch of statistics focusing on spatial or spatiotemporal datasets. In geology, geostatistical is used for numerical calculation of subsurface approach with several data such as geophysical or geological observation. Geostatistics modelling have several parameters setup to obtain best approach model. The parameters namely lithological boundary, geological structure and random seed number. Process for modelling used 23 drilling data with various lithological type. Two type geostatistical method is applied for the data that is Indicator Kriging (IK) and Sequential Indicator Simulation (SIS) with grid size 1000x1000 and 2000x1500. Distribution of lithology begin without parameters. Resulted shown that the model not appropriate with geological surface data and mismatch lithology position. To obtained better model, several geological information is included before geostatistical calculation. From regional geology surface data is obtained geological formation within lithological information. Then, geological structure describes the geology fault and formation boundary. Comparison between

Keywords: Geostatistics, subsurface, enhanced model, variance, random seed number

INTRODUCTION

This paper emphasis the use of geological information gathered from surface mapping and subsurface data, the method that used was mainly utilizing statistical information and deterministic model interpreted. Comparison model was built to calculate the deviation between realization, the calculation was furthered can be used as a uncertainty to make a better decision to choose the best realization.

Geostatistics can be used as a bridge between the statistics information and the geological interpretation. The spatial information was extracted from the geo special data.

23 shallow drilling data that contain lithological information is used to make the model. The model was built by using indicator kriging, Sequential indicator simulation, and Sequential indicator simulation bounded by deterministic geological interpretation. The aim of using the three methods listed above is to make a comparison model.

Indicator Kriging

Indicator Kriging (IK) as a technique in resource estimation is over fifteen years old. Since its introduction in the geostatistical sphere by Journel in 1983, many authors have worked on the IK algorithm or its derivatives. The original intention of Journel, based on the work of Switzer (1977) and others, was the estimation of local uncertainty by the process of derivation of a local cumulative distribution function (cdf) (Glacken and Blackney, 1999).

Indicator kriging will need statistical information such as variogram and/or variance model that extracted from the data itself. For comparison purposed the model was built by using standard isotropic medium range (1000 X 1000 M) and experimental variogram model that includes the geological knowledge in the area mapped (figure 1.)

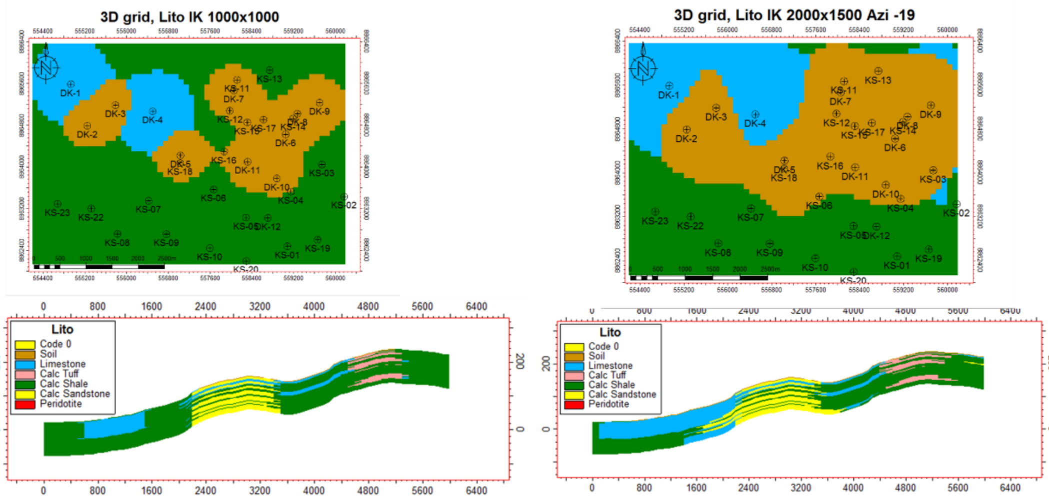

Figure 1. Comparison between indicator kriging simulation using isotropic 1000 X 1000 m range (left) and anisotropic 19^0 CCW 2000 X 1500 (right)

Figure 1 shows that the unrealistic geological model achieved if the spatial statistics model was not honored. The isotropic model tends to give a relatively circular lithology distribution outside the well position, while if the spatial information was included in the model, the range was estimated based on the geological knowledge in the area. Anisotropic trend with 19^0 CCW is known as the lithological distribution trend with 2500 X 1500 range. Output model will create a more favorable result regarding the geological sense. The model has shown that the spatial statistics is a very important parameter in modeling the data. Vertical section was made to shows the vertically distribution in both model, even if lateral distribution shows a good distribution in the model, but vertically was not very different in both result, thus we need more sophisticated method to capture the heterogeneity.

Sequential indicator Simulation

Sequential indicator simulation (SIS) simulates discrete variables, using SGS methodology to create a grid of zeros and ones (Deutsch, C.V. and Journel, A.G. 1998), As described in the literature, the general sequential simulation process is (Deutsch, C.V. and Journel, A.G. 1998),:

- Perform a normal-score transformation of the raw data.
- Randomly select a node that is not yet simulated in the grid.
- Estimate the local conditional probability distribution function (lcpd) for the residuals at the selected node. The residuals can be calculated by subtracting the grid of an unconditional simulation from a kriged grid of the unconditional values sampled at the geographic coordinates of the wells.
- Create a newly simulated value by adding together the randomly drawn residual value and the mean of the transformed data.
- Include the newly simulated value in the set of conditioning data, within a specified radius of the new target location. This ensures that closely spaced values have the correct short-scale correlation.
- Repeat until all grid nodes have a simulated value.
- As with turning-bands simulation, each time a new random walk is defined, a new and different result will occur. In

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this case, though, the lcpd is updated continually by the previously simulated values.

Both realization that used in indicator kriging was used in the SIS model to (figure 2)

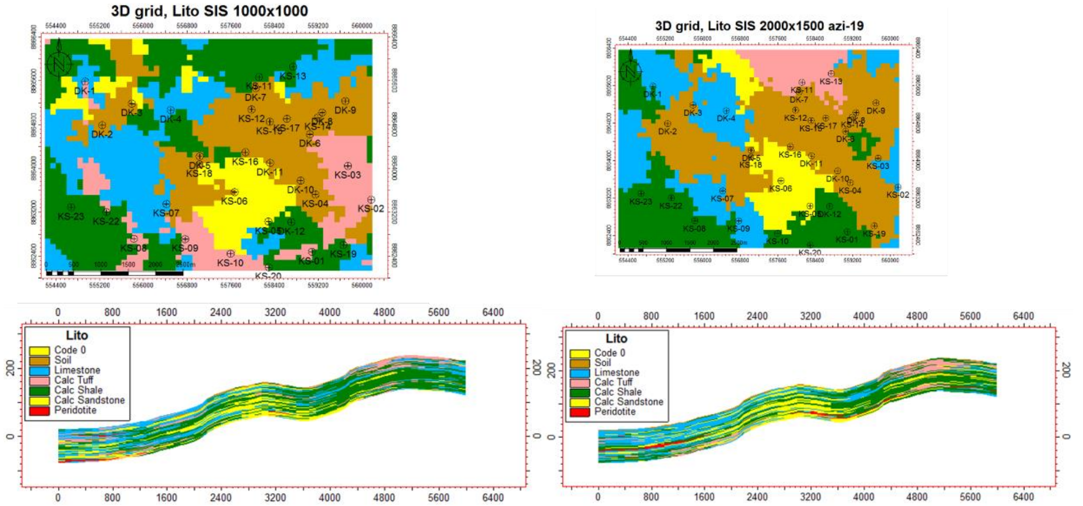

Figure 2. Comparison between indicator sequential indicator simulation using isotropic 1000 X 1000 m range (left) and anisotropic 190 CCW 2000 X 1500 (right)

Figure 2 shows that the Sequential indicator simulation gives more reliable model with relatively geological approved. Both horizontal and vertical heterogeneity was preserved that makes the model is better. Although both models have been able to describe the geological condition of the study area, further improvements should be made to incorporate conventional geological interpretation, as the resulting model has a high degree of uncertainty.

SIS method shown more reliable model for lithological geology distribution, several models from SIS calculation is produced to compare the variance distribution of geological model. Result of the several models shown in figure 3.

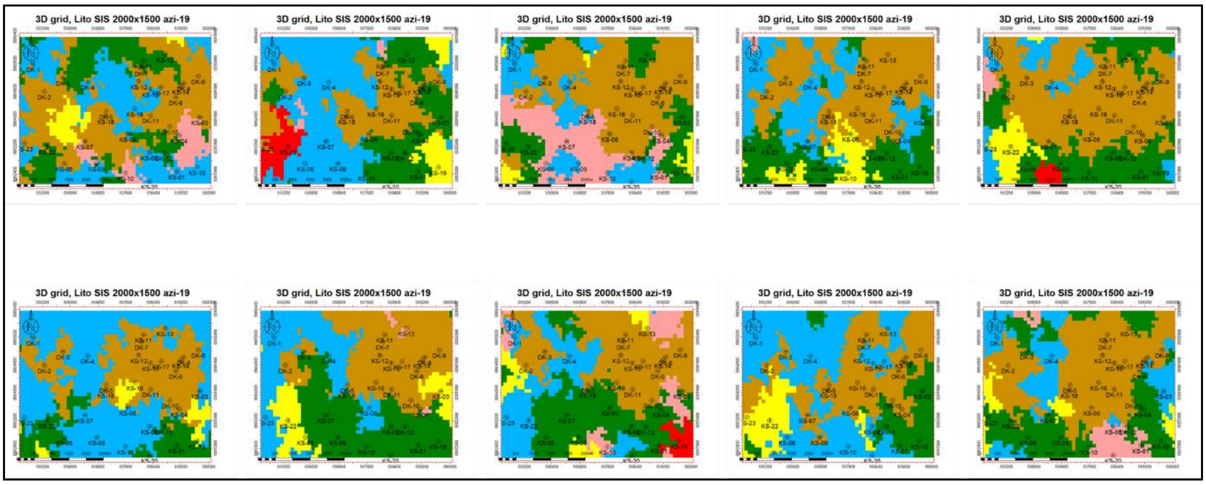

Figure 3. Several SIS calculation model simulations

The simulation is concluded that without any boundary of geological knowledge included in simulation, the seed model always produces geological lithology differently, especially the lithology always appears in random location. Even though SIS simulation produces better model than indicator

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kriging, geological knowledge boundary is importance due to limited variance archived model.

To obtain more better model, parameter of geological surface data is included before calculation process. In this location, there are three lithology types and structure boundary (figure 4):

1. West area is dominated with limestone lithology and illustrated with blue color
2. NE area dominated with shale lithology and illustrated with yellow color
3. SE area dominated with sand lithology and illustrated with green color
4. Boundary of the lithology is separated with fault role as structure of geology.

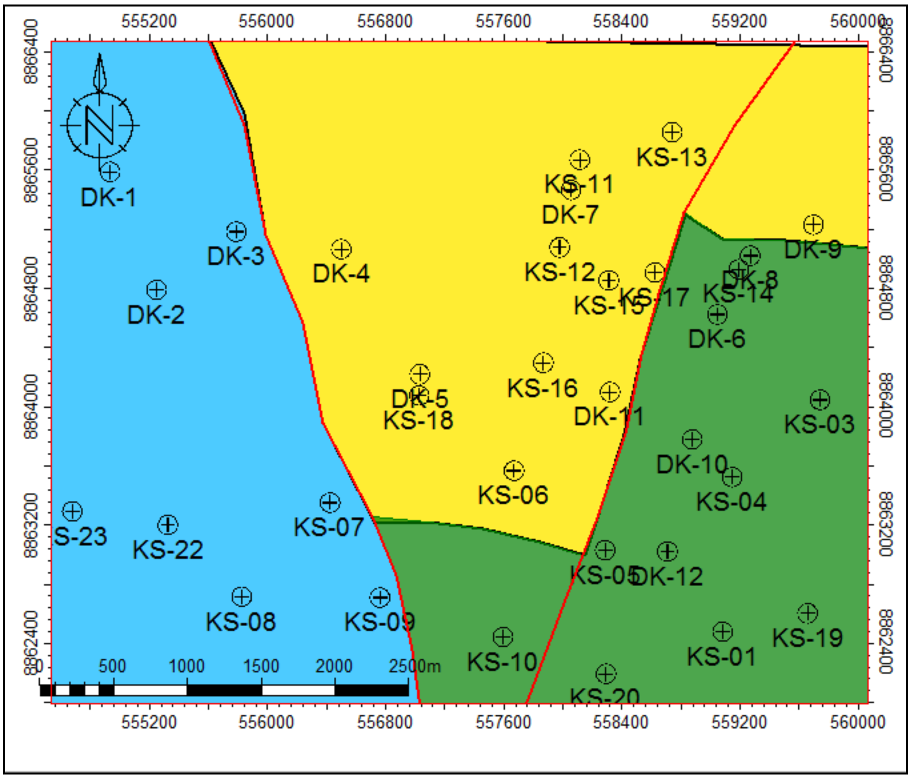

Figure 4. Geological knowledge which is obtained from regional surface data role as boundary for simulation calculation.

The boundary is made to limit the calculation of the simulation to be performed, so the resulting model is more reliable compare with surface lithological data that has been determined with the limitation. From this boundary expected could support produce more reliable subsurface geological model.

The boundary is applied same as process before. Begin with indicator kriging simulation and SIS geostatistical method. Figure 5 shown the calculation comparison between isotropic medium range (1000 x 1000 M) with geological surface data and anisotropy 2000 x 1500 m range with experimental geological knowledge and geological surface data.

Better model is obtained in this process, indicated by the distribution of lithology in the eastern part area is dominated by blue color correlated with limestone lithology, if previously process only appeared on the northern and circular distribution, simulation with included surface geological data parameters produce the distribution of limestone is spreading until south area in accordance with the reliable limestone

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distribution and limitation of the structure to make the distribution of limestone is not spread to the east area.

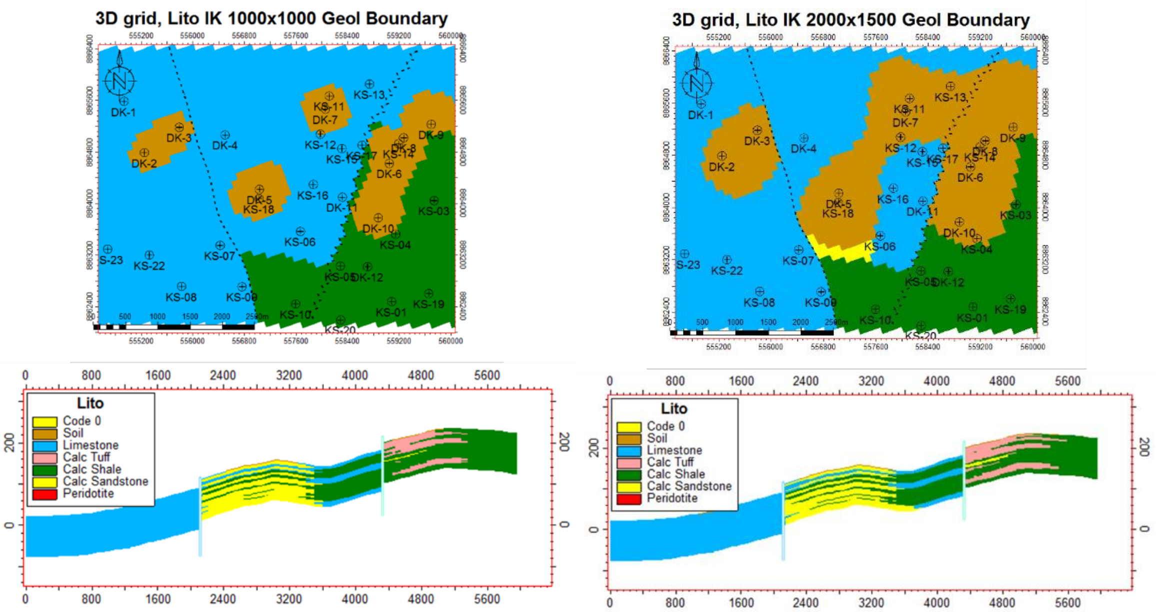

Figure 5. Comparison between indicator kriging simulation using isotropic 1000 X 1000 m range with geological surface data (left) and anisotropic 190 CCW 2000 X 1500 with experimental geological knowledge and geological surface data(right)

Sandstones in surface geological data did not appear in the NE area from modeling results due to on the surface drilling data there is no presences indication of sandstones lithology. The process shown the boundary parameters which are made still be correlated with the main data, so the resulting model produces synchronized surface geological information and main data.

The same method is also done with the SIS method, and produce a better model (figure 6).

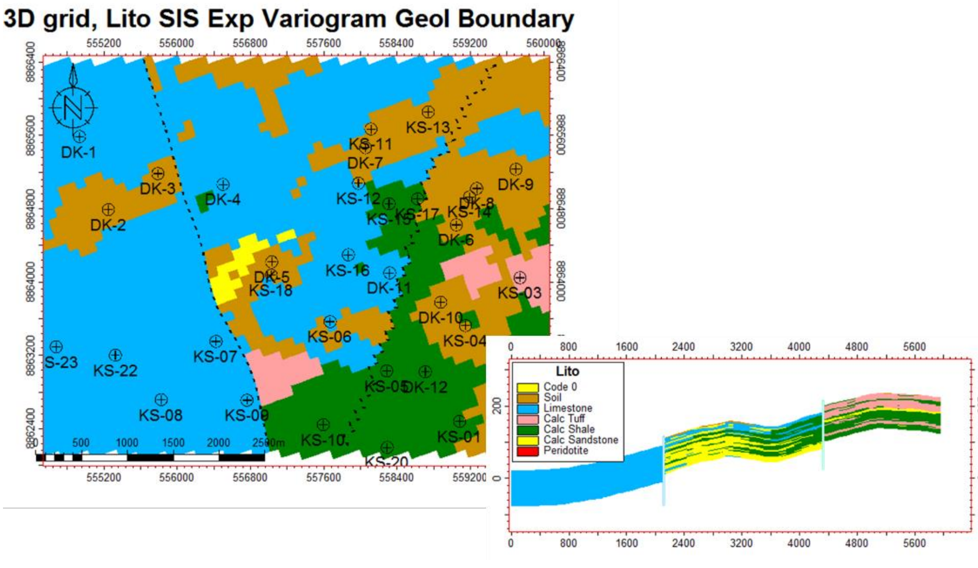

Figure 6. Sequential indicator simulatin with experimental variogram and geological boundary.

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The models produced using experimental variogram and geological boundary (figure 6) show more geologically acceptable results, suggesting that limestone dominance (blue color) lies in the western region of a very geologically acceptable model. Other lithologic dominance is also in the right place. The vertical distribution of each lithology has also been well distributed.

Several model realizations were also performed on this model (figure 7), it can be seen that the modeling results have been able to give a more consistent model result in each realization. A change of realization that demonstrates this good consistency can be the basis of the modeling being said to be better. The horizontal distribution of each model looks more consistent.

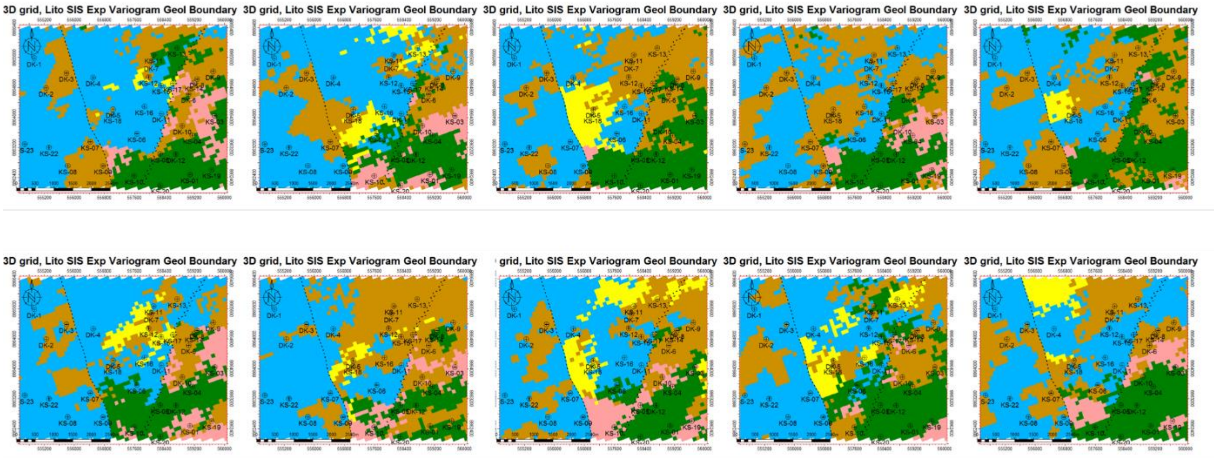

Figure 7. ten realization with sequential indicator simulation

Of the ten realizations that have been made, then calculated the degree of uncertainty by calculating the lithologic differences obtained in the tenth realization (figure 8). From the calculation of the uncertainty figures it is known that the model in the area close to the well data indicates good consistency (18% variance) while the distant location of the well data shows a high variance value (47%). Mathematically, this level of uncertainty is geologically acceptable.

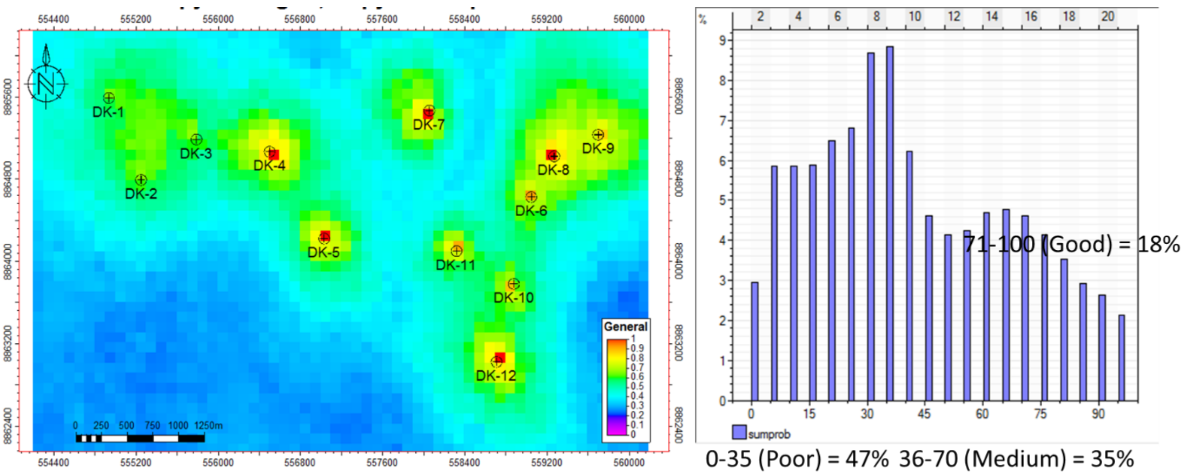

Figure 8. variance map of ten realization

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Conclusion

1. The geological model created by the kriging indicator method is good enough to describe the geological conditions in the research area, but it takes a conventional geological interpretation and a good variogram
2. Good statistical model was achieved by combining hard data (litology), and soft data (geological interpretation, and spatial statistic)

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