A Petrel Plugin for Surface Modeling

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Structure and thickness uncertainty are important components of any uncertainty study. The exact locations of the geological picks are known only at the wells which, in general, are sparse. Although the surface picks and thicknesses are only known at sparse wells, 3D seismic data (time interpretation and time-to-depth seismic) and Geostatistical techniques can be used to assess the uncertainty in the surfaces and the thicknesses. A basic geostatistical assumption is that the base case surface is unbiased and that deviations from the base case follow a Gaussian distribution. If the distribution is known better, then a normal score transformation and back transformation would replace the simple (non)standardizing approach taken in this paper. Using Petrel's Ocean API, the surface modeling engine has been written as Petrel plugin. This allows Petrel users to do surface modeling using the picks, base case surface and the uncertainty associated with time interpretation and time-to-depth seismic surfaces. In addition to Petrel plugin the prototype code is also presented.

Introduction

Structural modeling is one of the important steps in reserve calculation, reservoir characterization and simulation and in general in all reservoir uncertainty studies. The uncertainty in top and bottom reservoir surfaces has effect in the uncertainty of the reserve. In this paper a methodology is presented to model the structural surfaces with reasonable amount of uncertainty. The methodology is based on sequential Gaussian simulation.

Methodology

Basically the deviations from the base case surface are modeled. At well location since the picks are available the deviation is zero but far from the well we can assume that the deviations from base case are not zero and the distribution of the deviations follows Gaussian distribution. The required input parameters are listed below:

1. The base case value (structure or thickness): ($z_b(\mathbf{u})$, $\mathbf{u}$ in A) –a 2-D grid of values coming from the seismic. In general these values are fitted to the well picks.

2. A global estimate of the uncertainty in the base case surface σ_Δ – a single number established from time interpretation uncertainty and time to depth uncertainty. It could be calculated from:

$$\sigma_\Delta = \sqrt{\sigma_{TI}^2 + \sigma_{TD}^2}$$

   Where TI refers to the time interpretation standard deviation and TD refers to the time-to-depth standard deviation. These would be based on a review of the seismic data and, perhaps, differences between different interpretations.

3. Uncertainty in the mean – calculated from the number of independent data (widely spaced wells) or the spatial bootstrap

$$\sigma_{\bar{\Delta}} = \frac{\sigma_\Delta}{n_i}$$

   Where n_i refers to the number of independent data.

4. A map of locally varying uncertainty could be considered: (f ($\mathbf{u}$), $\mathbf{u}$ in A) –a 2-D grid of values coming from an understanding of the seismic variability. f ($\mathbf{u}$) will be 1 when the uncertainty is like the global estimate (point 2), it will be higher than 1 in more uncertain areas and less than 1 in more certain areas.

These four parameters must be established from the available reservoir data. The simulation proceeds by establishing a target mean, that could be different from 0.0, simulating the deviations and adding them to the base case surface. The procedure for simulation can be summarized by the following steps:

1. Establish a target mean for the simulation
   a. Draw a random number and convert to a standard Gaussian value: $y^l = G^{-1}\left(p^l\right)$
   b. Convert to a non-standard value $\overline{\Delta}^l = y^l \cdot \sigma_{\overline{\Delta}}$, which is the target mean for this simulated realization.
2. Establish the conditioning data for the realization. The conditioning data are always zero, that is, we want to reproduce the data exactly; however, we need to use non-zero conditioning data so that the back transformed values are zero. The conditioning data are calculated as:

$$y^l\left(\mathbf{u}_\alpha\right) = -\frac{\overline{\Delta}^l}{\sigma_\Delta \cdot f\left(\mathbf{u}_\alpha\right)}$$

3. Simulate standard normal values (sgsim with transformation turned off) using the conditioning data established in step 2. This provides (y^l($\mathbf{u}$), $\mathbf{u}$ in A).
4. Non standardize the standard normal simulated values and add to the base case:

$$z^l\left(\mathbf{u}\right) = z_b\left(\mathbf{u}\right) + y^l\left(\mathbf{u}\right) \cdot \sigma_\Delta \cdot f\left(\mathbf{u}\right)$$

5. Repeat steps 1 to 4 for many realizations.

There are some practical considerations. Firstly, different random numbers should be used at each step to avoid unwanted correlations – this is easy. Secondly, the conditional simulation of step 3 amounts to condition to values that are all negative if $\overline{\Delta}^l$ is positive and all positive if $\overline{\Delta}^l$ is negative. Depending on the range of the variogram, this tends to work against a full sampling of the uncertainty. For example, if we draw a positive mean of 5m, the Gaussian values will come out preferentially negative and the back transformed mean will be less, say, 3 m. The uncertainty in the average may need to be increased to account for this.

A typical workflow would be to model the top structure and work with isochore thicknesses down through the stratigraphic column. Care should be taken to ensure data conditioning and reasonable standard deviations at each step. For the purposes of sensitivity study, the base case thicknesses could be used for the realizations of top structure, then the thicknesses could be varied holding the top structure at the base case. Of course, all values should be varied to quantify uncertainty.

Petrel Plugin

Schlumberger Ocean allows the Petrel users to add their new developed algorithms to Petrel as a plugin. The Petrel plugin gets the required input from the user, reads the data from Petrel, calls the DLL, receives the output from the DLL, and saves the data into Petrel objects.

In this work we used Ocean 2008 to generate surface modeling plugin for Petrel. Since some parts of our algorithm (such as SGS) were previously coded as a FORTRAN subroutine within GSLIB, we generated the main surface modeling engine in FORTRAN. The next step was to convert the surface modeling code to a DLL. This DLL was called from the Ocean plugin.

The surface modeling plugin user interface can be opened via the process menu or workflow manager in Petrel. Figure 1 shows the surface modeling user interface.

There are 11 parameters that should be specified before running the program. Base case surface (zb(u)), well data, and local uncertainty map (f (u)) can be set by selecting an object and pressing the blue arrow or by dragging and dropping the object into surface modeling plugin window. Other parameters including uncertainty in base case surface, uncertainty in mean, random number seed, and number of realization to generate can be specified in the related boxes. Since there is no specific information to calculate and model the variogram for the variable (deviation from base case surface) in this application, a generic variogram structure may be considered. Gaussian and spherical variogram can be chosen for variogram type menu. Azimuth, maximum, and minimum ranges should also be specified to define the variogram structure.

Pressing apply or ok button will run the program. The output will be stored in a Pillargrid object.

Example

In order to verify both the algorithm and the plugin the following case is examined. Consider an area with Easting of 920 m and Northing of 1300 m. Four vertical wells are drilled in this area. The elevation of specific surface (such as top of Mcmurray) is known at all four wells. A seismic-derived base case surface is available for this area. Figure 2 shows the location of wells and the base case surface. A locally varying uncertainty map is considered for this example. Figure 3 shows the locally varying uncertainty map. Based on the local uncertainty, three different cases of 0.1m, 0.3m and 0.7m are considered. For each case five realizations are generated. For all cases the uncertainty in mean is set to 0.03. A Gaussian variogram with isotropic range of 100.0 m is assumed. Figure 4 to Figure 6 shows simulated realizations for different base case surface uncertainty value. In order to check the validity of models, each realization is compared to the base case surface and the difference map (Δ) is calculated. The mean and standard deviation of difference map is calculated for all five realizations. Table 1 shows the results for the first case (local uncertainty of 0.1m). The averages of mean and standard deviation for five realizations are 0.0039 (close to zero) and 0.0975 (close to 0.1), respectively. The deviation of mean and standard deviation from 0.0 and 0.1 may be due to the data conditioning.

Table 1. Summary statistics for five realizations generated with local uncertainty of 0.1m.

Realization Number	Mean of Δ	Standard Deviation of Δ
1	0.0002	0.0967
2	0.0071	0.0995
3	-0.0093	0.0949
4	0.0069	0.0958
5	0.0145	0.1007
Average	**0.0039**	**0.0975**
Standard Deviation	0.0080	0.0022

References:

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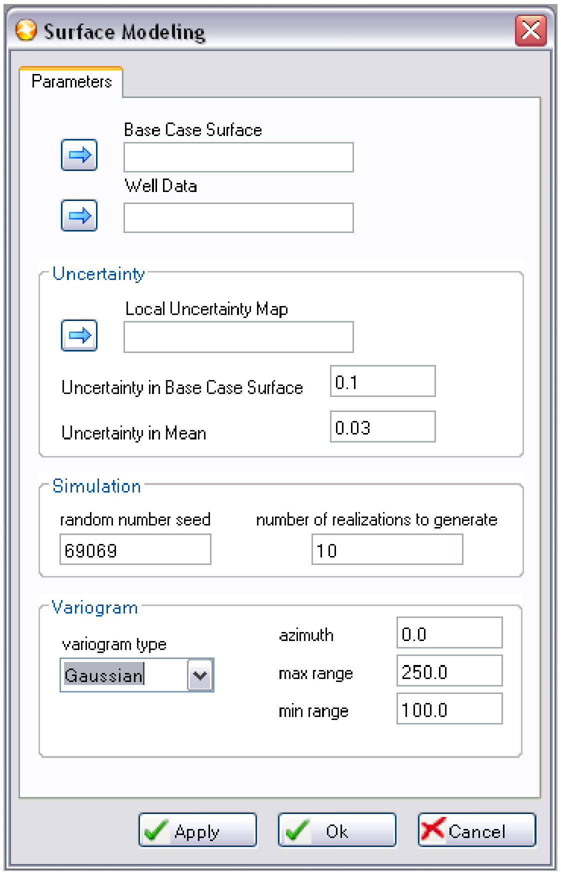

Figure 1. User interface for surface modeling Petrel plugin.

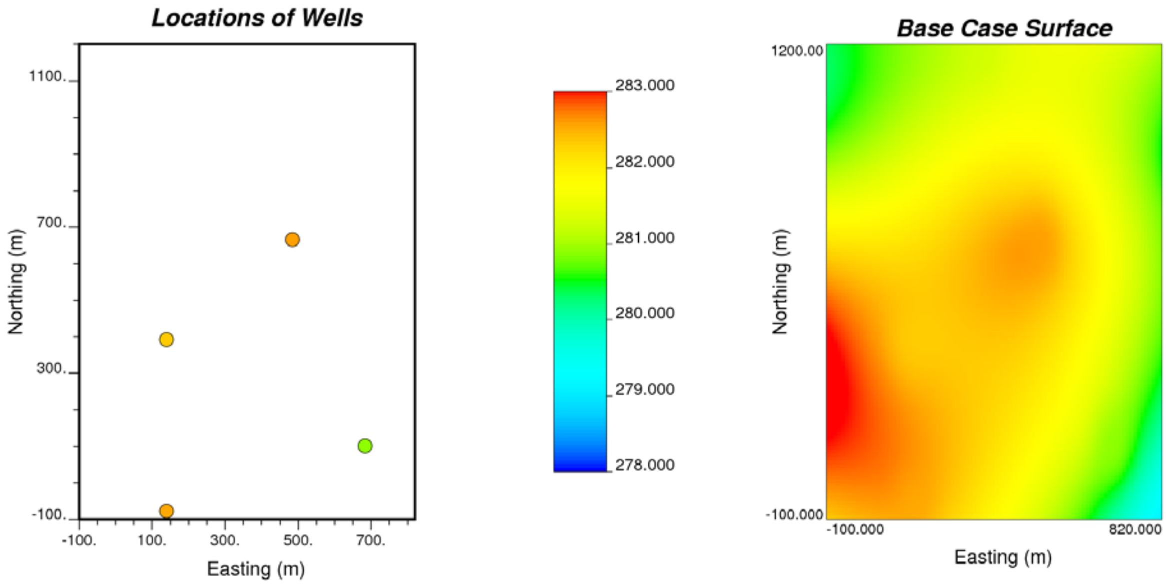

Figure 2. Location of wells in modeling area (left) and base case surface map (right).

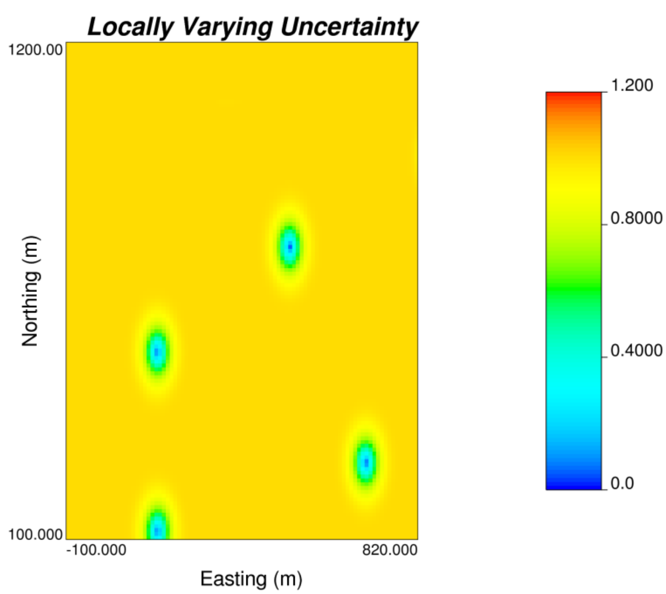

Figure 3. Map of locally varying uncertainty

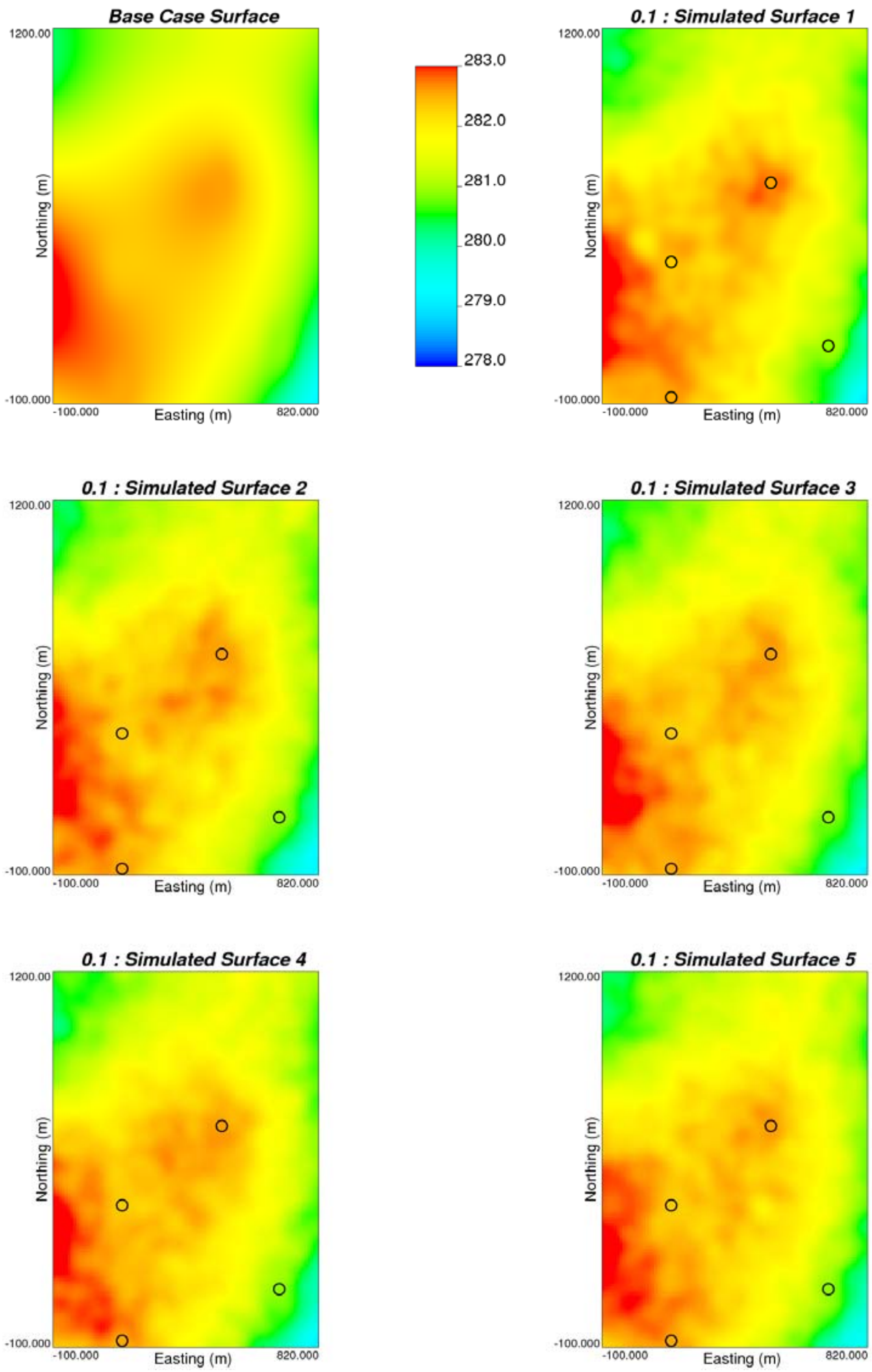

Figure 4. The base case surface (top right) and five simulated realizations with uncertainty of 0.1m in base case surface.

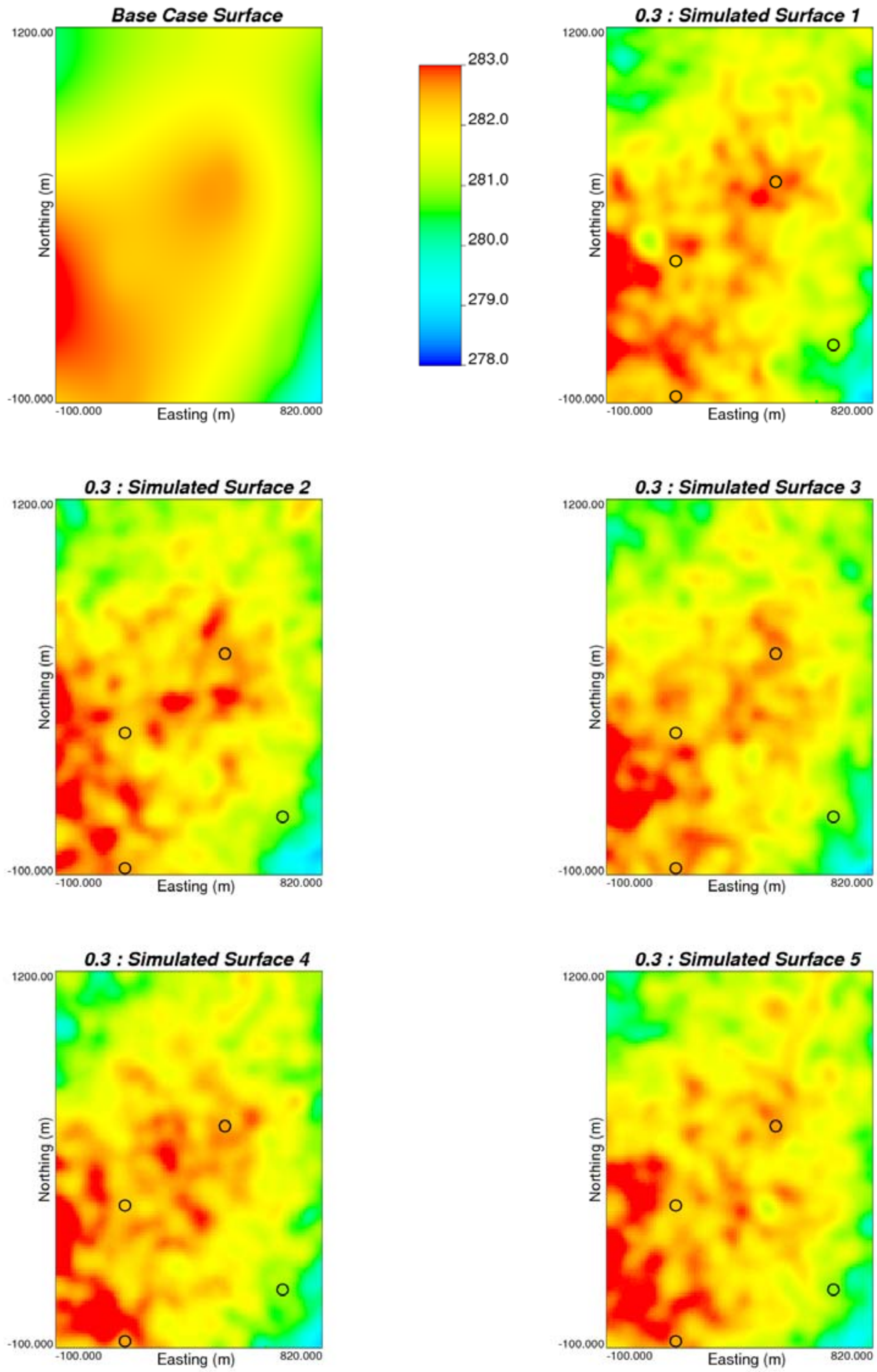

Figure 5. The base case surface (top right) and five simulated realizations with uncertainty of 0.3m in base case surface.

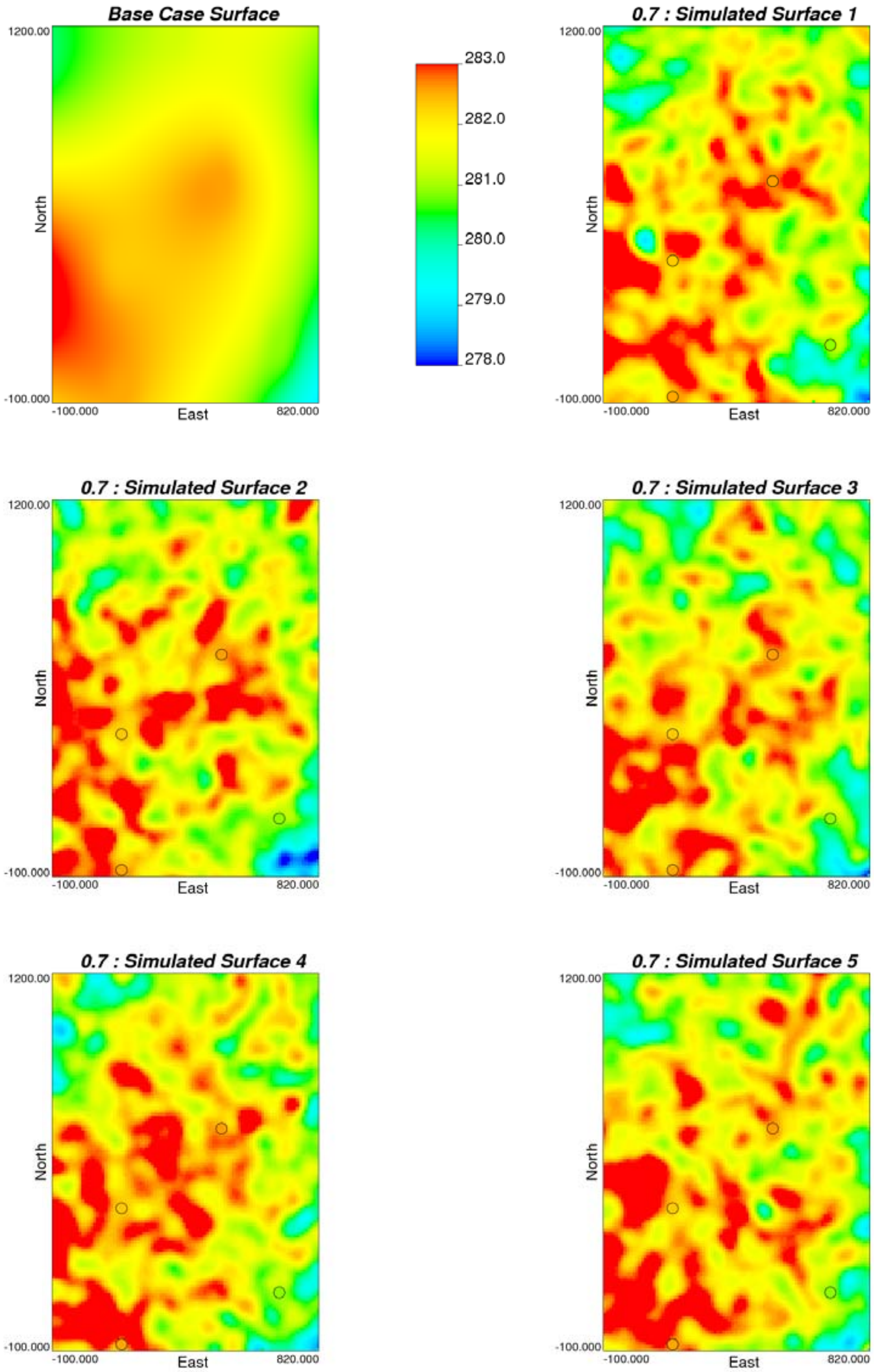

Figure 6. The base case surface (top right) and five simulated realizations with uncertainty of 0.7m in base case surface.