Introduction

A common issue in Depth conversion and Volumetrics calculation is the estimation of the range of variation of important reservoir parameters, like structural closure depth or reservoir volumes, which are often poorly estimated. For example, the GRV and hydrocarbon volumes in most of the developed reservoirs are found to be closer to the P90 than to the P50 determined at the exploration phase, which means that the range of variation is often underestimated.

Combining data sources of varying precision and accuracy such as seismic data, CCAL, SCAL or logs, which correspond to different scales, is a difficult issue. It requires appropriate mathematical tools, like the ones provided by Geostatistics (Correia et al., 2019). This paper details the geostatistical techniques than can be used for calculating geological models and quantifying the associated uncertainty. Focus is put on the role played by input data accuracy and precision in the final estimation of GRV and hydrocarbon volumes range of variation, accounting for the varying accuracy and precision which can be managed in practice. The methodologies and results are illustrated with a simplified modelling based on a real dataset, emphasis being put on structural modelling in this example.

Geostatistical methods for combining data of varying accuracy and precision

Geological modelling requires maps of geological horizons, faults surfaces, a 3D grid based on horizons and faults with an internal layering which depends on stratigraphic rules, and a spatial distribution of properties (Facies, Porosity, Permeability) inside the grid. Geostatistics proposes several algorithms for mapping continuous or categorical variables, in 2D or 3D, with the advantage of providing an estimation of the uncertainty attached to mapping results.
Two techniques can be used in geological modelling, to combine data of varying accuracy and precision, Stochastic Conditional Simulations and Kriging, in particular, the two variants of the latter being Kriging with External Drift and Kriging with Measurement Error (Chiles & Delfiner, 2012).

Stochastic Conditional simulations are a set of n realizations of a given variable, calculated on 2D or 3D grid. Each realization is a possible representation of the reality (a Depth-converted Horizon, for example) which honours the true variability of experimental data, the variogram calculated on experimental data and the value of the variable measured at data points. To account for uncertain input data, a specific set of input data is defined for each realization. Then, the different realizations are conditioned by different data sets, according to the uncertainty level of input data. When making statistics on the full set of realizations, the uncertainty on each input data is automatically accounted for. Simulations can be conditioned by Kriging with External Drift, which allows including auxiliary data of various scale and accuracy (Time map, seismic derived Porosity) in the process. Such Drifts (geological trends from auxiliary variables) can be affected by uncertainty, each point of the Drift being then associated with a variance. By using Conditional Simulations and kriging with measurement error, we can generate several Drifts that we use in the calculations on the main variable.

The accuracy of each dataset is important. In cases of low accuracy, the conditioning data generated for each realization may be far from the true value. Combined with a high precision, it can result in biased values that are systematically higher or lower than the true value. This will induce a bias in Volumetrics. To avoid this effect, in cases of biased data suspicion, it is better to consider that the precision is low, to ensure that the true value is inside the range of variation of the input data.

Application example

A Time-Depth conversion has been done on a dataset made of well data and Time maps. The uncertainty related to the calculation process, which is due to the under sampling of the field, has been evaluated by means of geostatistical conditional simulations. In this example, the depth of structural closure was calculated at the end of the conversion process and its sensitivity to input data has been tested. Figure 1 shows the impact of input data precision.

***Figure 1** CDF of structural closure depth, accounting for uncertainty on markers depth, or not.*

In this example, the depth markers at wells have been considered as certain or uncertain. Figure 1 demonstrates that this can significantly change the distribution of the structural closure depth CDF.

Different displays can be used to highlight uncertainty on results. A CDF, as in Figure 1, is useful in risk analysis, for estimating P10, P50 and P90. Another display can help visualizing the relative impact of different sources of data. HC volumes are shown in Figure 2, with the GRV CDF and two additional parallel curves representing the impact of the possible maximum and minimum Porosity and Saturation when multiplied by the GRV.

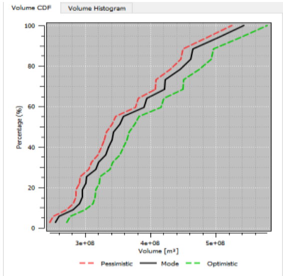

***Figure 2** Three cumulative density functions highlighting the relative effect different sources of data.*

Discussion and conclusion

The combined use of advanced geostatistical techniques offers a solution for quantifying and visualizing uncertainty on reservoir geometry and volumes. Stochastic conditional simulations allow integrating the uncertainty on Time maps or Velocity maps, on fault location and on markers at wells. In the end, they allow quantifying the global uncertainty resulting from all the uncertainties on each data source. If all the specific uncertainties associated with the different data sources are taken into account in Time-Depth conversion, then the range of variation on the results (reservoir GRV, Depth and location of Spill points, HC volumes within user-defined areas and stratigraphic intervals) will be realistic. If all the intermediate uncertainties are included in the calculations, it is obvious that the provided ranges of variation on results may be quite wide, but more realistic than a narrow range resulting from an underestimation of the intermediate uncertainties. This allows decision makers to take the most appropriate decisions concerning the field development. In addition, all these techniques have been packaged in semi-automatic workflows, allowing fast and efficient sensitivity tests to input parameters, one by one or simultaneously, facilitating decisions.

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