Solving an intricate problem with ease

Approximation of the topologies of geological objects like ledges, sandbars, salt domes etc. with continuous surfaces is one of many nontrivial tasks to be solved in seismic data interpretation, velocity modeling and geological modeling. The problem of describing spatial structures like these lies in the fact that some points with given X, Y coordinates must be related to several Z-coordinate values. Description of such type of geological bodies with a multiple Z-coordinate, continuous surface (multi-Z surface) is not supported by the majority of applications that are currently available in the geoscience software market. Thus, complex objects are traditionally described by several segments being subsequently mapped independently from each other. The process takes a lot of time as a rule and results in substantial simplification of the interpreted objects.

The interpretation cycle time may be significantly reduced and the quality considerably enhanced with the opportunity to represent complex geological objects with a single horizon followed by creation of a triangulated multi-Z surface. Paradigm software solutions offer advanced tools to carry out modeling projects during all stages of the oil field life cycle from data processing to geologic modeling to reservoir simulation. This article is based on a modeling example of a complex topological object. In the course of that study seismic data has been interpreted, a geological model has been developed and the directionally well path has been designed.

Structural and Dynamic Interpretation

Both structural and dynamic (amplitude) interpretation have been performed in the Paradigm® Shell Earth® package. An abnormality has been revealed in the seismic amplitudes during the initial data scanning stage that was presumed to be associated with a geological object. The amplitude abnormality has been associated with a multi-valued horizon. A surface has been constructed to get the basic concept of the object under study. Triangled surfaces not only provide the advantages of multi-Z surface representation, but they also provide the opportunity to perform interactive editing of that surface by simply activating any of its nodes and specifying the required direction of correction. Amplitude cubes slices were incorporated to improve object shape, but the object was not clearly apparent from interpretation of the time slices. Additional seismic attributes have been calculated based on the input amplitude cubes. The Coherence sequence appeared to be the most informative with horizontal slices revealing the object geometry more clearly. This structural attribute enabled the revision results of the initial structural interpretation and the ability to pay heed to the more complex shape of the geological body under study. The first iteration of the dynamic interpretation stage was comprised of the analysis of additional seismic attributes and object refinement (Fig. 1). A seismic facies map calculated with Paradigm Stratigraphic® package for the second iteration was based on the analysis of the wave-shape pattern variations within the area under study. The map revealed one more minor “satellite” extension of the object related by its index to the same seismic facies that the main object under study (Fig. 2). To understand the correlation between those objects, a third iteration has been carried out that involved a seismic facies cube calculation based on the entire seismic attribute set. The calculations have been performed with the SeisFaces™ application of Stratigraphic package.

That seismic facies cube was analyzed with the voxel-visualization tools of Paradigm VoxelGeo® package. By iterative adjustments of transparency and strining for specific seismic facies imaging, it has been ascertained that the previously revealed objects represent the parts of a comprehensive whole geological body featuring a considerably more complex shape than it was originally envisioned (Fig. 3). Special editing tools used in a hands-off operation mode enabled all the elements of the geological object to be interpreted and matched with each other at the final stage of the structural and dynamic interpretation. The shape of the geological object under study that has been revealed as a result of the interpretation performed, bore a strong resemblance to a brewing teapot and for that reason the object was named respectively later on. Interpretation is a subjective process and every point of the surface of the object contains some uncertainty component. Therefore, an unlimited number of equi-probable objects meeting the initial condition could be obtained by calculating an error value. This calculation was performed in the Alea module of the Paradigm GOCAD® modeling suite. (Fig. 4). The most optimal realization has to be chosen from that endless set in order to perform additional geological modeling stages, traditionally comprised of grid model construction, property allocation and estimation of reserves.

Geological Modelling

A grid model could be easily and quickly built in the Paradigm SKUA/GOCAD® modeling suite regardless of the object's complex configuration. For that purpose, a single volume of a given cells dimension is created with angular coordinates. In the next step, that volume is transformed to fit geological boundary conditions, so that a surface of any complexity level could be inscribed in the grid volume that has been created. As the object has not been explored by boreholes, it has been considerably represented with a single lithographic type. Porosity modeling within the object's borders, was performed with a colocated co-kriging algorithm with the assumption of a normal distribution that is typical for the objects of that kind. An acoustical impedance cube, obtained by AVA inversion in Paradigm Vanguard® package, was incorporated in the porosity modeling process, with the impedance property serving as the second variable (trend). The seismic data has been preliminary rescaled from the seismic cube into a grid model (Fig. 5). As a result, several porosity distribution realizations were obtained. A trend effect is noticeable to the naked eye in all those realizations. Trend utility allows us to guide the stochastic modeling into a desired course and to attach geological properties to the conceptual geological model (Fig. 5).

Reserves Assessment and Drilling Works Planning

The most promising intervals of the enhanced porosity have been examined within the object as a result of properties distribution modeling. Drilling targets have been specified within one of those intervals and a directional hole has been designed (Fig. 6).

The model that has been obtained enables reservoir engineers to perform reserves estimation. To enhance reserves assessment accuracy, it is recommended to use stochastic as well as deterministic approaches. Both of them are implemented in Jacta module of the SKUA/GOCAD modeling suite. With specified uncertainty values of each parameter involved in reserves assessment formula and the number of realizations generated, a distribution bar chart could be obtained that enables the reservoir engineer to estimate pessimistic, optimistic and the most probable scenarios (P10, P50, P90).

Conclusion

A comprehensive process chain for complex geological object study has been implemented by the authors based on modern Paradigm software solutions, beginning from the interpretation stage to geological model construction. This approach enables the geoscientists to attain the maximum amount of information derived from the input data and to create the most comprehensive representation of geological object under study irrespective of the level of its complexity thus ensuring drilling risks to be minimized and reserves estimation to be performed with higher truthworthiness (1). Indeed, the geological object in question has been presimulated specially for presentation of Paradigm software capabilities to the customers. The surface describing a well-known object (brewing teapot) has been initially constructed in the SKUA/GOCAD® modeling suite (2). Using flexible tools from SKUA/GOCAD®, the input wave field within the object's surface was specially deformed in order to create a “bright spot” effect in amplitudes. That cube was then used as input data set for presentation of technological solutions for complex geological objects interpretation and modeling.

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