Interactive Reservoir Geomodelling from Uncertainty*

Ronan Amorim[1], Emilio Vital Brazil[1], Daniel Patel[2], and Mario Costa Sousa[1]

Search and Discovery Article #41309 (2014)
Posted March 31, 2014

*Adapted from extended abstract prepared in conjunction with presentation at CSPG/CSEG/CWLS GeoConvention 2012, (Vision) Calgary TELUS Convention Centre & ERCB Core Research Centre, Calgary, AB, Canada, 14-18 May 2012, AAPG/CSPG©2014

[1]Department of Computer Science, University of Calgary, Calgary, Canada (rmamorim@ucalgary.ca)
[2]Christian Michelsen Research (CMR), Statoil, Calgary, Canada

Abstract

Constructing structurally complex reservoir models at the appraisal stage is a complex task, with a high-degree of uncertainty. The lack of an intuitive set of modeling and visualization tools that support expert visual interpretation from geophysicists and geologists significantly increases the challenge. We present a set of interactive software tools to reservoir modeling in the appraisal stage. Our project use sketch-based modeling tools to allow the users to guide the model process with his/her expertise intuitively and quickly. We propose two different approaches that depend on the input data. The first approach is to create “what if” scenarios and start with no data or sparse data. The second one is to edit horizons, which will form the horizon and fault network, and start using the seismic volume and a pre-extracted horizon.

Introduction

Reservoir models are built incrementally using the available knowledge about the reservoirs, including: (1) the reservoir data (geophysical, geological, reservoir and production engineering data) and (2) the expert interpretation of that data by multi-disciplinary teams (Figure 1). Building a reservoir model involves integrating both of these sources (Cosentino, 2001; Fanchi, 2002; Love and Purday, 2008). The first reservoir models are constructed at the appraisal stage, when geologists interpret seismic, outcrops and well data to develop a geological model for the reservoir. During this appraisal stage, the available data presents inaccuracies, sparseness and a high degree of uncertainty (Iske and Randen, 2006; Jones et. al., 2004; Sech et. al., 2009); consequently, different results can be seen from different teams when interpreting an identical dataset (Patel et. al., 2009). A fundamental problem at this appraisal stage is the lack of computational tools to support interactive, intuitive visual interpretation and integration of geophysical data leading to robust conceptual, prototype structural model of the reservoir (Patel et. al., 2009; Geiger et. al., 2009). This model consists primarily of a network of horizons and faults, providing the basis for subsequent model refinement and integration with other data and applications.

This work addresses the problem of rapid modeling structurally complex reservoirs. These reservoirs contain an array of fine-scale, complex geological structures (like fractures and folded sedimentary layers) that are below the resolution of seismic images. These features impact flow behaviors and recovery, yet the upscaling process for sector and field-scale reservoir simulations are obscured by those impacts. By identifying situations in which sub-seismic structures can introduce significant departures from full-field flow predictions the impact may be lessened (Agar et. al., 2010; Gringarten, 2006; Matthäi et. al., 2007). Constructing structurally complex reservoir models at the appraisal stage is a complex task, with a high-degree of uncertainty. The lack of an intuitive set of modeling and visualization tools that support expert visual interpretation from geophysicists and geologists significantly increases the challenge.

Challenges and Goals

One of the main challenges is the fact of the available data presents inaccuracies, sparseness, a high degree of uncertainty and they are prone to different interpretations from domain experts. Currently techniques used by geophysicists and geologists for interpretation at the appraisal stage have manual and hand-draw stages, other good challenge is how to encode these traditional techniques establishing the direct and intuitive manipulation of the geometry and topology of complex heterogeneous structures representing the geological model.

Our goals is to create a set of interactive software tools applying direct manipulation approaches, such as Sketch-based Interface and Modeling (SBIM) techniques (Olsen et. al., 2009) to allow intuitive, direct interpretation, manipulation and modeling of appraisal data into a stratigraphic grid of the reservoir by using sketches extracted directly from user input. The resulting model will be used for subsequent gridding, characterization and flow simulation studies.

Data and Method

A rapid reservoir modeling approach should reduce the time necessary to construct reservoir models while still allowing for re-design and/or augmentation at any stage of interpretation and integration throughout the field development cycle. An interactive visual modelling and manipulation tools, including sketch-based interface and modelling (SBIM) techniques, will be developed to allow rapid, intuitive creation, manipulation and subsequent annotation and refinement of models by using visual manipulation (i.e. sketches and gestures) extracted directly from user input. The user will directly manipulate and annotate over the dataset to visually interpret, identify, construct, integrate, and edit individual horizons, faults and the corresponding network. These tools will be integrated with other algorithms for interpolating and extrapolating sparse data to construct geological surfaces. This information will be used with statistical methods to measure the uncertainty of the predicted surface geometry (Figure 2).

Applications

We developed two approaches, one for sparse data and another for dense data. Despite both approaches have the same aim, (to create the structural model) the input data change the utility of the application. When working with sparse data the expert would like to create “what if” scenarios. On the other hand, with the dense data the expert would like a tool to help him/her to describe his/her interpretation of the seismic volume.

Sparse Data: Our approach to create rapid reservoir modeling based on sparse data could start with outcrop and well log information, or start from scratch. In the first case, the well log works as a surface constraint and the user can use the outcrop as a guide to create the curves to define the geological horizon. For both approaches, with and without information, we use parametric surface to model the horizons, and an adaptive mesh as a final representation. Since our constraints are boundary curves we choose Coons surfaces, because it is defined by four curves, which is a natural generalization of Loft surfaces. The final scenario can be composed with many horizons (Figure 3).

Dense Data: The first version of a reservoir model is constructed at the appraisal stage by interpreting seismic data. Often, the first step is to use automatic or semi-automatic algorithms for extracting rock layer boundaries, called horizons. These boundaries are approximate and come with several topological and geometrical errors. Therefore, the geologist must use his/her expertise to correct them. However, no methods have been developed for fast manipulation of such surfaces. Our goal is to create a set of sketch-based tools to allow the expert to directly manipulate the model for intuitively and quickly shaping a more correct geological horizon. For fast horizon creation, we adapt the method proposed by Patel et al. (2010) where an approximate but automatic horizon tracking has extracted all possible horizons from a seismic volume. The user can then create a horizon by assembling parts of the pre-extracted horizons. In addition, a distance volume to all horizons is created (se image below). The distance volume allows free hand drawing of horizons to be snapped into place in areas with good horizon candidates (Figure 4).

Conclusions

Interactive Reservoir Geomodeling from Uncertainty is a project that attempts to address some of the main issues of reservoir modeling in the appraisal stage. The presence of inaccuracies, low data coverage, and a high degree of uncertainty requires a new type of modelling tools, which are fast and sketch-like as opposed to the existing slow but accurate CAD inspired ones. We suggest using sketch based tools, where the user can guide the modeling process with his/her expertise intuitively and quickly. The two approaches proposed, sparse and dense can create "what if" scenarios and powerful tools for edit/create realistic 3D geological models.

Despite being an ongoing work, our first results show the potential of these projects to change the process of construction of reservoir models. There are some natural further steps for sparse and dense approaches. Both need more investigation about which sketch based operators are useful. Besides, the implementation should be more flexible and allow different kind of surfaces representations. The experts' feedback and evaluation are one of the main future work. The implementation of one system totally integrated, that allows start from scratch or combine sparse and dense data is our main goal.

Acknowledgements

This research is supported by the NSERC / Alberta Innovates Academy (AITF) / Foundation CMG Industrial Research Chair Program in Scalable Reservoir Visualization.

References Cited

Agar, S.M., S. Geiger, S.K. Matthai, A. Immenhauser, R. Always, S. Tomas, R. Shekhar, J. Paul, G. Benson, Z. Karcz, and L. Kabiri, 2010, The Impact of Hierarchical Fracture Networks on Flow Partitioning in Carbonate Reservoirs: Examples based on a Jurassic Carbonate Ramp Analog from the High Atlas, Morocco: OnePetro SPE #135135-MS, 19 p.

Cosentino, L., 2001, Integrated Reservoir Studies: Technip, Paris, 310 p.

Fanchi, J.R., 2002, Shared Earth Modeling: Methodologies for Integrated Reservoir Simulations: Elsevier, New York: Elsevier, 305 p.

Geiger, S., S. Matthäi, J. Niessner, and R. Helmig, 2009, Black-Oil Simulations for Three- Component, Three-Phase Flow in Fractured Porous Media: SPE Journal, v. 14/2, p. 338-354.

Gringarten, E., 2006, Ten Reasons why 3D Geo-Modeling and Flow Simulation Must Be Integrated: GEO ExPro, 3 p.

Iske, T., and T. Randen, 2006, Atlas of 3D Seismic Attributes, Mathematics in Industry, Mathematical Methods and Modelling in Hydrocarbon Exploration and Production: Springer, Berlin, 451 p.

Jones, R. R., K. J. W. McCaffrey, R. W. Wilson, and R. E. Holdsworth, 2004, Digital Field Data Acquisition: Towards Increased Quantification of Uncertainty during Geological Mapping, *in* A. Curtis, and R. Wood, eds., Geological prior information; informing science and engineering: Geological Society Special Publication, v. 239, p. 43-56.

Love, F., and N. Purday, 2008, 3D Visualization Technology, Reducing Cycle Time and Improving Performance, from Basin Scale Assessment through Prospect Identification to Optimal Drill Site Selection: Offshore Technology Conference #19596, 9 p.

Matthäi, S. K., S. Geiger, S. G. Roberts, A. Paluszny, M. Belayneh, A. Burri, A. Mezentsev, H. Lu, D. Coumou, T. Driesner, and C. A. Heinrich, 2007, Numerical Simulation of Multi-Phase Fluid Flow in Structurally Complex Reservoirs. Geological Society Special Publications, London, v. 292, p. 405-429.

Olsen, L., F. Samavati, M.C. Sousa, and J.A. Jorge, 2009, Sketch-Based Modeling: A Survey: Computers & Graphics, v. 33/1, p. 85-103.

Patel, D., Ø. Sture, H. Hauser, C. Giertsen, and M.E. Gröller, 2009, Knowledge-Assisted Visualization of Seismic Data: Computers & Graphics, v. 33/5, p. 585-596.

Patel, D., S. Bruckner, I. Viola, and M.E, Gröller, 2010, Seismic Volume Visualization for Horizon Extraction: IEEE Pacific Visualization , v. 3/2, p. 73-80.

Sech, R. P., M. D. Jackson, and G. J. Hampson, 2009, Three-dimensional Modeling of a Shoreface-Shelf Parasequence Reservoir Analog: Part 1. Surface-based Modeling to Capture High-Resolution Facies Architecture: AAPG Bulletin, v. 93/9, p. 1155-1181.

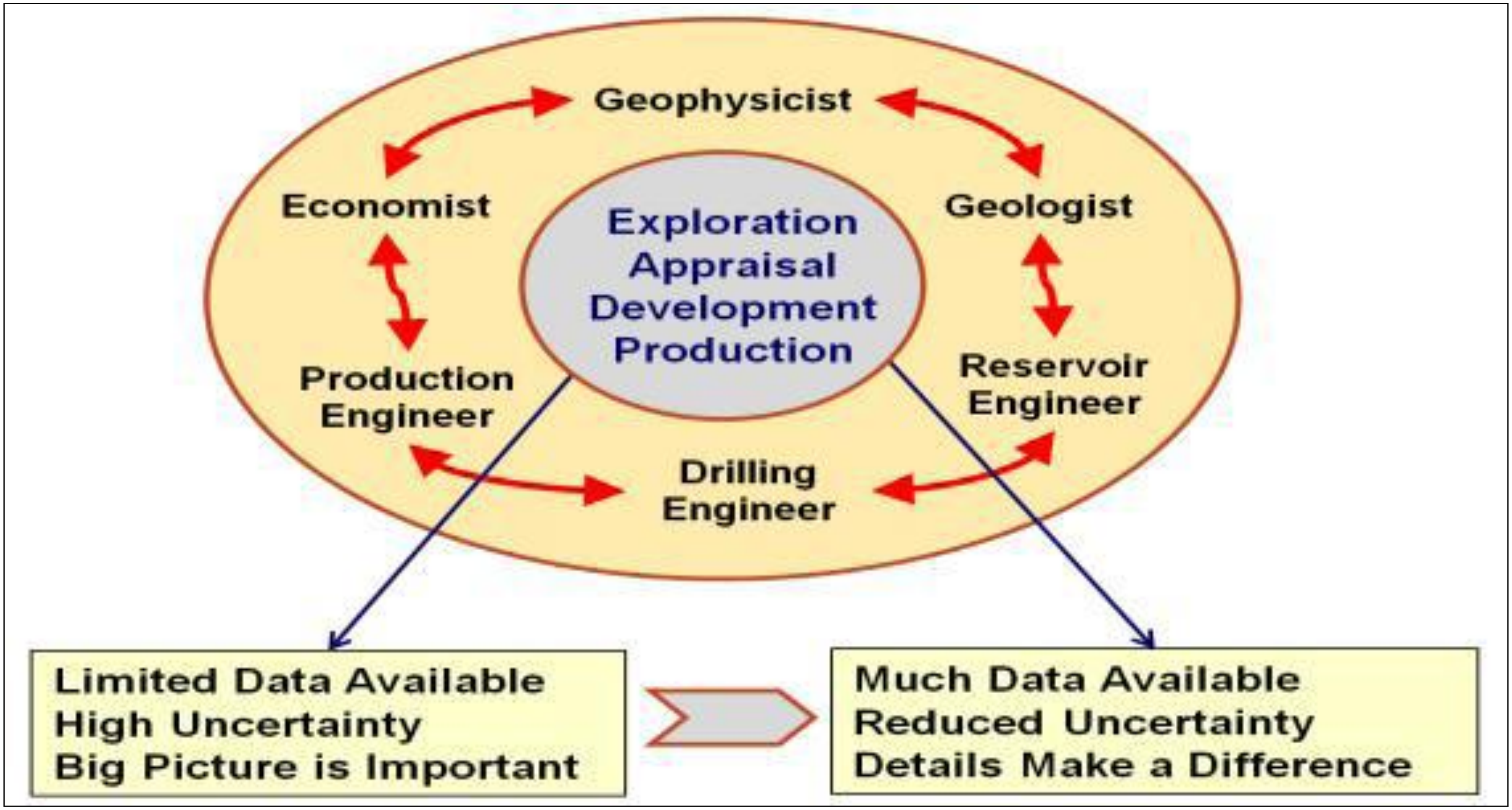

Figure 1. Field development cycle.

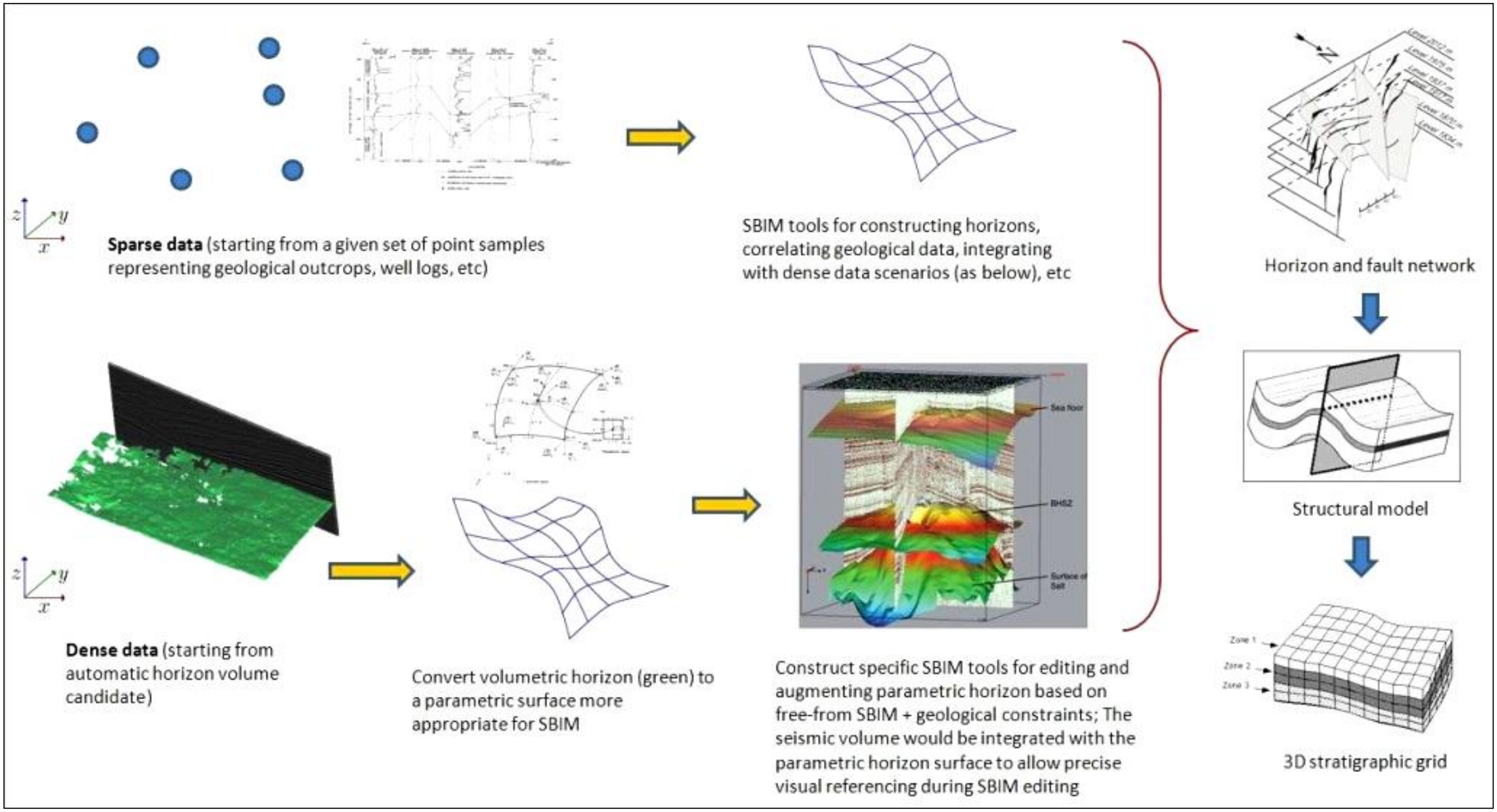

Figure 2. Workflow for two different types of input: sparse and dense data.

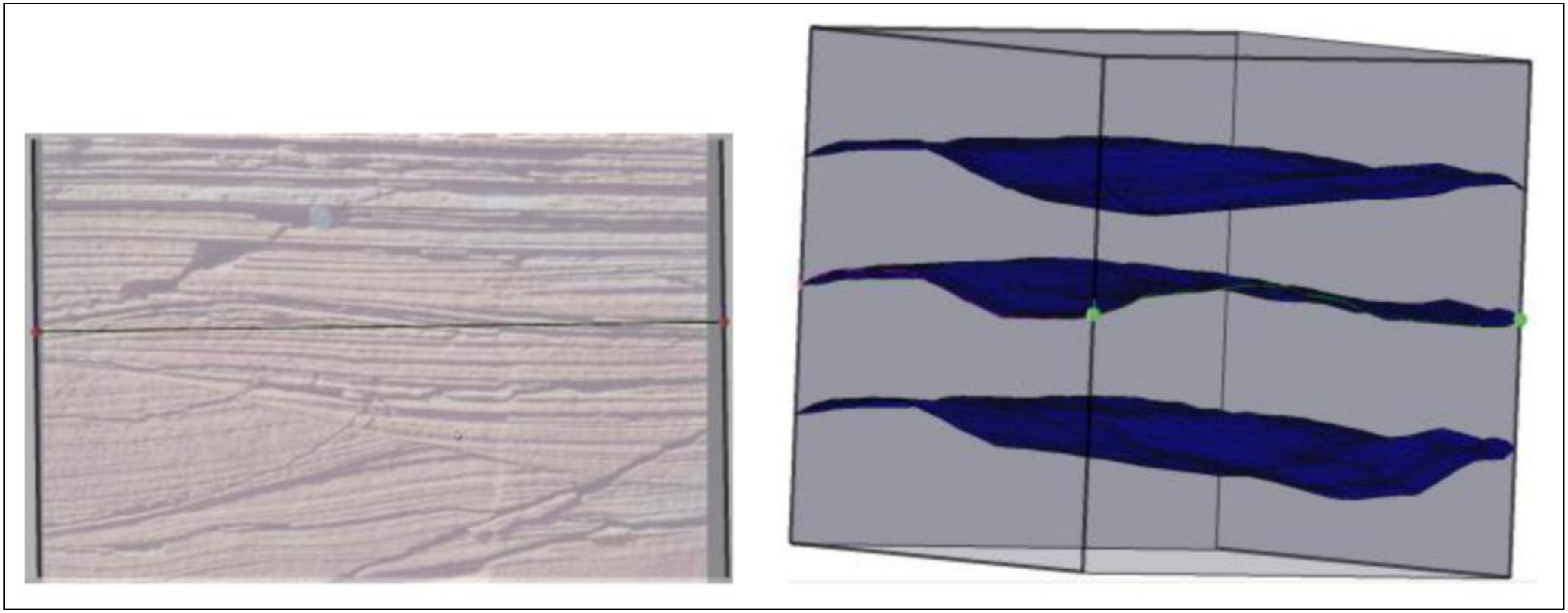

Figure 3. Creating reservoir modeling from sparse data.

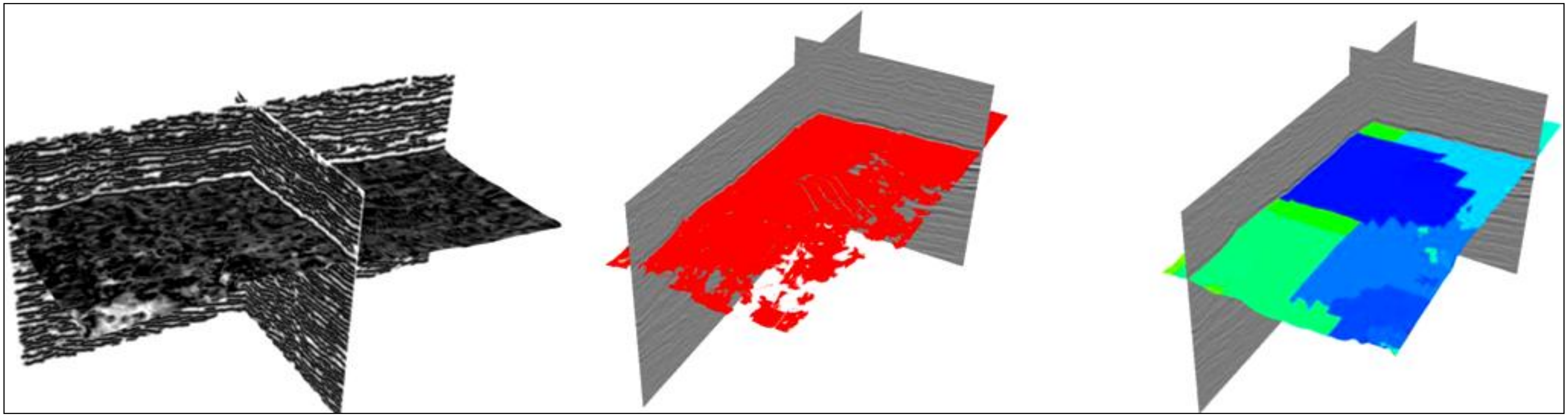

Figure 4. The distance volume to all horizons (left), pre-extracted horizon (center) and surfaces-part's ID (right).