EA Geocellular Model for Tertiary Reservoirs in Manhera Tibba Gas Field, Jaisalmer Basin, Rajasthan, India*

Rajesh Pandey[1], B.P. Nonia[1], S. Mahanti[1], U.C. Pradhan[1], and Abhayanand S Maurya[2]

Search and Discovery Article #20456 (2019)**
Posted March 18, 2019

*Adapted from extended abstract prepared in conjunction with poster presentation given at 2018 International Conference and Exhibition, Cape Town, South Africa, November 4-7, 2018
 DOI:10.1306/20456Pandey2019

[1]Oil and Natural Gas Corporation, Dehradun, Uttarakhand, India (pandey_rajesh@ongc.co.in)
[2]Indian Institute of Technology, Roorkee, Uttarakhand, India

Abstract

Manhera Tibba gas field is located in the Jaisalmer Mari High of the Jaisalmer Basin, Rajasthan. The field has been producing gas from Tertiary carbonate reservoirs since 1994. The main gas bearing reservoirs are the B2 limestone (Bandah Formation), B4 and C2-C4 limestones (Khuiala Formation), and D4 limestone (Sanu Formation). The field represents a NW-SE trending faulted anticlinal closure with two main culminations. The current study is attempting to carry out Geocellular Modelling of the Manhera Tibba Field to decipher the vertical and lateral heterogeneity and fine-tuning regional correlation of lithofacies within identified gas bearing reservoirs. The model has been prepared by integrating all G&G data viz. well, seismic, geological, petrophysical, and reservoir considering the presence of thin clay streaks within the limestone sections.

Stratigraphic Framework Model, Well Model, and Attribute Models are three basic constituents of the Geocellular Model. The model clearly demonstrates the variation in the reservoir properties and better locales for the exploitation of locked hydrocarbon reserves. Seismic horizons corresponding to the top of the Khuiala and Sanu formations as well as associated faults interpreted from 3D seismic have formed the basic input for the model. Additionally, Root Mean Square (RMS) velocity data is used to establish the spatial distribution of lithofacies and petrophysical properties. The reservoir level depth maps have been prepared using well picks as hard data and seismic as soft conformable surfaces using RMS (Reservoir Modelling System) software of M/s ROXER. The processed electric logs have been used for modelling that produces realistic descriptions of petrophysical parameters in the form of trend and distribution of porosity and gas saturation throughout the reservoir.

The Geocellular Model, thus prepared, stemmed in bringing out the static model of the field depicting vertical and lateral heterogeneity of carbonate pays as well as helps in estimation of in-place volume of gas in these reservoirs, which will be an important input to carry out reservoir simulation for further development of the field.

Introduction

The Geocellular Model represents a 3D reservoir model with stratigraphic envelop, reservoir sub-layers, and faults. It provides better visualization of the reservoir using modern workstations (Shepherd, 2009), and has three basic constituents: Stratigraphic Framework Model, Well Model, and Attribute Model (Jain et al., 2004). Such models are helpful to established spatial and temporal variation of reservoir heterogeneity (porosity, water saturation, and permeability). The vertical variation of the properties in the field is derived from drilled wells. To capture the horizontal variations, RMS attribute maps at a finer level were generated and used with geostatistics for population around the drilled well. This is the maiden attempt in the Jaisalmer Basin to understand the reservoir level complexity of the field.

Manhera Tibba Field

The Manhera Tibba Field is a part of the Rajasthan Shelf, located in the Jaisalmer Basin and covers an area of 24.00 Sq Km (Figure 1). It has two structural highs, located in the central part of the field, trending in a NW-SE direction. The field was discovered in 1967 and put on production in 1994. In this field, ONGC has established the hydrocarbon potential of the Jaisalmer Basin after extensive studies. The subsurface stratigraphy of the area has been revised based on the deepest drilled well in the study area (bottomed in the Lathi Formation). General stratigraphy has been established on the basis of lithological changes, core data, wire line log evaluation, and biostratigraphic studies in the basin (Mishra et al., 1993). The stratigraphic column has been subdivided into four geochronologic sections, with corresponding lithofacies and interpreted environment of deposition. The general stratigraphy of the basin is shown in Figure 2. Four main hiatuses have been identified in the sedimentation history of the Rajasthan Basin (Narayanan, 1964 and Willim, 1964): Late Cambrian to Early Carboniferous, within the Early Jurassic, Late Cretaceous to Early Palaeocene, and Early to Middle Eocene.

A total of 21 wells have been drilled in the field so far to establish commercial gas in Tertiary and Mesozoic reservoirs. Out of these, 10 wells are gas bearing. The main producing reservoir of the field is the C2-C4 limestone of the Khuiala Formation (Eocene). The other established and producing reservoirs are the B2 limestone of the Bandah Formation, B4 limestone of the Khuiala Formation, and D4 limestone of the Sanu Formation. All the reservoirs are hydrodynamically supported with GWC. The pays are separated from each other by clay/shales of varying thickness. Except the B4 pay, which comprises limestone and clay alterations, all other pays are clean, thick, fossiliferous limestones. The Mesozoic reservoirs have also been tested in the field and produced gas. The current paper deals with the reservoir characterization of Tertiary reservoirs which has cumulative gas production of 0.290 BCM (as on 01.04.2017).

Petrophysical Evaluation

The petrophysical evaluation for the Tertiary reservoirs has been carried out with the following phase and objectives in the Manhera Tibba Field:

- Log data of the entire field was processed and interpreted using in-house software ELAN PLUS with multi mineral model.

- To provide depth matched log data for geological correlation of reservoirs of the field.

- To provide reservoir parameters (water saturation, effective porosity, shale volume) of limestones for attribute analysis in fine scale geological model.

- Cut-offs on porosity, Vclay, and water saturation have been determined as 0.08, 0.35 ,and 0.75 respectively.

- To generate Paralog from the processed log data for reservoir evaluation and for future reference.

Reservoir Parameters

Well logs are the direct measurements of the physical parameters viz. resistivity, bulk density, interval transit time, spontaneous potential, natural radioactivity, and hydrogen content of the formation. A few of these parameters can be used as petrophysical parameters whereas others may be derived or inferred to translate into desired petrophysical parameters of porosity, hydrocarbon saturation, producibility, lithology etc. These measured parameters are integrated responses of all the constituent minerals, fluids, and environments within the bore hole and in its neighborhood. The multibean processing was designed for quantitative formation evaluation of logs level-by-level by optimizing simultaneous equations described by one or more interpretation models which are known as inverse modelling technique. Reservoir parameters, water saturation (SUWI), flushed zone water saturation (SXWI), effective porosity (PIGN), volume of shale (Vcl) etc. have been computed at each depth point. These data have been used for making the geological model.

Geocellular Model Methodology

Prominent seismic reflectors of the Tertiary Formations i.e. Khuiala Top and Parh Top were tied up with 3D seismic data using synthetic seismogram and mapped throughout the Manhera Tibba Field. Top of Khuiala is one of the best correlatable markers. It is continuous, throughout the field. Pay limestone has lower amplitude and dilation event fading away from the structural highs (Figure 3). Time-Structure maps prepared at the Khuiala Top and Sanu Top clearly bring out the structural framework of the area. The area is represented by two sets of faults trending NW-SE and NNE-SSW. NW-SE faults are younger crossing N-S faults. Two major structural culminations are seen (Figure 4). Different limestone and clay layers were not mapped separately in the seismic volume. An isopach map between the Khuiala Top and Sanu Top was prepared considering well picks to prepare reservoir level maps (Figure 5). Geocellular Modelling of the defined area has been carried out in the following stages listed below:

Fault Modelling: Fault modelling is the process of generating fault surfaces so that a faulted 3D grid can be created. Subsequently, horizons, zones, and layers can be inserted. Grid Increment is the spacing between grid nodes. The Smoothing Factor is a percentage, higher the values smoother the surface. Too much smoothing can cause the deviation from actual fault stick orientation hence proper smoothing factor was applied and a consistent Fault Model was generated. The fault model thus generated is shown in the Figure 6.

Horizon Model: Horizon modelling is the process of creating surfaces from input data within a structural framework. Before the horizon modelling process stratigraphic framework of the field was defined. A Reference Horizon Model was built using two seismic interpreted surfaces (Khuiala and Sanu) and well picks as input data (Figure 7). Based on the Reference Horizon Model, isopachs were constrained to fit between reference surfaces and well picks. Reservoirs between the Khuiala and Sanu were taken conformable to both the surfaces. Reservoirs above the Khuiala have only bottom conformable and reservoirs below the Sanu have only top conformable. The Reference Horizon Model was fixed, and the rest of the horizons were generated using well picks as hard data considering continuous deposition without any major erosion/non-deposition (Figure 8).

3D Gridding: In order to prepare the Geological Model, the zones in the Structural Model must be divided into cells. Creating the grid is the process of creating these cells. When the grid is constructed to represent faults, many cells may be far from orthogonal. In addition, neighboring cells may differ considerably in volume. If the grid will be used for a purpose where it is important to avoid these effects, the grid construction offers an option for creating a Regularized Grid. A Regularized Grid was created using the Final Horizon Structural Model (Figure 9).

During gridding, faults may be treated as pillar faults or may be stair-stepped. RMS uses a best-fit algorithm to define the slope of the grid pillar representing a fault. The Pillar Adjustment slider can be used to control the slope of the fault pillars. Values range between 0 and 100%, where 100% tells RMS to use the best-fit algorithm. A value of zero will represent the fault as vertical in the grid. Values between zero and 100% will lead to more or less verticalization of the fault pillar.

For reservoir zones, numbers of cells/layers were decided on the basis of thickness of reservoirs and for non-reservoir zones only one layer was created. The increment X and Y was kept as 50 *50.

Blocking of Wells: Facies Upscaling: The well data has to be upscaled to the resolution of the 3D grid. The cells intersected by the well tracks are identified, and each cell was given an average value for each selected log property. Both Continuous (PIGN, SWE) and Discrete logs (Facies) were upscaled. For continuous logs Arithmetic Average algorithm was used. Quality Analysis/Quality Control of Upscaled logs were performed by comparing histograms of input raw logs and output upscaled logs (Figure 10).

Property Modelling: Property modelling includes facies modelling, porosity modelling, and saturation modelling. The Facies Indicators Model was used to generate a discrete 3D facies parameter. Each cell in the parameter was assigned a facies code defining the facies type (such as limestone or shale) present in that cell, based on probabilities calculated from well data and user-defined input. It is a stochastic pixel-based facies modelling technique, based on probabilities calculated from well data and user-defined input. The calculation method depends on our input selections; we can select well data only without trend or well data with trend using vertical proportion curve or Well data and Seismic as trend. Most of the combinations of these trends were tested for stochastic facies modelling and the results were checked. Finally using Vertical Proportion curve with Well data as primary trend and Seismic (RMS attribute map) as secondary spatial trend were used and facies were populated using Indicator Variograms.

Porosity was modelled for each zone and facies dependency for each facies association was provided. To model a petrophysical parameter, trend and residual components of the blocked well log data are separated, it includes:

- Estimation of the geological trends and variability, which represents the geological variability of the petrophysical variable. This is normally achieved through analysis of well logs to find spatial/geological trends in the data and using general geological knowledge. It approximates to a normal (bell curve or Gaussian) distribution, with a mean of zero.

- This estimation is used to specify the statistical operations that transform the input well data, separating the known variability from the residual distribution. Transformation sequence of Mean, Truncate, Depositional Trend, and Normal Score was provided (Figure 11).

- Variogram model: In Variogram Estimation settings necessary parameters like Azimuth, Max Lag, Lag Length, Max Width, and Width Angle were provided for each facies. Using these variogram estimation settings, Variogram Modelling was done. Variogram ranges of Parallel to azimuth, Normal to azimuth, and vertical were set to be used in Porosity Modelling (Figure 12).

- Most popular method of predicting the initial water saturation is the saturation-height method. This method helps to predict the saturation anywhere in the reservoir for a given height above the free water level and for a given reservoir porosity and permeability. Log derived water saturation values were plotted against height above free water level for each zone. No visible trend was observed. Hence SUWI was populated using Sequential Gaussian Simulation method.

- Trends and transformations were applied to the SUWI values in well logs. A Transformation sequence of Mean, Truncate, Cloud Transform, and Normal Score was provided (Figure 13).

- Cloud Transform: The Cloud transformation is a way of relating a petrophysical parameter (P) to either seismic or another petrophysical parameter with the assumption of an underlying bivariate distribution for P. Here cloud transform reproduces the conditional distributions of SUWI with height above free water level. This allows specifying a model that reproduces the scatterplot from the (blocked) wells in a 3D volume. This estimated distribution will then be the basis for the cloud transform.

- Variogram model: In Variogram Estimation settings necessary parameters like Azimuth, Max Lag, Lag Length, Max Width, and Width Angle were provided for each facies. Using these variogram estimation settings, Variogram Modelling was done. Variogram ranges of Parallel to azimuth, Normal to azimuth, and vertical were set to be used in Saturation Modelling. The final output is shown in (Figure 14).

Conclusions

- The Geocellular Model has clearly brought out the vertical as well as lateral heterogeneity of the Tertiary reservoirs.

- The model will also be helpful to identify prospective areas to enhance the production based on new development wells.

- The static model prepared during the study will be useful for calculation of in-place reserve volume of the field as well as dynamic simulation of the gas field using the production performance of the existing wells.

Acknowledgements

Authors are grateful to the management of ONGC for giving permission to publish this work. Authors also acknowledge Shri N K Punjrath, GGM-Basin Manager, Frontier Basin, ONGC, Dehradun, for providing an opportunity and all necessary facilities to prepare this paper. Authors wish to acknowledge the support given by all colleagues in the group. The views expressed in the paper are of the authors not the organization, they belong.

References Cited

Jain, V.K., P.K. Cherukupalli, R.N.S.G. Rao, A.S. Bohra, and P.K. Tewari, 2004, Reservoir Characterization - Geocellular Model for Mandapeta Sand of Mandapeta Field, KG Basin –A Holistic Approach: 5th Conference and Exposition on Petroleum Geophysics, Hyderabad, India, p. 704-709.

Misra, P.C., and N.P. Singh, 1993, Litho-stratigraphy of Indian Petroliferous Basin, Western Rajasthan Basins: KDM Institute of Petroleum Exploration, Oil, and Natural Gas Commission, Dehradun (Unpublished).

Narayanan, K., 1964, Stratigraphy of the Rajasthan Shelf: Proceedings of the Symposium on Problems of the Indian Arid Zones, Jodhpur, Government of India publication, New Delhi, p. 92-100.

Shepherd, M., 2009, 3-D Geocellular Modeling, *in* M. Shepherd (ed.), Oil Field Production Geology: American Association of Petroleum Geologists Memoir 91, p. 175-188.

Willim, C., 1964, A Contribution to the Geology of Jaisalmer and Oil Possibility: ONGC-IFP Report (Unpublished).

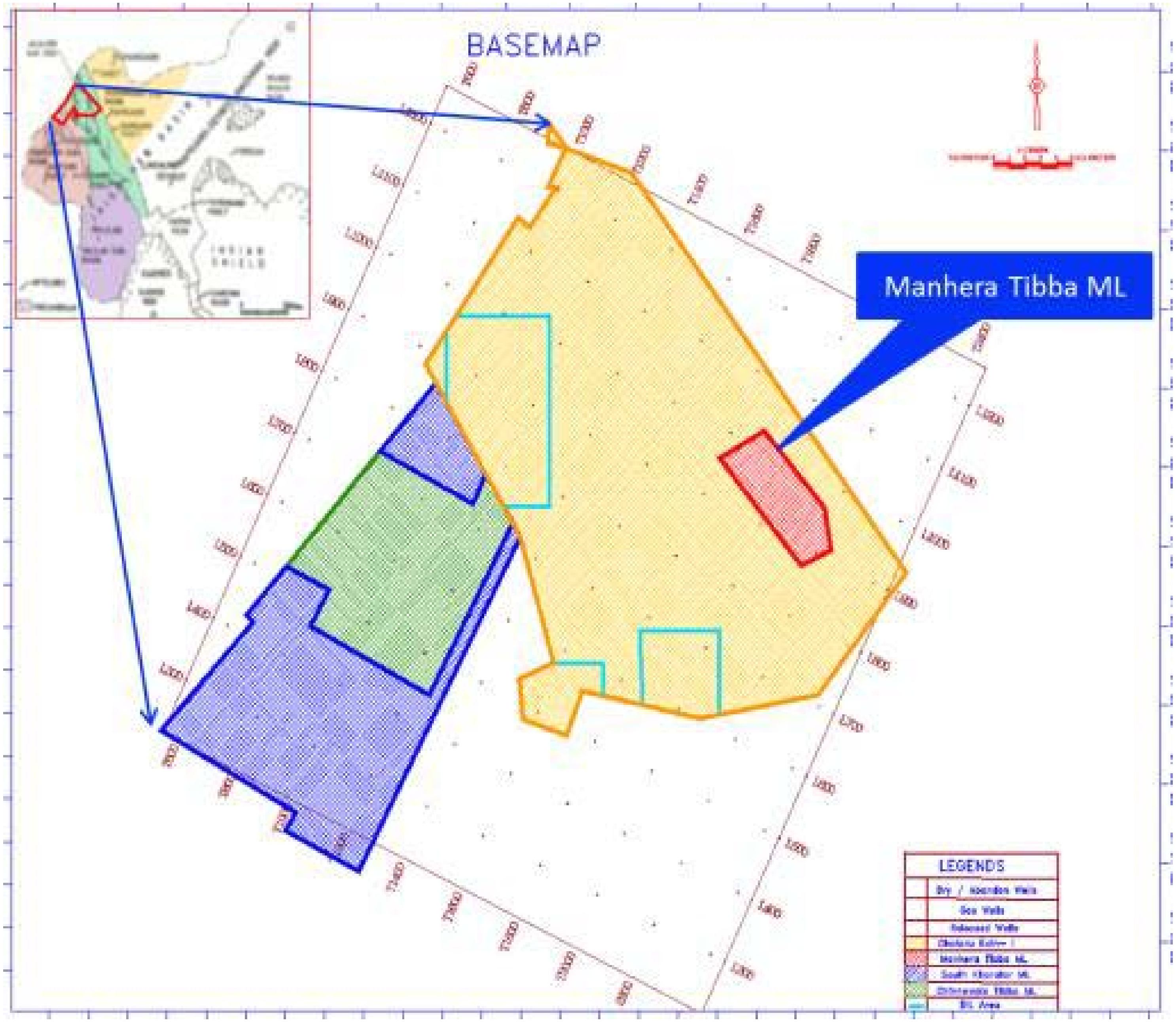

Figure 1. Location Map of Manhera Tibba Field along with ONGC ML acreages.

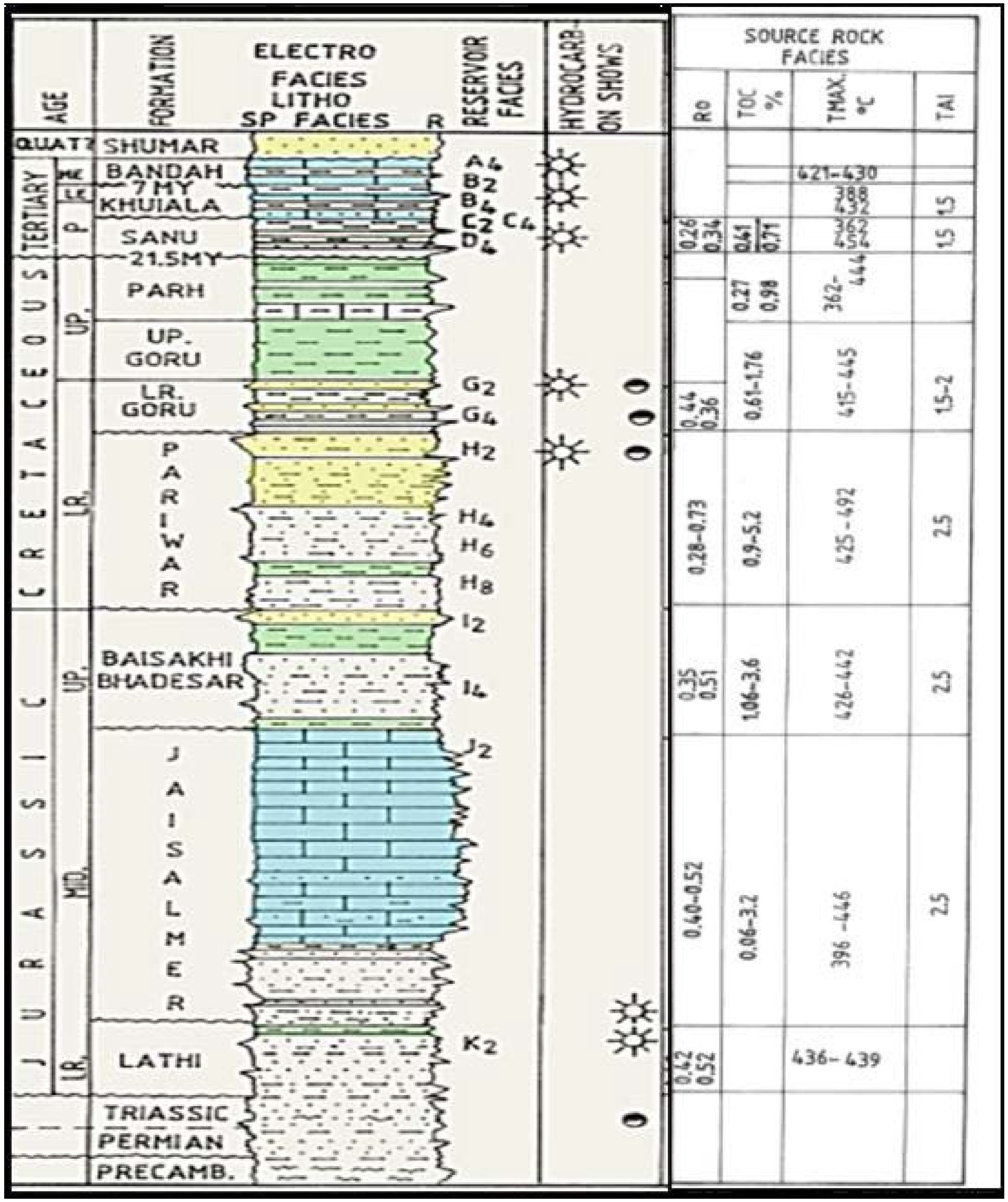

Figure 2. Generalized Lithostratigraphy of Jaisalmer Basin.

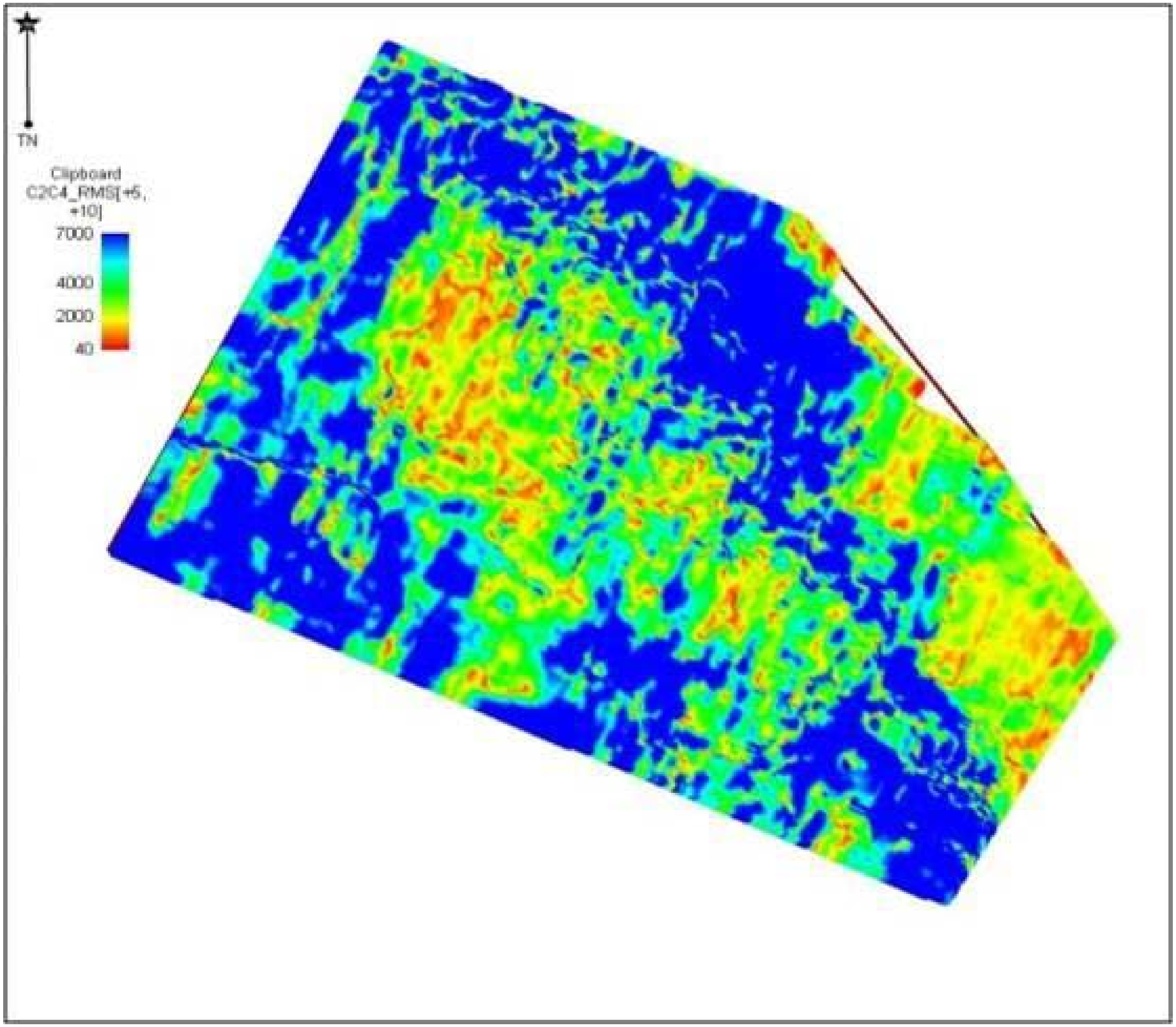

Figure 3. RMS amplitude map on top of C2-C4 reservoir, Khuiala Formation.

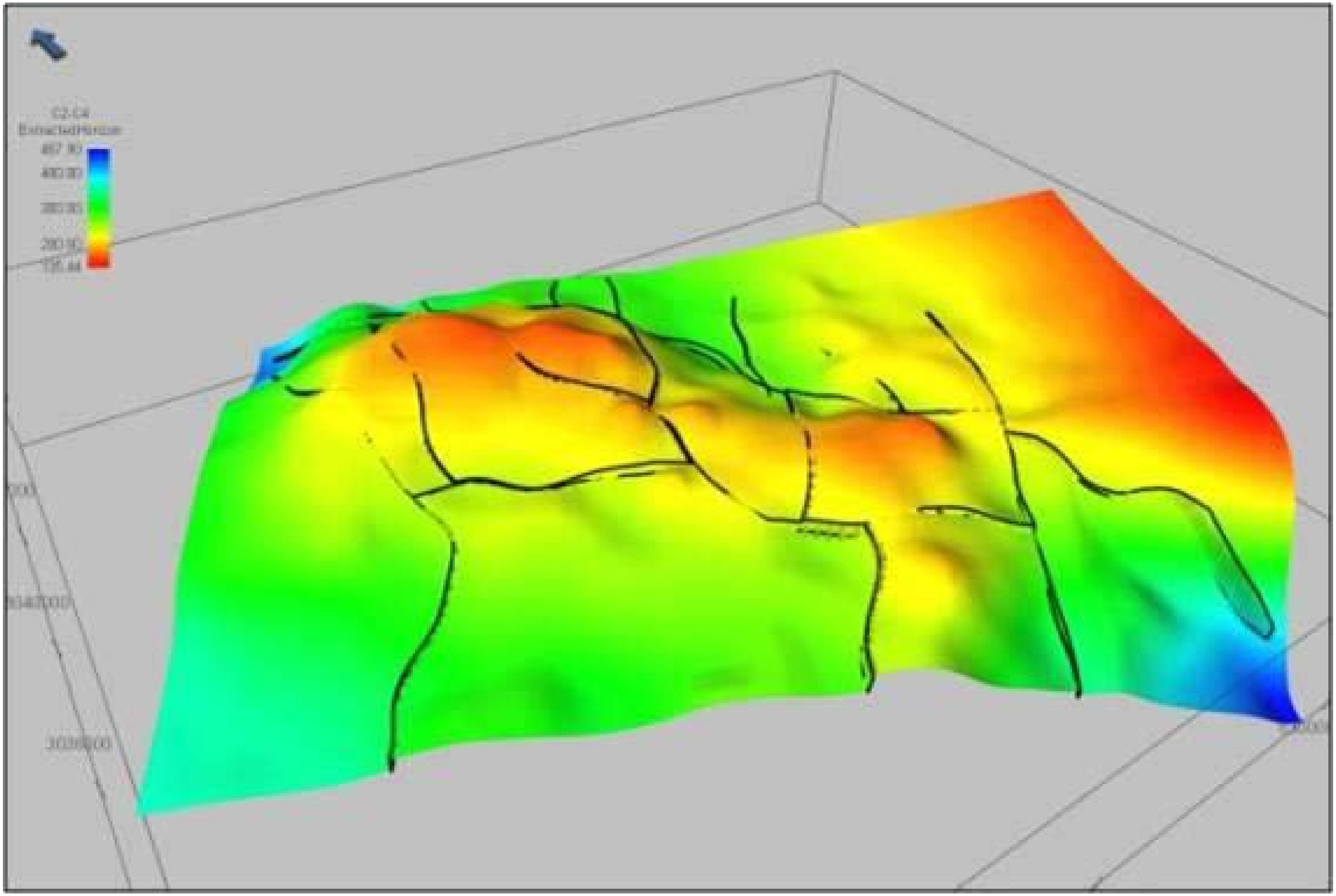

Figure 4. Study area representing structural culminations and fault trends NW-SE and NNE-SSW.

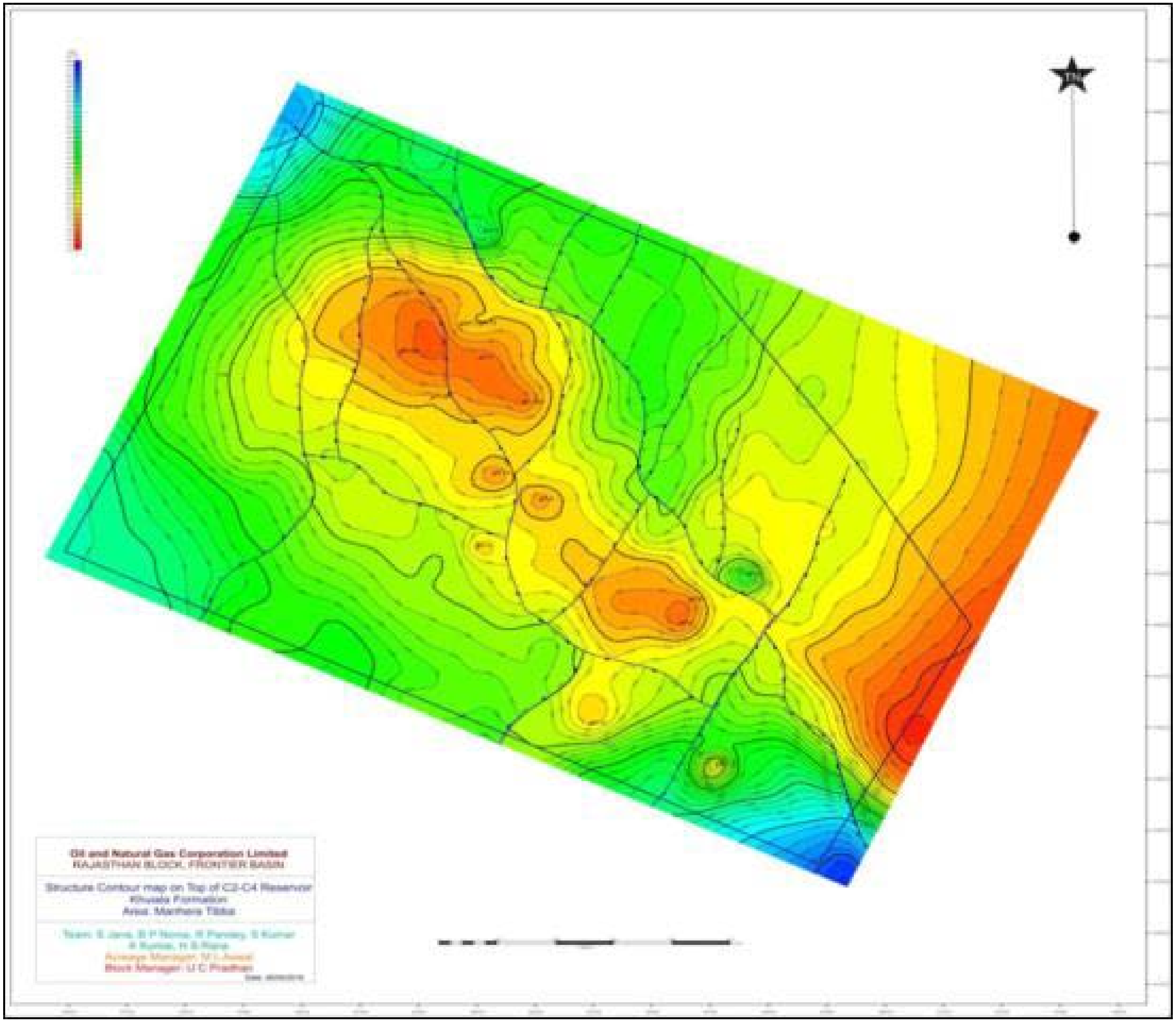

Figure 5. Structure contour map prepared on top of C2-C4 reservoir of Khuiala Formation.

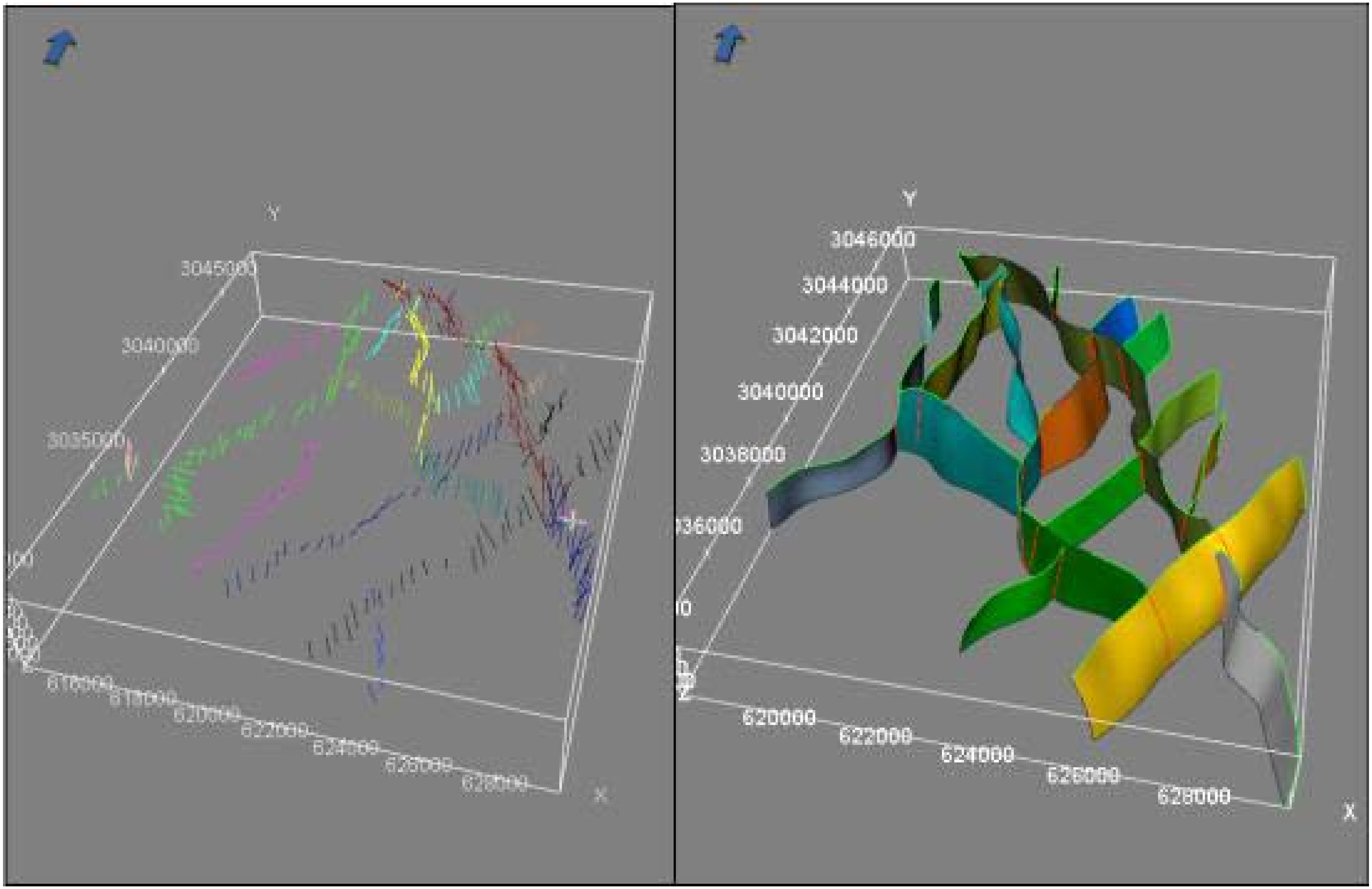

Figure 6. Fault sticks and Fault Modelling in RMS showing Fault Plane.

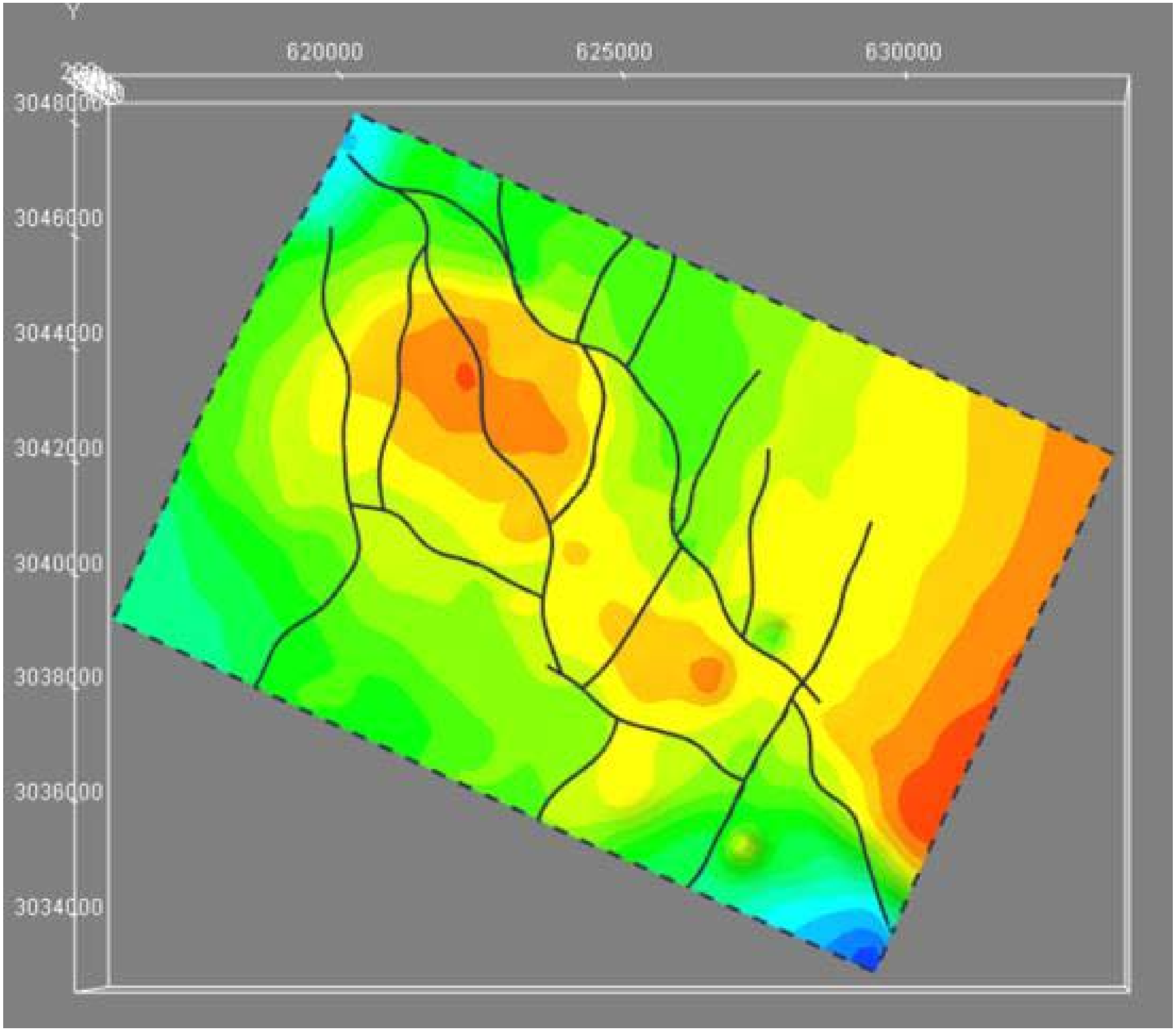

Figure 7. Reference Horizon Model of Khuiala constructed using depth horizon and well picks.

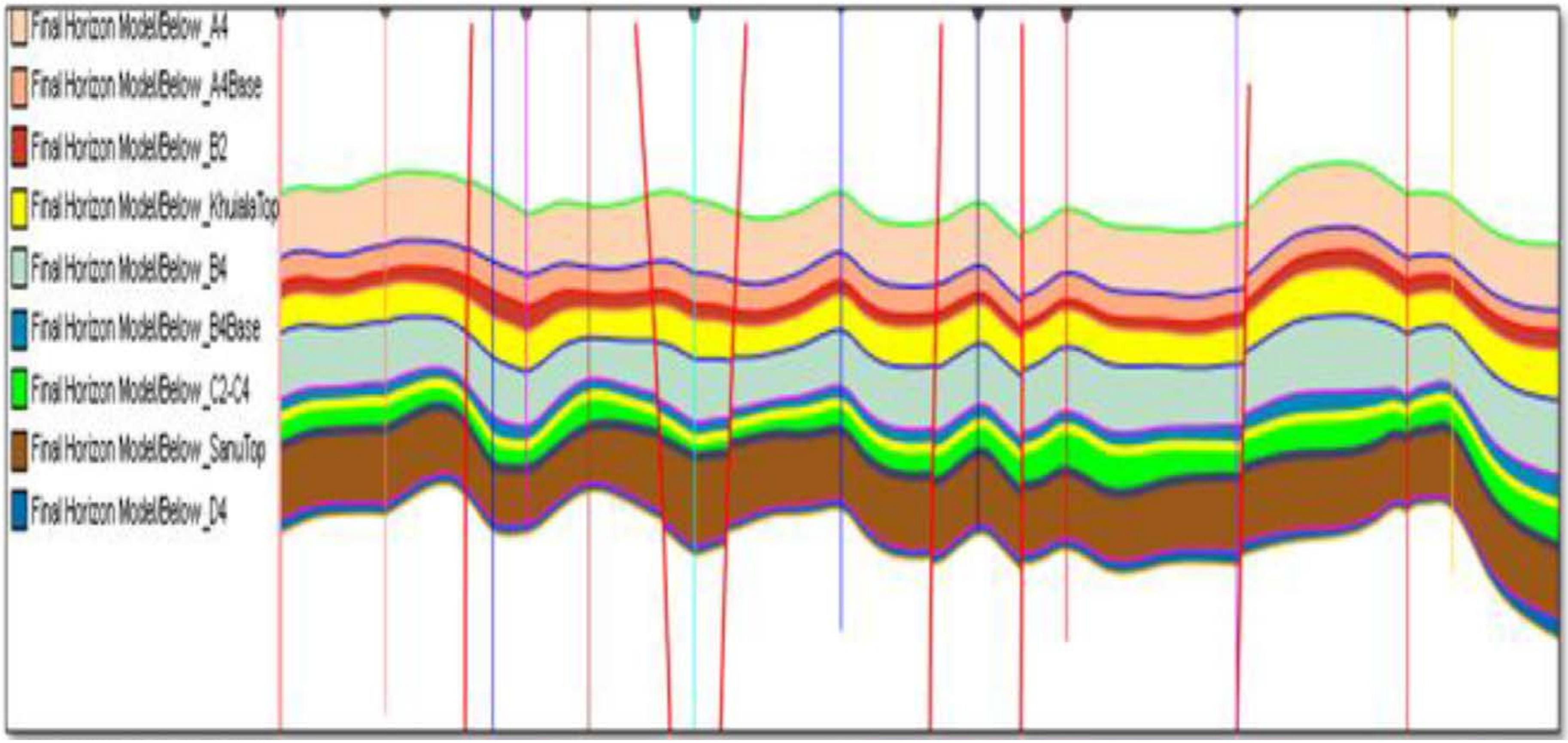

Figure 8. Geological cross section passing through different wells representing different modeled horizons.

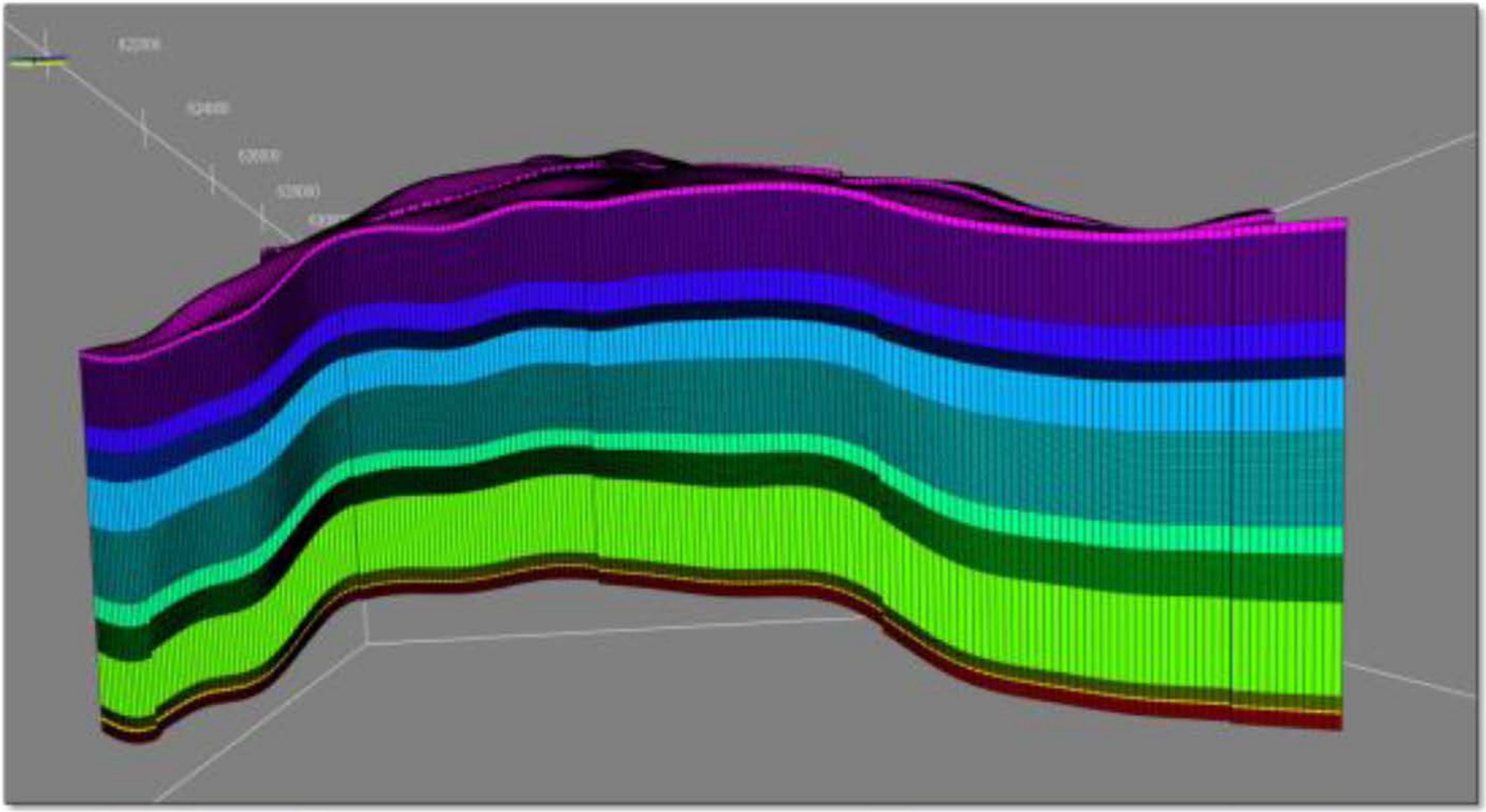

Figure 9. 3D View of Zones showing fine layers within each zone.

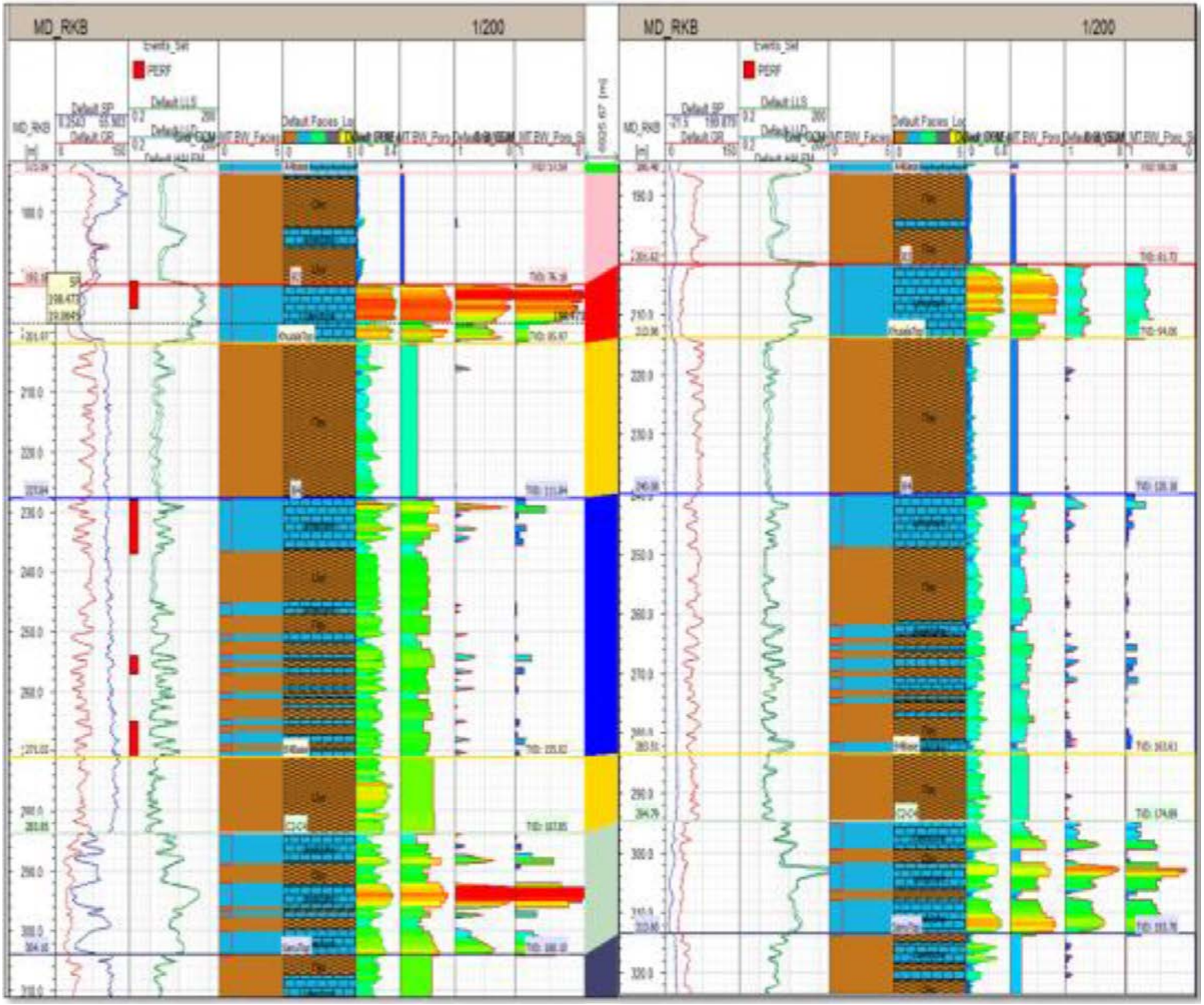

Figure 10. Up Scaled logs and their match in Layers.

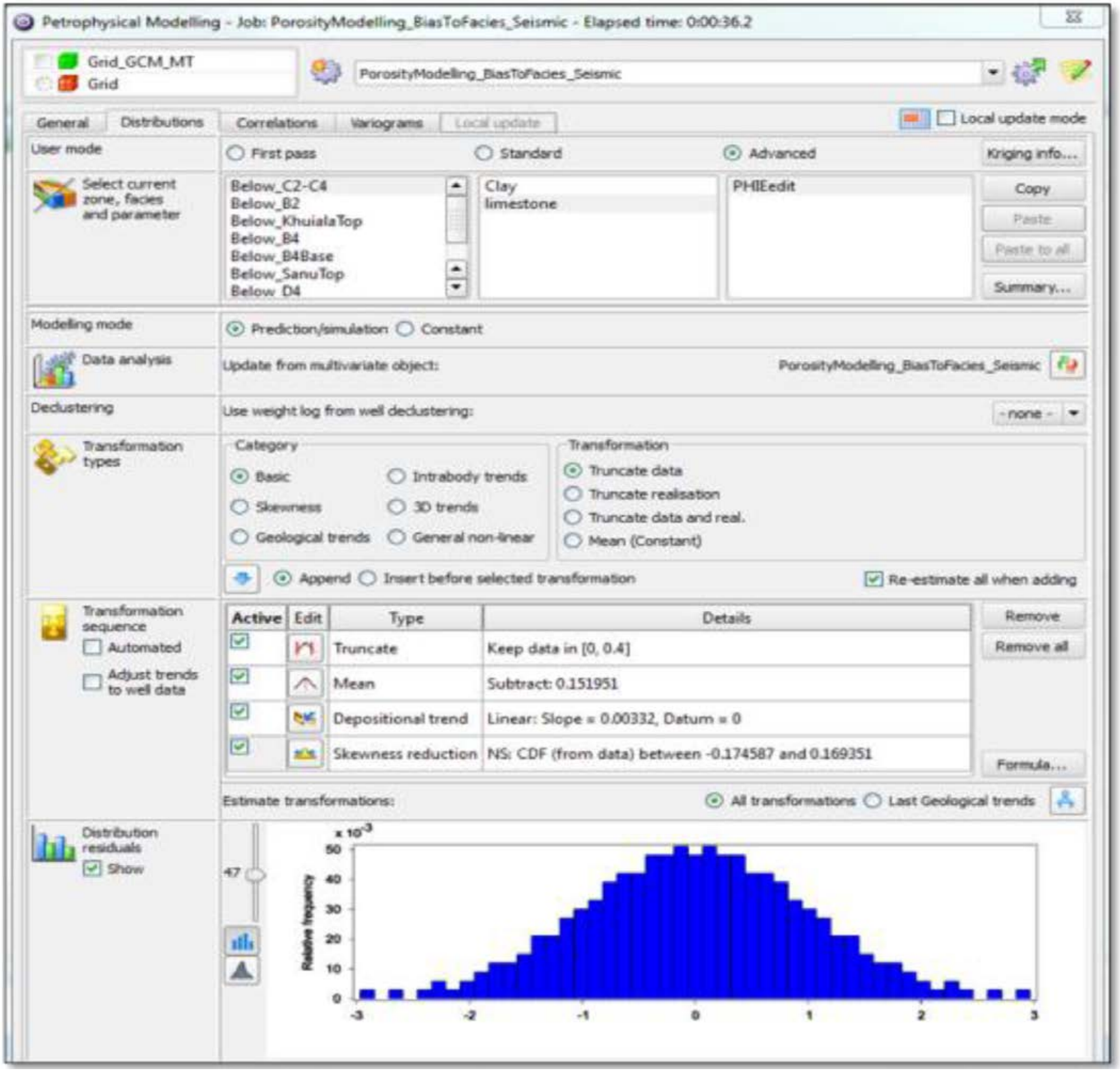

Figure 11. Showing the transformation sequence of Mean, Truncate, Depositional Trend, and Normal Score.

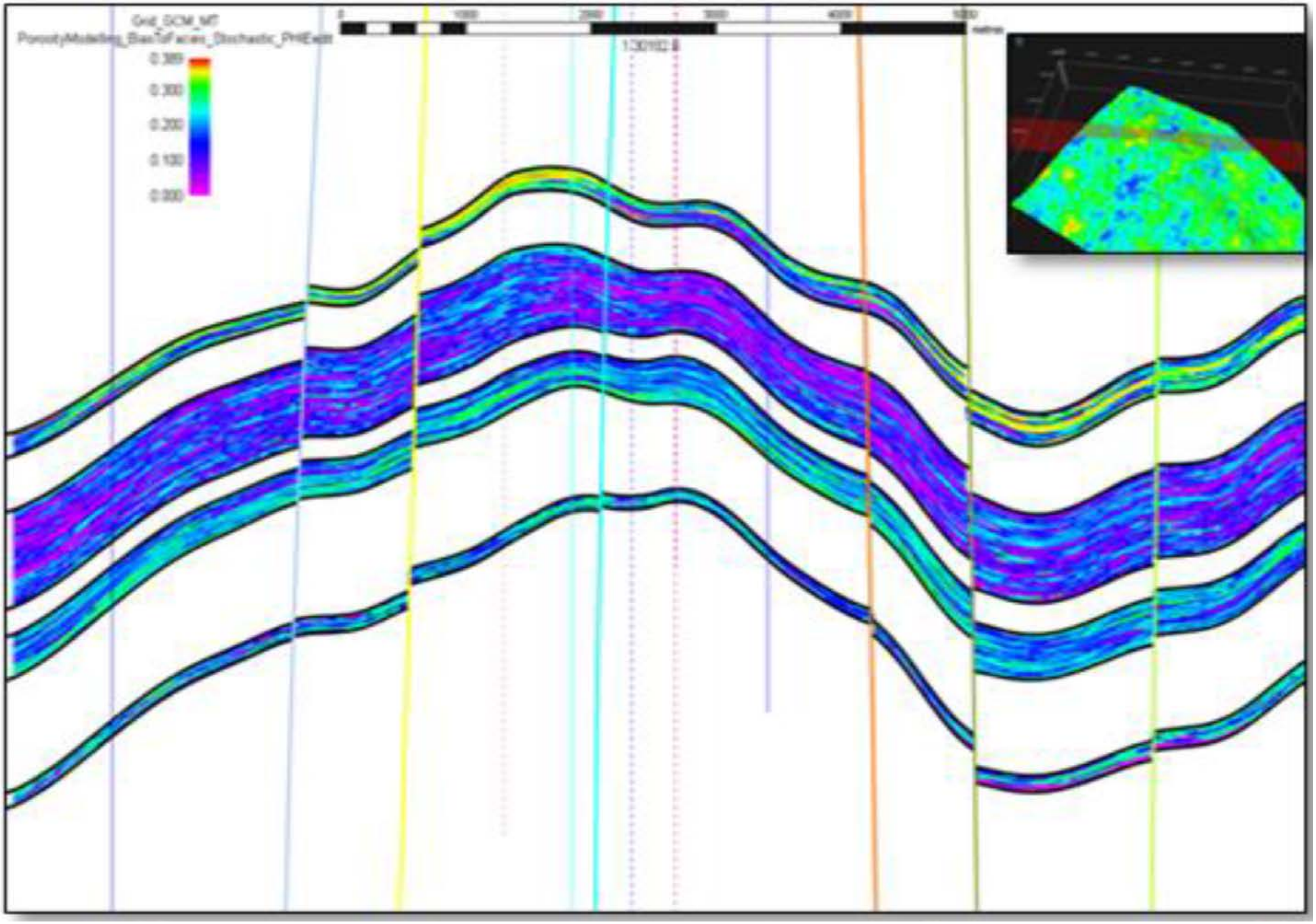

Figure 12. East West Dip-Section showing Porosity distribution in the model.

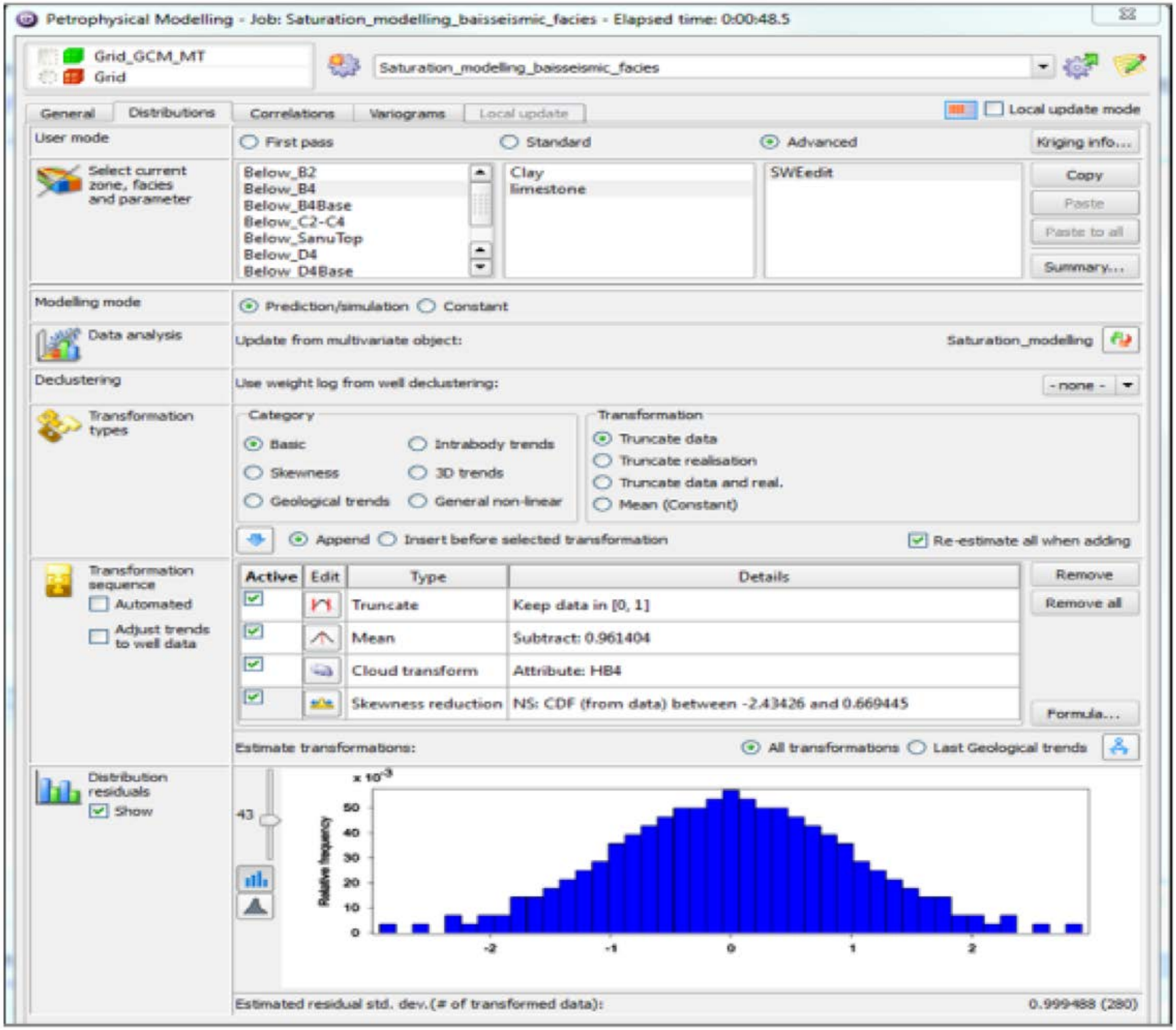

Figure 13. Showing the Trend and Transformation for water saturation modelling.

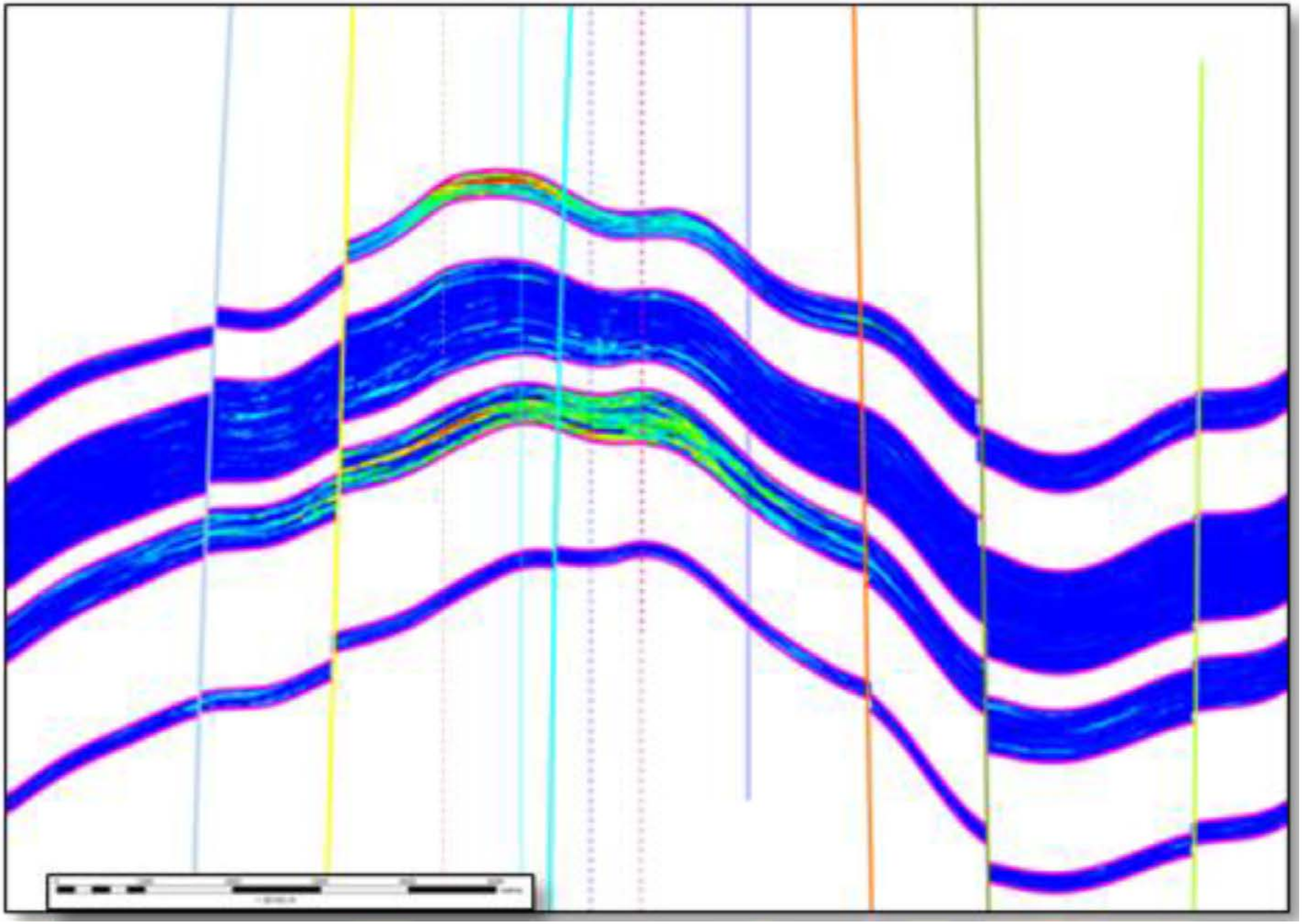

Figure 14. Saturation distribution in the reservoir layer derived from modelling.