How to maximize the value of mature HC fields?

Object Base Modelling in a Turbidite Type Reservoir

Case Study: Pusztaföldvár UGS, Hungary

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Contents

Pusztaföldvár UGS: Overview

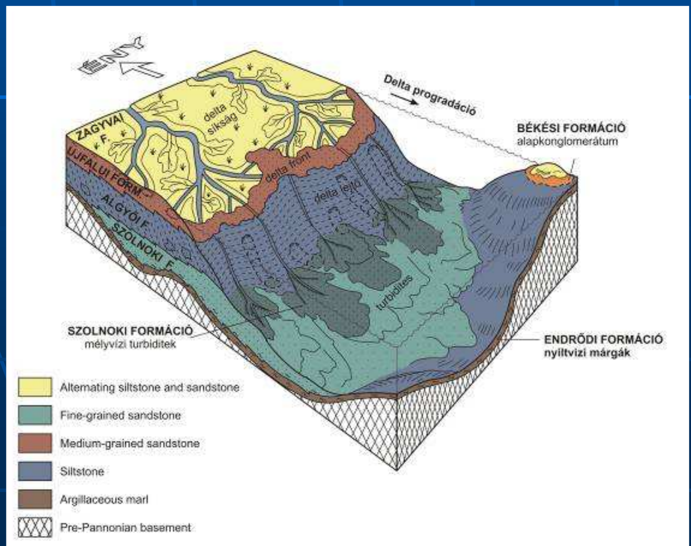
- Location: 58 km NE from Szeged, 30 km SW from Békéscsaba and 13 km SE from Orosháza
- Geology: 3 gas reservoirs (Földvár Felső A-1, Földvár Felső A-2, Földvár Felső A-3) located in a deep water turbidite system as part of the Szolnok Formation (Pannonian s.l.)
- Year of discovery: 1958
- Start of production: 1963

- Number of wells penetrating the above mentioned gas reservoirs : 161
- Producers: 22
- Gas Initial in Place (GIIP): 5.66 Bm^3 of which 83.5% have been produced (2009)
- 2008 onward, Underground Gas Storage planning in cooperation with Gazprom

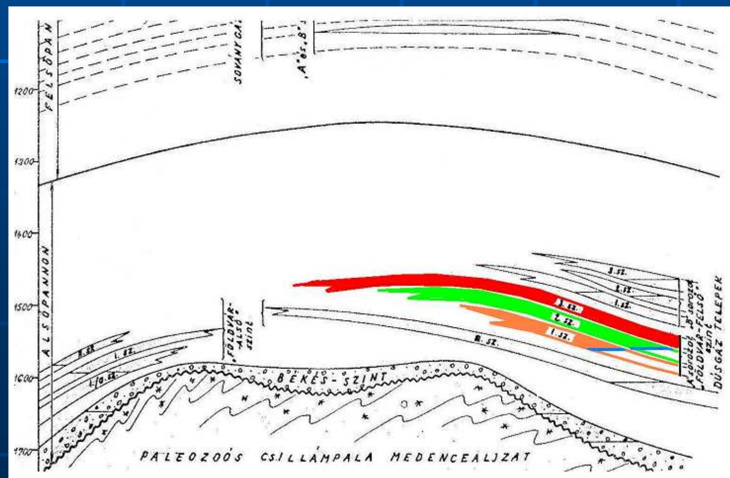
Pusztaföldvár UGS: Stratigraphy

Era	Period	Epoch	Lithology	Lithostratigraphy	Abbr.	Dep. Environment
Cenozoic	Neogene	Pliocene	Sand, Clay	Zagyva Formation	$^{z}Pa_2$	Alluvial Plane
			Sandstone, Shale	Újfalu Sandstone Formation	$^{ú}Pa_2$	Fluvial Delta Plain
			Sandstone, Shale	Algyő Formation	$^{a}Pa_{1-2}$	Delta Front, Delta Slope
		Miocene	Marl, Marly Sandstone, Sandstone	Szolnok Formation	$^{sz}Pa_{1-2}$	Deep Water Turbidite System
			Marl, Calcareous Marl	Endrőd Formation	$^{e}Ms\text{-}Pa_2$	Deep Water
			Sandstone, Conglomerate	Békés Formation	$^{b}Pa_{1-2}$	Foreshore, Shoreface
			Hiatus			
Mesozoic	Jurassic	Upper	Limestone, Calcareous Marl, Marl, Sandstone	Pusztaszőlős Formation	$^{P}J_3\text{-}K_1$	Shoreface, Deep Water
			Hiatus			
		Lower	Crinoidal Limestone	Menyháza Formation ?	J_1	Shallow Water
			Hiatus			
	Triassic	Upper Middle	Dolomite, Marl	Csanádapáca Formation	$^{C}T_{2-3}$	Deep Water
			Hiatus			
Paleozoic			Rhyolite, Gneiss, Micashist, Phyllite	Battonya Complex	$_{B}Pz$	-

Local Stratigraphic Chart



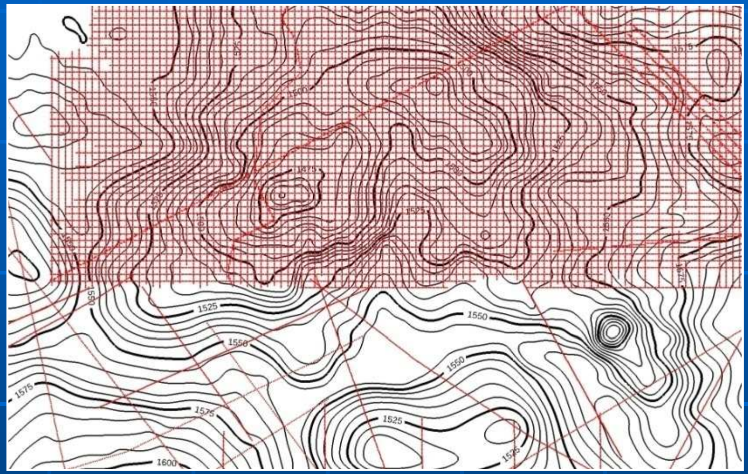
Local Stratigraphy Model



Old Conceptual Model

Available Input Data for 3D Modelling

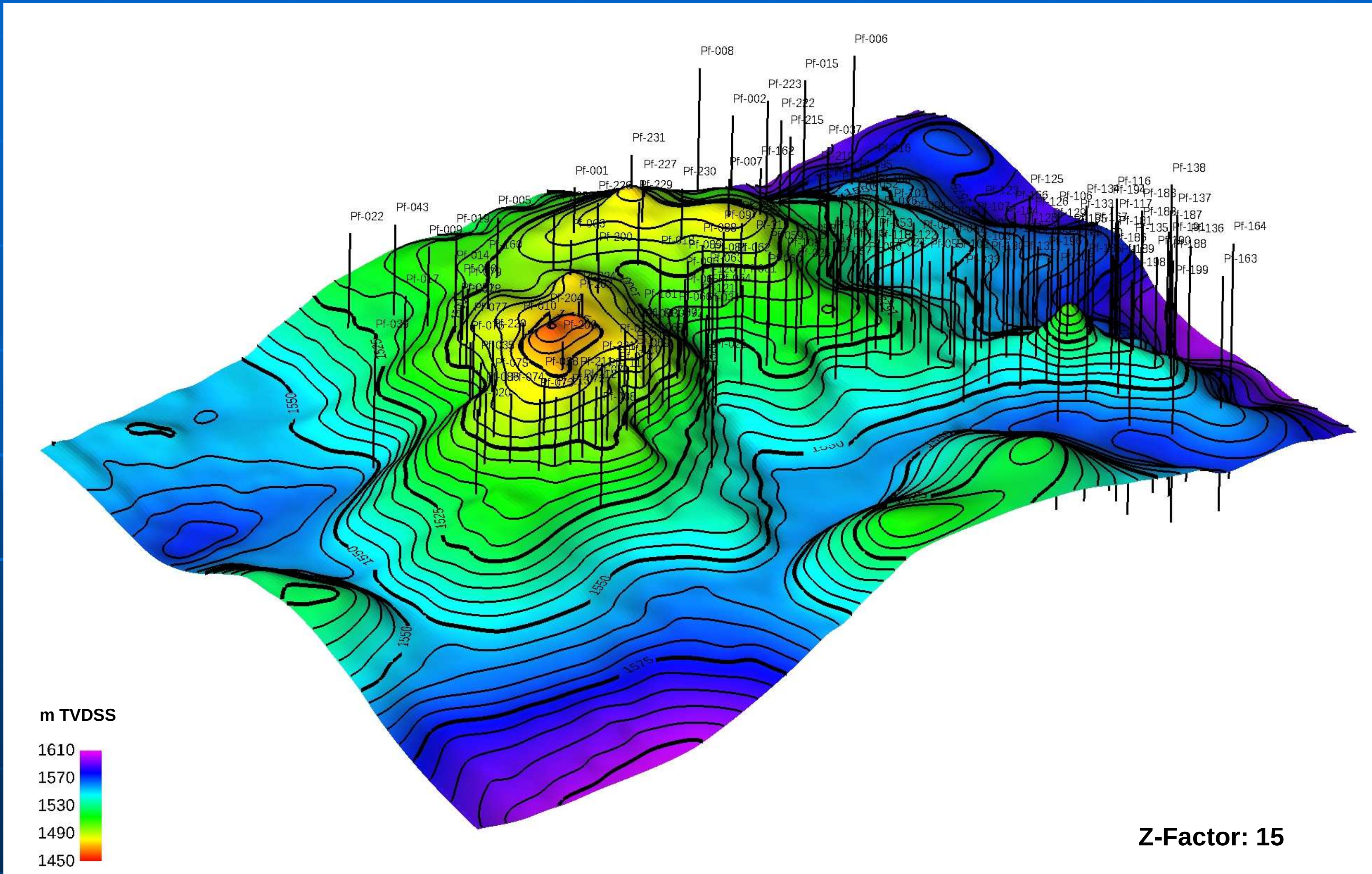
- Low quality 3D seismic (migrating gas from lower reservoirs) covering ¾ of the target area
- 2D seismic lines covering the leftover
- Top map of Földvár Felső A-3 based on geophysical interpretation (different reservoir levels below could not been seen on seismic)
- 160 vertical wells with wireline logs (GR, RT, SP)



Földvár Felső A-3 Top Map with Seismic Lines

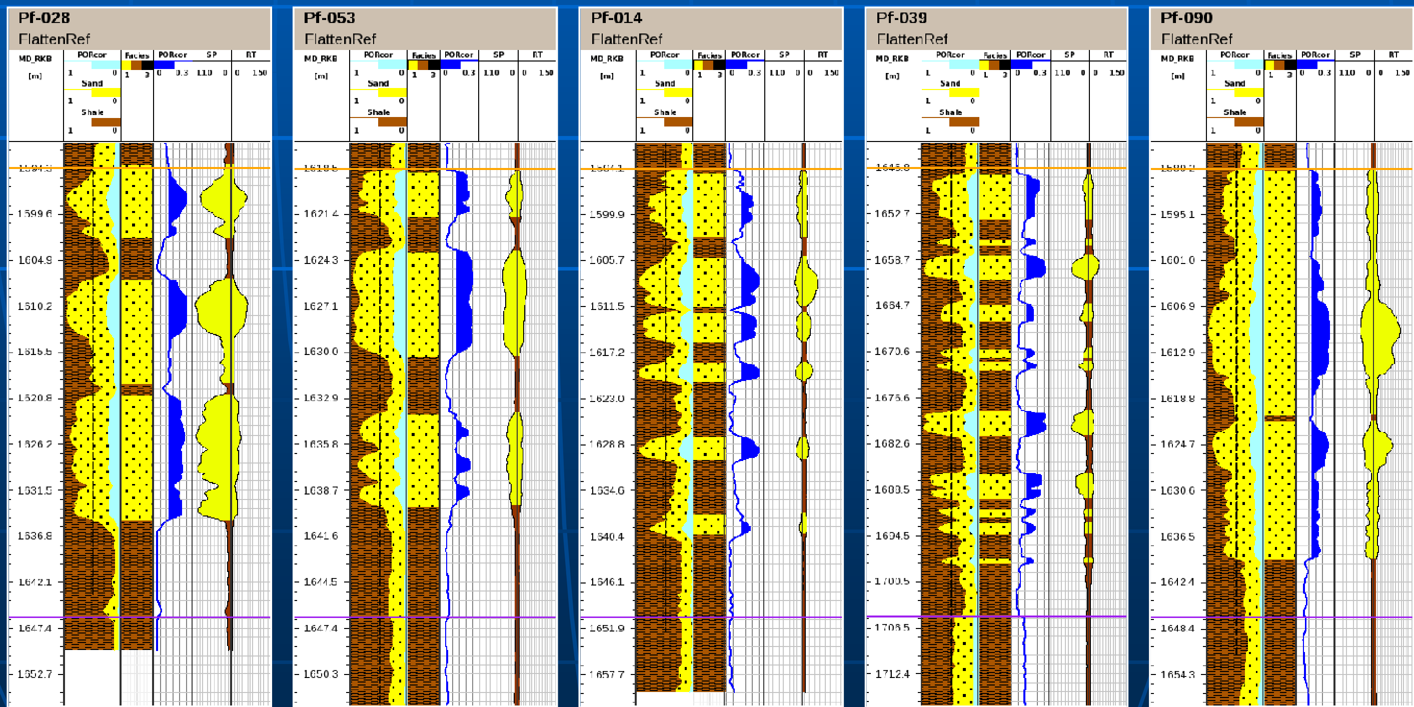
- Petrophysical quantitative interpretation (Por, Sw, Perm and clay volume) for reservoir sections in each well
- Core measurements of porosity and permeability of 27 wells (122 measurements)
- Capillary pressure curves of 2 wells (8 measurements)

Available Input Data for 3D Modelling: Top Map Földvár Felső A-3



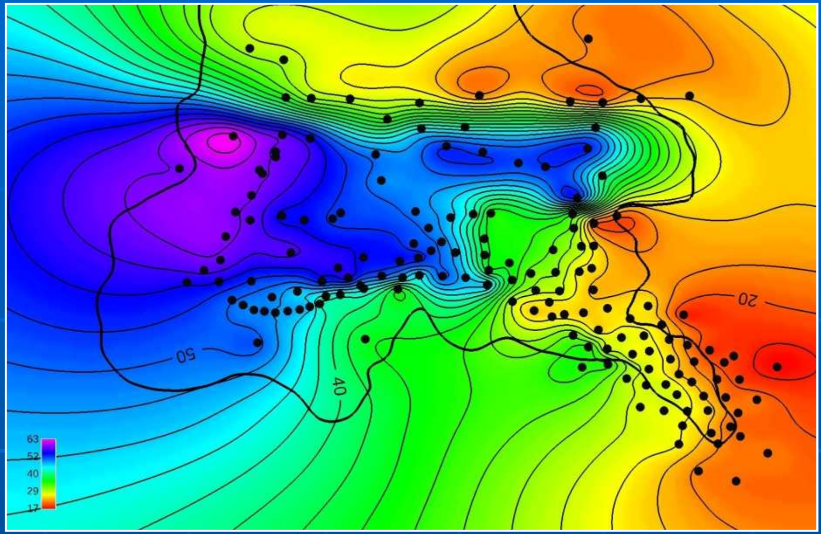
Drawback of Old Conceptual Layer Cake Model: Correlation

- Could a deep water turbidite environment result in 3 continuous sand layers embedded in clay?
- Would it be realistic to correlate the 3 sand intervals all over the reservoir?
- Is a turbidite system rather a static or a dynamic environment?
- Isn’t it rather a system formed by hundreds or even thousands of underwater avalanches, occurring one after the other with passive periods in between?

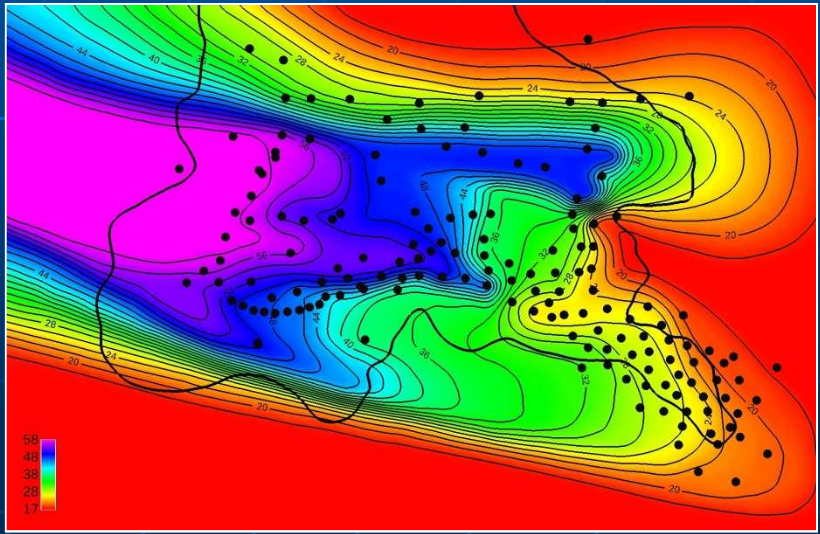


New Aspects: Isochor Map

- The conceptual model has been reassessed considering the possibility to treat Földvár Felső A-1, 2 and 3 as one system including passive periods
- It has been assumed that most time is captured in clay layers
- It was considered that the turbidite is deposited on the top of a clay base
- In accordance to these assumptions, the base of the reservoir has been defined 10 m below the last sand occurrence
- The resulting isochor map has been analysed and the bottom clay thickness adjusted to produce a continuous (realistic) environment
- In case of missing well information, the isochor map has been modified honouring the main concept of the raw map and finally used to construct the reservoir bottom



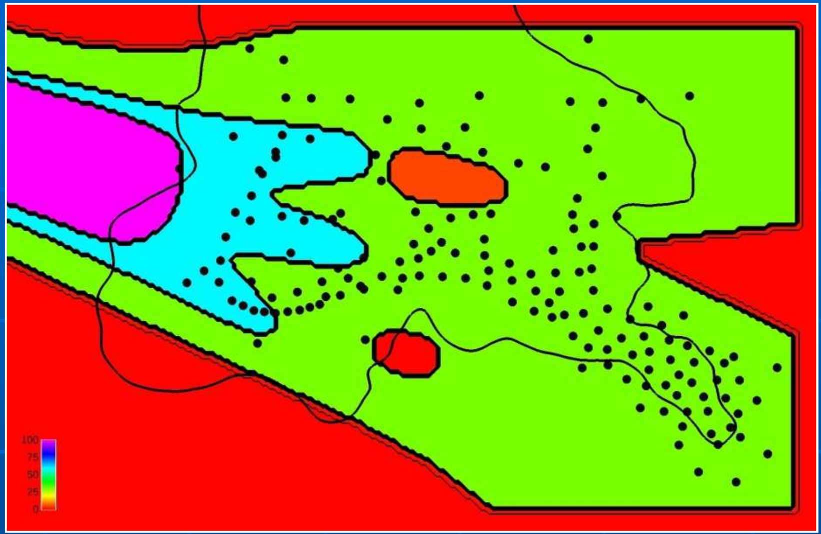
Raw Isochor Map



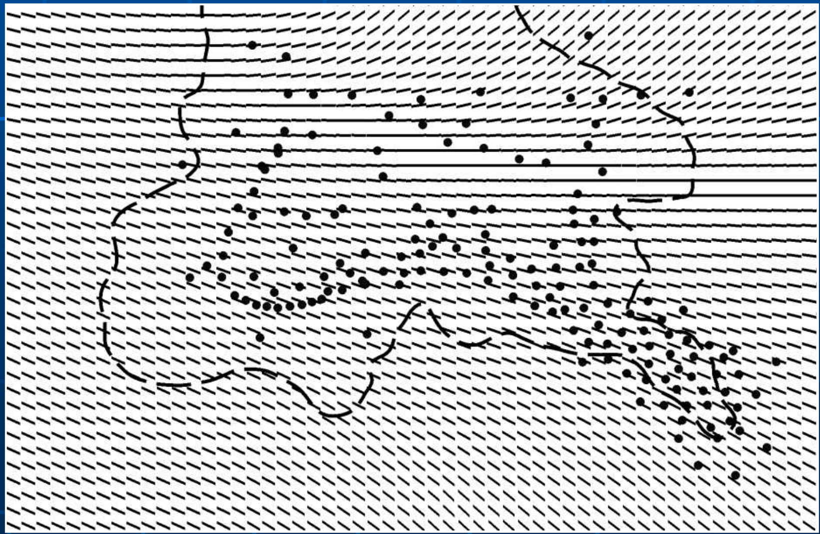
Final Isochor Map

New Aspects: Relative Intensity Map and Vector Field

- Based on the final isochor map, the well information and the production history of the field, the turbidite dynamic system has been analysed
- A relative intensity map has been constructed defining the trigger probability of turbidite currents. This map was a preliminary approach and later calibrated during the facies modelling workflow
- The sand body thicknesses as well as their vertical distribution in the wells furthermore helped to create a vector field, defining the average azimuth of the turbidite main axes



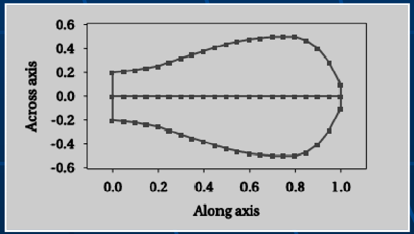
Relative Intensity Map

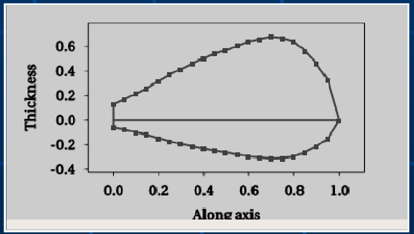


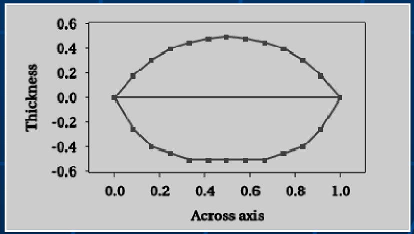
Azimuth Vector Field

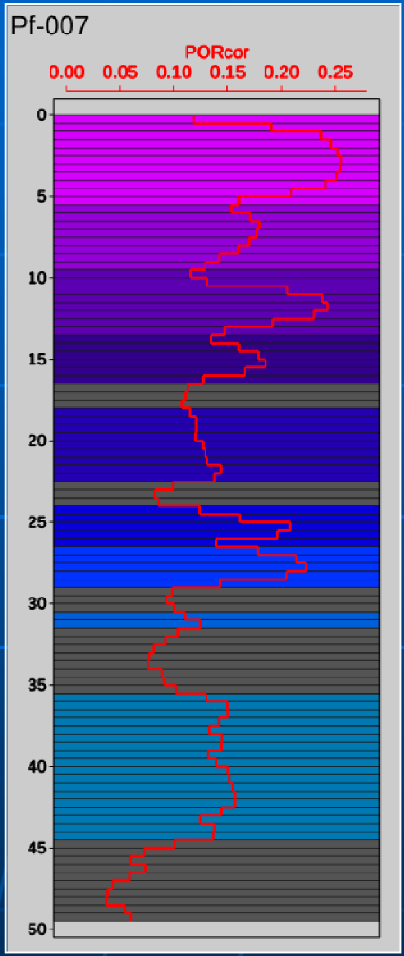
Object Based Facies Modelling: Turbidite Definition

- In each well, sand intervals has been split in different bodies based on the porosity log. Very small fluctuations (nano-cycles) have been neglected to keep the system as simple as possible
- Obviously, it is not a matter of a classical turbidite. The increasing porosity at the beginning stands for an other process which has not been fully understood yet
- Based on literature and well log information, a general turbidite body geometry has been designed:
  - Length: Normal distribution, mean = 2500, std. = 1000, min. = 500, max. = 5000
  - Width: Normal distribution, mean = 200, std. = 300, min. = 100, max. = 800
  - Height: Normal distribution, mean = 3, std. = 2.5, min. = 0.5, max. = 17





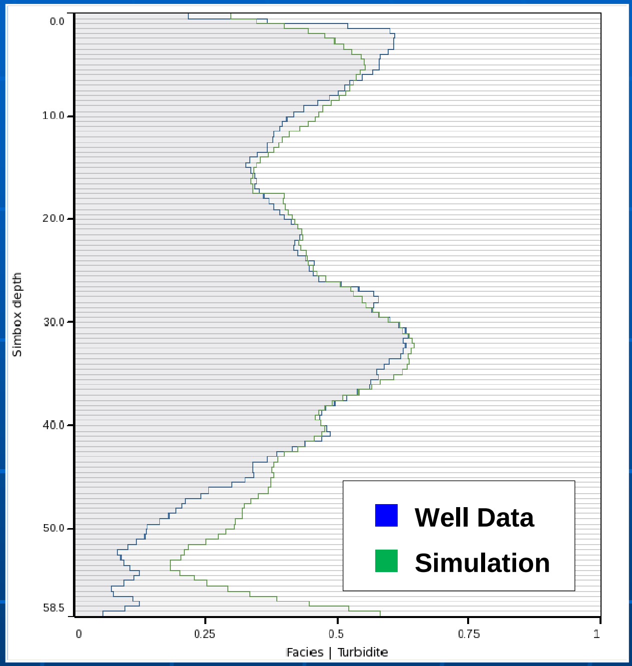




Blocked Porosity Log with Bodies

Object Based Facies Modelling: Irap RMS Simulation & Calibration

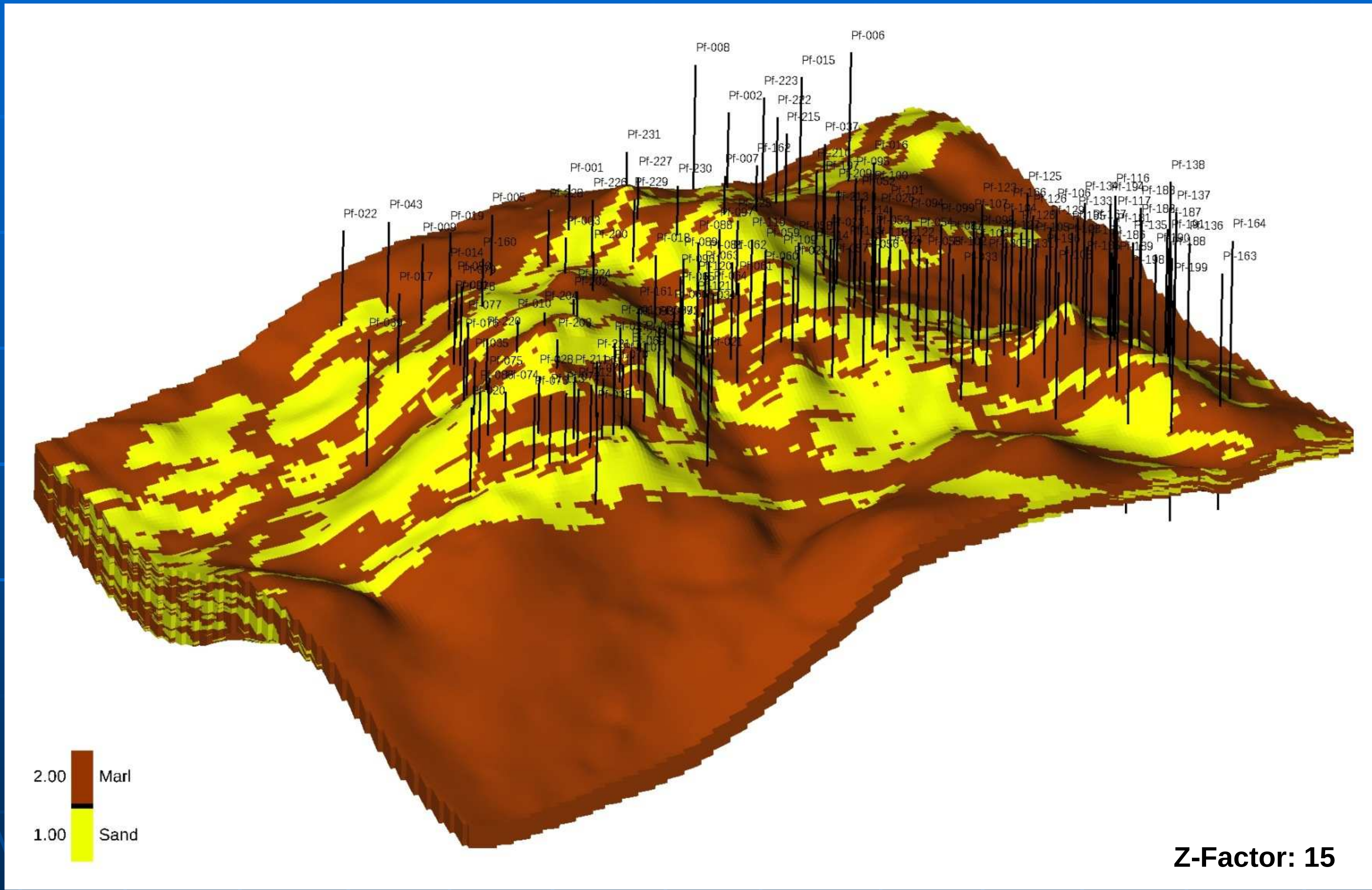
- For all 3 main axes of the body, amplitudes and rugosities have been implemented to guarantee each body uniqueness and a close approach to nature
- The predefined vector field including a variability of 5° and the relative intensity map helped furthermore to simulate this complex environment
- The elaborated input parameters have been used for a 3D simulation with the help of the Facies Composite module of IRAP RMS 2010.1
- The majority of the listed parameters were assumptions based on literature, well data and experience, difficult to verify based on available input data



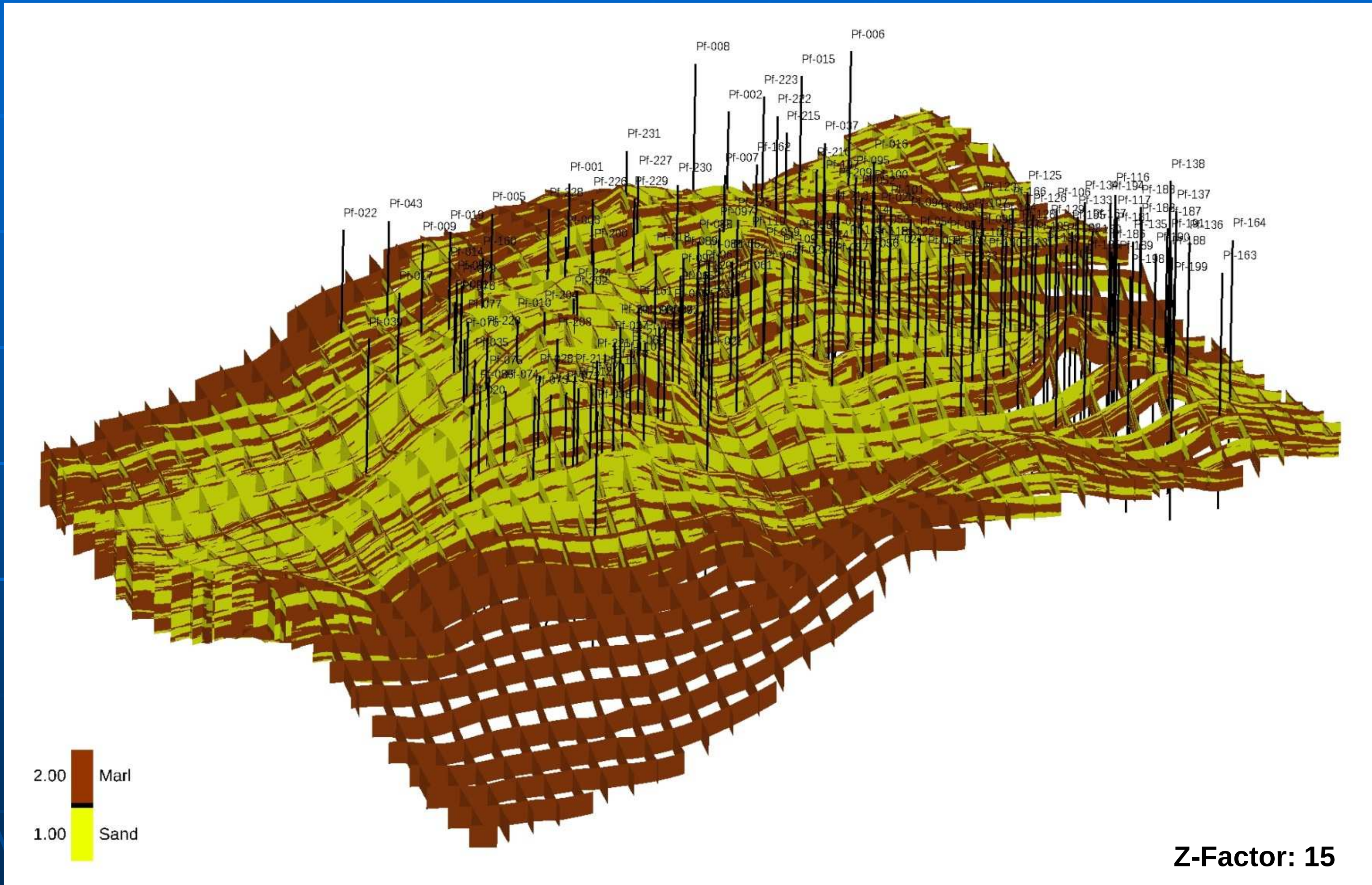
Vertical Proportion Curve

- Parameter calibration therefore was indispensable based on geological understanding of a turbidite system, visual control in 3D as well as the help of vertical proportion curve (VPC). These aspects provided an excellent insight into the system and allowed to achieve a satisfying result

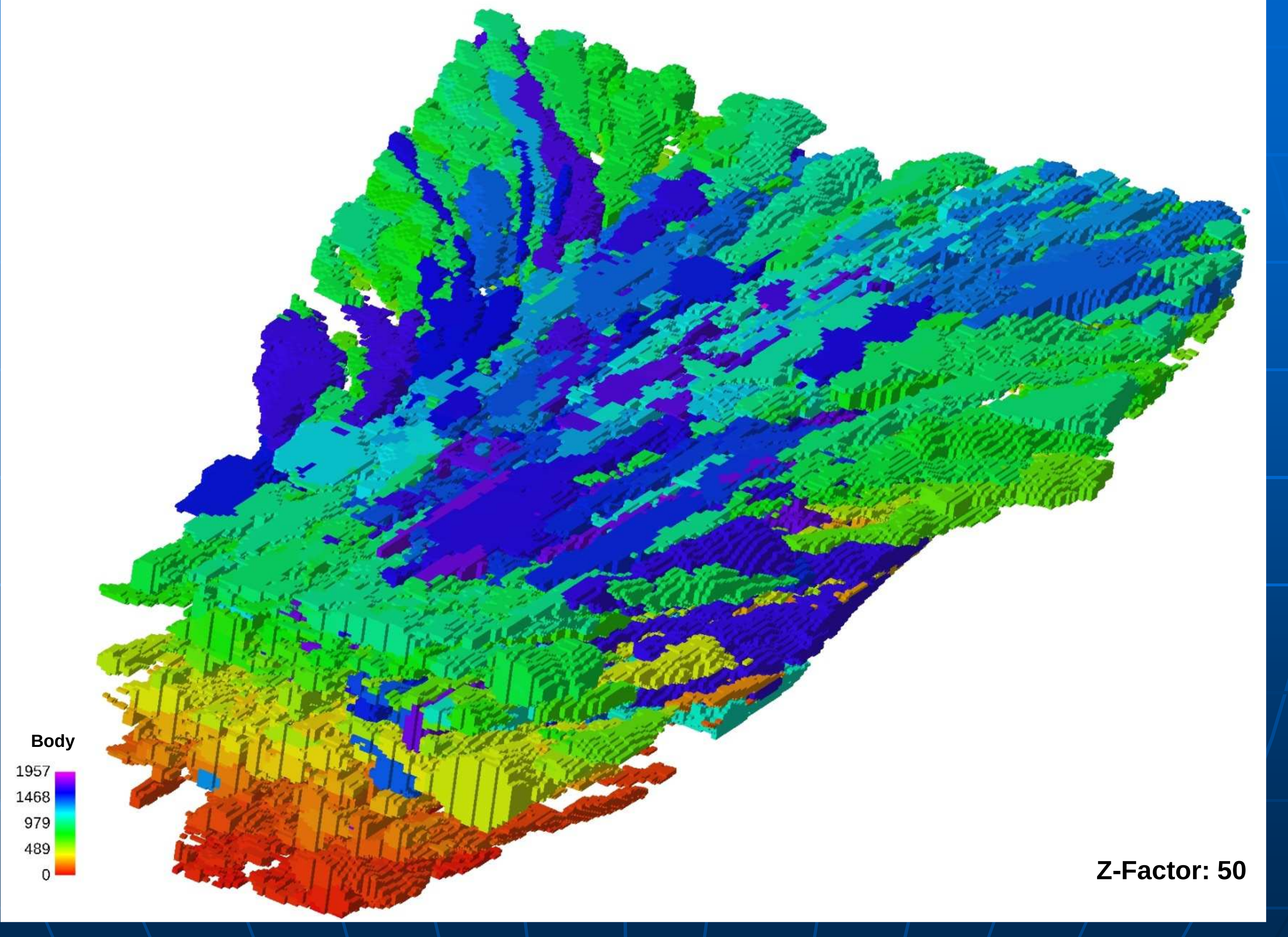
Object Based Facies Modelling: Resulting Model in 3D



Object Based Facies Modelling: Resulting Model in 3D

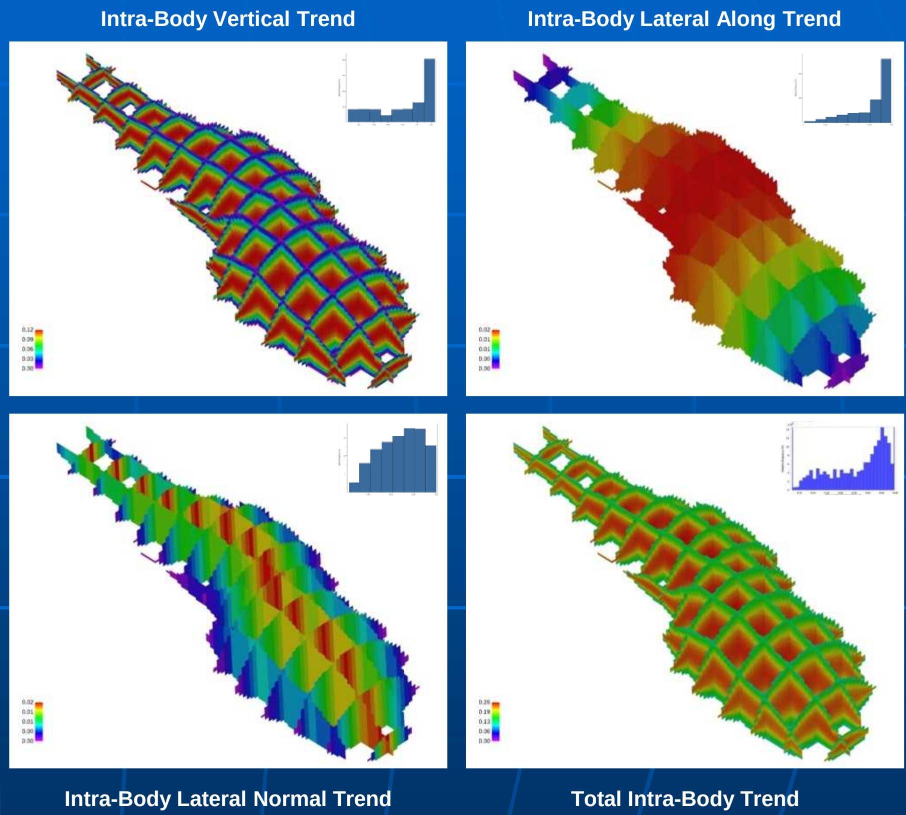


Object Based Facies Modelling: Simulated Turbidity Bodies in 3D



Porosity Modelling: Conceptual Trend Model Design

- A conceptual model has been developed for the porosity distribution inside the turbidite bodies
- A main trend in z direction and minor ones in x and y has been considered as the most suitable concept for the Pusztaföldvár environment
- The elaborated conceptual model was applied to the well data and thereby the predefined trends deducted. This procedure was necessary to separate the residuals for further simulation



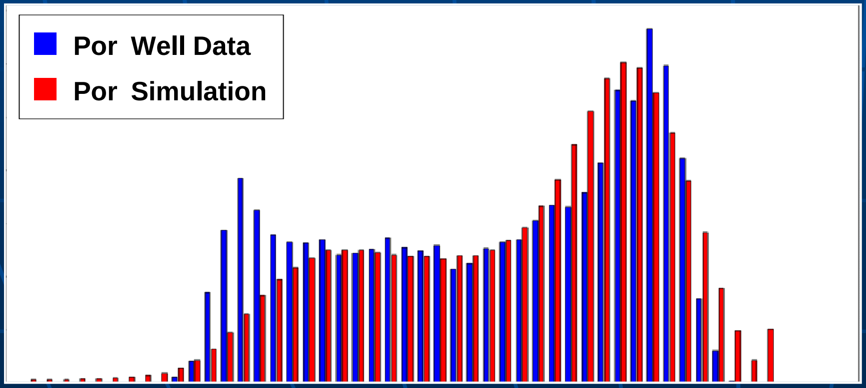
- After a normal score transformation of the residuals, variography could be applied which directly gave a feedback about the quality of data transformation

Porosity Modelling: IRAP RMS Simulation

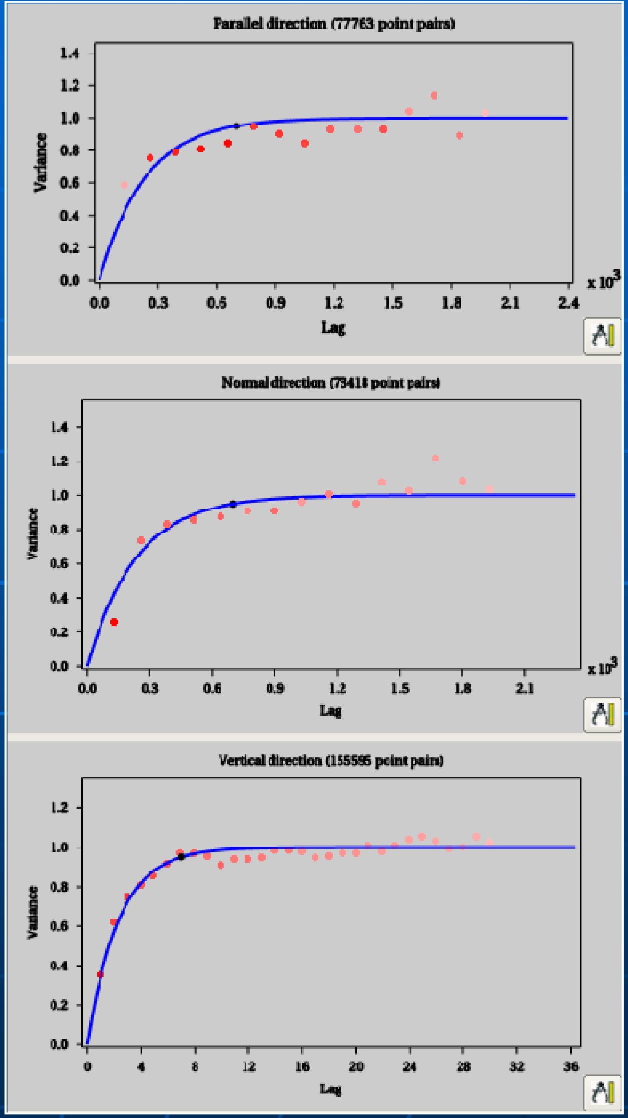
- The analysis results:
  - Trend reduction
  - Normal Score transformation
  - Variograms

  have been fed into the Petrophyscial Modelling module of IRAP RMS 2010.1 and the porosity parameter was simulated

- This workflow enabled to handle the complex environment with 2 facies. Even though the assumption is very simple, the simulation managed to reproduce a similar porosity distribution as observed in the well data

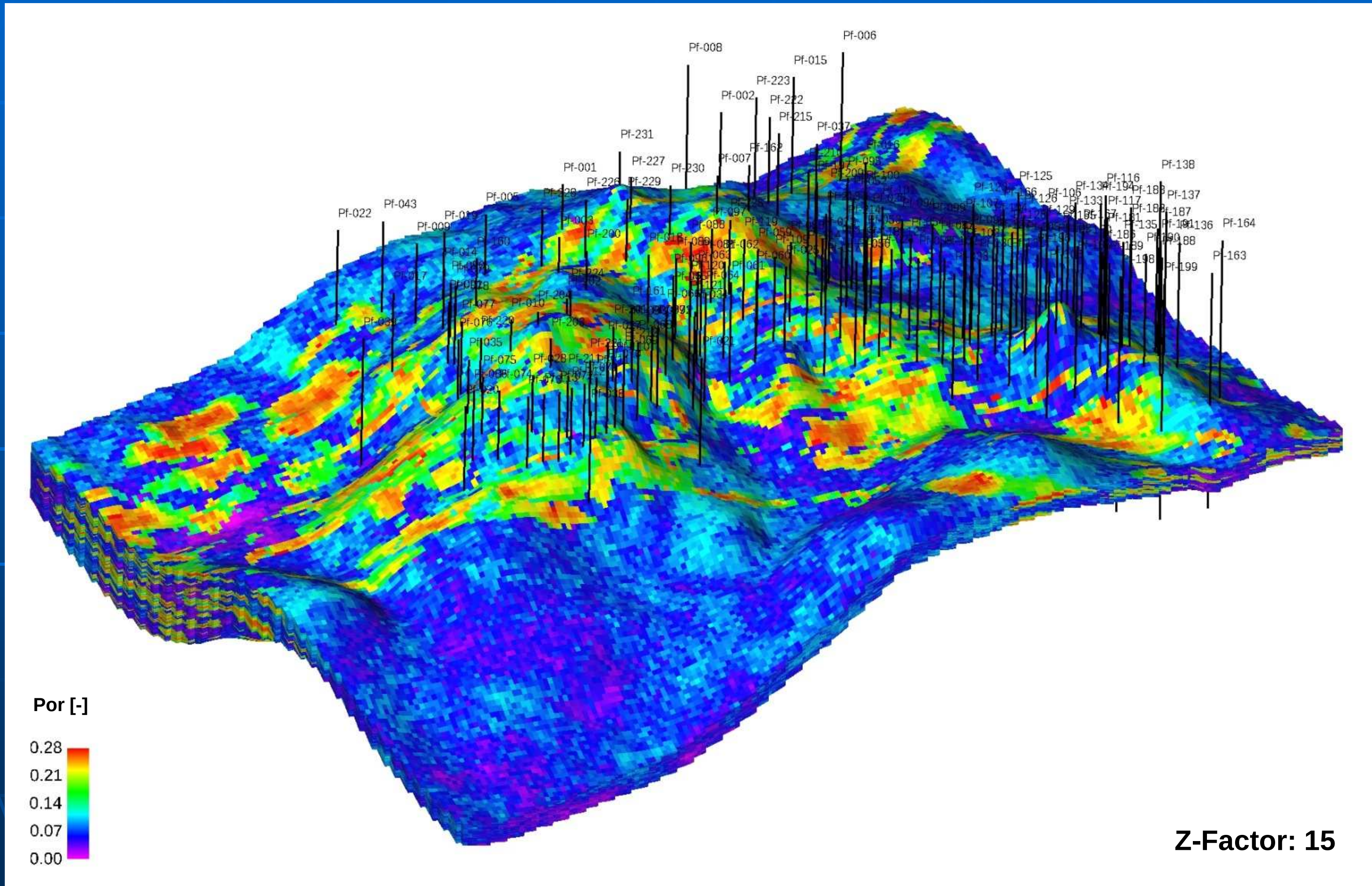


Porosity Histogram

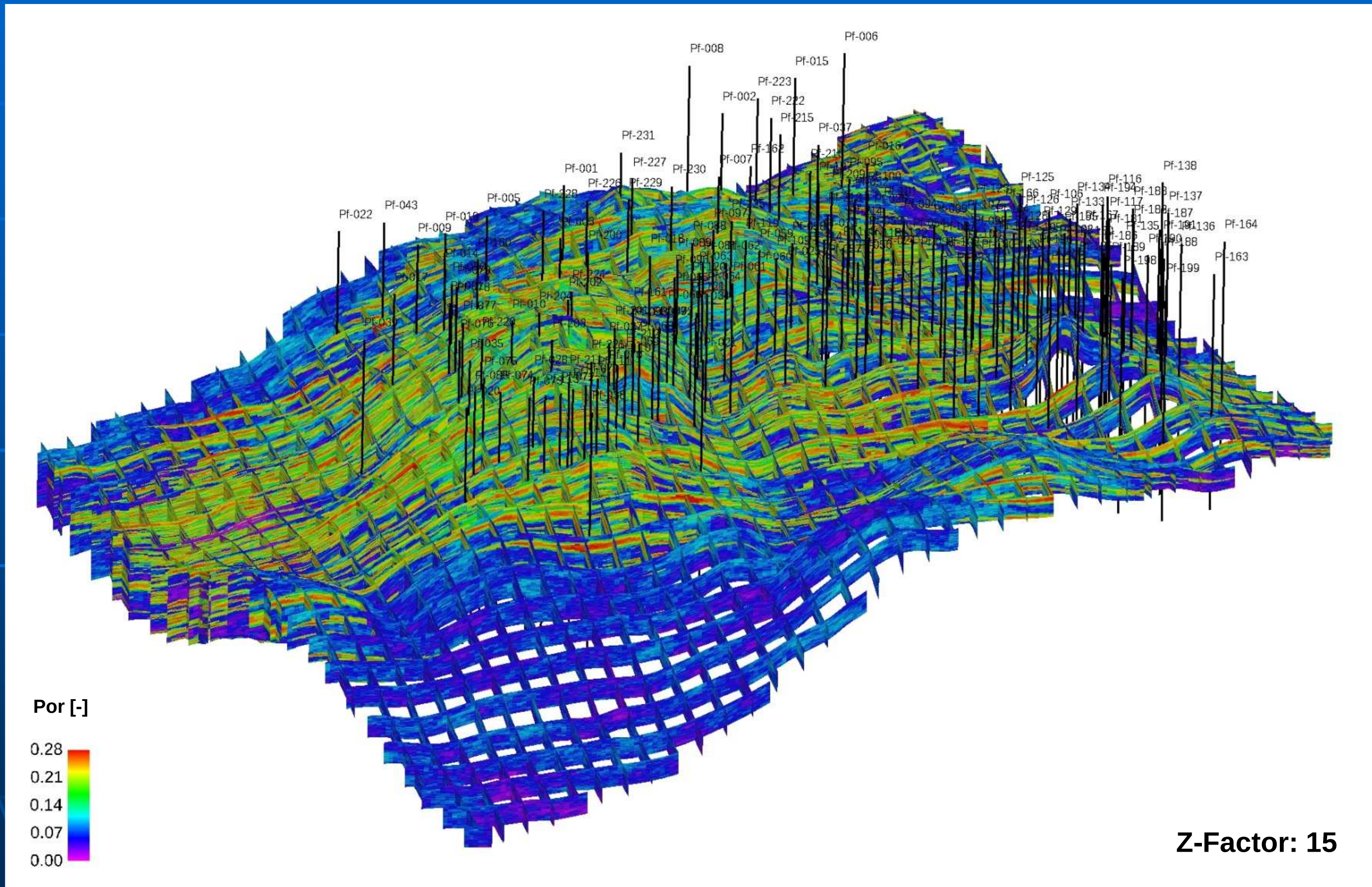


Porosity Residual Variogram

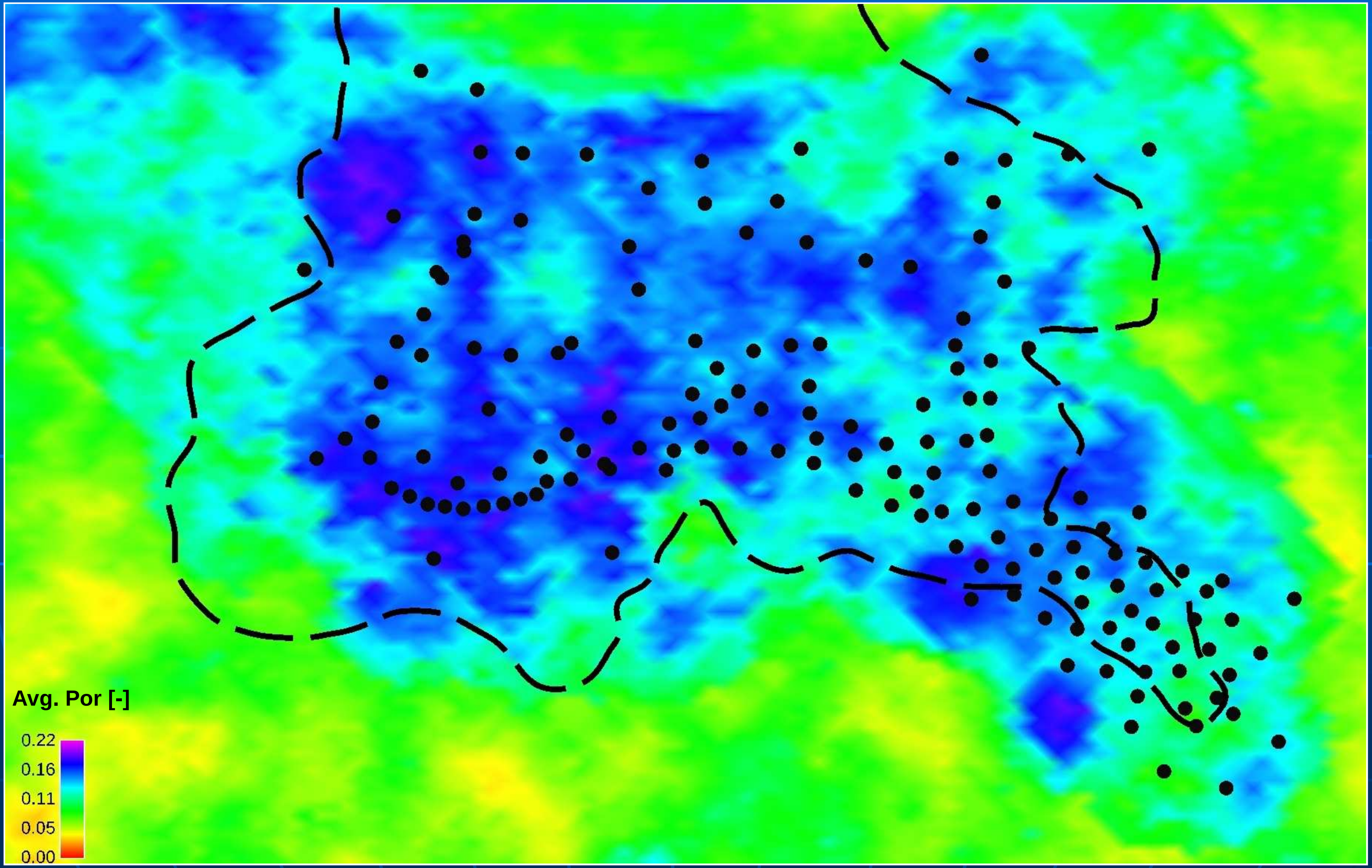
Porosity Modelling: Resulting Model in 3D



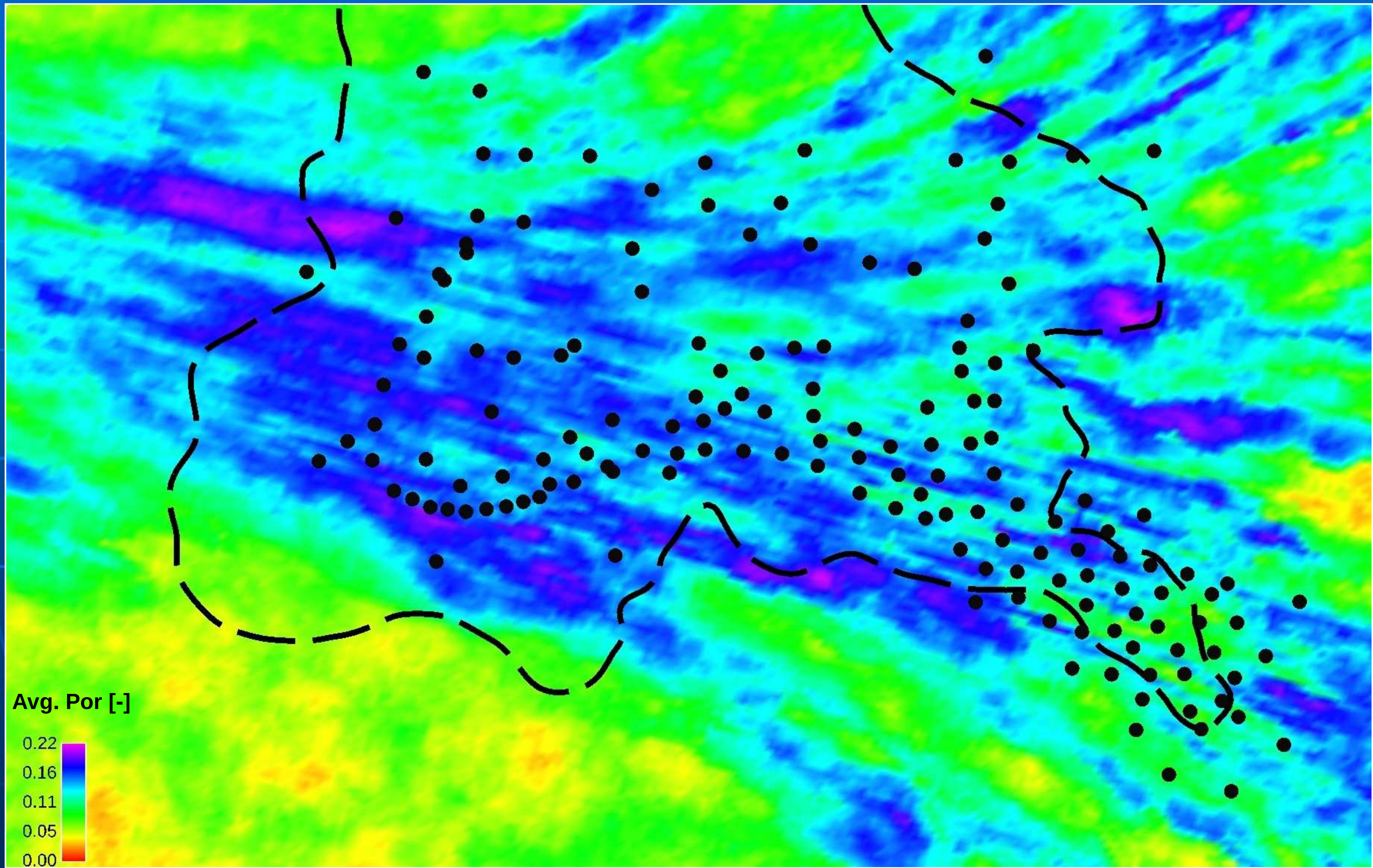
Porosity Modelling: Resulting Model in 3D



Porosity Modelling: Avg. Porosity Map of Layer Cake Model



Porosity Modelling: Avg. Porosity Map of Object Based Model



Conclusions

- The applied workflow has a more complex theoretical background than the classical layer cake modelling approach, but it is not necessarily more costly in terms of time
- The object based modelling is based upon various assumptions, difficult to specify. However, VPC is an excellent tool for calibration and facilitate a realistic result
- The relative intensity map allows quick model modification without alternating the grid which is a tremendous advantage compared to the classical approach
- History matching illustrated that minimal modifications and time were necessary for a reasonable match. In case of the classical approach a comparable result was only achieved after serious modifications which often were difficult to explain by a natural system
- Intra body trends can only be honoured in case of an object based model. This aspect will not affect the reservoir volumetric, but tremendously the flow dynamic. Especially in mature fields, the reservoir behaviour (transition zone, water inflow, etc) could be better matched, studied and forecasted

Thank you for your attention!