Development of the abandoned Penészlek gas province

New geological insights into a volcanoclastic gas reservoir and lessons learnt from state of the art exploration techniques

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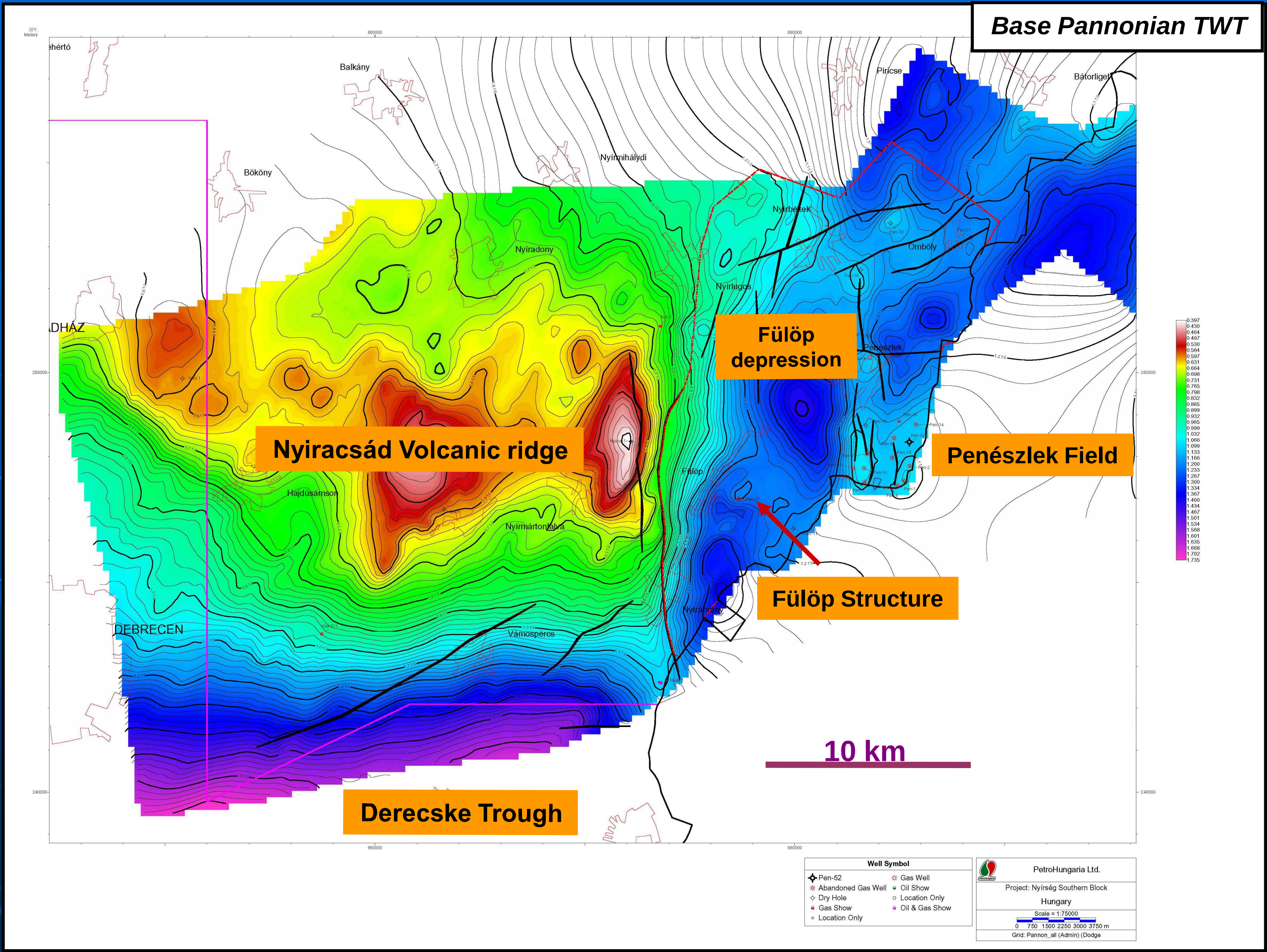
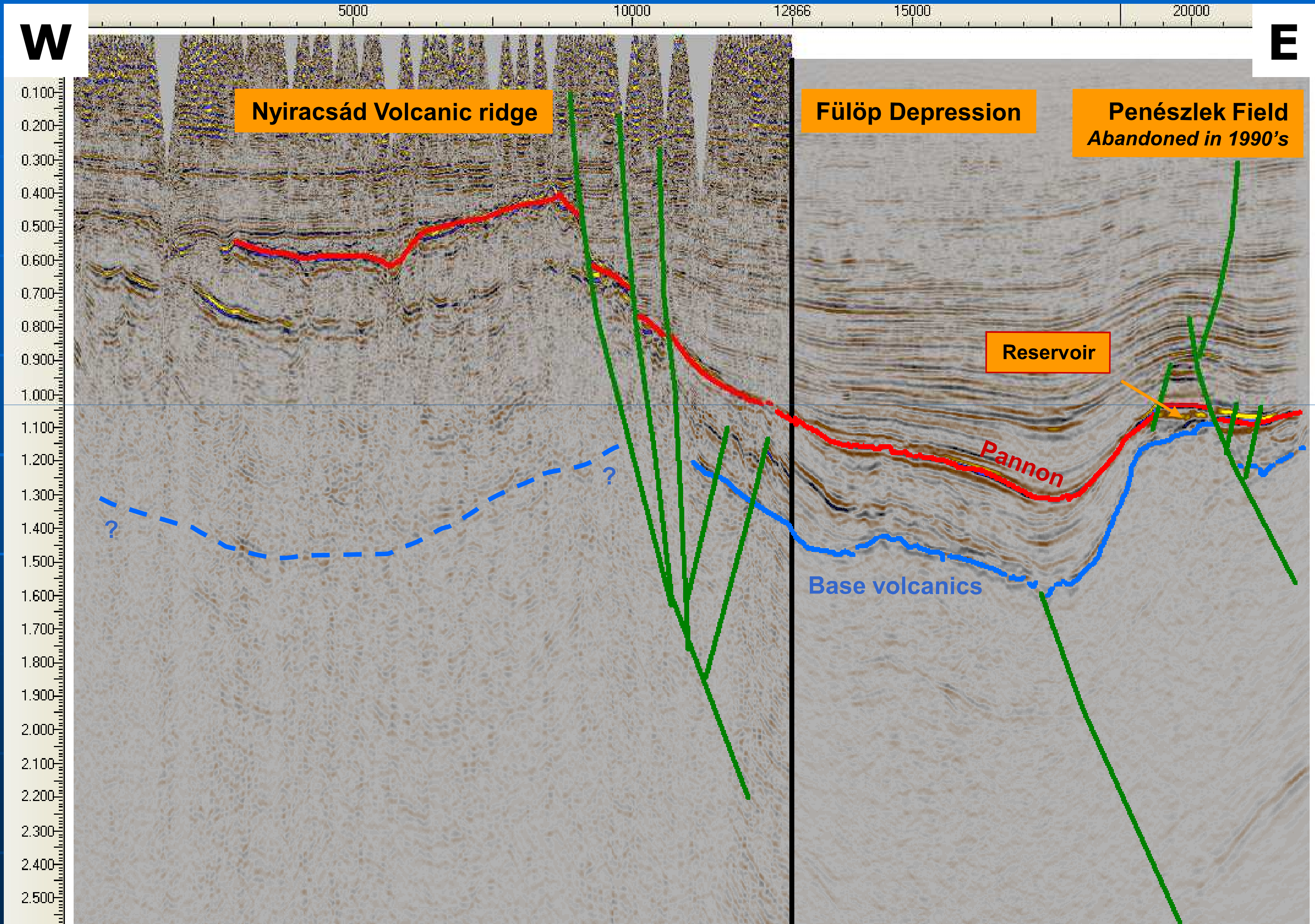
Introduction: licence location



Introduction: tectonic setting



PetroHungaria's exploration activity

- Data collection, G&G evaluation (2004-2005)
- 160 km 2D seismic acquisition (2005)
- Drilling phase #1 (2006): Pen-104, Pen-102; discovery of the Penészlek P104 lower pannonian satellite field
- 100 km^2 3D seismic acquisition (2008)
- Seismic modelling, seismic-, geological- and geochemical evaluation of the reservoir
- Drilling phase #2 (2009): Pen-104A, Pen-104AA, Pen-105; development of the Fülöp-North field; redevelopment of the Penészlek field

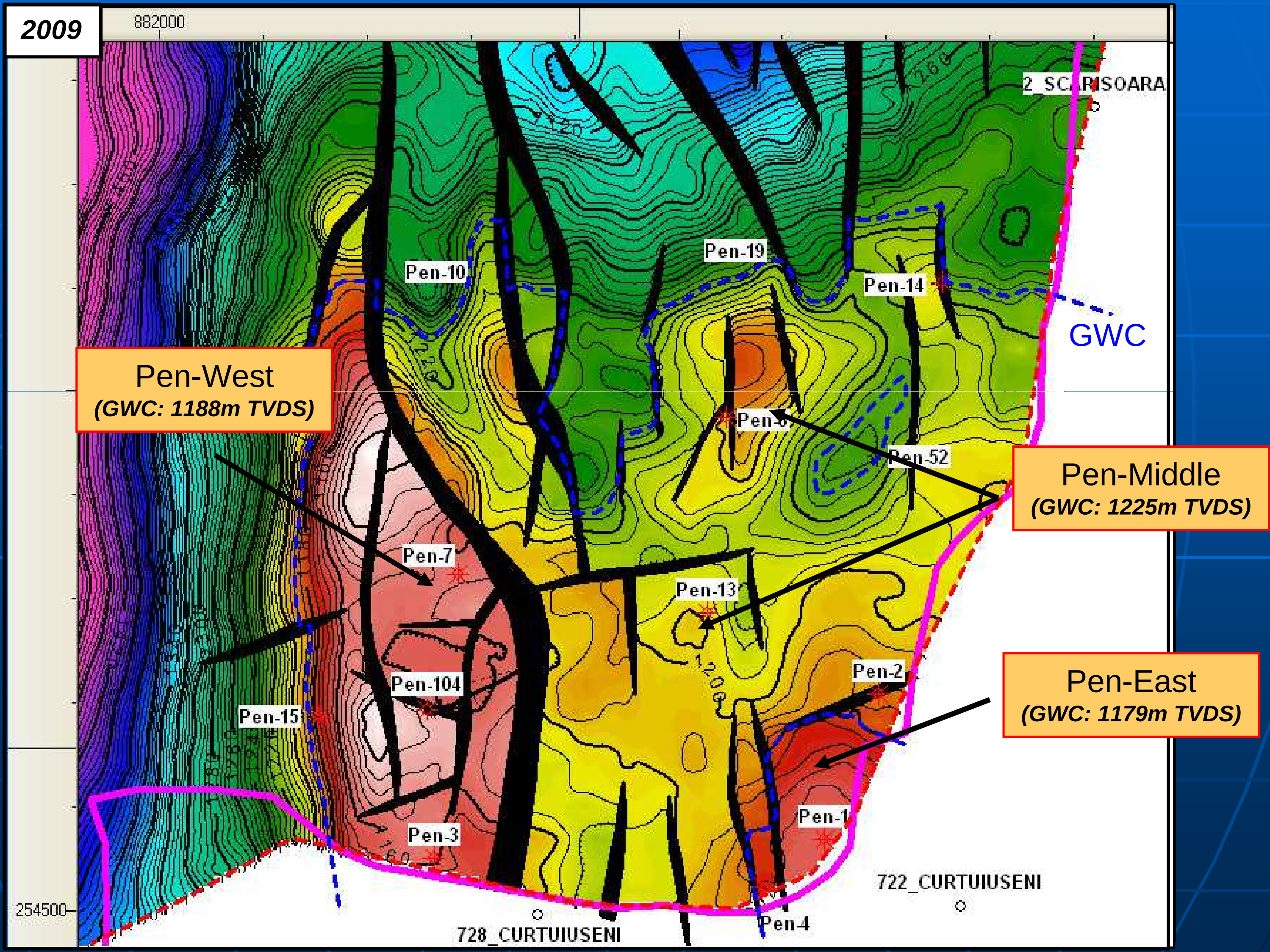
What have we learnt?

Lesson #1:

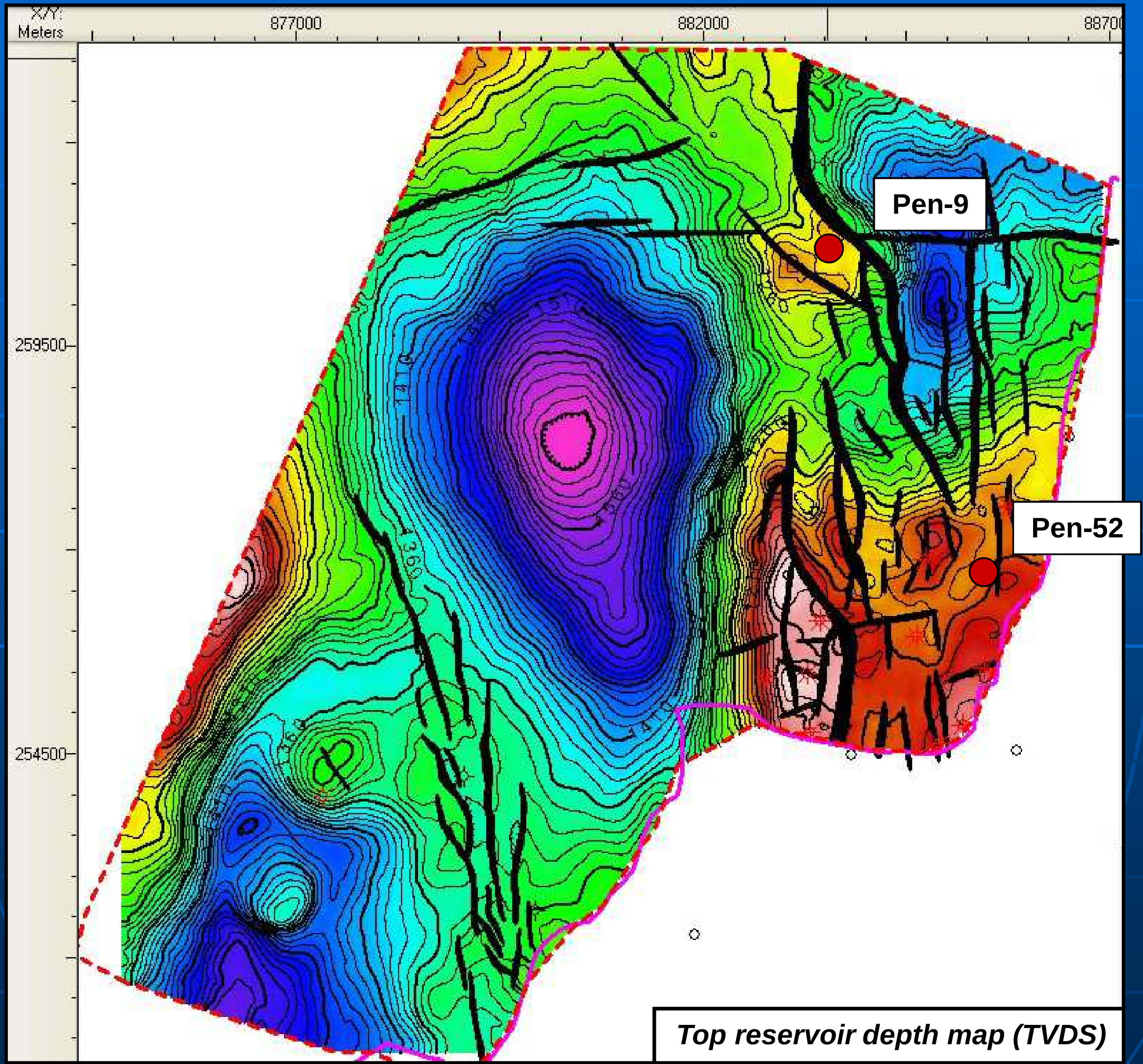
Clear structural view is essential for the understanding of the well performances

Penészlek Field: Evolution of the structural model

Borehole-corrected top reservoir depth map and GWC-s of the Penészlek Field



Miocene structural setting from 3D seismics

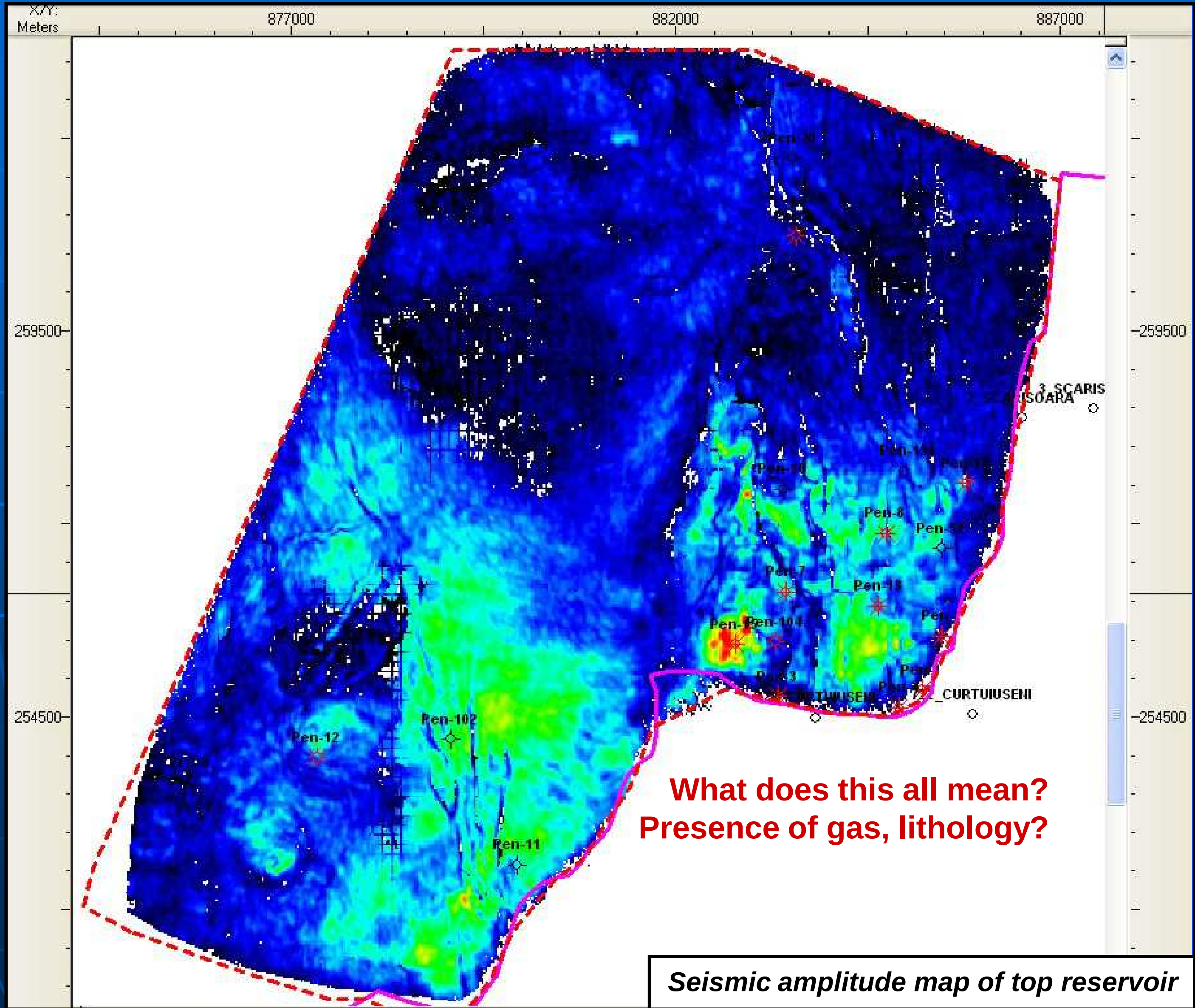


What have we learnt?

Lesson #2:

In a lithologically complex reservoir clear view on the structural setting is not enough. Very good understanding of the reservoir geology is required by squeezing out as much information as just possible from the available G&G database

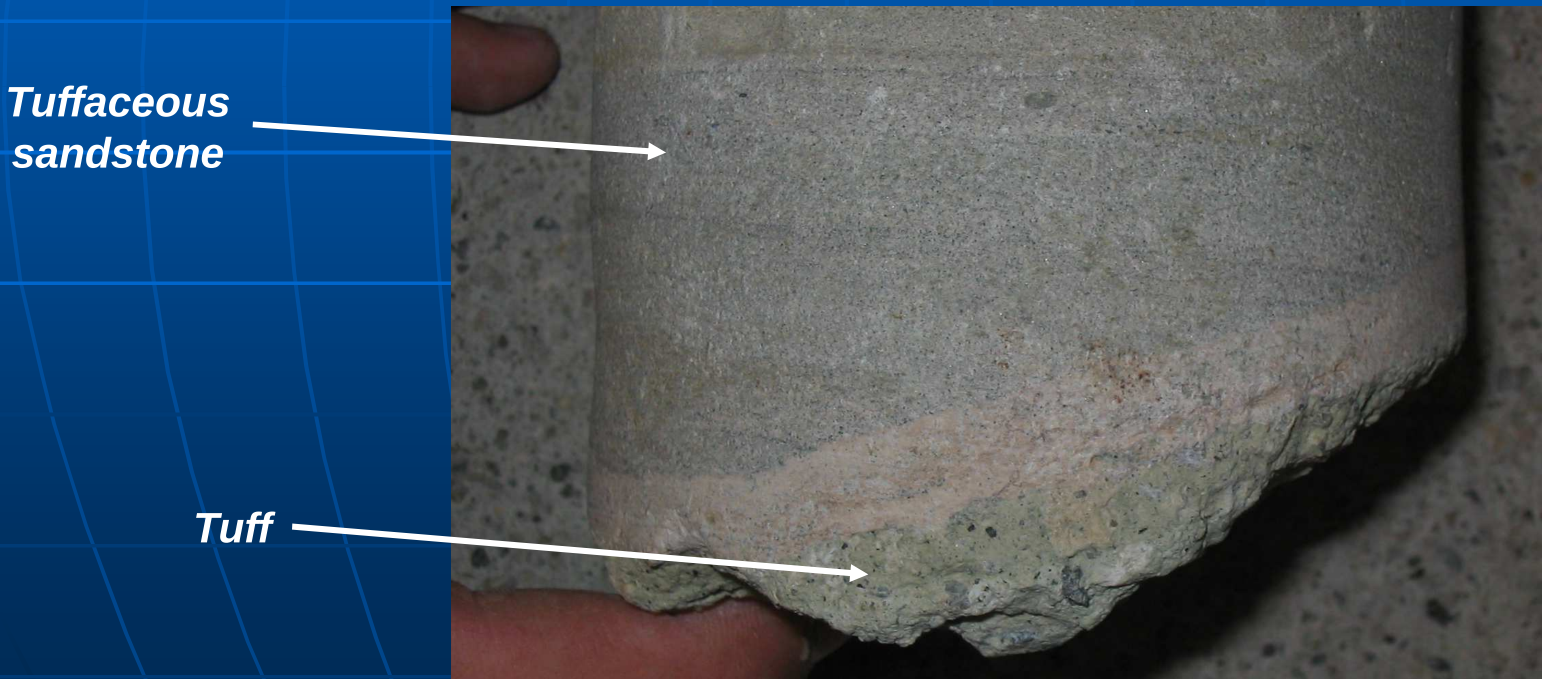
Seismic attribute mapping of the miocene



Seismic amplitude map of top reservoir

Top miocene startigraphy

- Erratic lithology: tuffaceous-calcareous sandstone, calcareous tuffite, limestone, tuff, marly tuffite
- Chaotic siesmic response
- Very variable but generally 17-28% porosity
- Very variable permeability 0.1-20mD
- Complex matrix effect on logs makes it difficult to evaluate petrophysically



Seismic modelling: Objectives

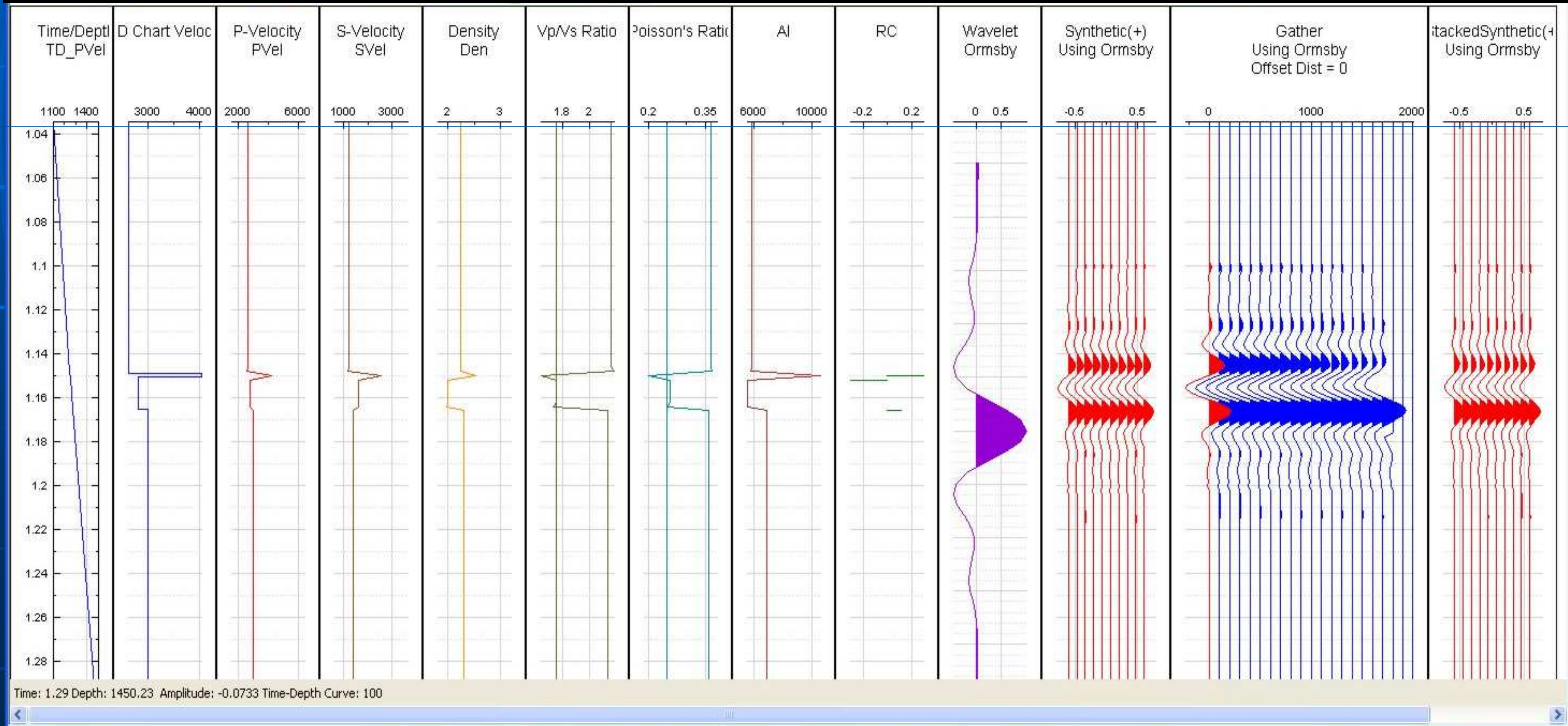
Preliminaries

- **Log data indicates the presence of a variable thickness, high-velocity calcareous section on the top part of the reservoir, which likely overprints the effect of hydrocarbons in the seismic data**

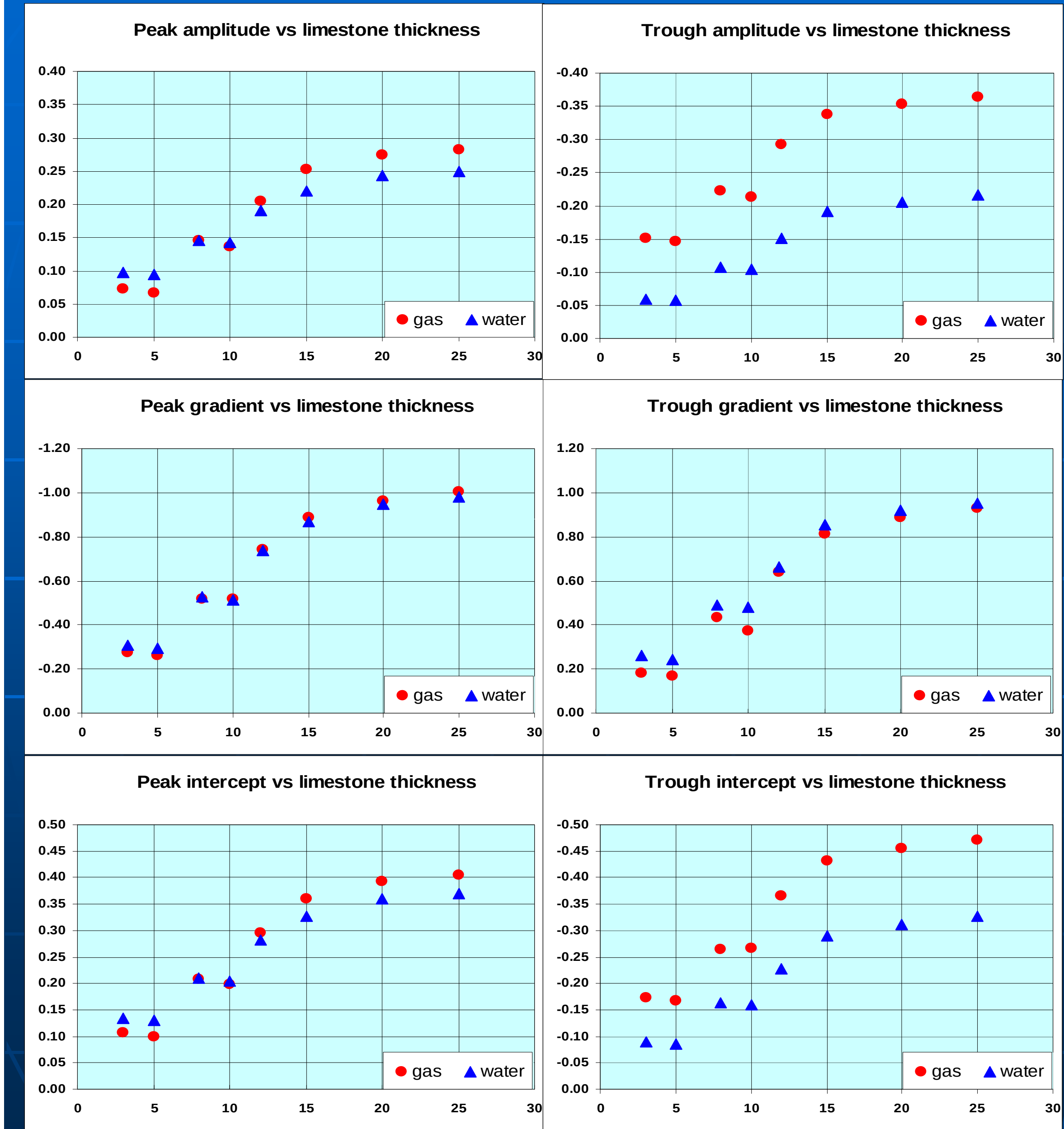
Objectives of the modelling

- **Investigation of the effect of this layer on the seismic response of the reservoir both in water and in gas-chared case**
- **Trying to remove the lithological effect from the amplitude map resulting in a gas-sensitive attribute map**

Input geological models as well as their offset-dependent and stack seismic responses



Seismic modelling: Results



Modelling results reveal that:

- **Calcareous sequence of large thickness causes the strongest reflection**
- **Due to the overprinting effect of lithology all three attributes of the top limestone (peak) reflector is practically insensitive to gas-saturation**
- **The overall characteristics of all three seismic attributes as the function of thickness are very similar for both water- and gas-saturated cases**

No differentiation is possible between a gas- saturated reservoir and a water-saturated reservoir capped with a limestone of larger thickness

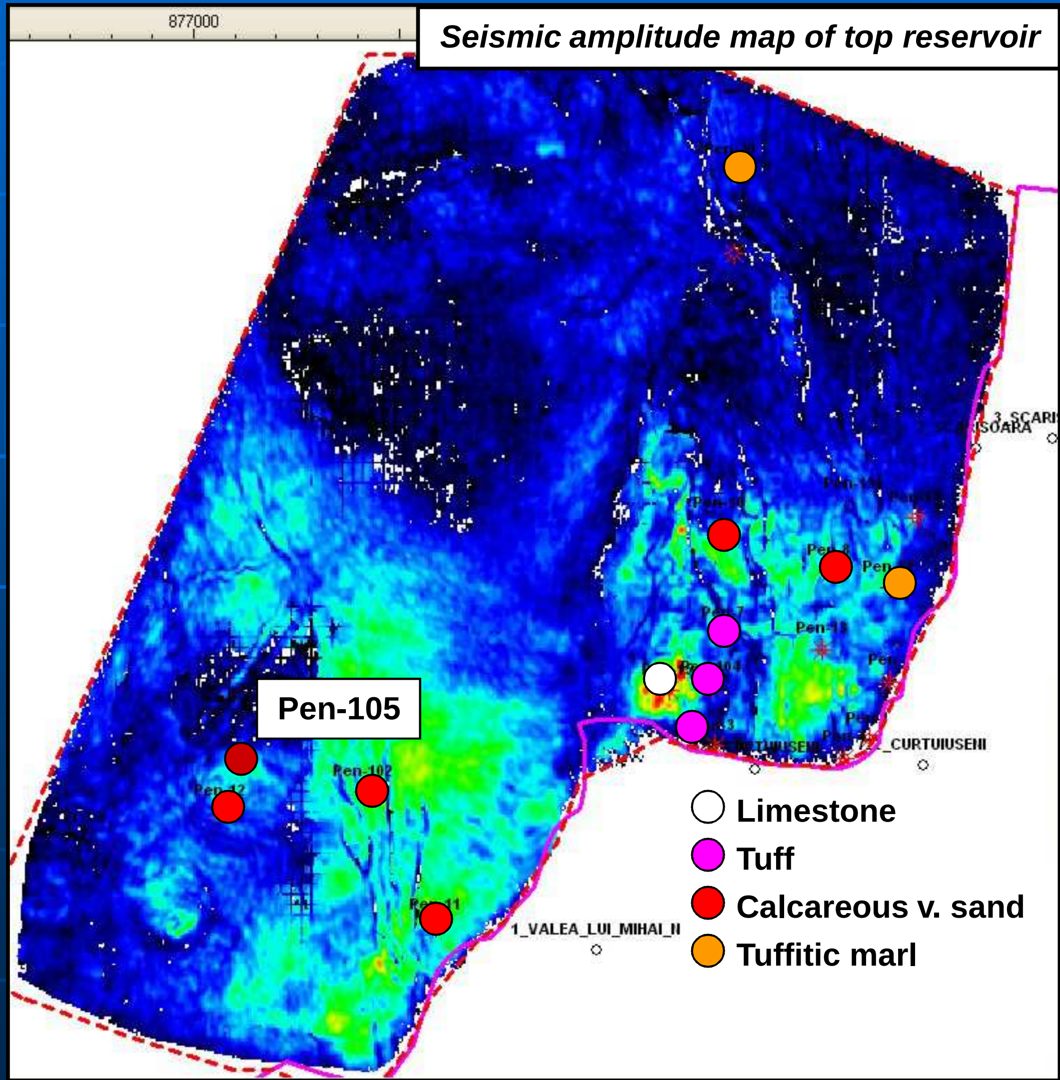
Areas of high seismic amplitude simply reflects areas of reservoir capped with a thick high-velocity sequence

Well and seismic correlation

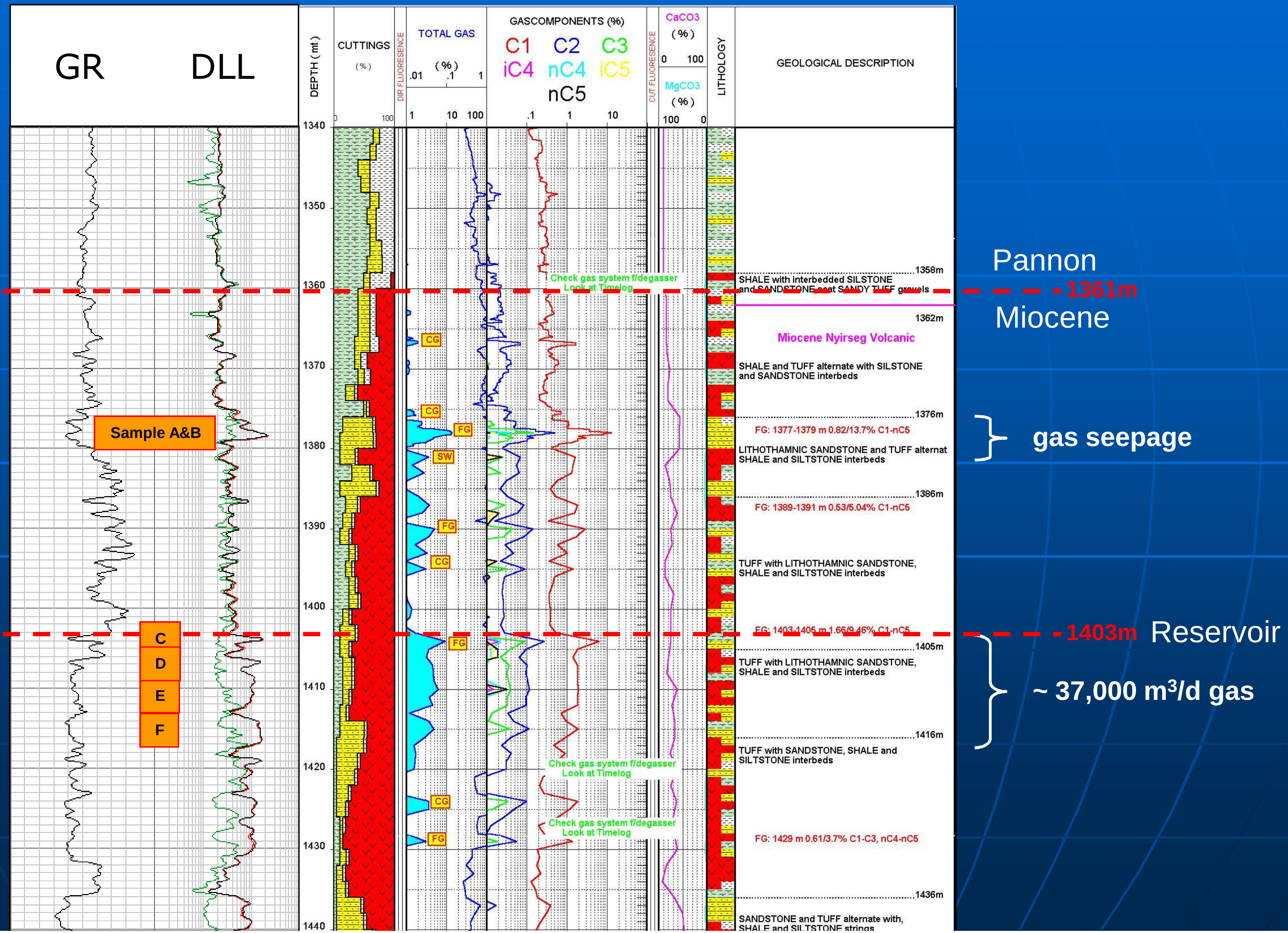
What does the well performance and the cuttings evaluation say ?

- Very good correlation between flow rate (water and gas) and reflectivity
- Strong seismic response = good reservoir
- Top miocene lithology from cuttings:
  - Limestone
  - „Genuine” (terrestrial) tuff
  - Calcareous, volcanic sand
  - Tuffitic marl with reduced sand content

The amplitude map is mainly lithology driven and shows us the areas with good quality calcareous reservoir



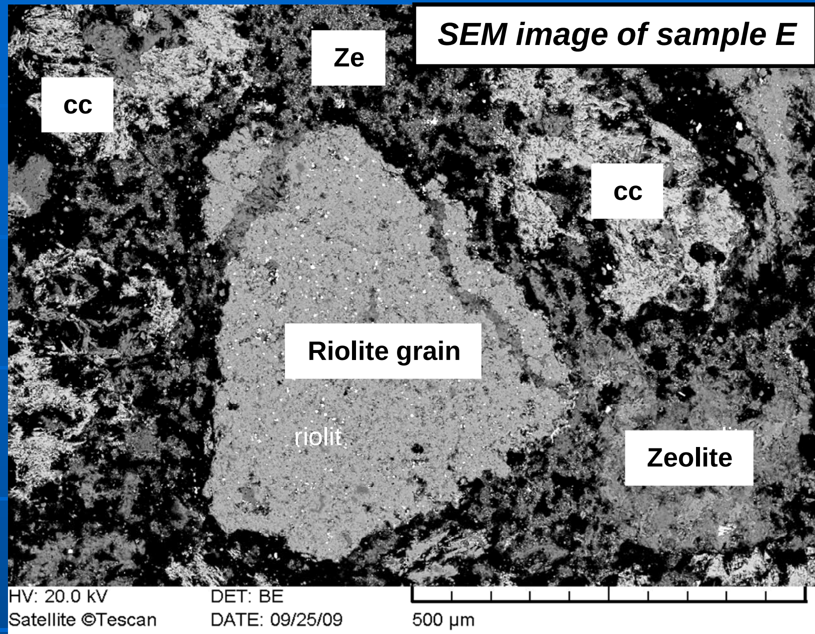
Pen-105 cuttings samples

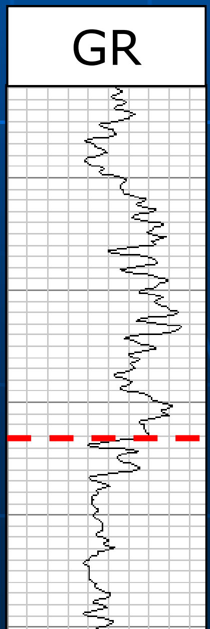


Pen-105 samples: XRD and SEM analysis

Geological results of cuttings study:

- Individual sedimentary components: siltstone debris of deeper miocene origin, riolite grains, calcite.
- The rock is considered to be a polymict sandstone, which was deposited in a marine environment
- Cementing and pore filling matrial is calcite and zeolite
- Zeolites (clinoptilolite) are K^+ poor and formed secondarily from K^+ rich volcanic glass during diagenesis
- Zeolitisation occured only in the permeable reservoir section. During this process the K^+ from the volcanic glass was freed-up and washed away



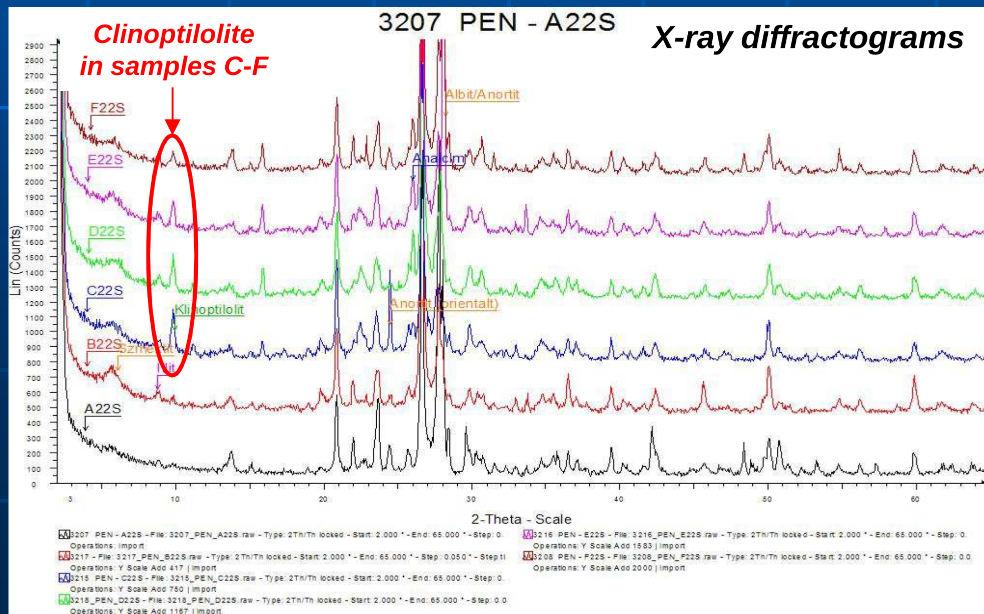


No zeolites, higher GR from K^+ in volcanic glass

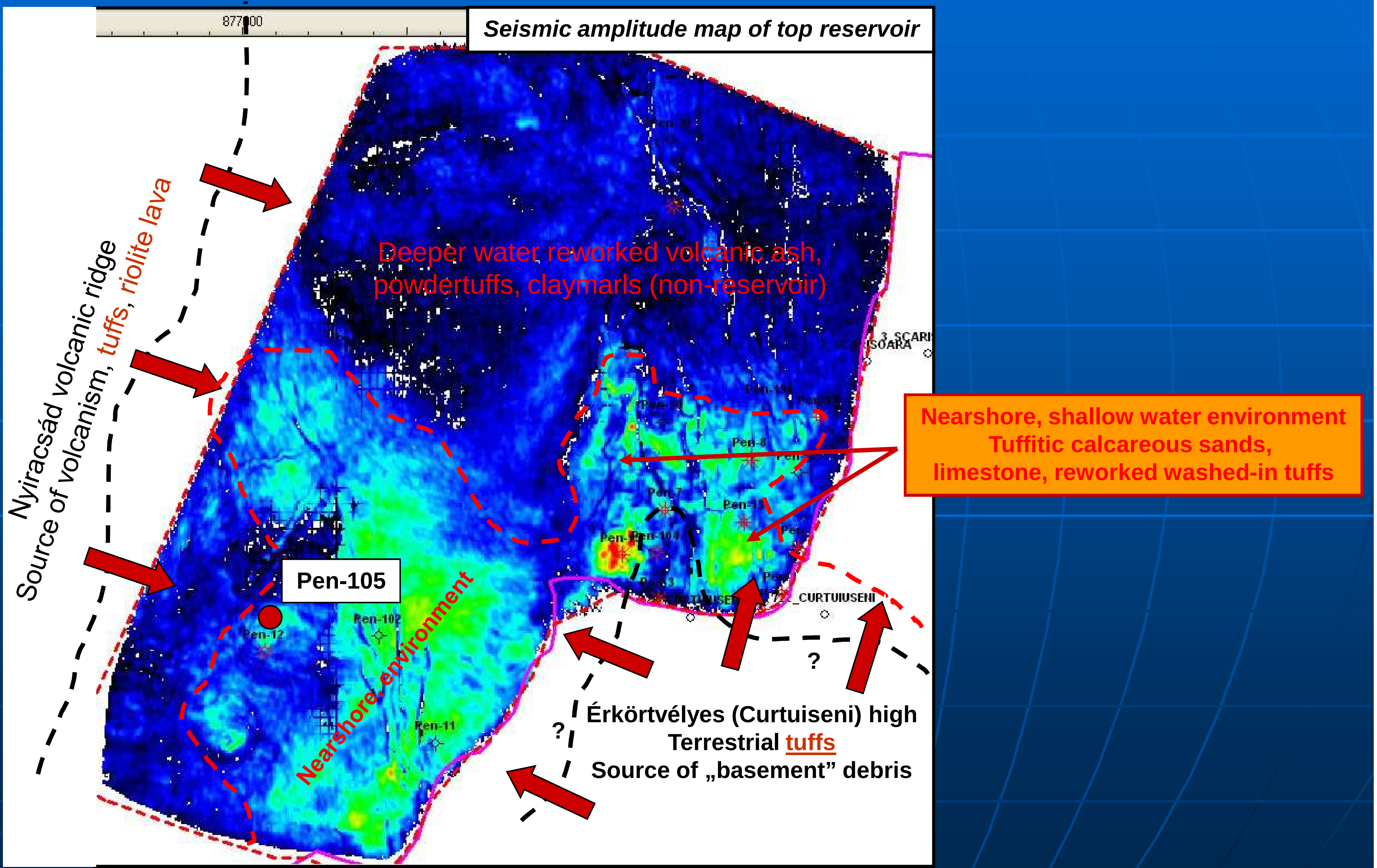
In contrast to a siliciclastic reservoir in this volcanoclastic miocene GR is a permeability rather than a lithology indicator !!

Reservoir

Zeolite present
Low K^+ → lower GR



Depositional model of the miocene reservoir



Applications: Pen-105 acid job

How can we benefit from the detailed geological/geochemical knowledge of the reservoir besides better positioning future wells?

- Zeolites in the reservoir have a high (3.5-5.2 mekv/100g) cation-exchange capacity making them highly water-sensitive
- Zeolites may swell and cause formation damage in case of an improper drilling- or completion fluid
- Initial production tests in Pen-105 indicated formation damage and insufficient WHP and flow rate for economic development of the well
- With a dedicated acid stimulation treatment the productivity of the well could be doubled making the development economic !!

Pre-acid: 6mm; 22k m^3/d; WHP=52bar

Post-acid: 6mm; 40k m^3/d; WHP=85 bar

Post-acid: 8mm; 59k m^3/d; WHP=69 bar

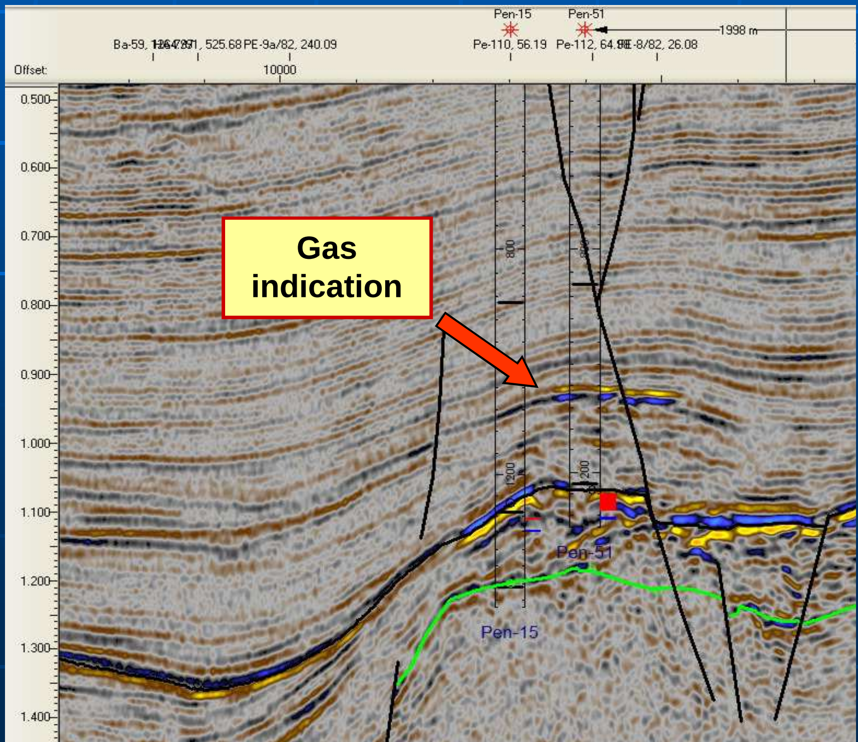
What have we learnt?

Lesson #3:

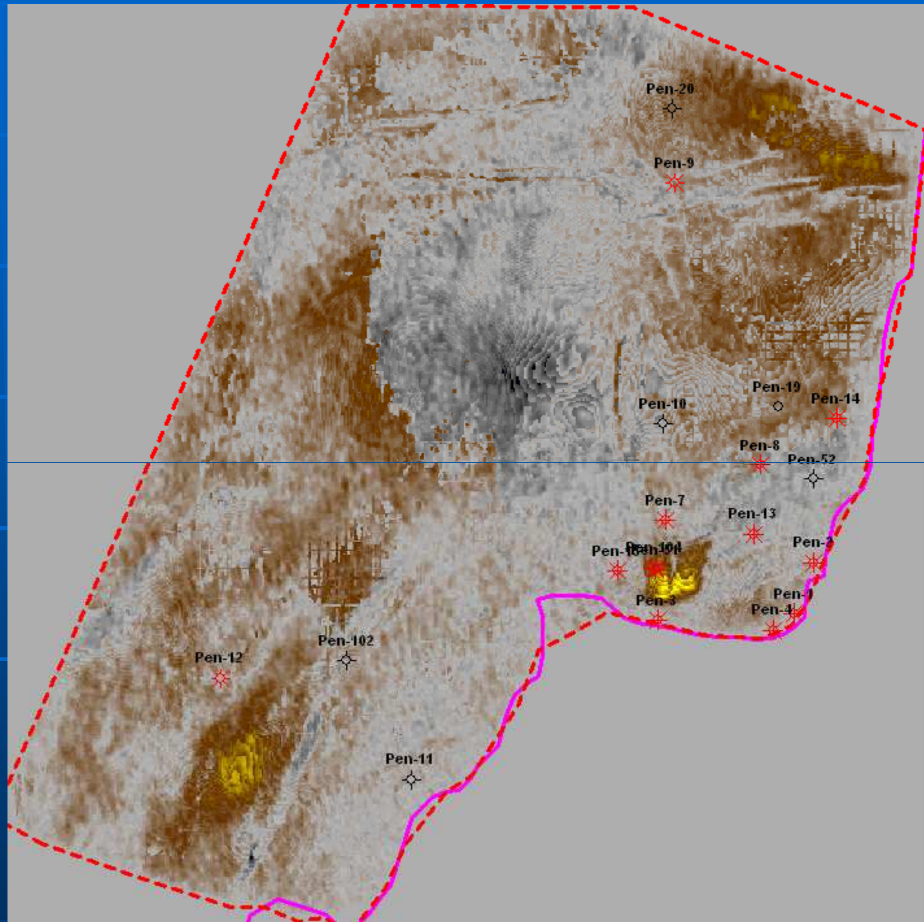
Don’t overlook the potential of small satellite accumulations

Penészlek P104 satellite field

- Surveys of the 2005 seismic campaign indicated an amplitude anomaly in the lower pannonian sequence above the Penészlek field
- AVO analysis confirmed the possibility of a gas accumulation
- Pen-104 well (2006) tested gas from a 4m thick lower pannonian sandstone (~90.000 m3/d)

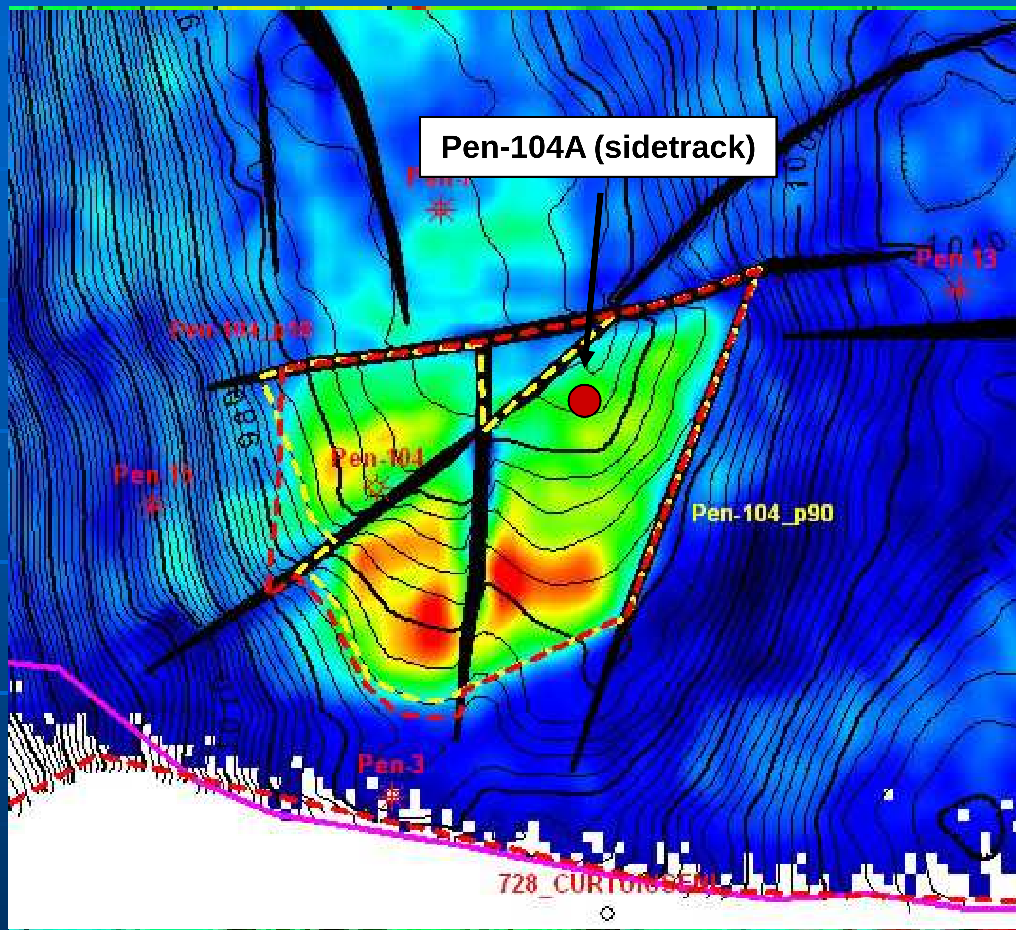


Horizontal slicing along the Pen104 pannonian sand



Development of the Penészlek P104 satellite field

- Pen-104 was based on a simple structural view obtained from 2D mapping
- After a while water-cut significantly increased and the well was prematurely shut-down
- New 3D seismic data provided a detailed structural understanding of the reservoir and revealed that Pen-104 production volumes were matching the gas volumes of the western block indicating that the N-S running fault is a flow barrier
- Pen-104A sidetracked into an optimal position of the eastern block and confirmed the presence of gas
- The reservoir has very high permeability and an active water-drive confirmed by pressure data
- To outrun the water the wells were pulled as hard as the surface facility allowed resulting in 75% recovery



Conclusion: in the current gas market with a detailed understanding of the reservoir behaviour and the structural setting even a few bcf gas reservoir can be economic to produce. The wells generated enough income to pay for all exploration and development costs and made the project self-sustainable

Summary & Conclusions

- A detailed depositional reservoir model of the sedimentary sequence is required to successfully develop a reservoir with complex lithology
- To achieve this however a very clear structural view as well as a detailed geological/geochemical knowledge of the reservoir is required, which can only be achieved by the integration of modern geochemical-, geological-, and 3D seismic techniques
- By developing of the P104 and Fülöp-North accumulations in the Penészlek area PetroHungaria has showed that this exploration strategy is although weary but rewarding on the long term, and that small, by-passed hydrocarbon accumulations in the 1000-1400m depth range of Pannonian Basin can be developed economically

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Thank you for your attention