

Lukoil improves drilling performance in Black Sea with integrated real-time technology and virtual teams

Timur Kasumov
Head of Complex Drilling Projects Division
Well Construction Department
LUKOIL



What's Next?

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Schlumberger

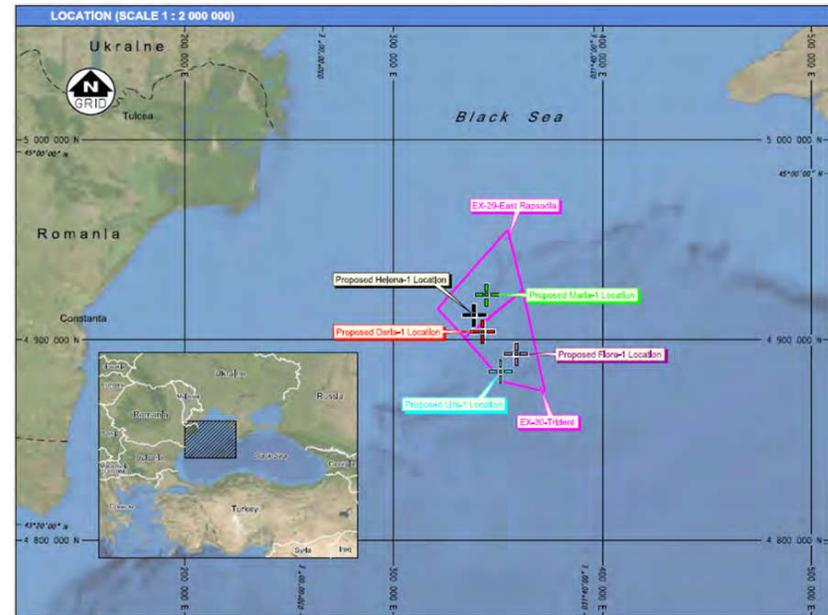
Summary

In 2015 Lukoil has drilled three exploration wells in the Black Sea offshore Romania.

The area is geologically complicated with significant lateral changes that limit the predictability from other wells.

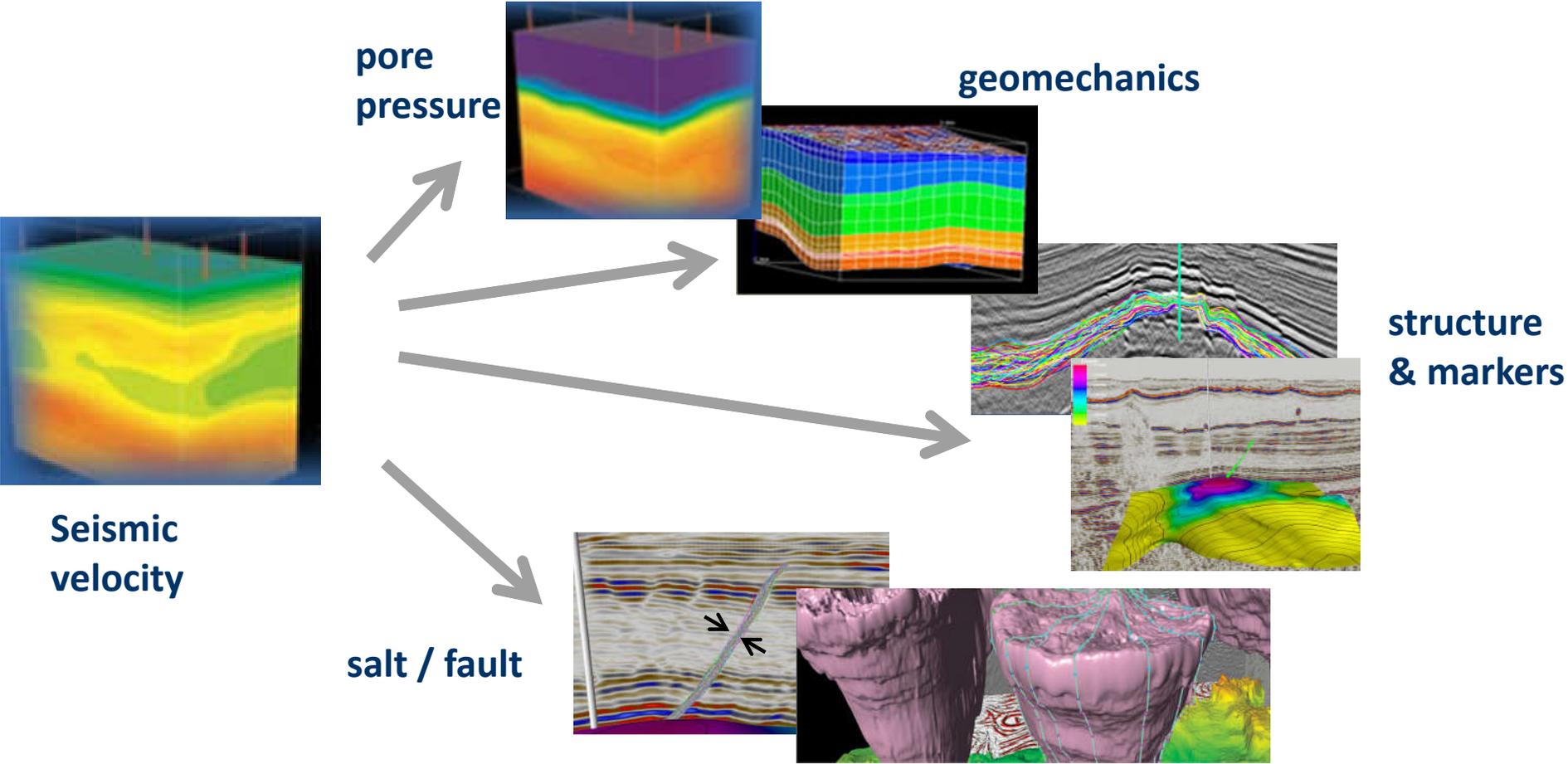
To address these challenges, in two of these wells, Lukoil integrated Schlumberger's Seismic Guided Drilling (SGD*) technology with real-time services producing a "live" drilling model updated with new drilling information predicting ahead of the bit.

The results were a significant improvement in AFE and schedule compared with the prior well drilled conventionally.

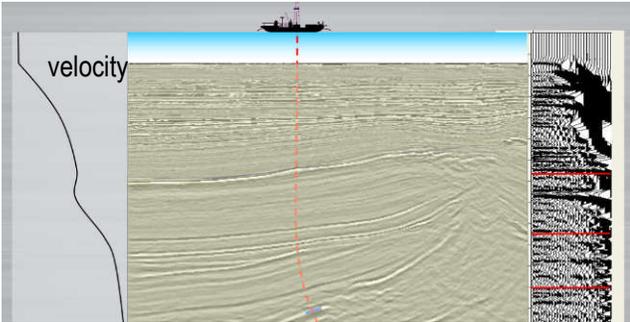


*Mark of Schlumberger

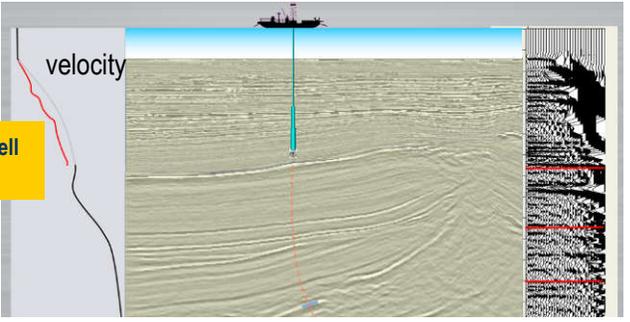
Seismic velocity drives all properties of a drilling model



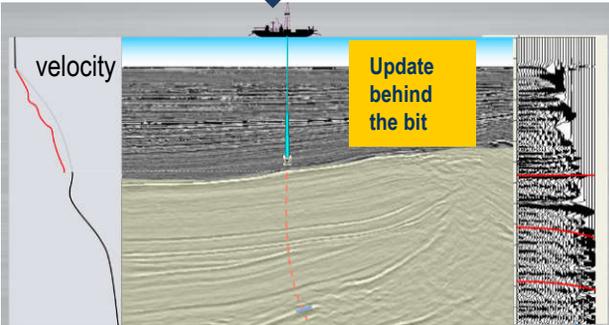
While-drilling model update with SGD



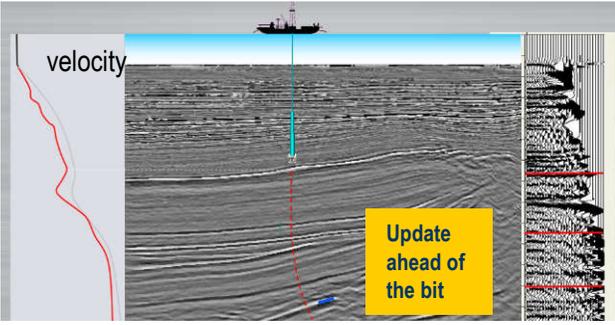
(1) Build pre-drill 3D earth model



(2) Acquire checkshot / logs while drilling



(3) Build pre-drill 3D earth model
Update behind the bit – match well data

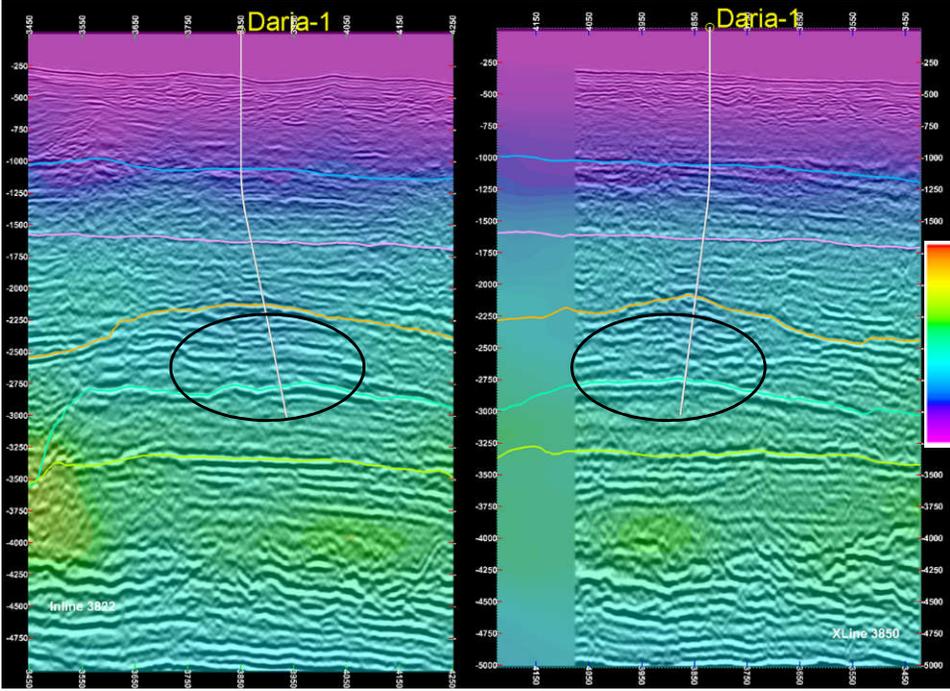


(4) Build pre-drill 3D earth model
Update ahead of the bit – match seismic

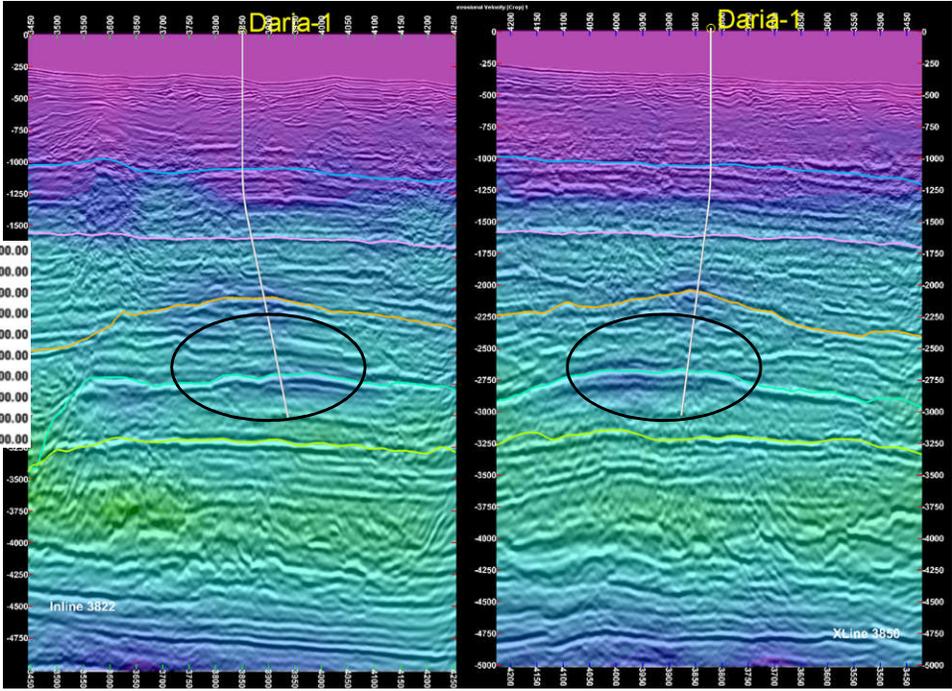


Daria – High-resolution velocities enabled to detect pore pressure ramps

Legacy



SGD



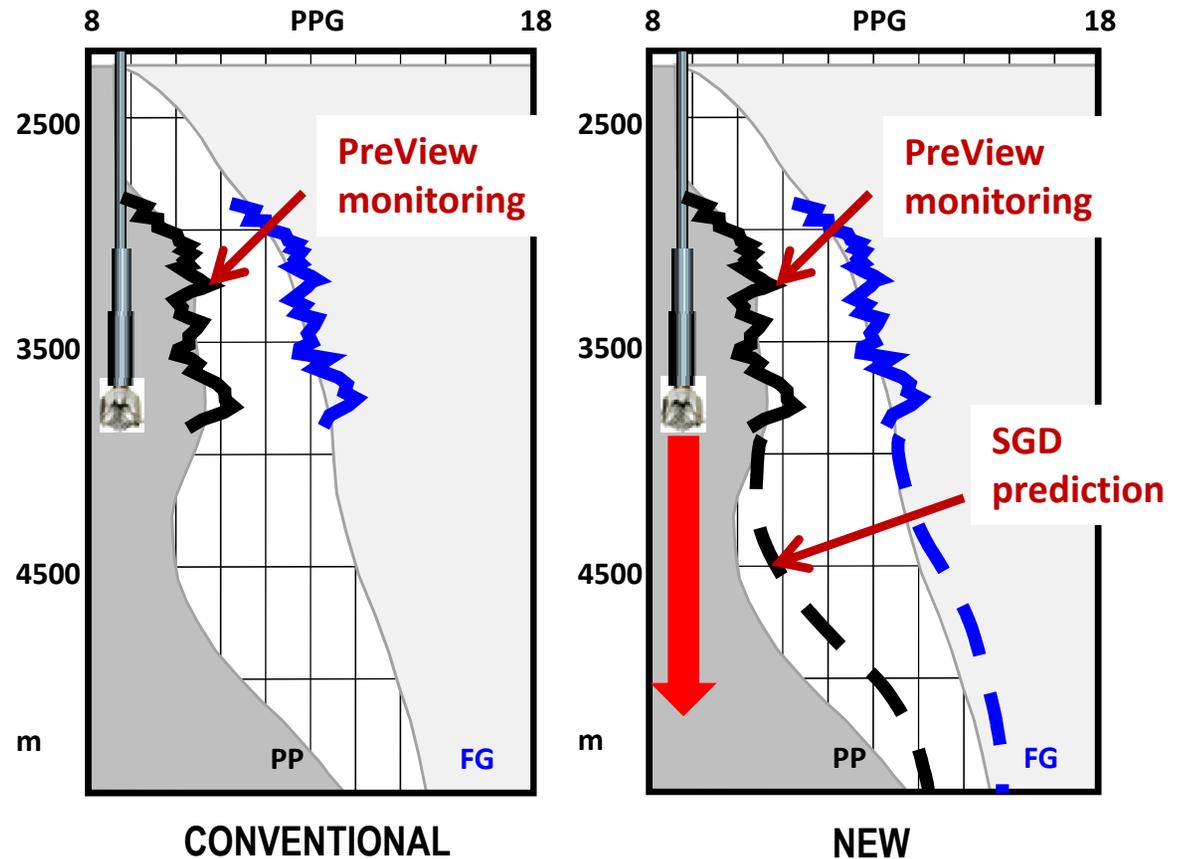
Daria – Integrated pore-pressure management

Conventional PP management

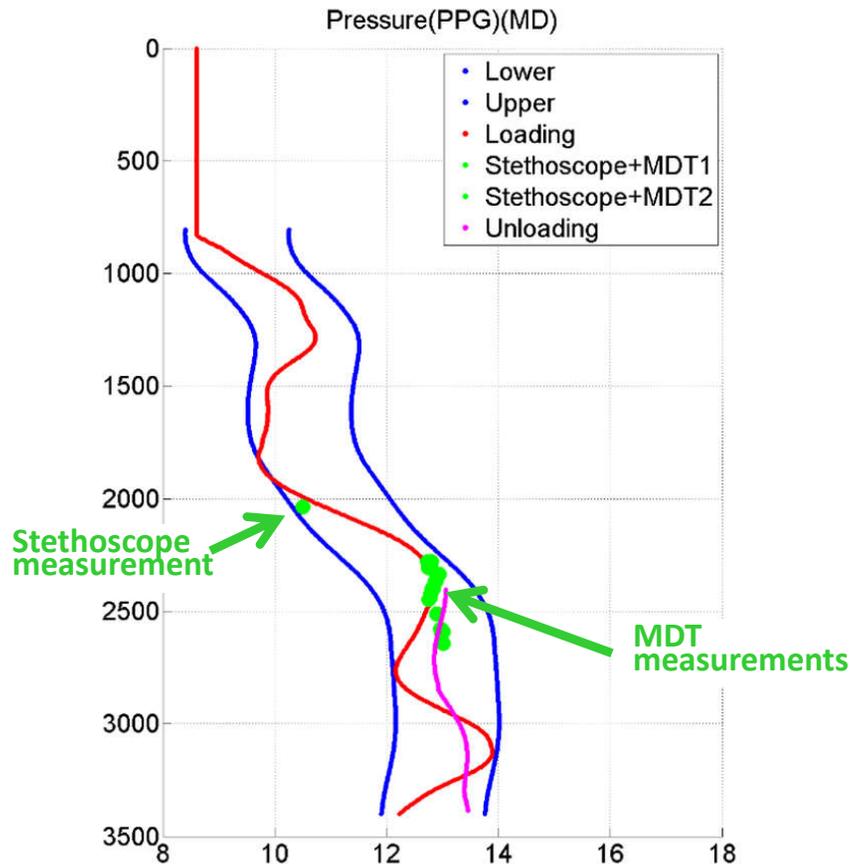
- Monitor PP behind the bit using LWD logs
- Predict PP ahead using unchanged predrill velocity

New Lukoil implementation

- Monitor PP behind the bit using LWD logs
- Predict PP ahead using updated SGD velocity & integrate with monitoring in daily reports

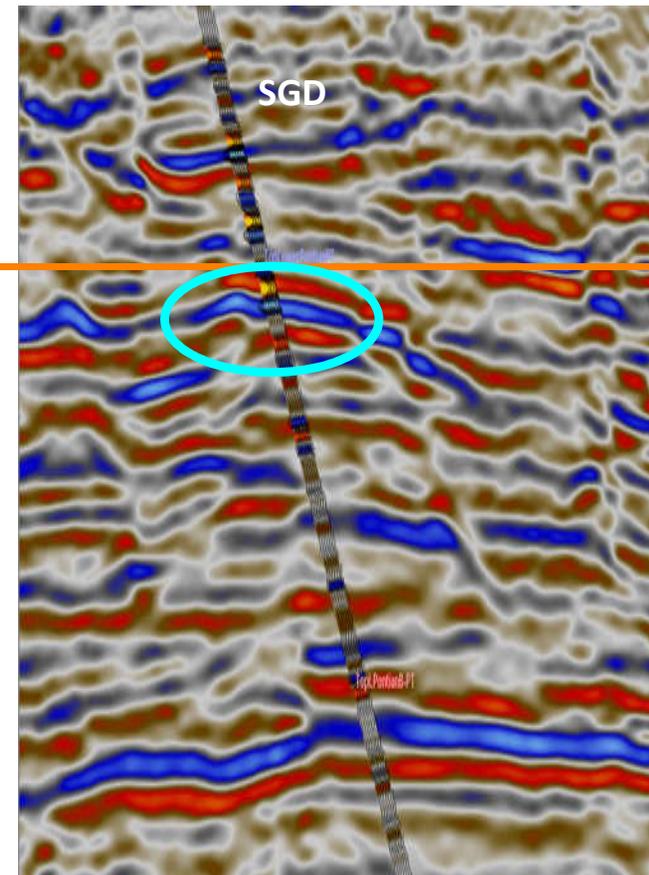
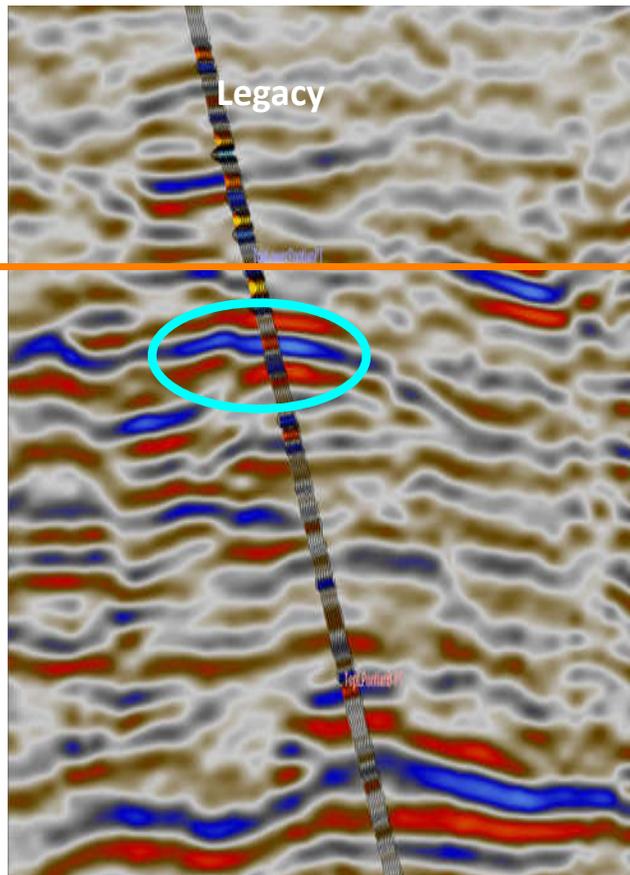


Daria – Pore pressure prediction ahead of the bit

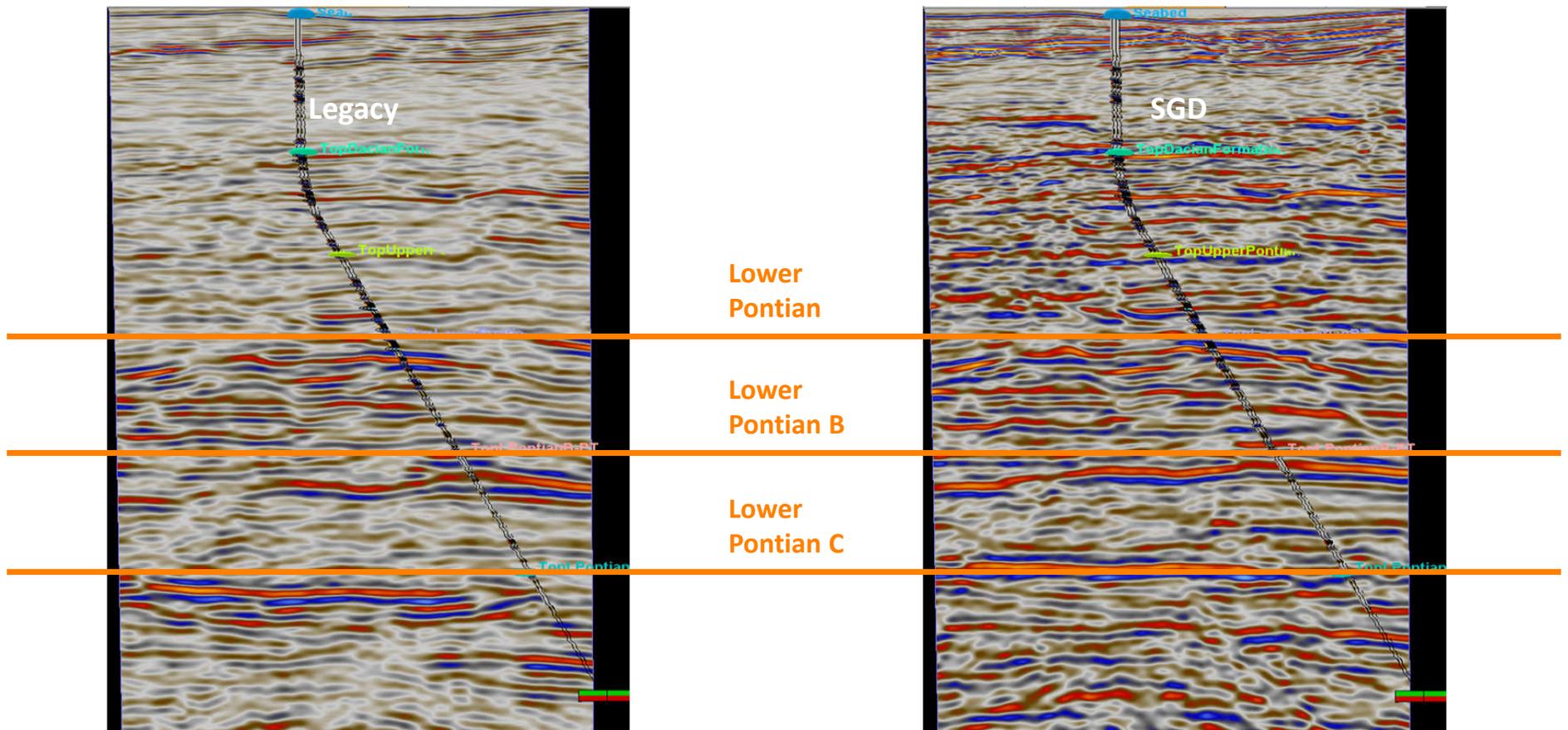


- At ~2000 m depth the velocity model ahead of the bit was updated and the rock physics model calibrated by using the Stethoscope pressure measurement
- Predictions (red and purple curves) showed a steadily increasing pore pressure ramp with a maximum pressure of 13 ppg
- With this information mud weight was adjusted and drilled ahead. The MDT formation pressure measurements at the end of the ramp (green dots) confirmed the predicted pressures.
- Predictions showed pressures remain below 14 ppg down to TD allowing safe and fast drilling ahead

Daria – Primary target depth prognosis improved from 49 m error in legacy to within 5m with SGD

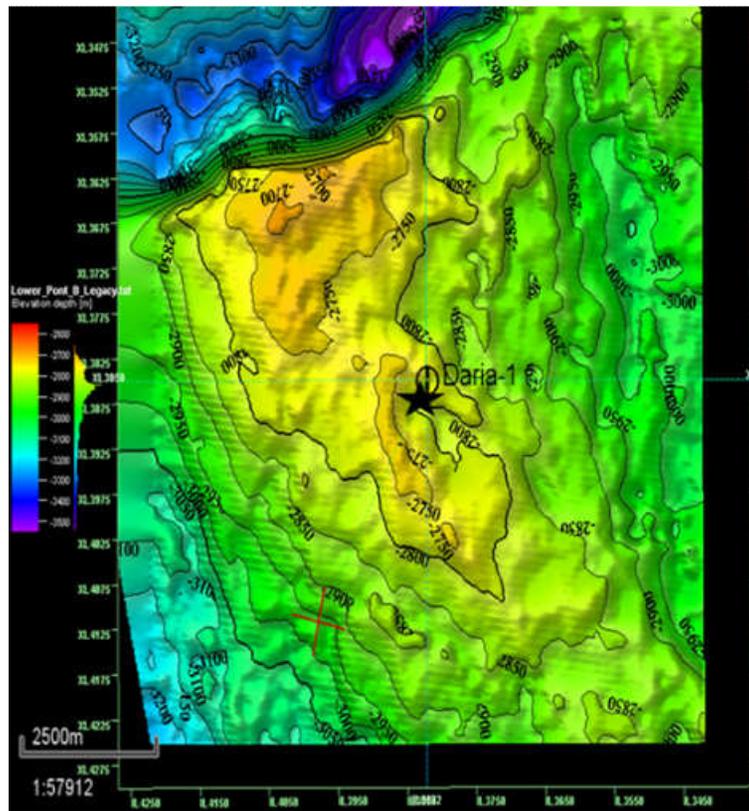


Daria – Three target positions have changed and confirmed with welltops

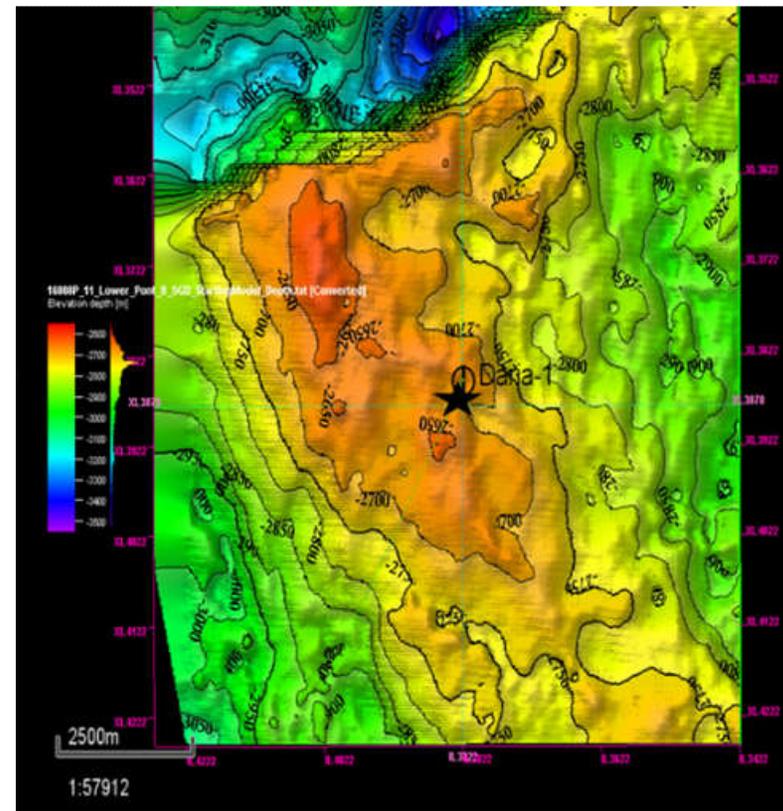


Daria – Structural interpretation of target horizon is better defined

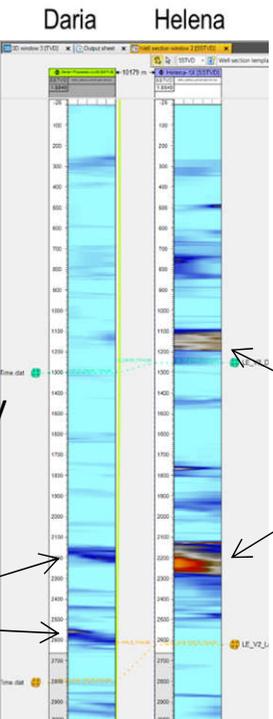
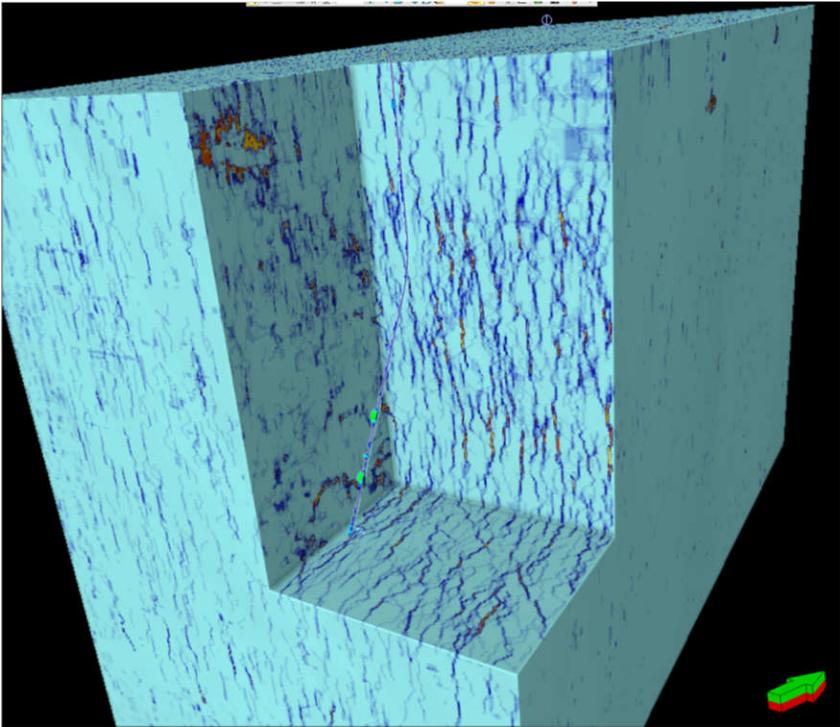
Legacy



SGD



Daria – New information about fracture networks



Daria shows only moderately fractured zones
Helped with mud-weight decisions

Earlier well shows severely fractured zones and had loss issues

Fracture density prediction along the well trajectory

2nd well Lira – similar SGD contributions to the drilling with larger depth corrections

- Predicted benign pressures and predicted low fracture density helped drill ahead the last section confidently to planned TD
- Measured pressure points matched well with SGD look ahead within about 0.25 ppg
- Reservoir position was predicted to within 10 m; compared with 76 m error in legacy
- Structural interpretation changed
- New information provided about fracture networks
- Gather flatness significantly improved and reservoir characterization enabled
- Imaging quality, clarity, and focusing of faults improved

Virtual team execution

Bucharest

- Lukoil operations teams for the wells
- Schlumberger drilling, well logging, data analysis, project management and geomarket teams

Moscow

- Lukoil HQ technical reviews
- Schlumberger inversion team

Houston

- Lukoil Overseas seismic technical supervision
- Schlumberger Earth Model Building and rock-physics teams
- Schlumberger real-time supervision

Pau

- Geomechanics model team



Conclusions

- Black Sea offshore Romania, with complicated geology and unexpected formation pressures changes, presented many challenges to drilling operations in three wells
- Two of these wells employed the Seismic Guided Drilling (SGD) technology based on Omega/Petrel platform with multidisciplinary virtual teams spread over three continents
- In these two wells pore-pressures changes ahead of the bit were successfully predicted and used in casing point and mud-weight decisions. Predictions were confirmed with later formation pressure measurements
- Target depths ahead of the bit were corrected in the first well by more than 40 m and in the second well by more than 60 m
- Both of these wells were completed at or ahead of AFE and schedule whereas conventionally drilled first well had significant delays due to uncertainties in geology