

# Accurate reservoir description and well placement using zone logs, DDR data, and depth to a fluid contact

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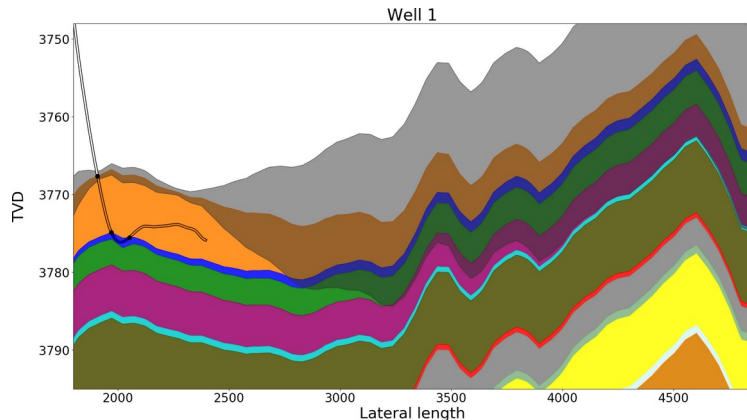
Geosteering and Formation Evaluation Workshop

Sola Strandhotell, Nov. 1 2022



# Outline of talk

- ▶ A realistic surface model is important for geosteering
- ▶ A realistic surface model must incorporate data uncertainties
- ▶ Stochastic description of surfaces and wells
- ▶ Enhancing depth predictions by successively adding more advanced types of well data
- ▶ A simulated drilling
- ▶ Summary



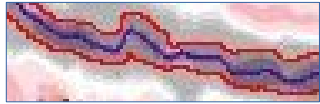
# A good surface model may be important when geosteering



The average drilling  
cost in the North Sea  
In 2018:

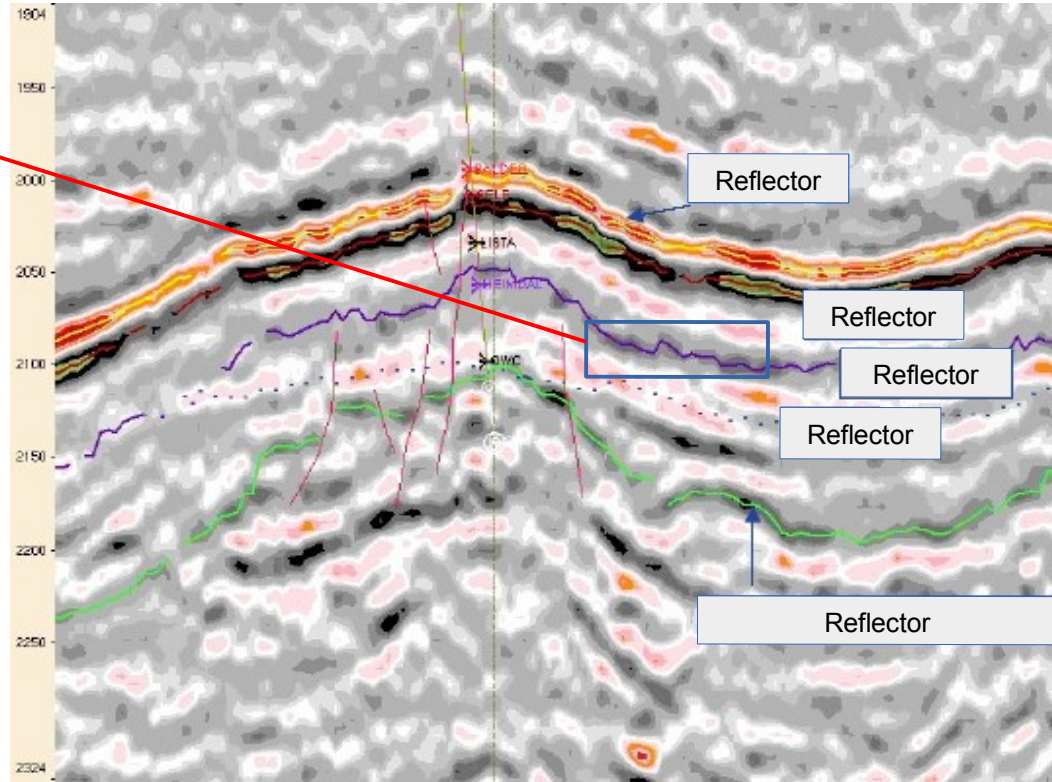
30 mill USD

# The time interpretation is uncertain



$$t \rightarrow t(x) + \varepsilon(x)$$

$\varepsilon(x)$  = uncertainty



# The velocity model is uncertain

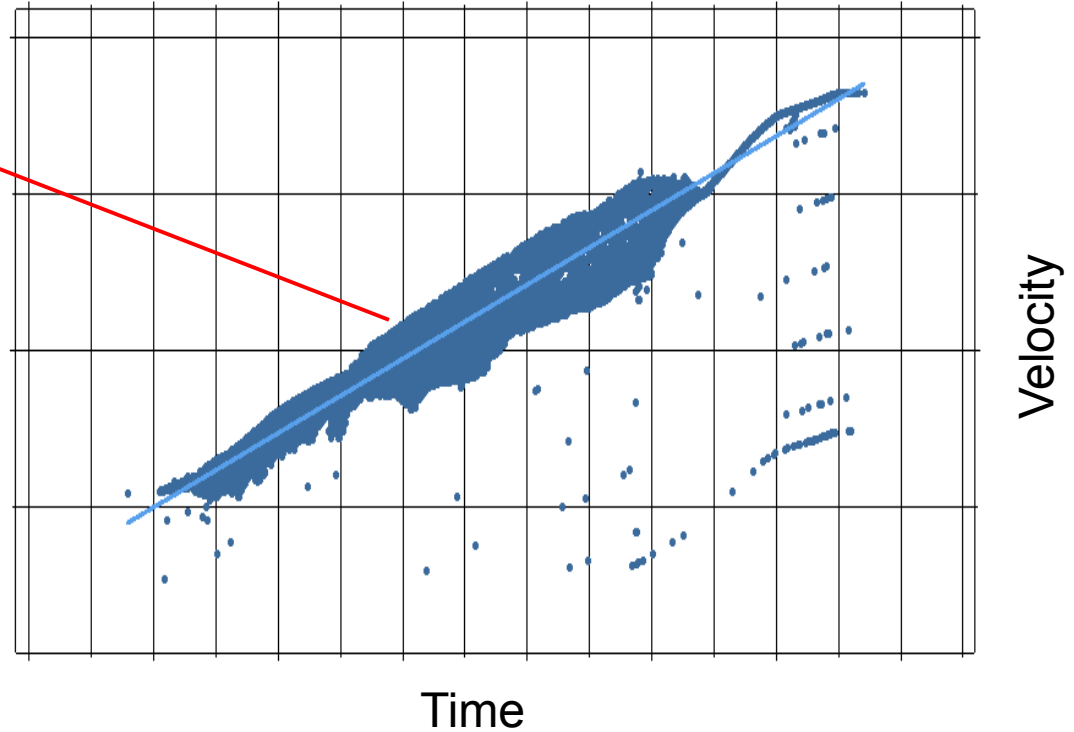
Seismic velocities

$$v = a + b \cdot t(x)$$



$$v = a + b \cdot t(x) + \varepsilon(x)$$

$\varepsilon(x)$  = uncertainty



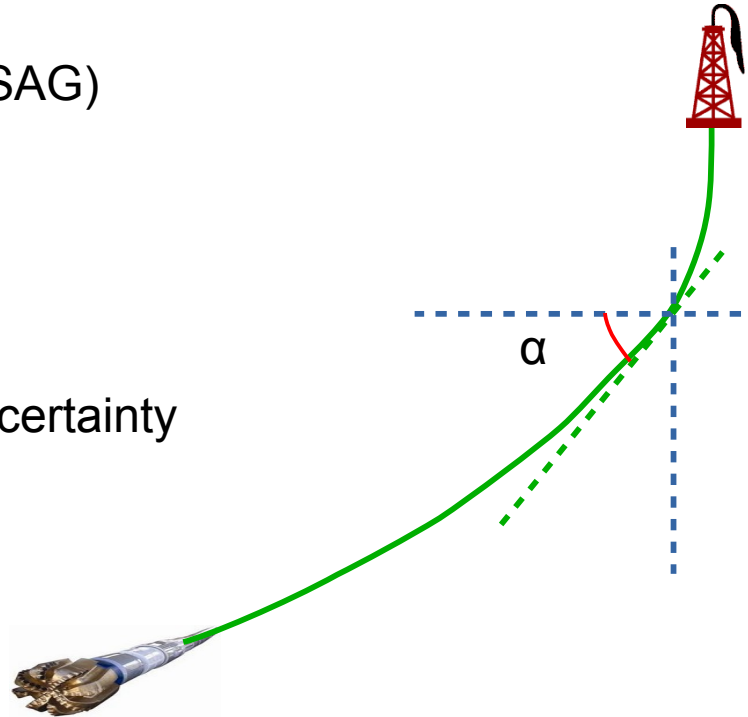
# The well path is uncertain

## Main uncertainties

- ▶ Sensors pointing in wrong direction (SAG)
- ▶ Uncertainty in compass
- ▶ Uncertainty in measured depth
- ▶ Magnetization of steel pipes

For a horizontal well of 10 km the vertical uncertainty may be 50 feet / 17 meters in the toe

$$z \rightarrow z(\text{MD}) + \varepsilon(\text{MD})$$

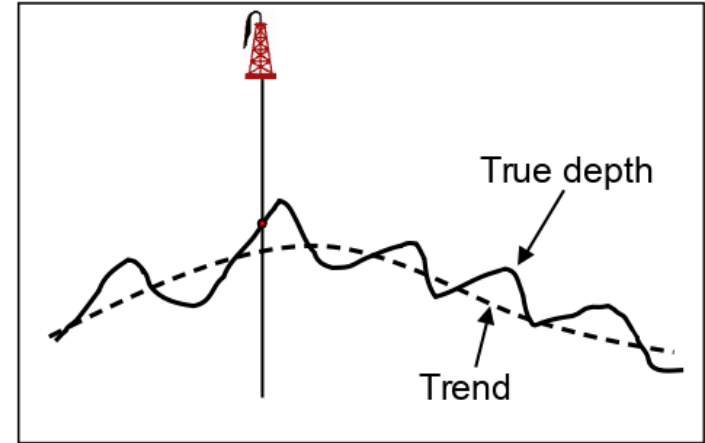


# The uncertainty can be integrated using stochastic modelling

Main idea: Depth = Trend + Residual

- ▶ Trends
  - Time interpretations, velocity trends
  - Geological interpretations (isochores, etc)
- ▶ Residual
  - Random variation (Gaussian Random Field)

$$\varepsilon \rightarrow N(0, \sigma)$$

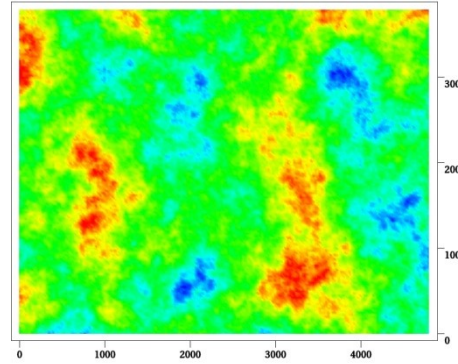


- ▶ Trends and residuals given well data can be estimated using kriging

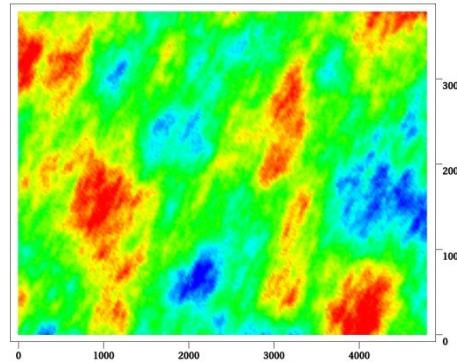
# The Gaussian Random Field defines the spatial structure

Characterized by

- ▶ Correlation function type
- ▶ Standard deviation
- ▶ Range
- ▶ Anisotropy



Spherical



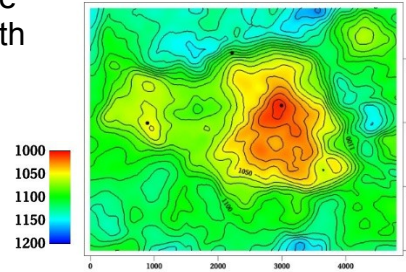
Spherical with  
anisotropy



# Kriging approach gives predictions and stochastic realizations

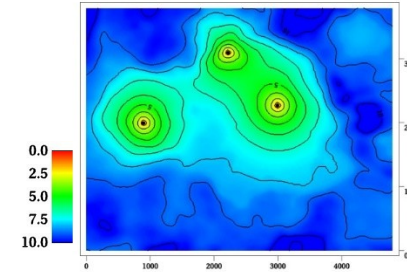
## Prediction

- “Most likely” given data and assumptions
- Unique
- Smooth



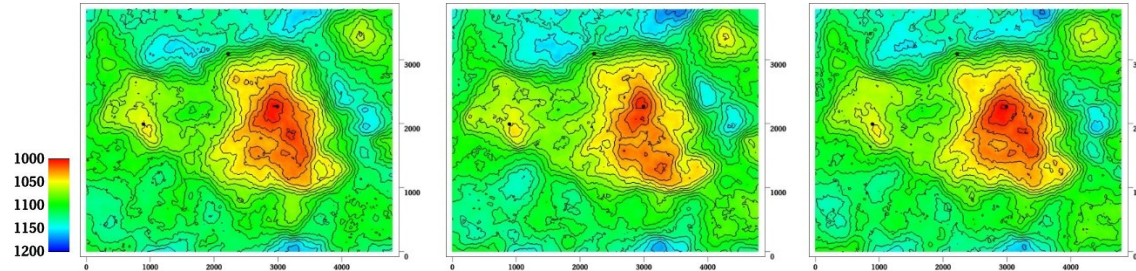
## Prediction uncertainty

*Local* uncertainty



## Stochastic realization

- Realistic variability
- A *set* represent spatial uncertainty

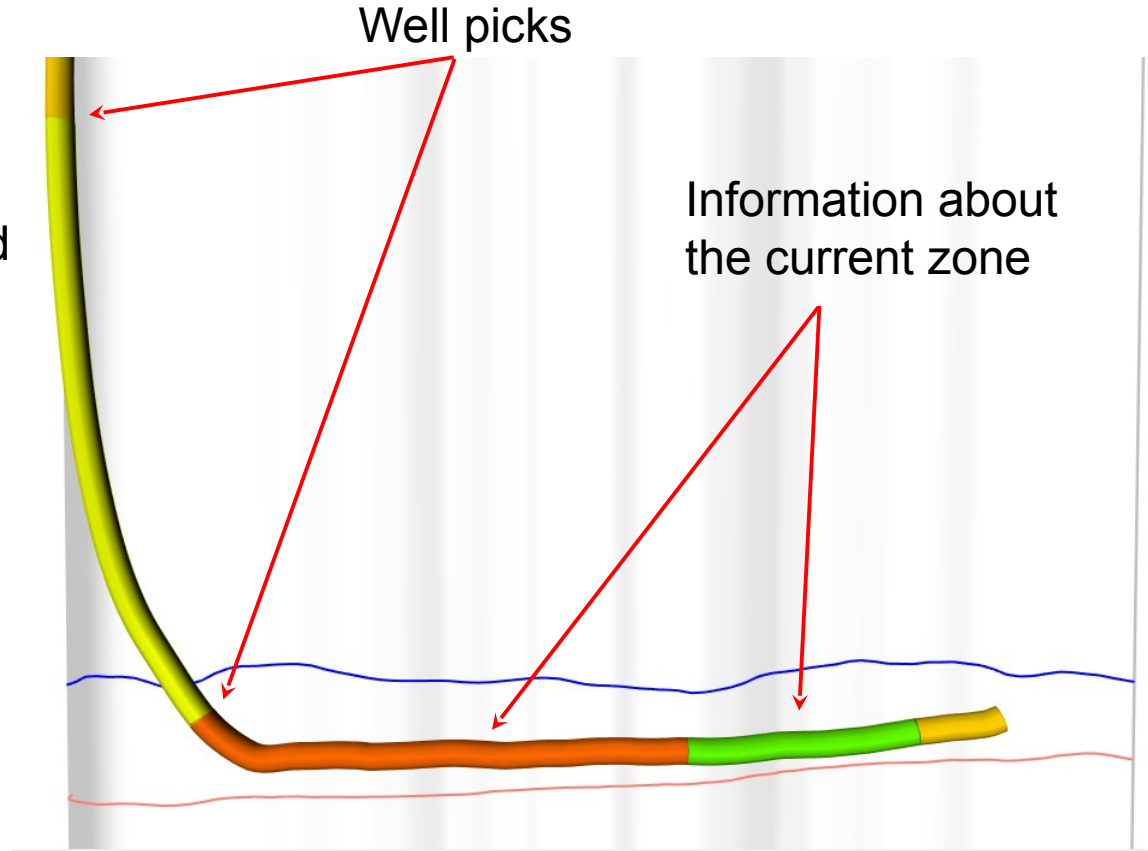


# Well data: Zone logs and well picks

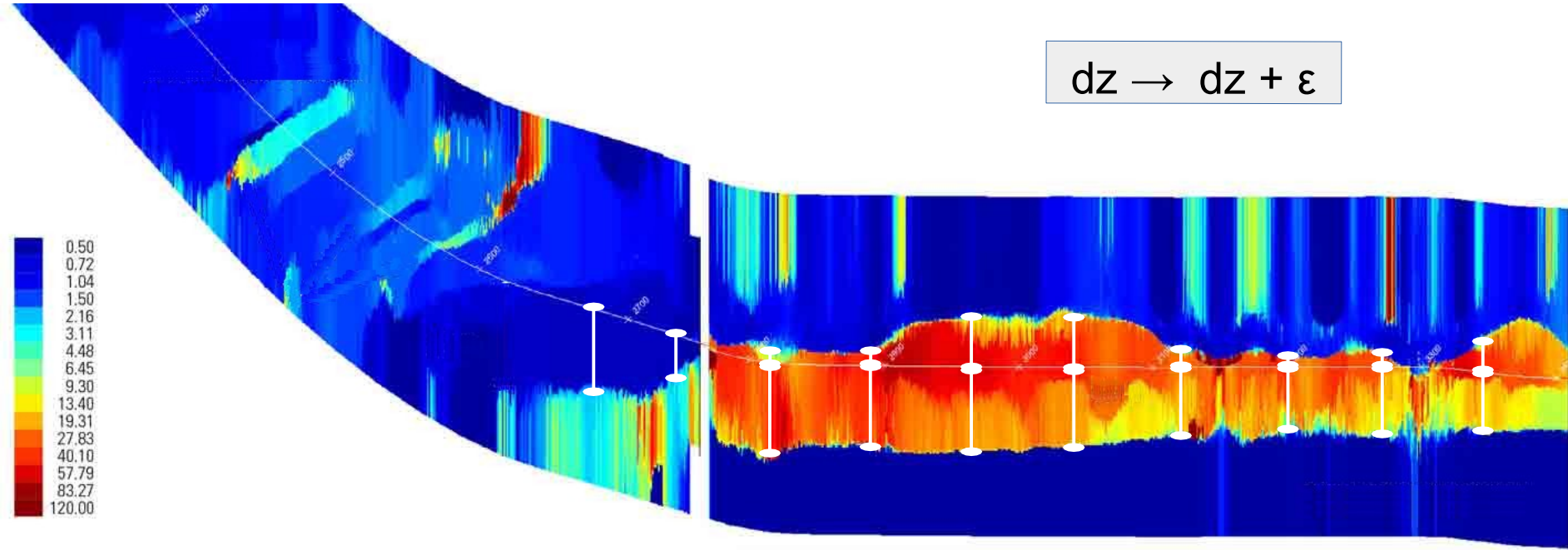
A well pick marks a zone transition

Each pick has an associated pick uncertainty

$$z \rightarrow z + \epsilon$$

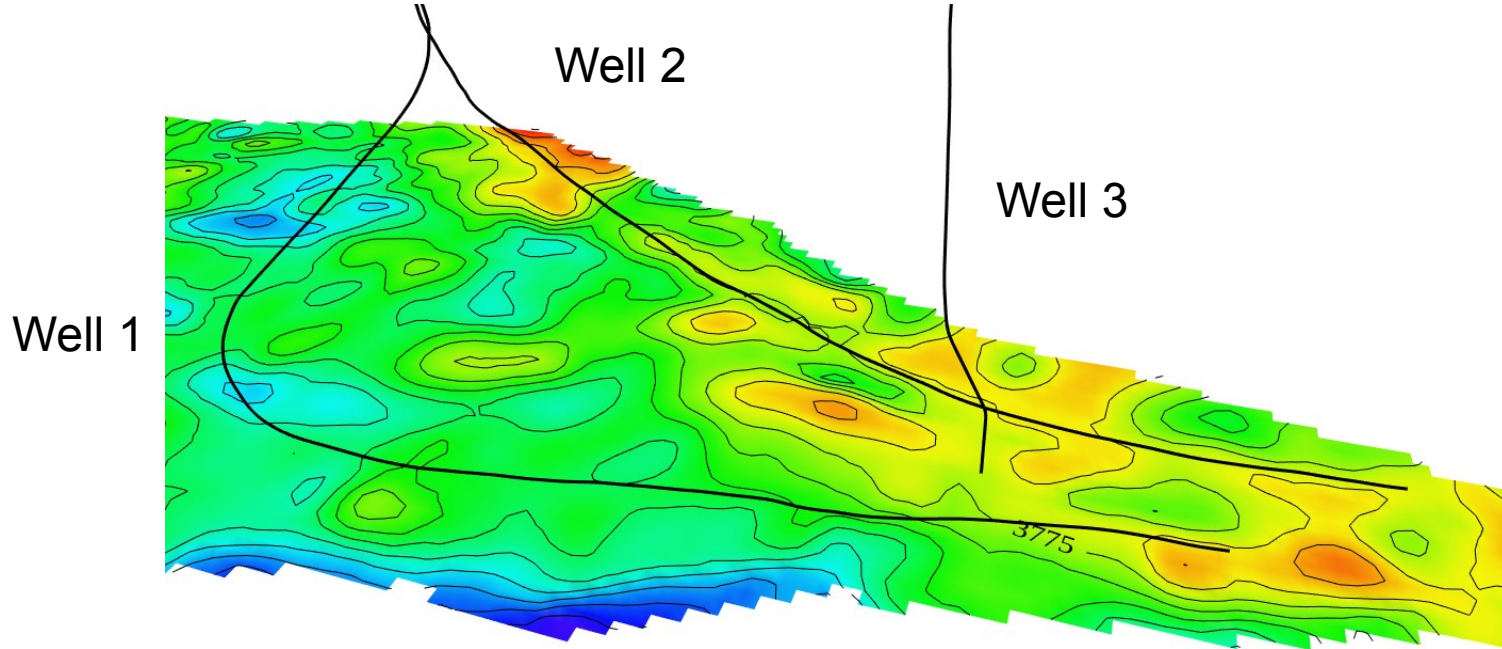


# Well data: Deep-Directional Resistivity (DDR) measurements



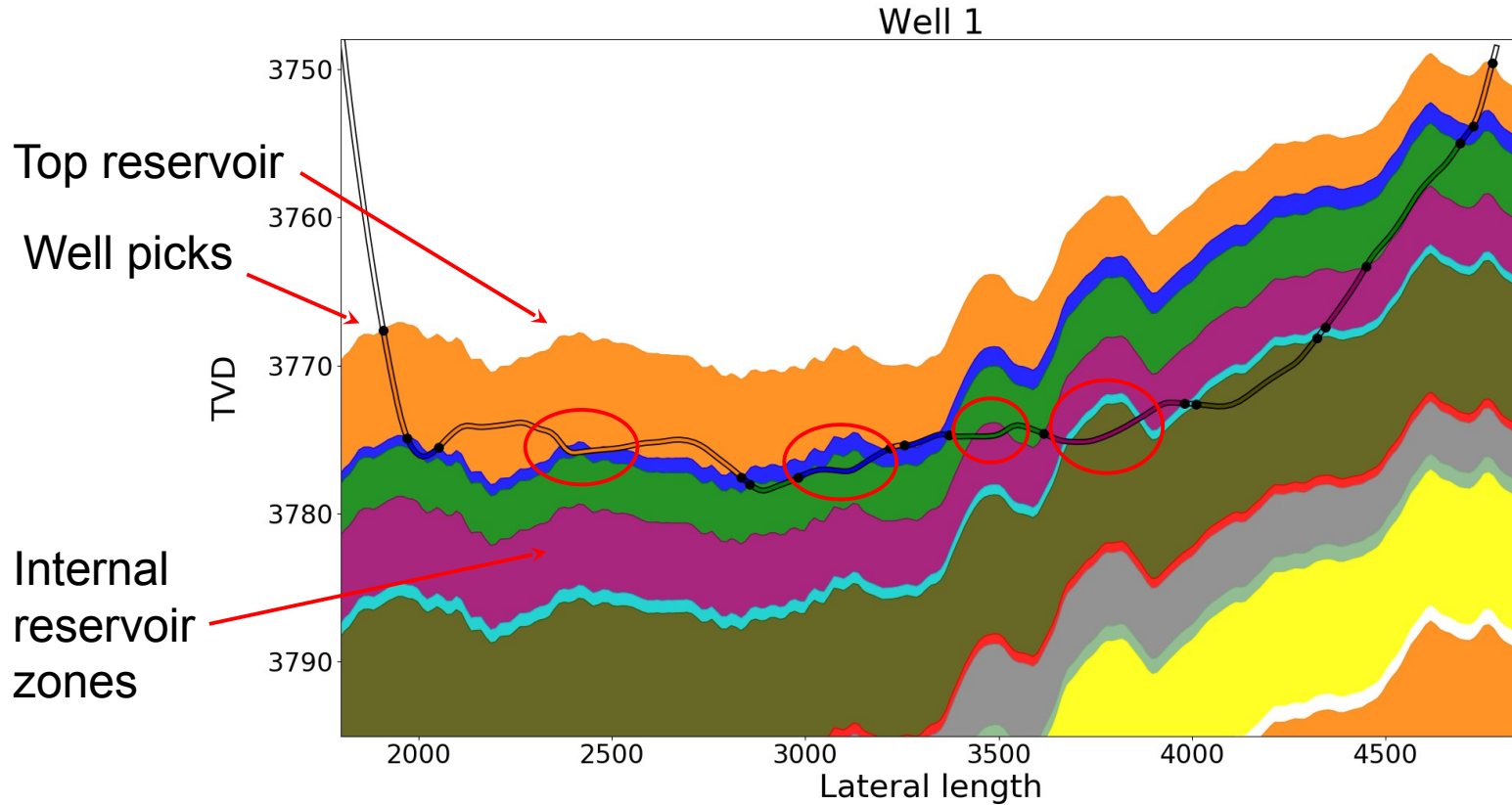
[Geosphere: Schlumberger case study from web site]

# Case study: Enhancing depth predictions by successively adding more types of well data

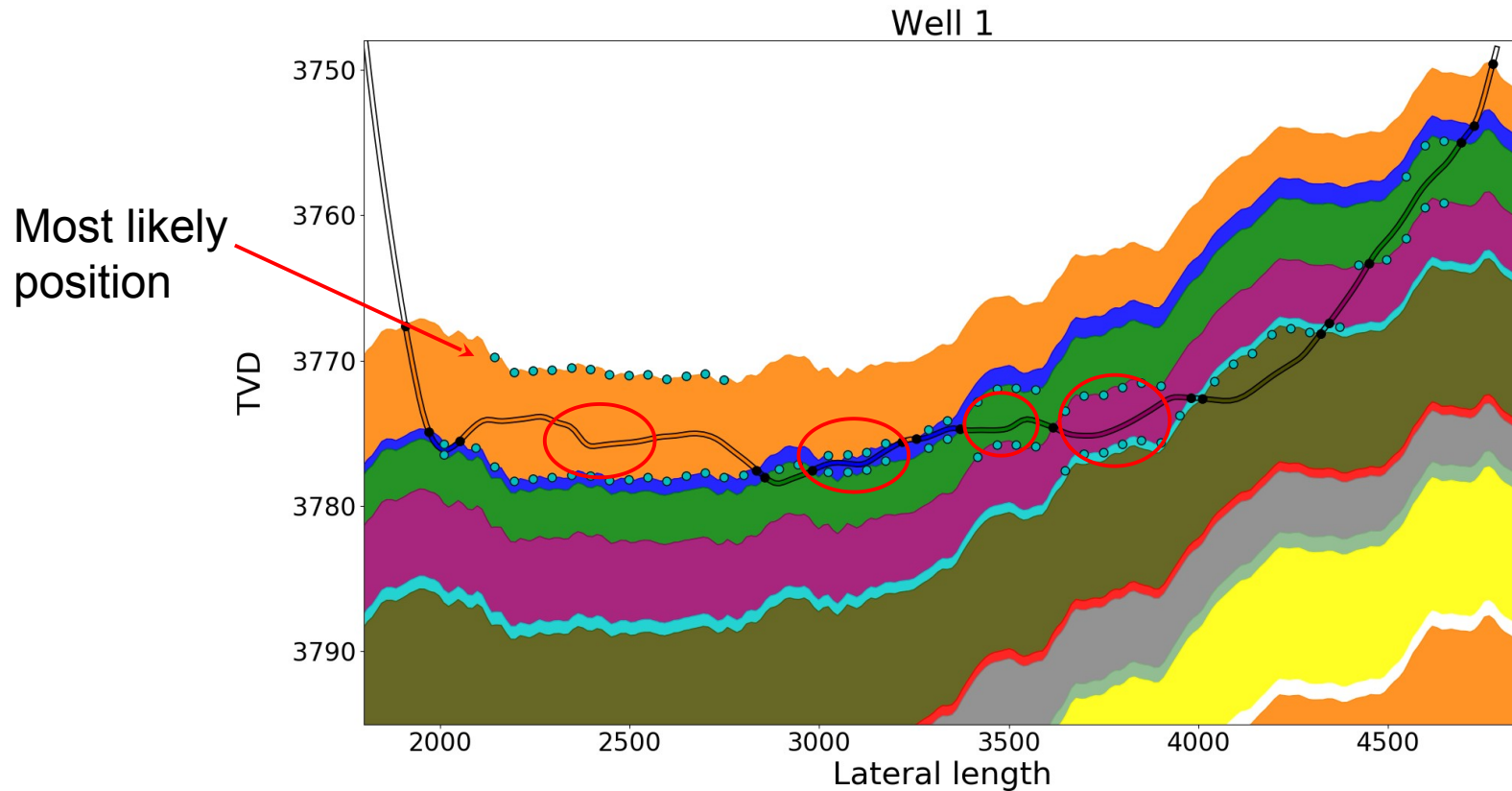


# Well 1

# Adjust surfaces to well picks

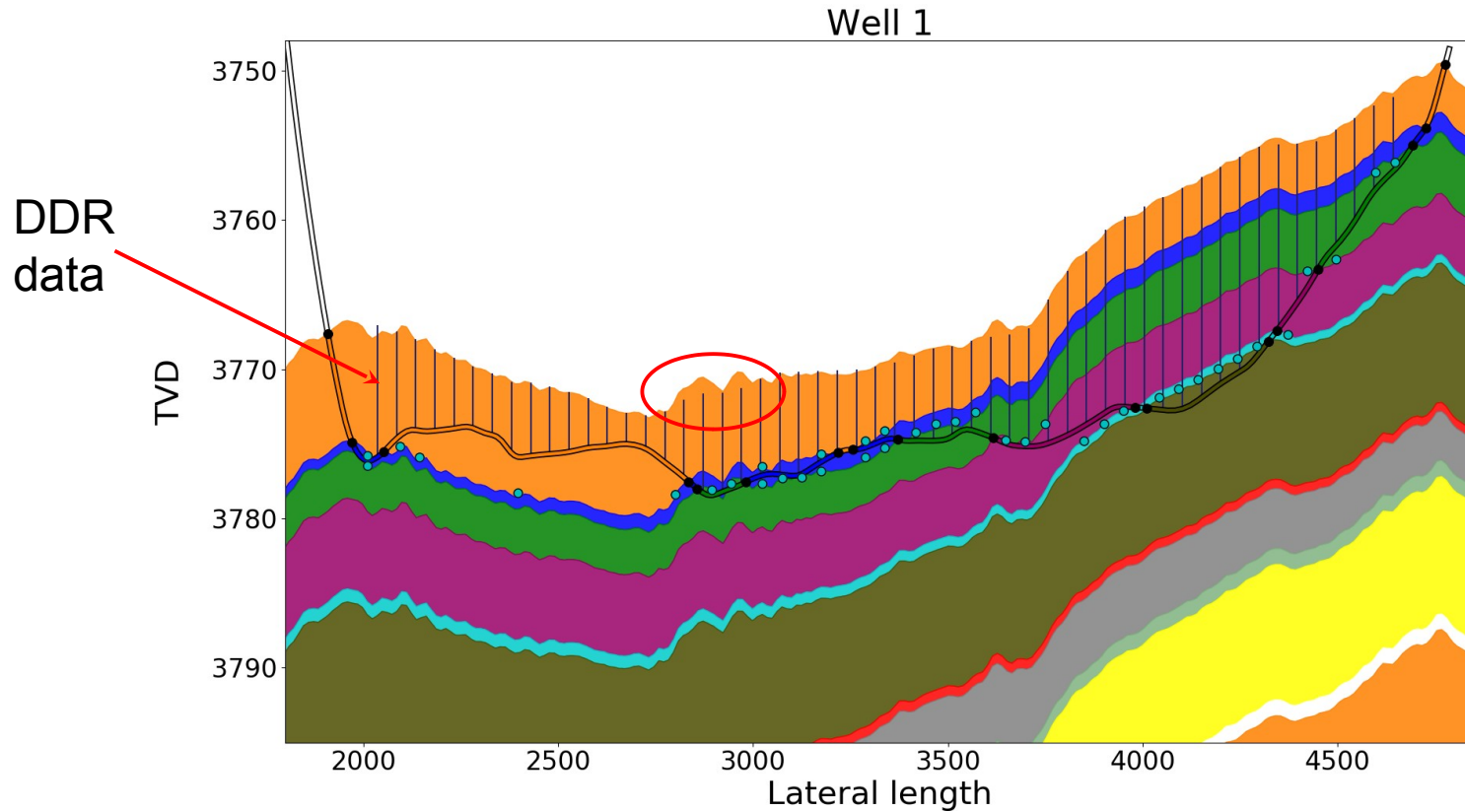


# Adjust surfaces to well picks + zone logs



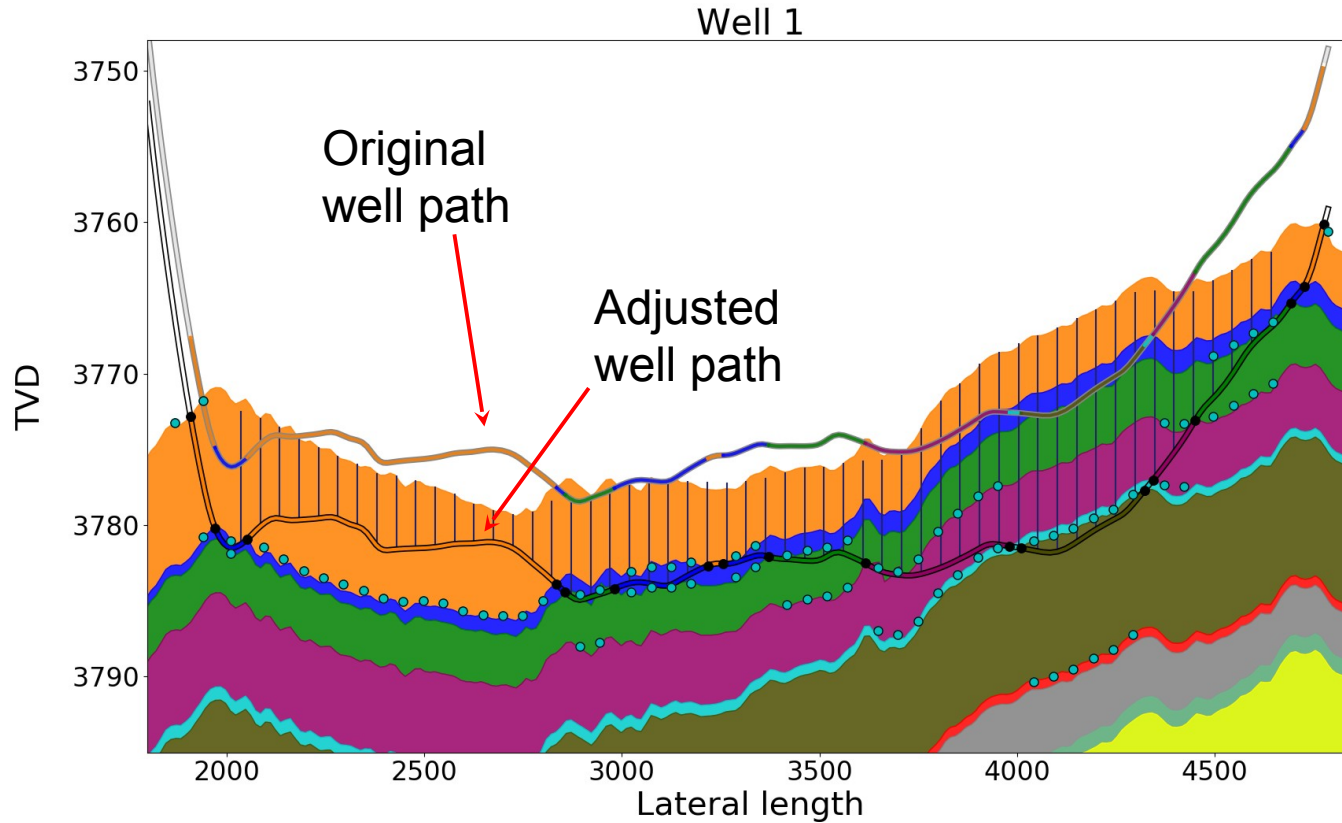


# Adjust surfaces to well picks + zone logs + DDR data

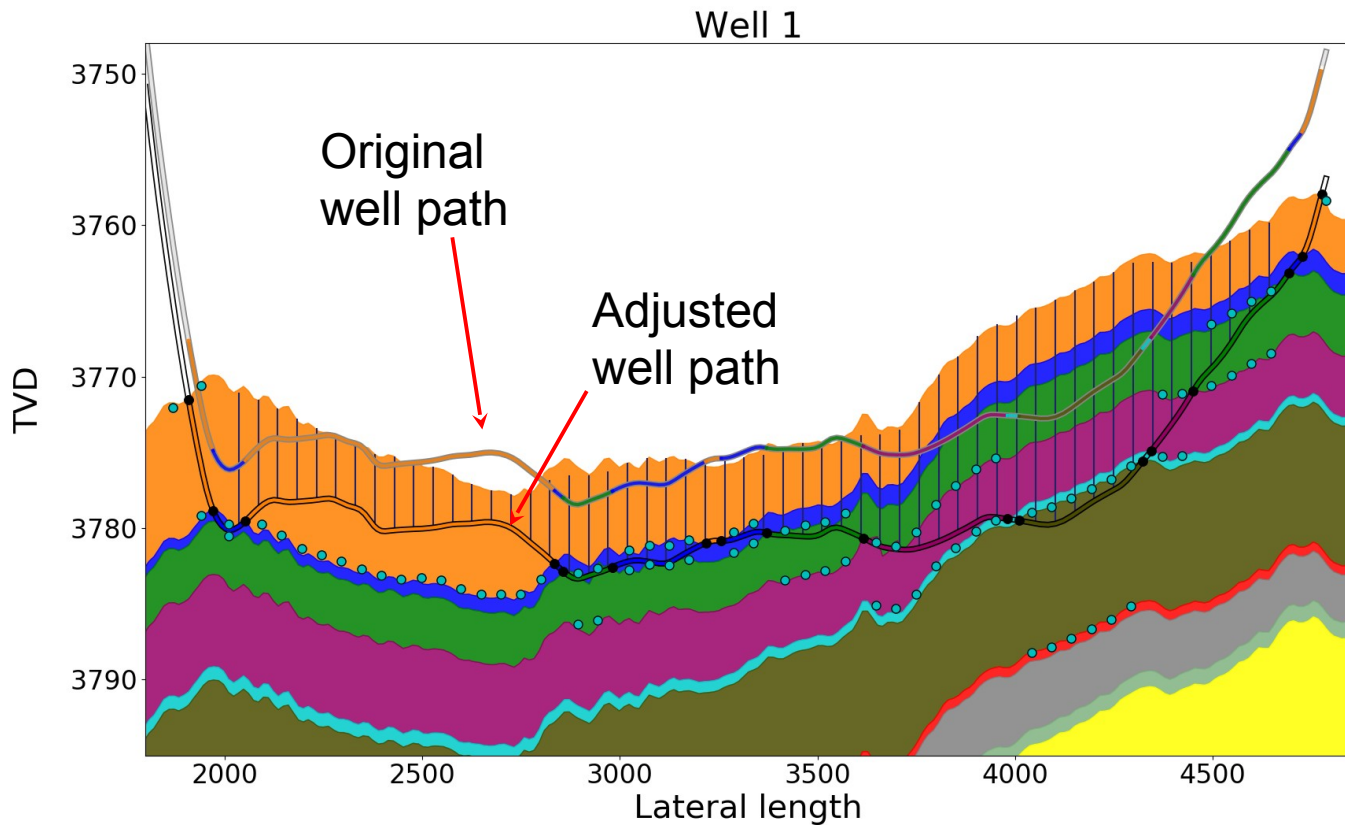




# Adjust surfaces and wells to well picks + zone logs + DDR data

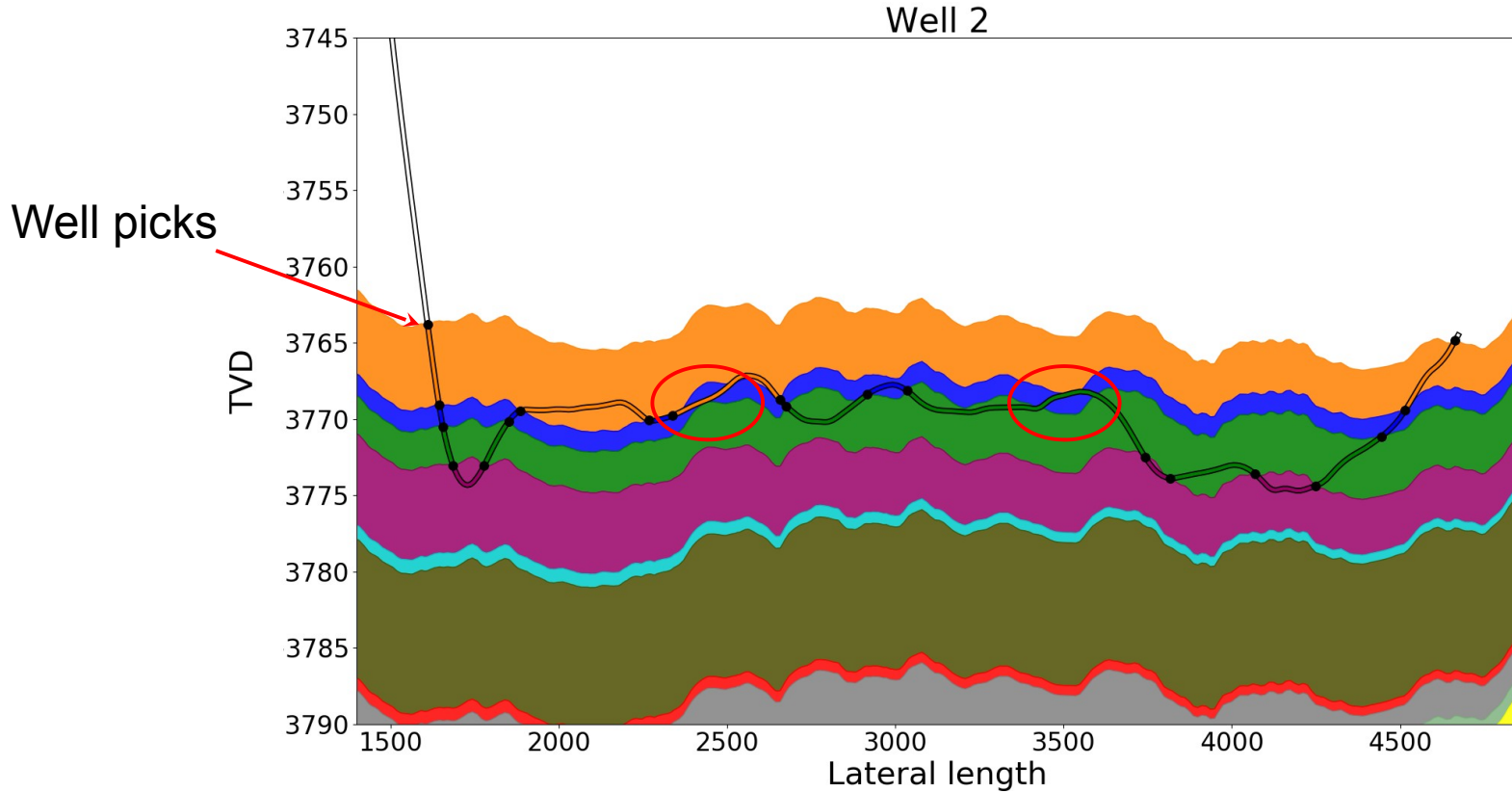


# Adjust surfaces and wells to well picks + zone logs + DDK data + contact

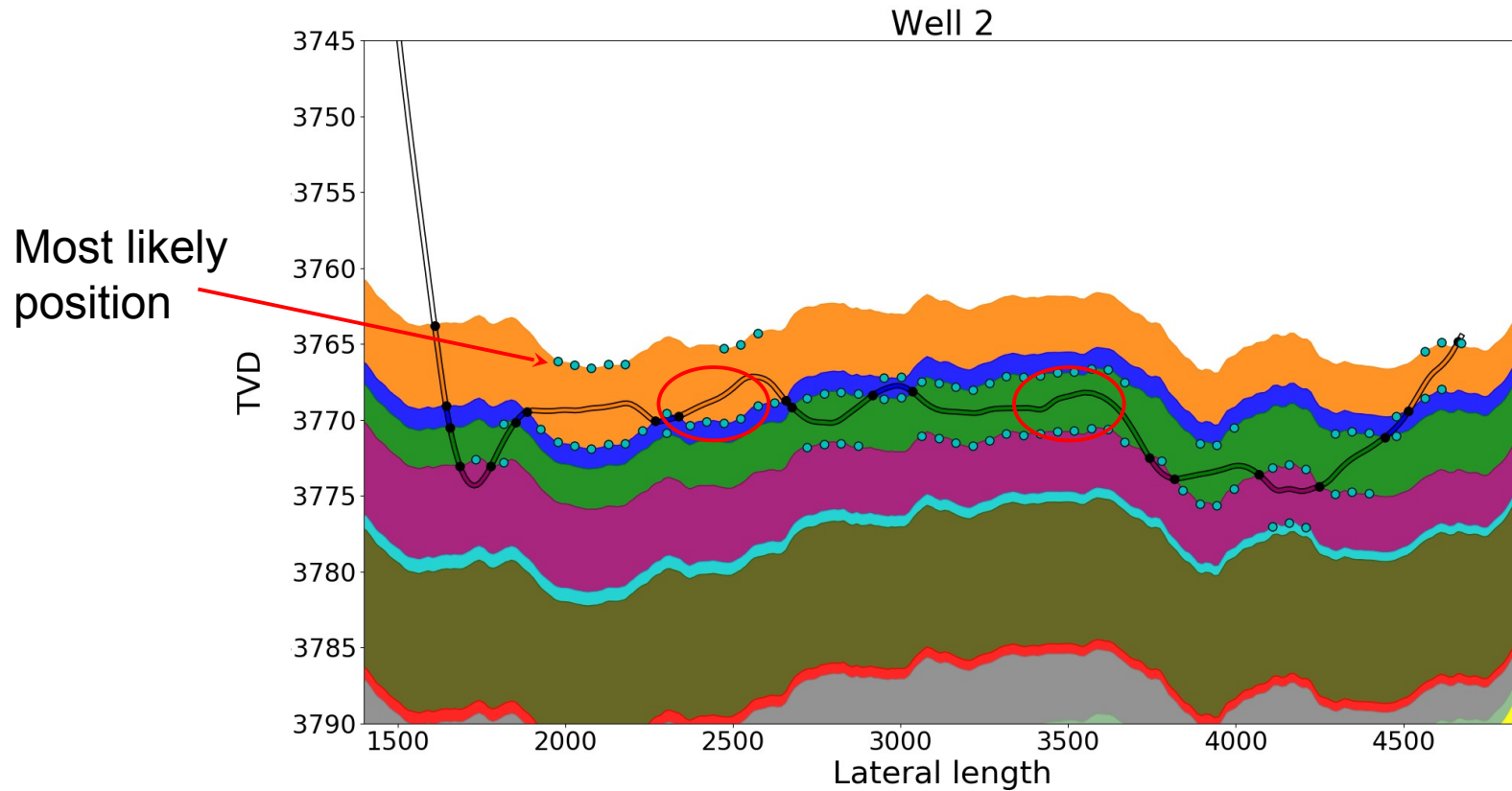


## **Well 2**

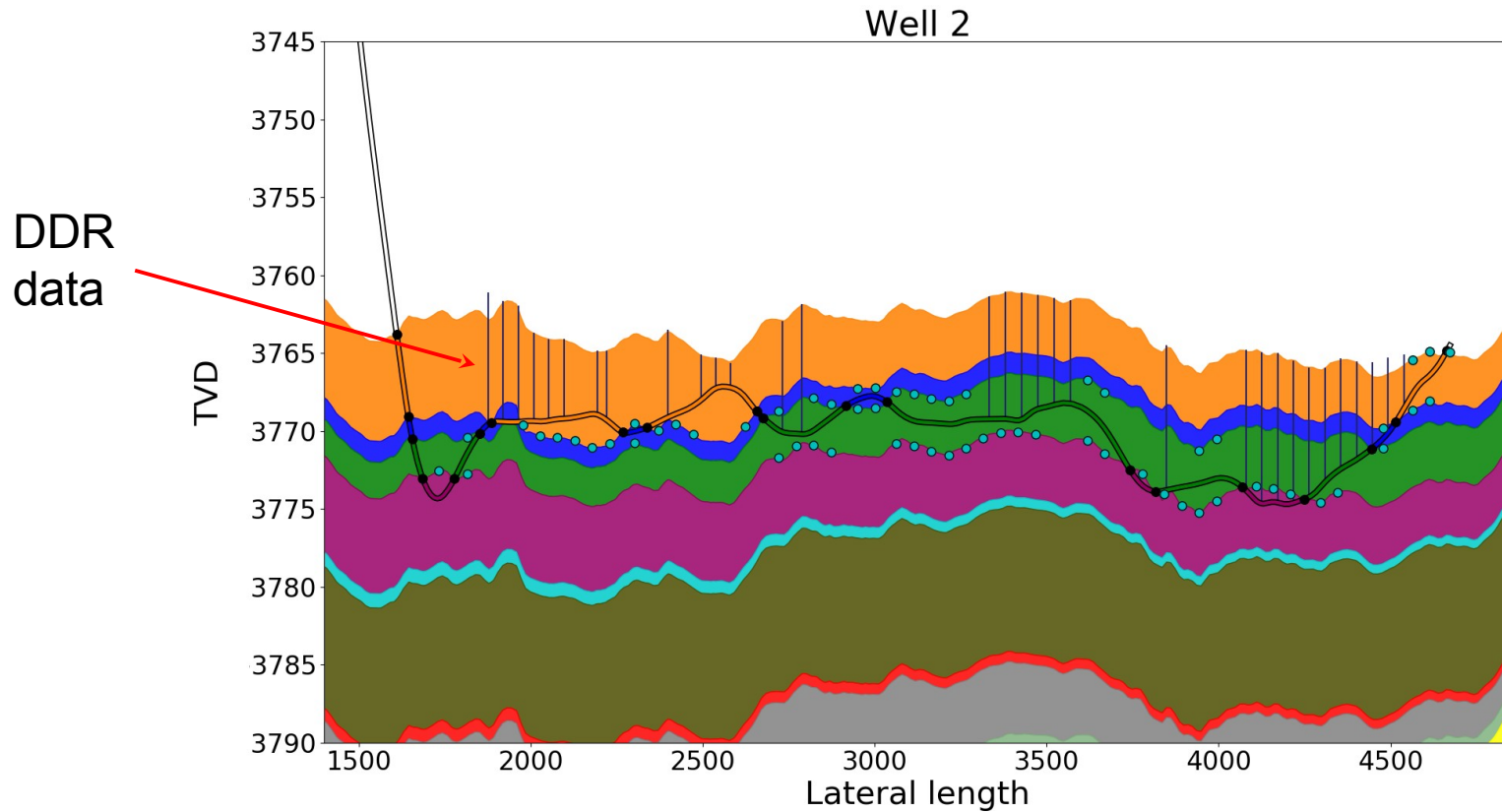
# Adjust surfaces to well picks



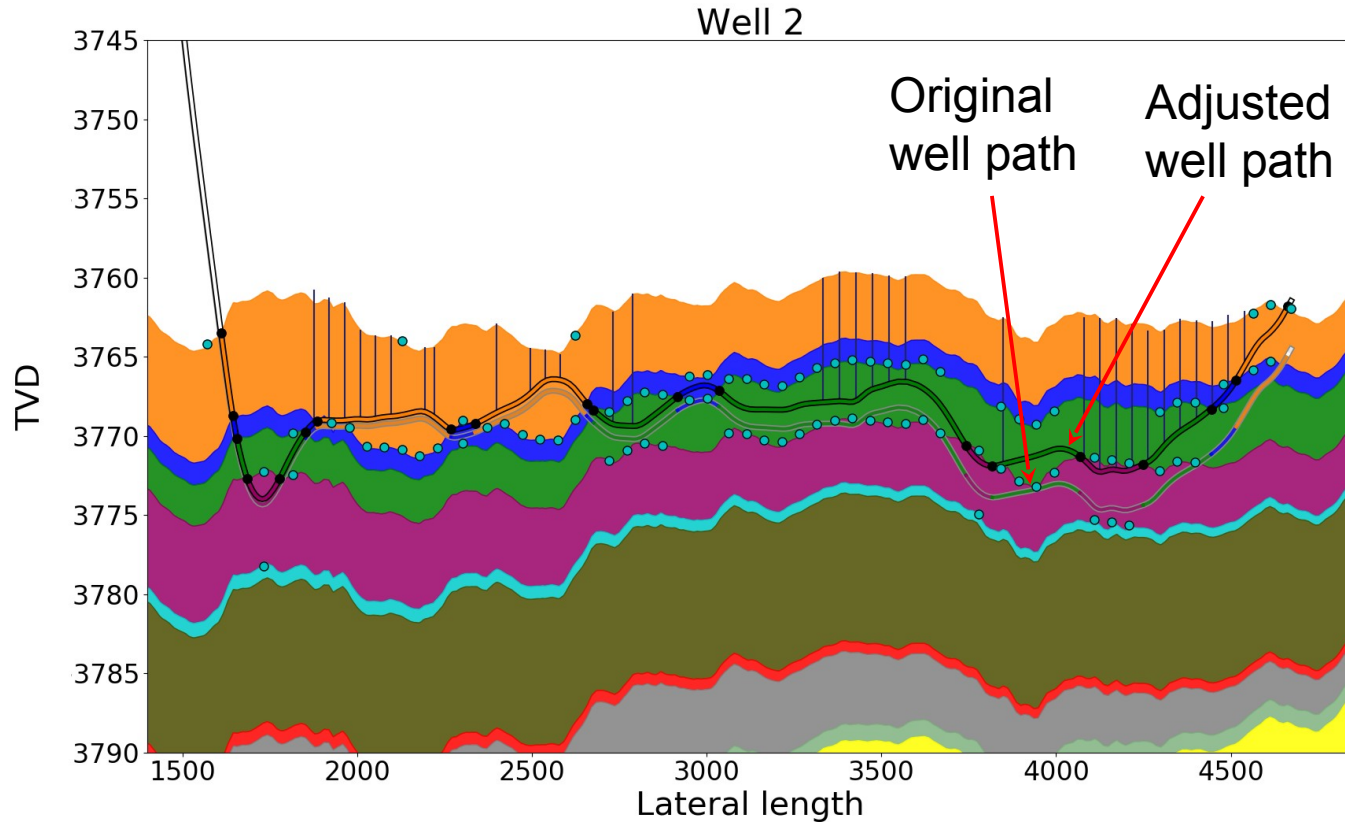
# Adjust surfaces to well picks + zone logs



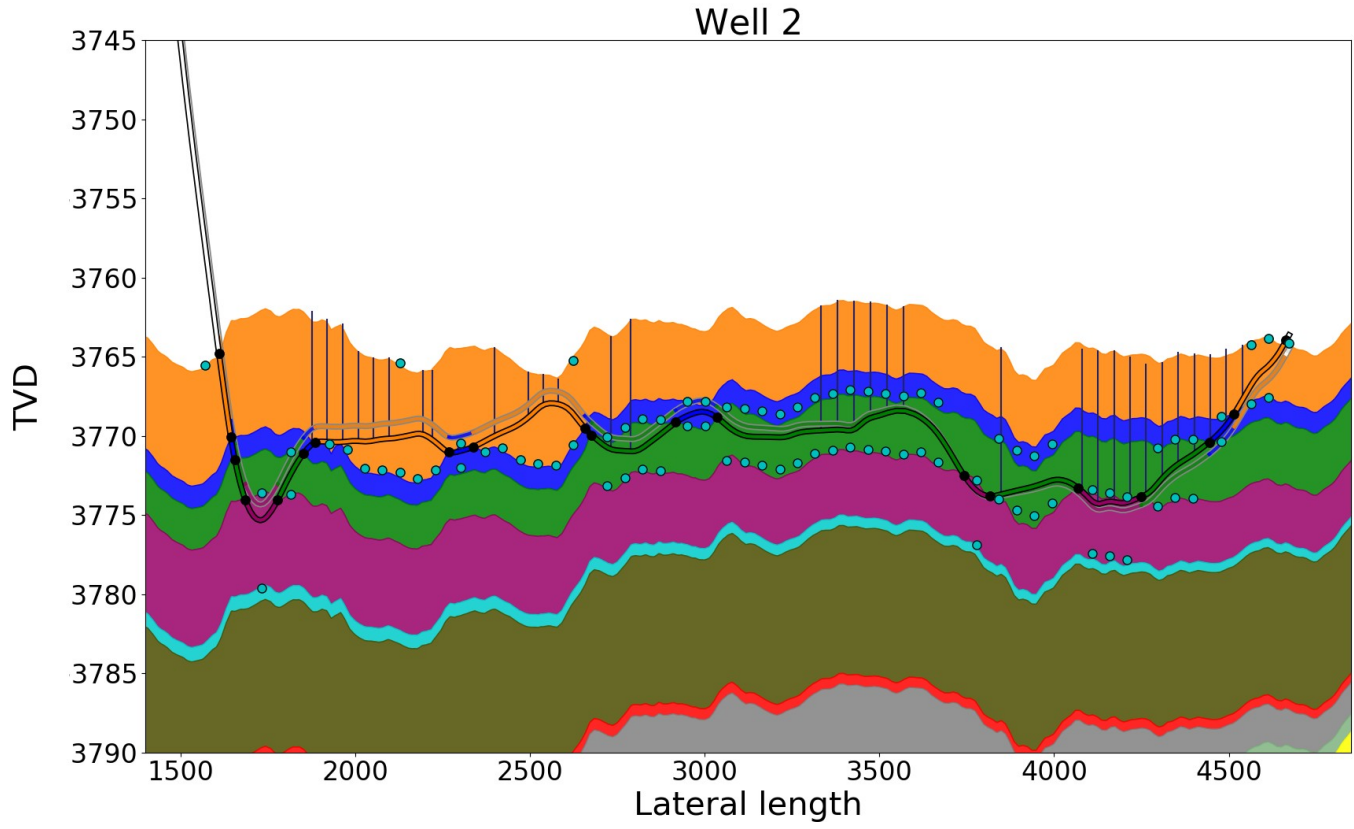
# Adjust surfaces to well picks + zone logs + DDR data



# Adjust surfaces and wells to well picks + zone logs + DDR data



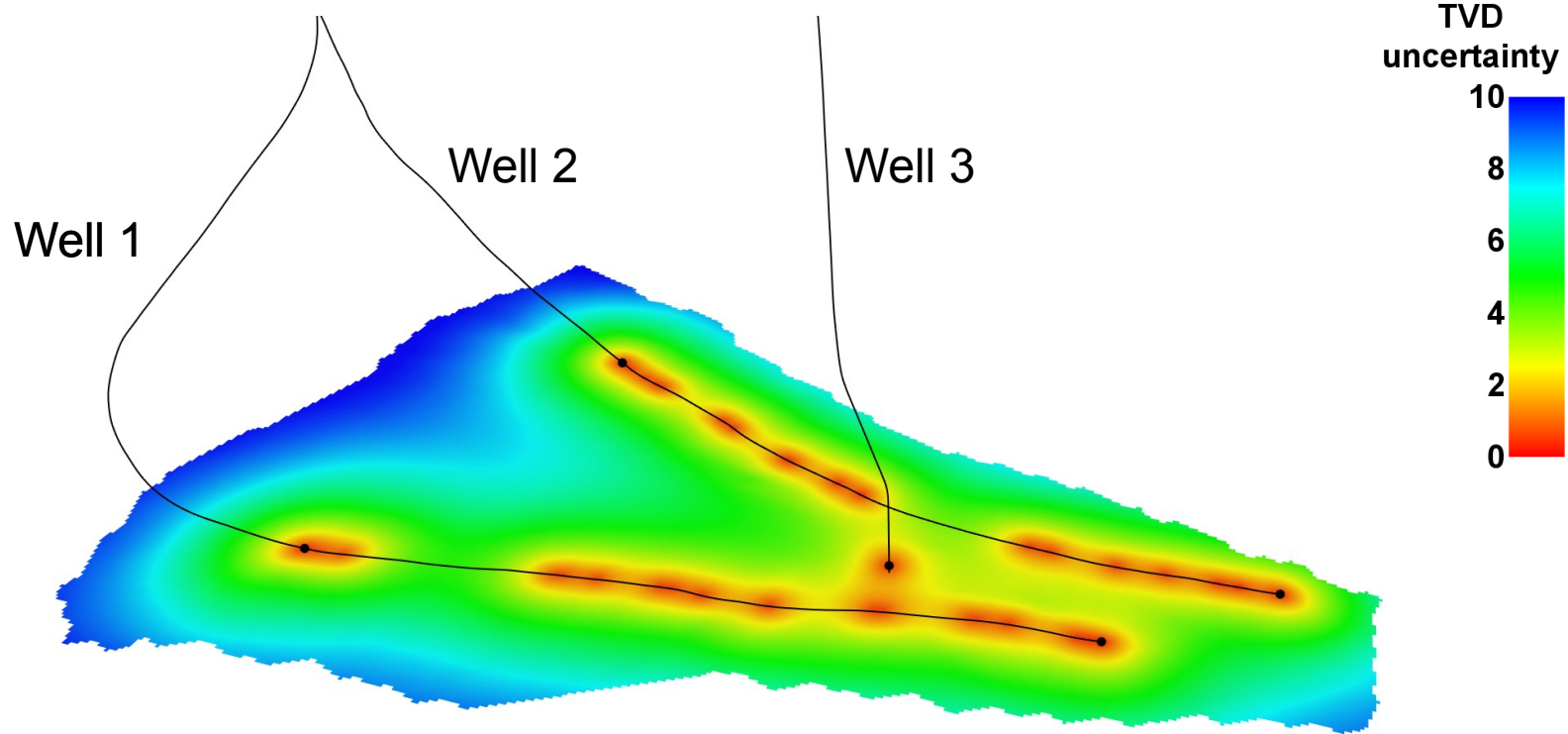
# Adjust surfaces and wells to well picks + zone logs + DDR data + contact



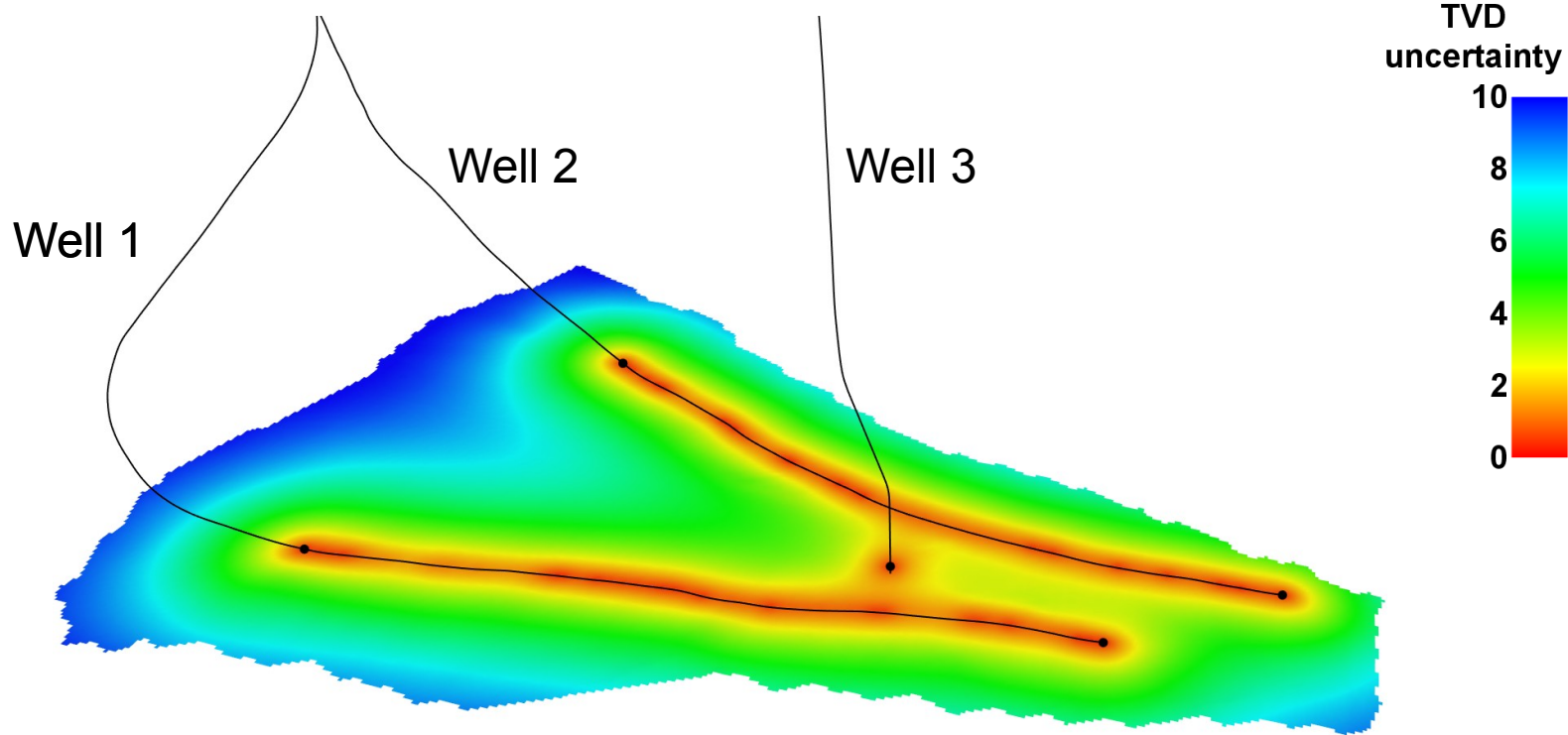


**The prediction uncertainty is reduced as more types of well data are added**

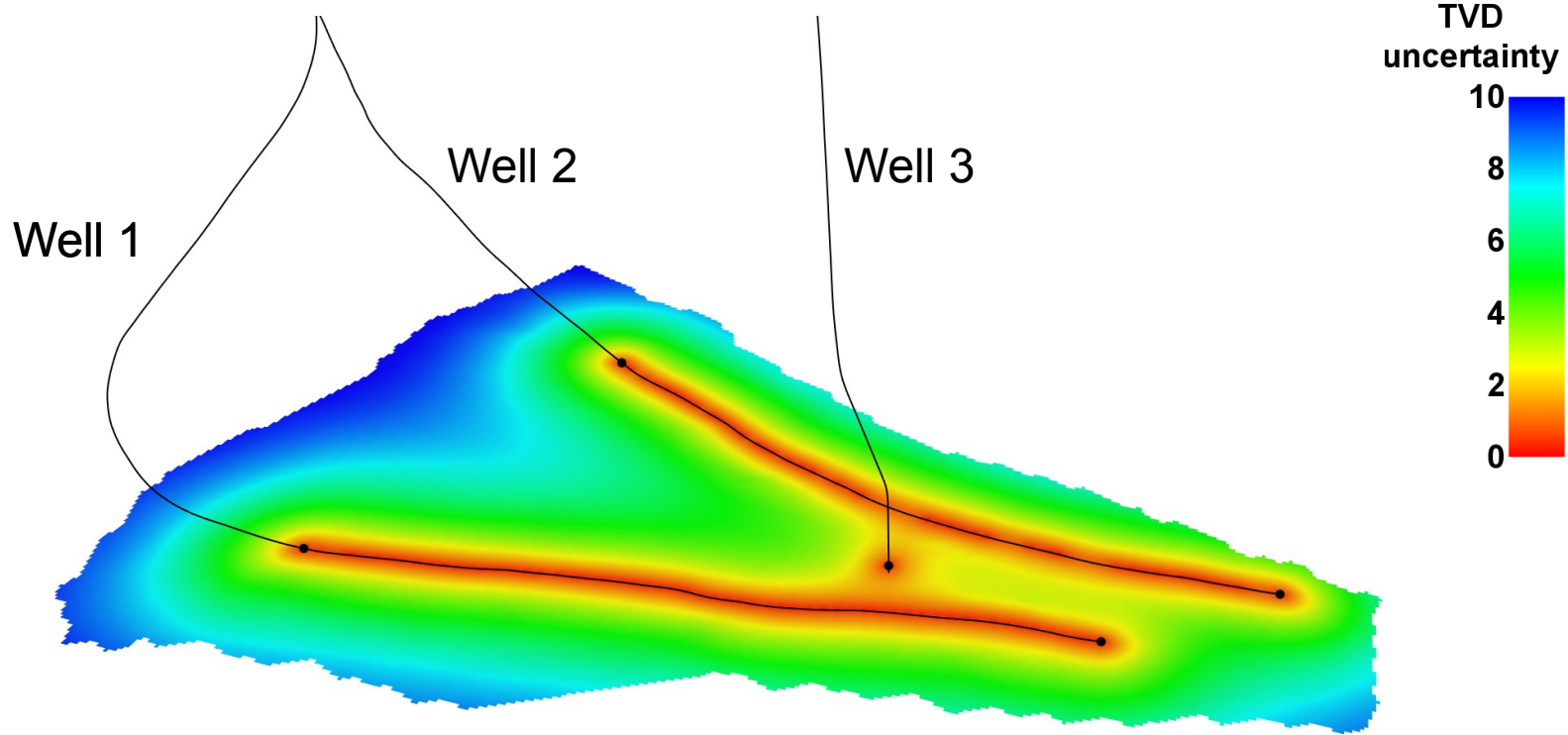
# Adjust surfaces to well picks



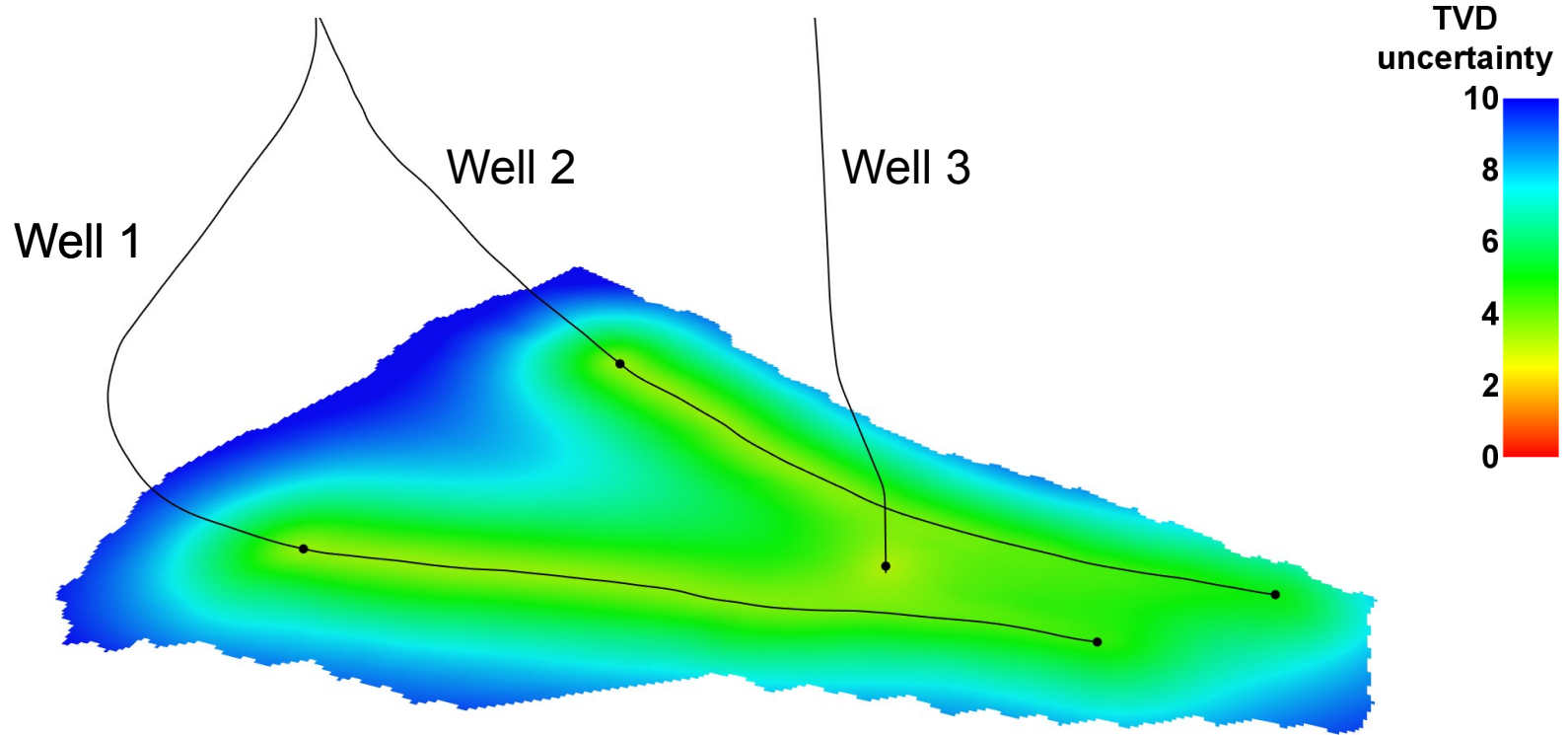
# Adjust surfaces to well picks + zone logs



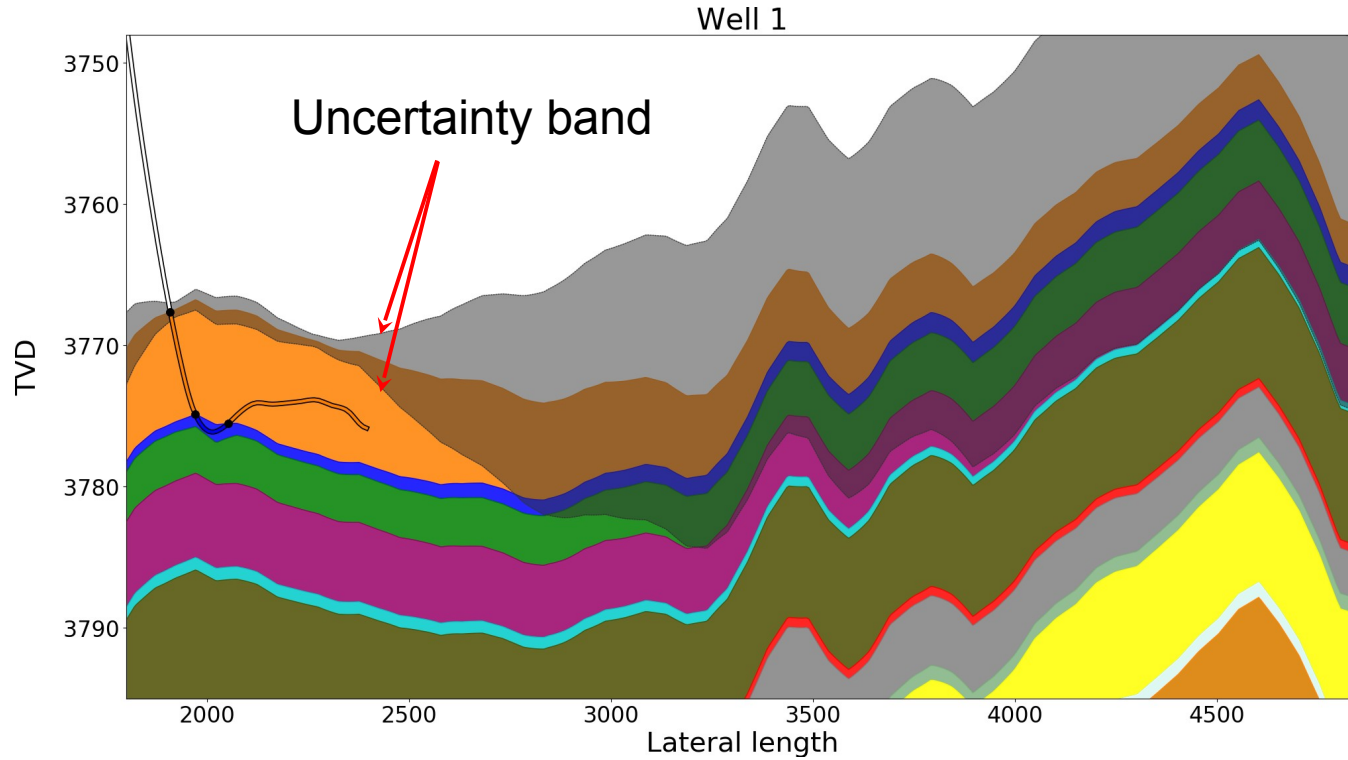
# Adjust surfaces to well picks + zone logs + DDR data



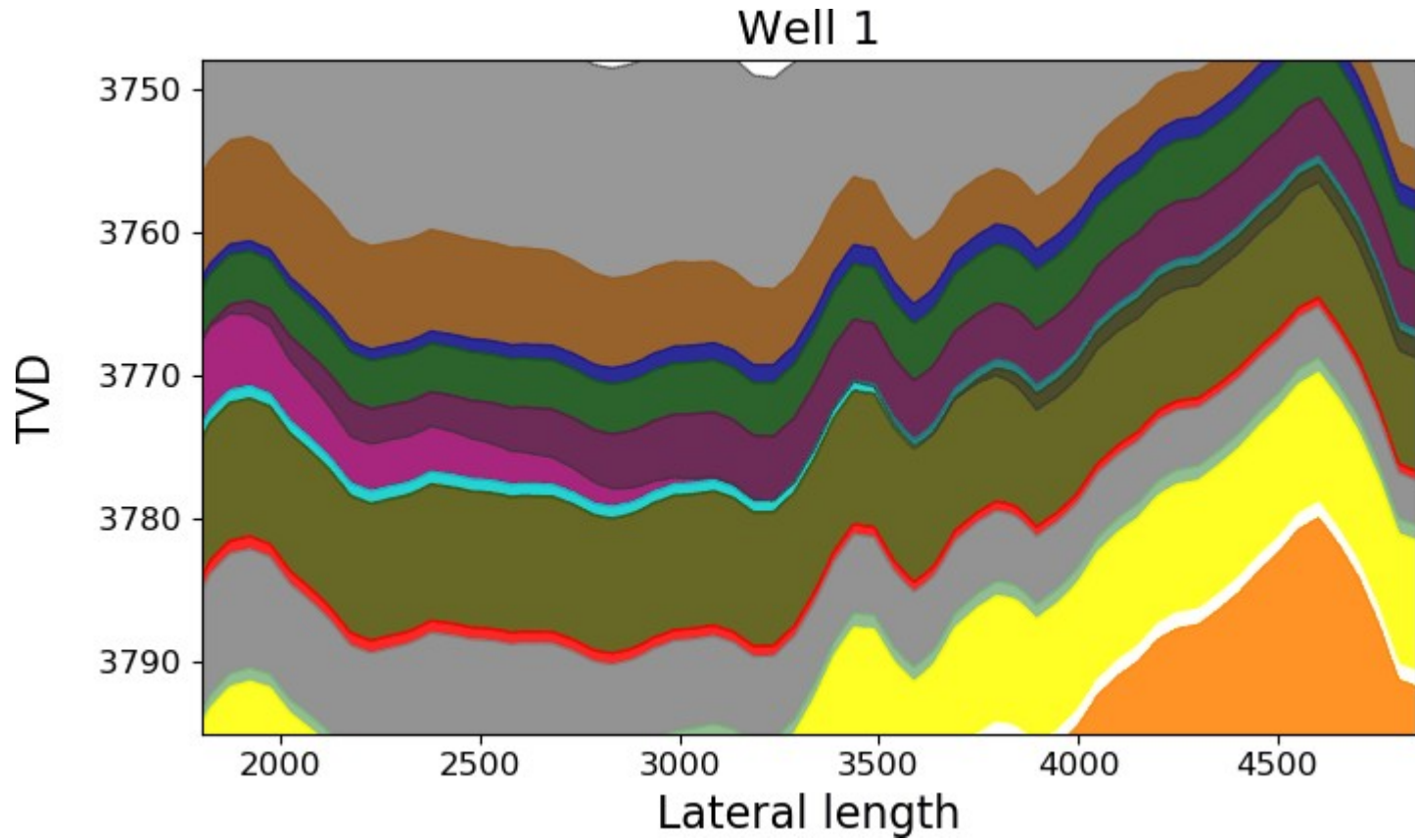
# Adjust surfaces to well picks + zone logs + DDR data. Uncertain well



# A simulated drilling



# A simulated drilling



# Summary

- ▶ We obtain realistic reservoir descriptions using
  - Time maps, velocities and isochores
  - Zone logs and DDR data
  - Uncertainties
- ▶ Both depth surfaces and well paths are adjusted
- ▶ The approach is quick and can be used while drilling



**Thank you for your attention**

# The well path is uncertain

