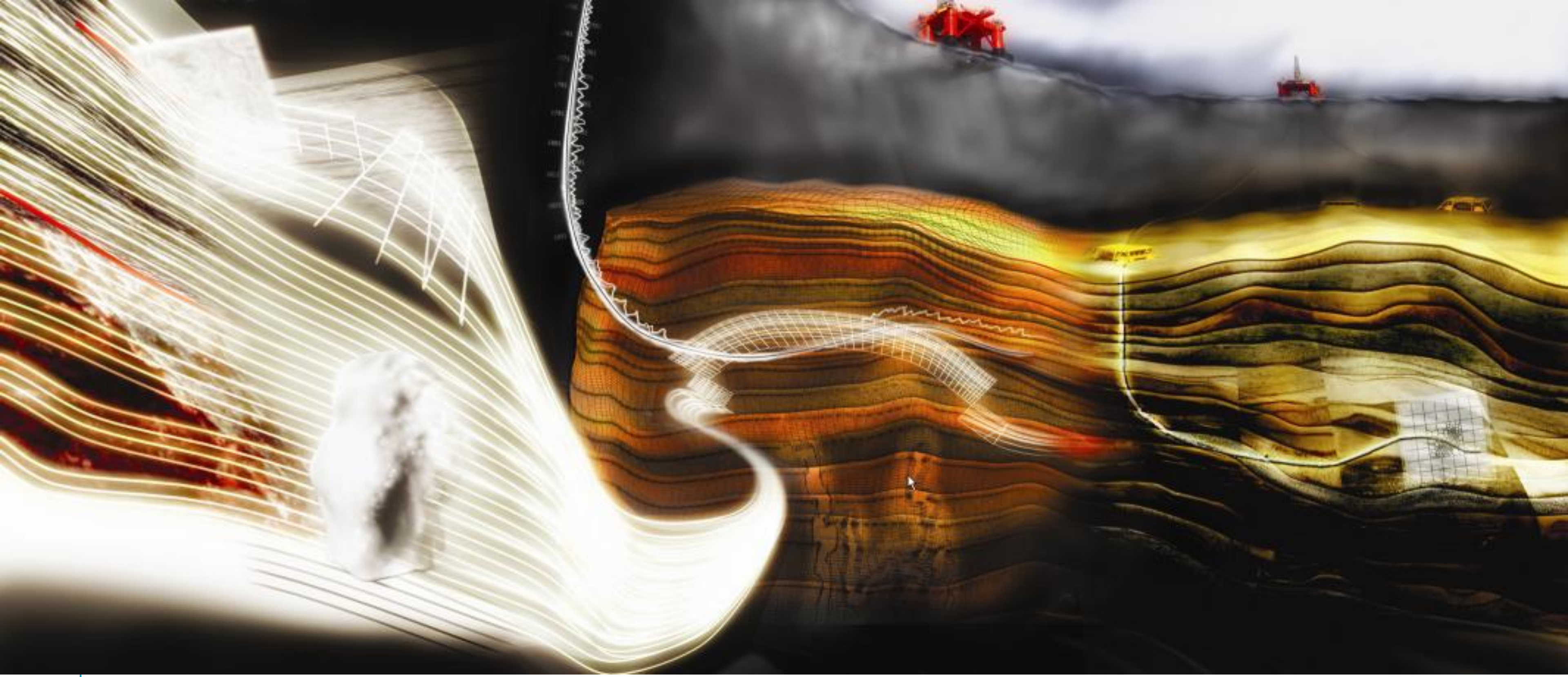


Anticipating troubles ahead

- Introduction
- Predicting troubles ahead better
- Updating predictions while drilling

By: Knut Midtveit
Knut.midtveit@emerson.com

Thanks to:
- Petter Abrahamsen,
Norwegian Computing Centre

- Hans Ivar Kallekleiv
- Henrik Horsås
- Arne Skorstad
Roxar Software Solutions

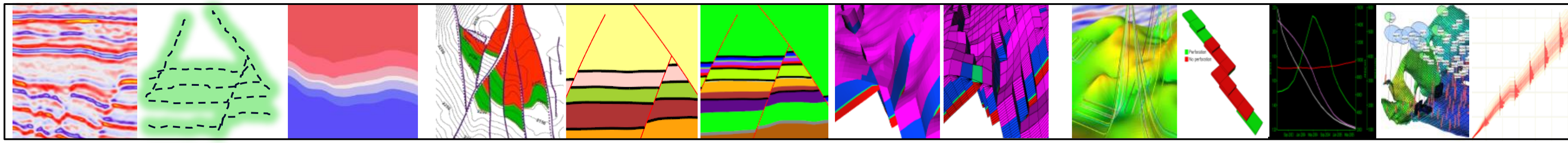
When they say
IT'S NEVER BEEN DONE BEFORE

EMERSON™

Roxar Software Solutions

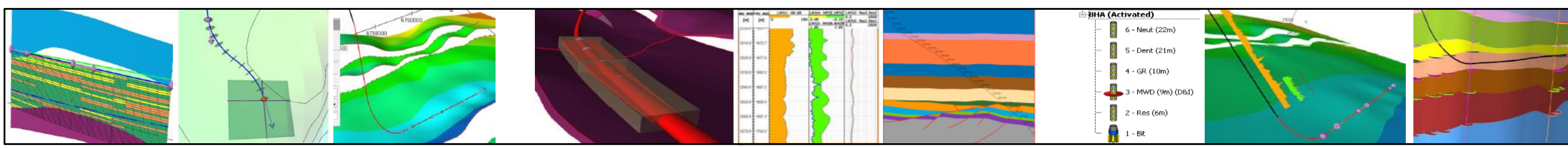
- Reservoir characterization

Geophysics | Geo-modelling | Reservoir engineering



- Well operations

Wellplanning | Well Prognosis | Well follow up Geosteering



DotRox Development Framework

3 important numbers on Recovery rates

- 22% Global conventional recovery
- 46% Norway Continental Shelf (NCS)
- 92% of NCS fields use Roxar Software

Modelled with Roxar
TROLL
EKOFISK
STATFJORD
OSEBERG
GULLFAKS
ÅSGARD
SNORRE
HEIDRUN
SNØHVIT
ELDFISK
VALHALL
SLEIPNER
GULLFAKS
KVITEBJØRN
GRANE
And many more

roxar
MAXIMUM RESERVOIR PERFORMANCE

EMERSON
Process Management

Common brown field drilling challenges

- Depleted reservoir
  - Mud weight limits difficult to meet
  - Critical to get casing point above reservoir right
  - Overburden challenges
- Drilling and operational challenges
- Delays, sidetracks, well integrity
- **Worst case:**

The Gullfaks C well incident

In 2010, we experienced a serious well incident at Gullfaks. We are now using all the learnings from this incident to further improve our safety performance.

Risk stops Statoil from drilling Gullfaks oil, gas field

Norwegian energy company Statoil said Monday it found major risks with drilling at the Gullfaks oil and gas field.

23 Nov 2010

Life of a well: From Cradle to Grave

Geophysics – Geology – Reservoir Engineering

- Identify targets
- Screen targets
- Optimize placement
- <u>**Make well prognosis**</u>

Planning

Drilling Engineers

Production Engineers

- Verify feasibility
- Assess Risk
- Optimize well path
- **Risk mitigation**

Drilling

New data

New data

New data

New data

- <u>**Update well prognosis**</u>
- <u>**Update well prognosis**</u>
- <u>**Update well prognosis**</u>
- <u>**Update well prognosis**</u>

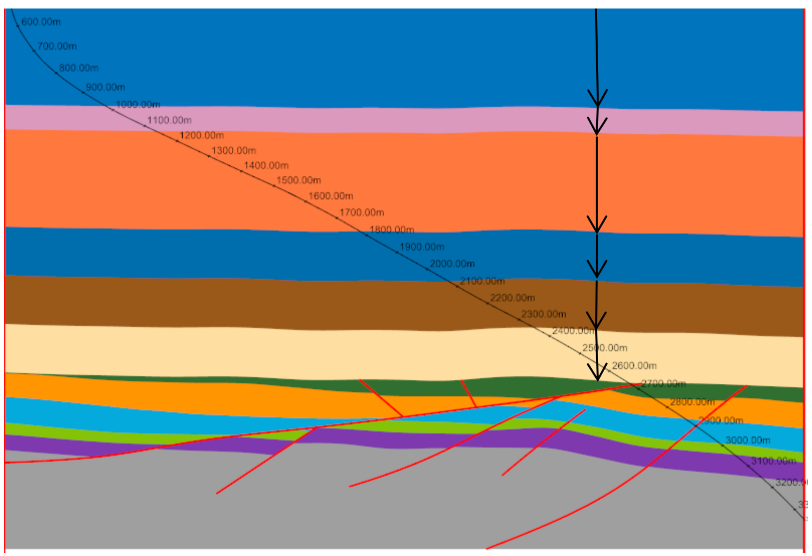
- **Risk mitigation**
- **Risk mitigation**
- **Risk mitigation**
- **Risk mitigation**

Use case: Improved well prognosis

Well prognosis before drilling

Traditional method – Educated guess

Educated guess

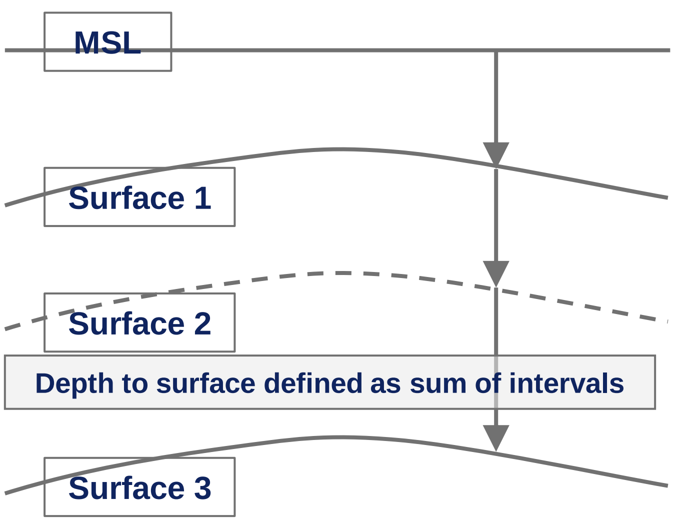


Well:	East	North	MD	TVD MSL	TBD RKB	Uncer tainty
Kick off	467278	6885939	720	600	640	
Top Shetland	469556	6891211	3389	1815	1845	
Top Sand High pressure	469756	6896211	4371	2611	2651	+8 / - 15
Top reservoir Low pressure	469796	6896911	4771	3652	3692	+-22

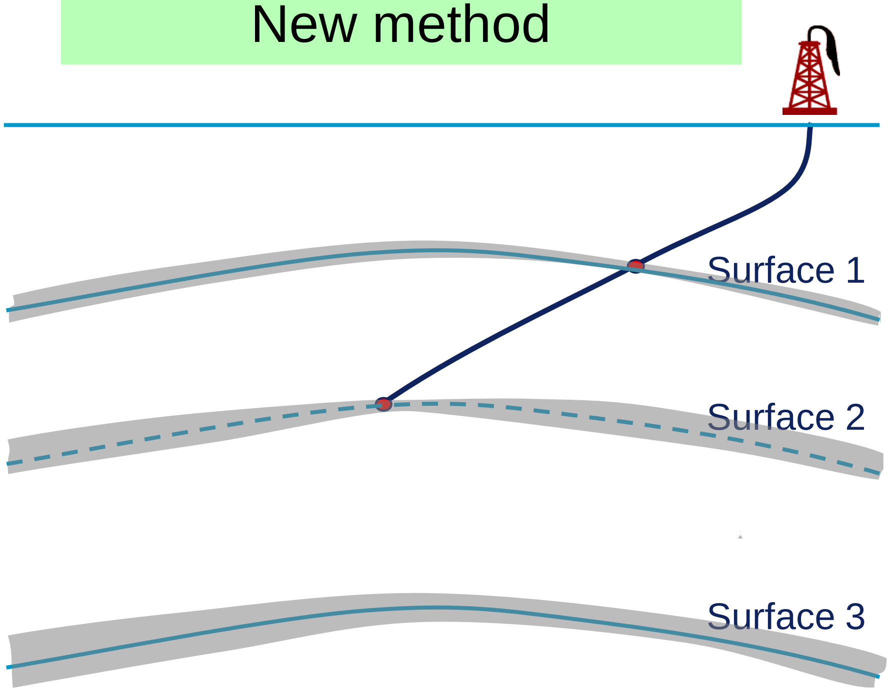
Better Well Prognosis with New technology

- Integrated approach with combined geophysics and geology modeling in one workflow
- Allow the experts to input their geological and geophysical knowledge about your reservoir
- Combine all uncertainties and **always** estimate resulting uncertainty

Old “Classical” method



New method

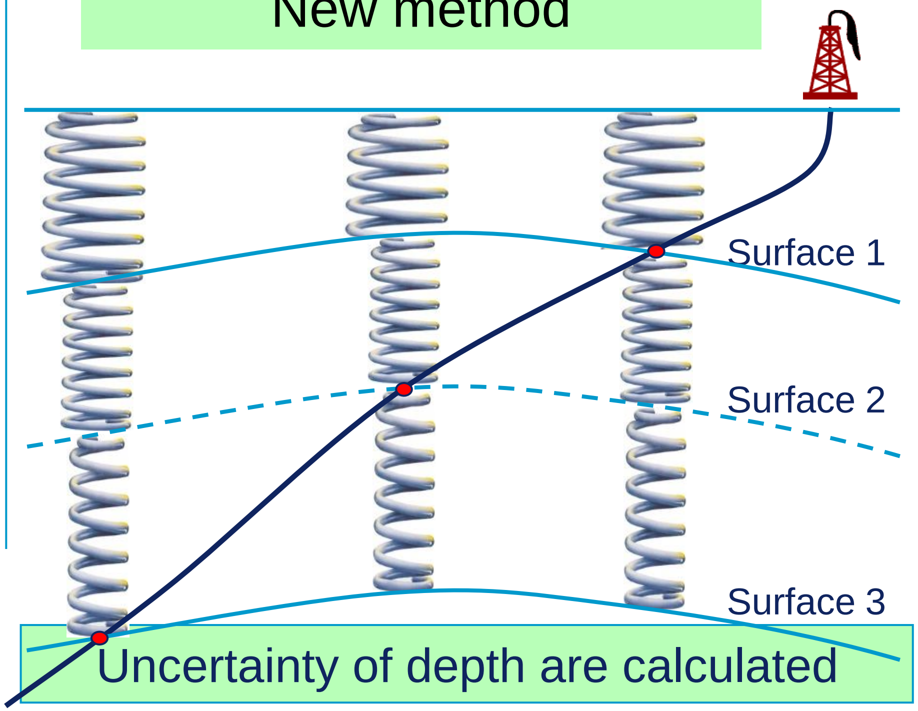


Uncertainty of depth are calculated

New method principles

- Whole package of layers are calculated
  (Not one at a time)
- Uncertainty of each input data are taken into account
  Resulting or combined uncertainty calculated
- Algorithm proven from volume uncertainty workflows
  for many years on many reservoirs

New method



SPE 159746

Added Value by Fast and Robust Conditioning of Structural Surfaces to Horizontal Wells for Real-World Reservoir Models

Vegard R. Stenerud, Statoil ASA, Hans Kallekleiv, Roxar Software Solutions, Petter Abrahamsen, Norwegian Computing Center, Pål Dahle, Norwegian Computing Center, Arne Skorstad, Roxar Software Solutions, May Hege Aalmen Viken, Statoil ASA.

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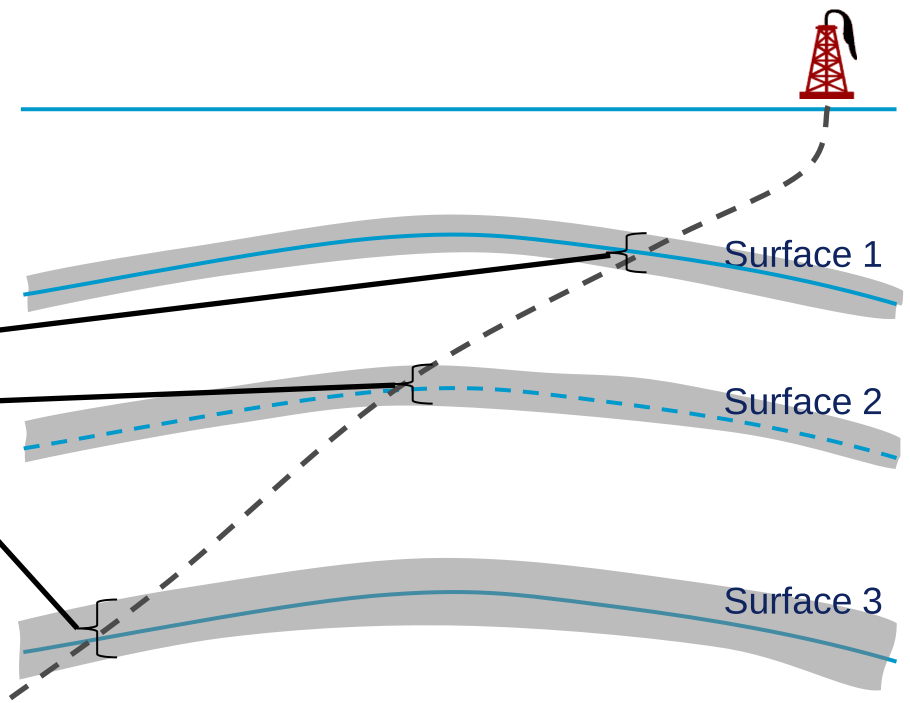
Well prognosis before drilling

- Uncertainty at each Surface

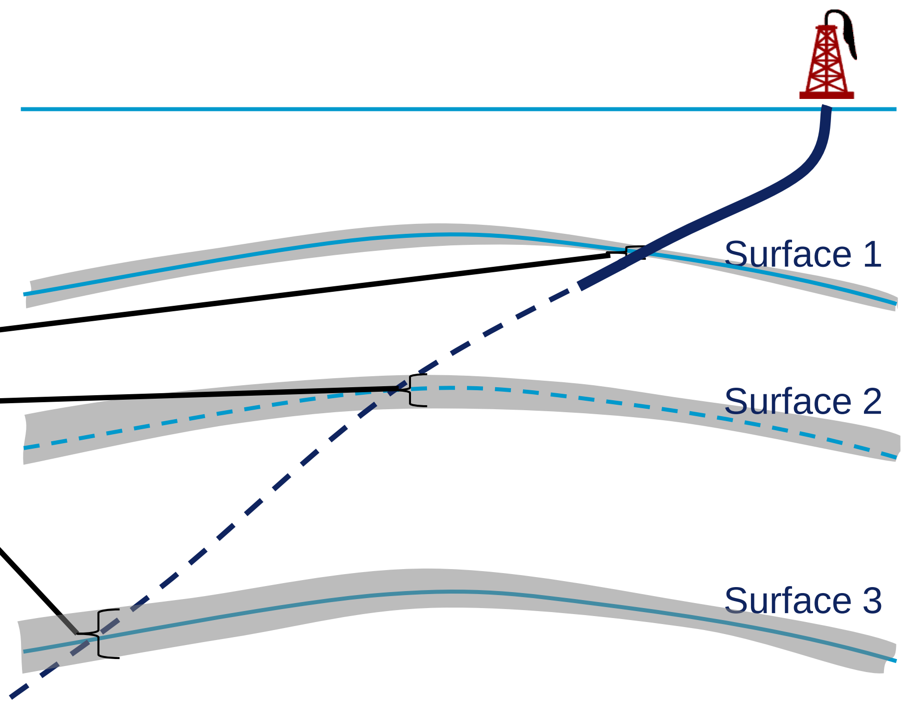
Well:	East	North	MD	TVD MSL	TBD RKB	Uncertainty
Surface 1	467278	6885939	720	600	640	± 10
Surface 2	469556	6891211	3389	1815	1845	± 12
Surface 3	469756	6896211	4371	2611	2651	± 17



Well prognosis while drilling-Update 1

- Real-time data from rig
- Update prognosis when needed

Well:	East	North	MD	TVD MSL	TBD RKB	Uncertainty
Surface 1	467278	6885939	720	600	640	±1
Surface 2	469556	6891211	3389	1815	1845	± 8
Surface 3	469756	6896211	4371	2611	2651	± 12



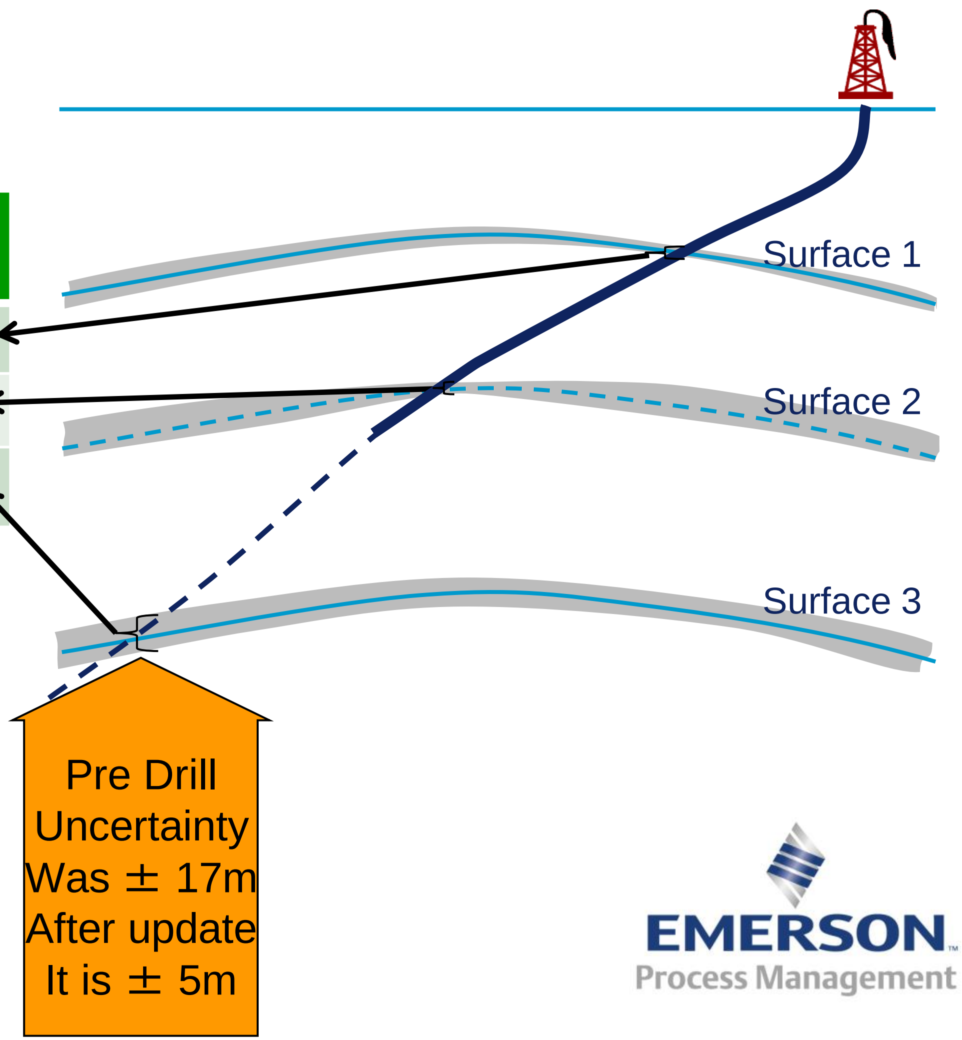
roxar MAXIMUM RESERVOIR PERFORMANCE

EMERSON Process Management

Well prognosis while drilling-Update 2

- Real-time data from rig
- Update prognosis when needed

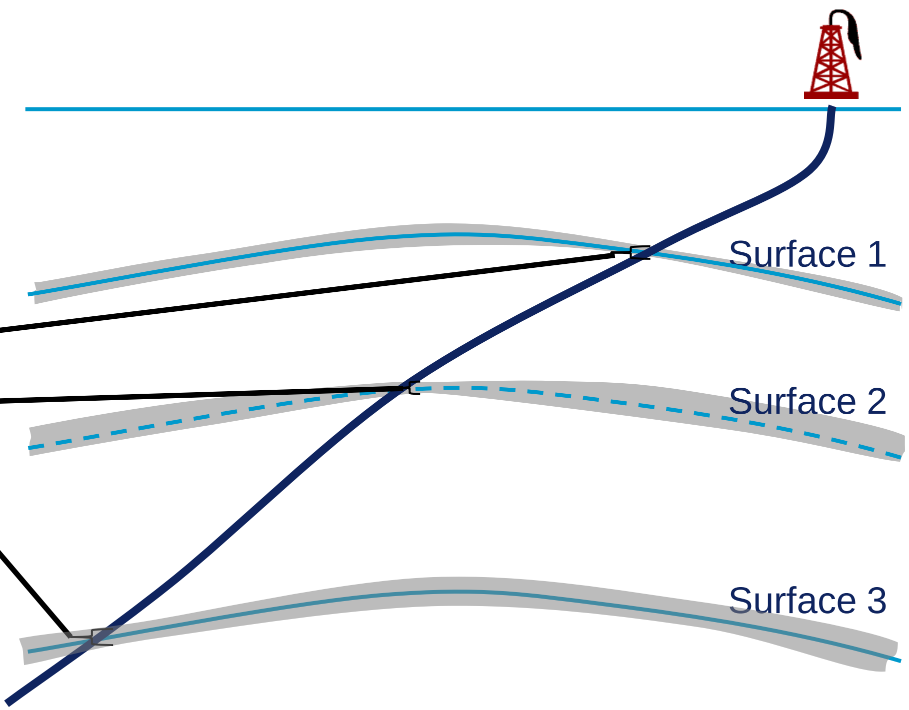
Well:	East	North	MD	TVD MSL	TBD RKB	Uncertainty
Surface 1	467278	6885939	720	600	640	±1
Surface 2	469556	6891211	3389	1815	1845	± 2
Surface 3	469756	6896211	4371	2611	2651	± 5



Well prognosis while drilling-Update 3

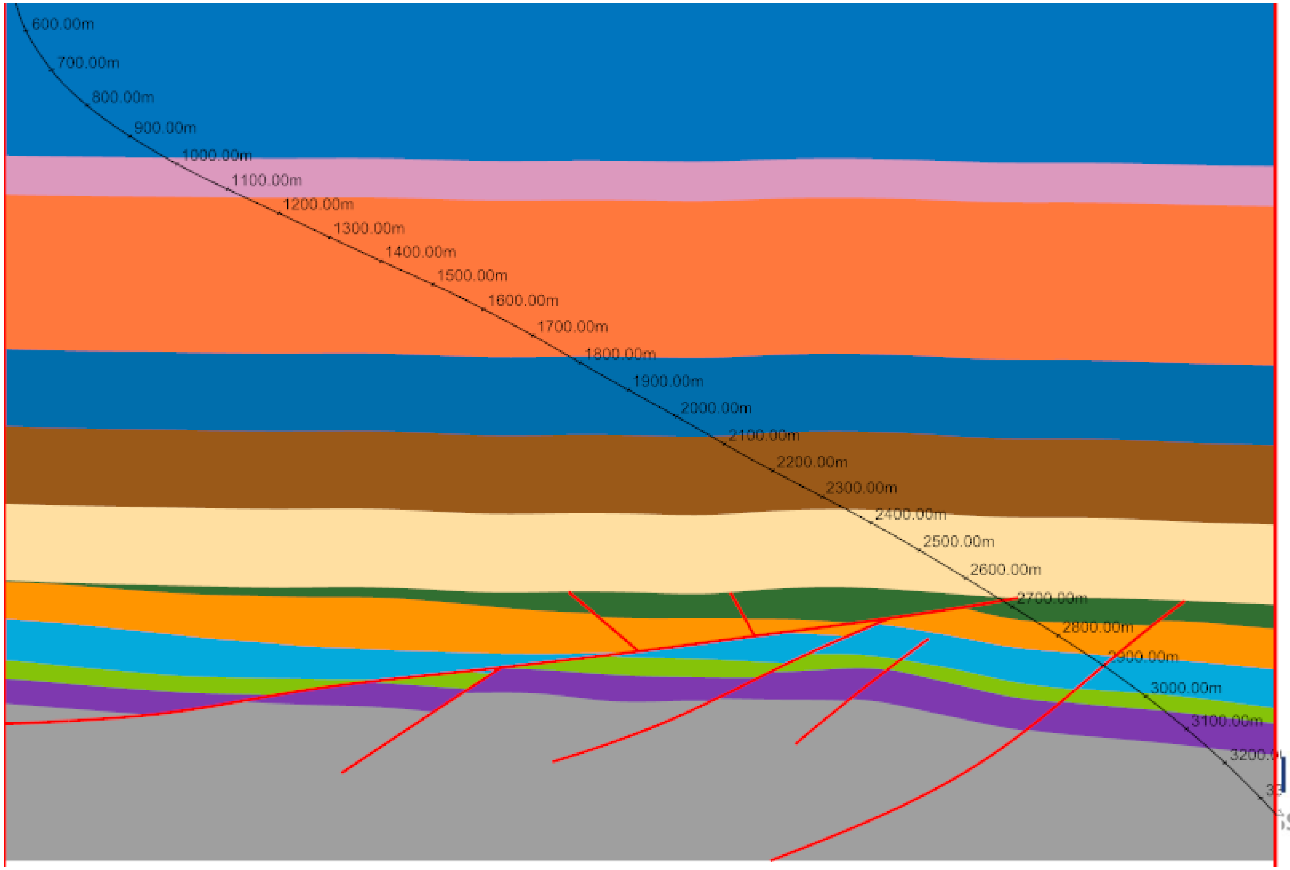
- Real-time data from rig
- Update prognosis when needed

Well:	East	North	MD	TVD MSL	TBD RKB	Uncertainty
Surface 1	467278	6885939	720	600	640	±1
Surface 2	469556	6891211	3389	1815	1845	±2
Surface 3	469756	6896211	4371	2611	2651	± 2



Other use of subsurface model for drilling

- Opportunity for drilling optimization
  - Better estimation of rock properties
- Use seismic 4D techniques to indicate pressure changes in overburden



Backup slides

Prediction of Depth and prediction error

- Examples from Norwegian Computing Centre
- Thanks to Peter Abrahamsen

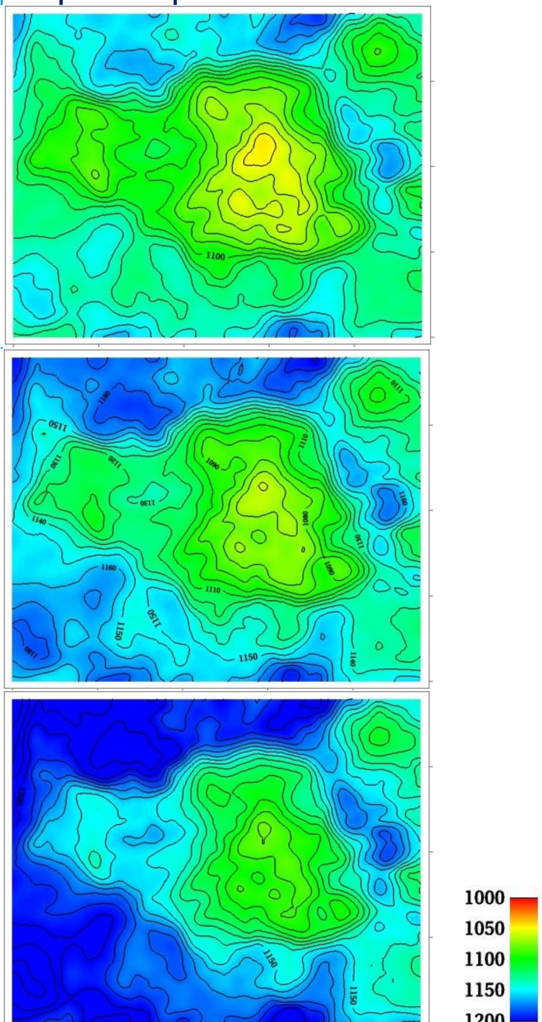
Prediction – one deviating well

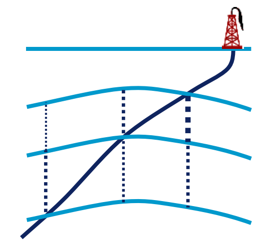
Depth map Pre drill situation

Upper surface

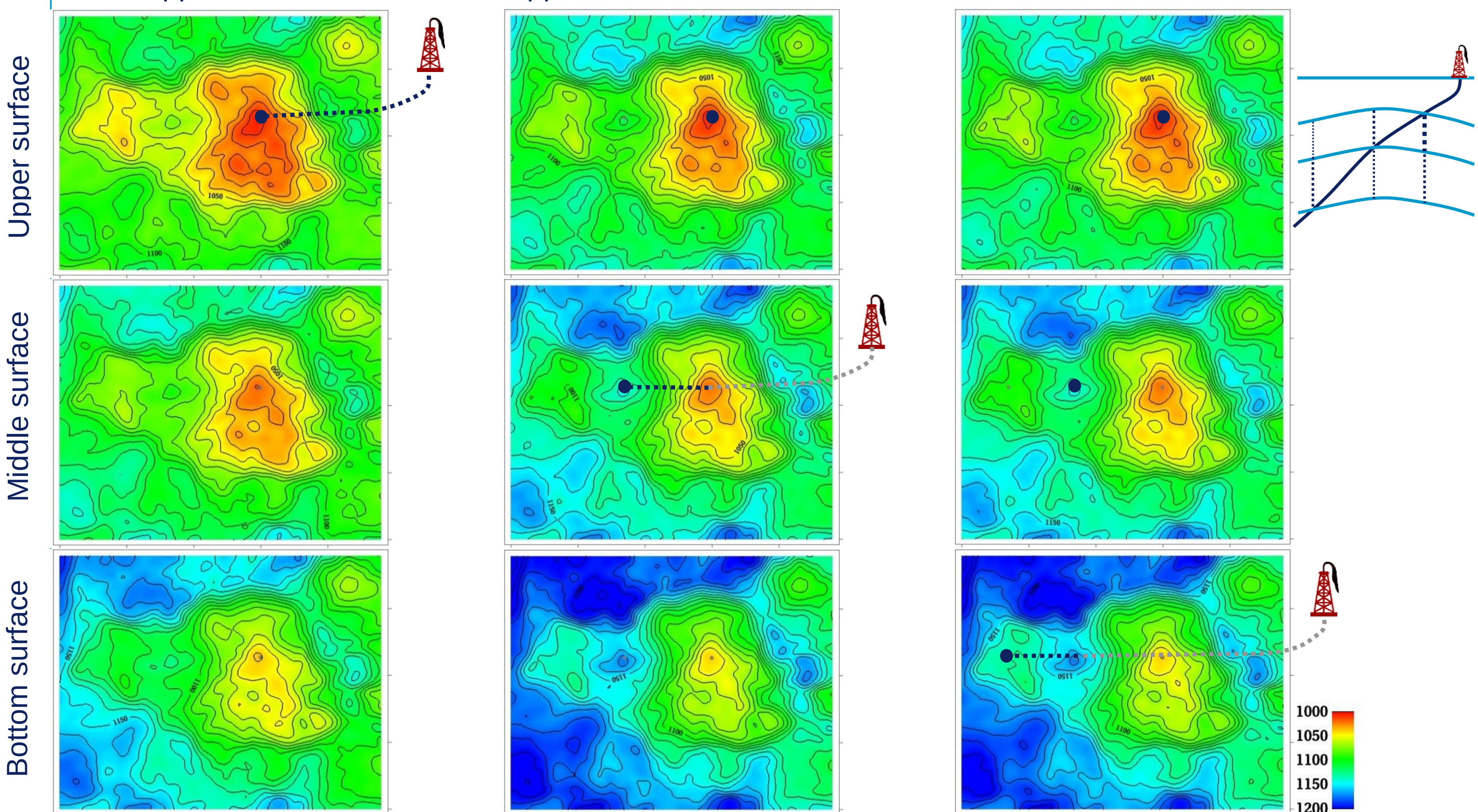
Middle surface

Bottom surface





Depth map prediction – one deviating well



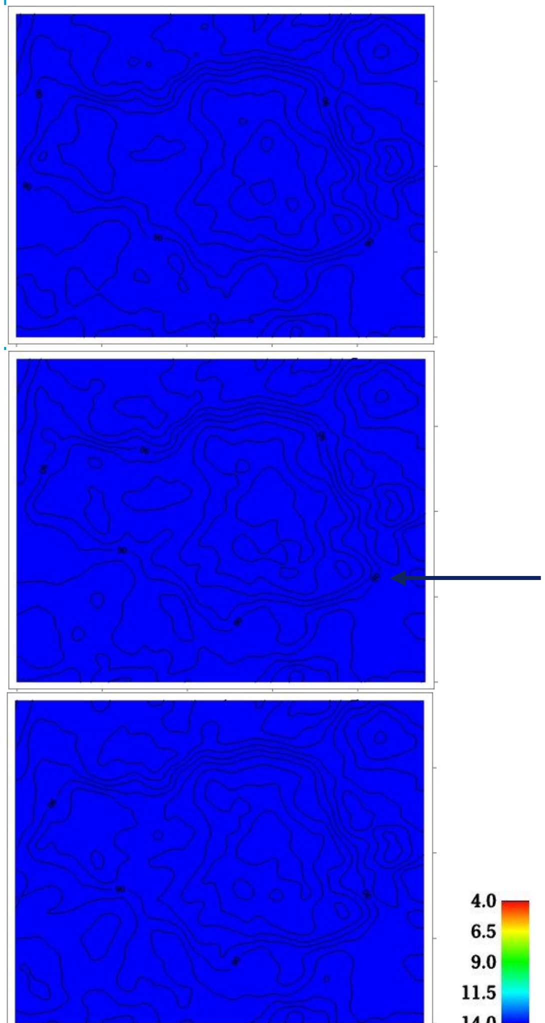
Prediction error – one deviating well

Pre drill situation

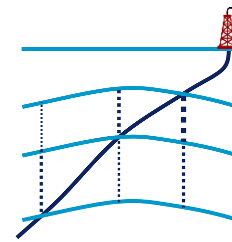
Upper surface

Middle surface

Bottom surface



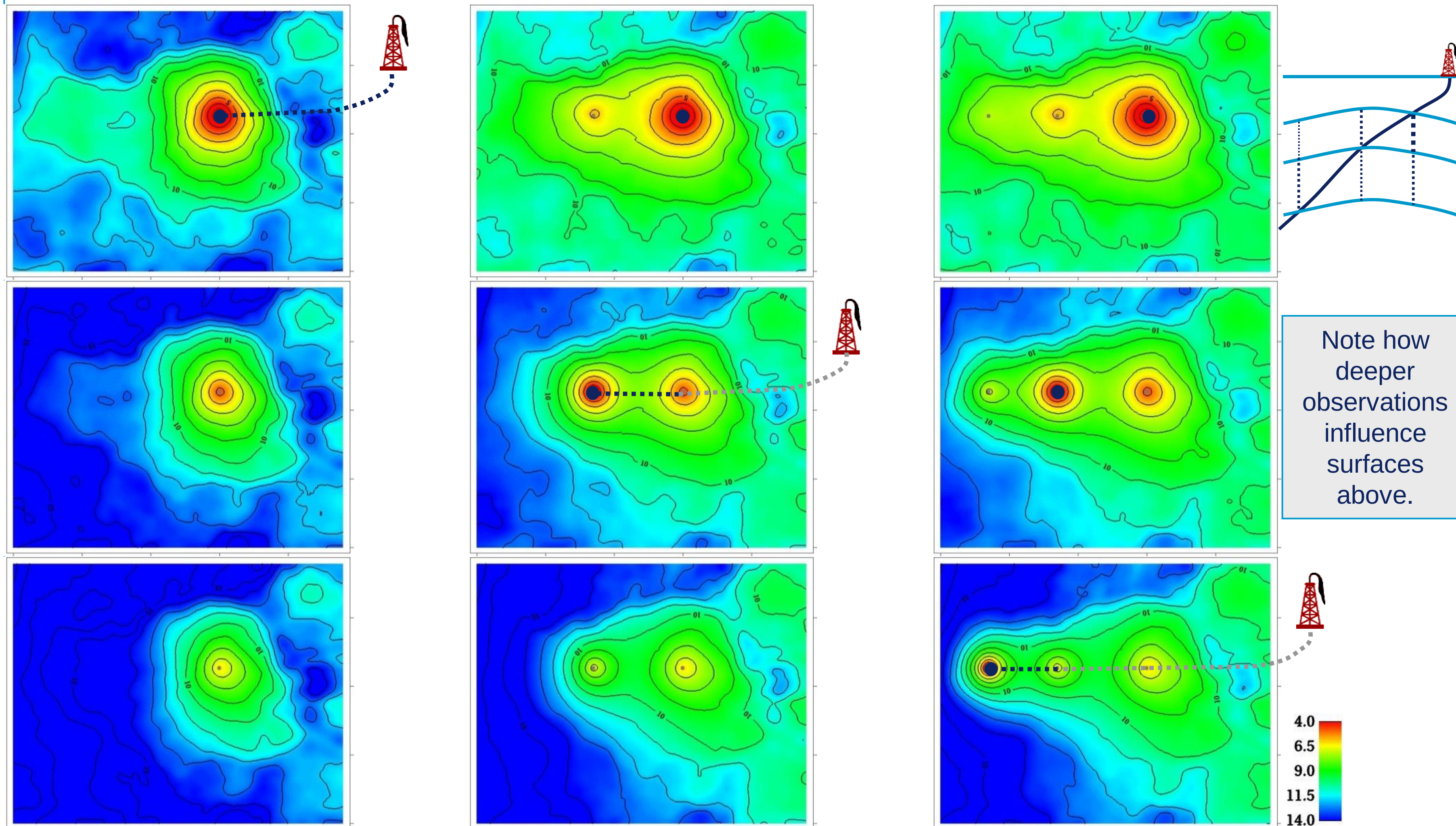
±90m



Prediction error – one deviating well

Upper observed | Upper and middle observed | All three observed

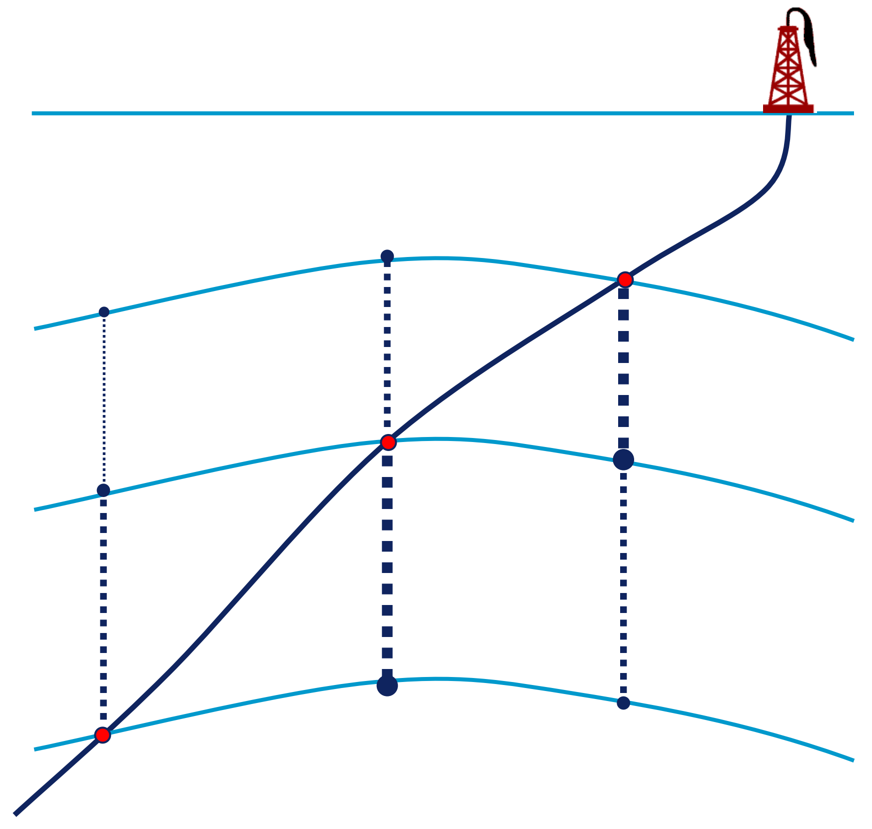
Upper surface / Middle surface / Bottom surface



Note how deeper observations influence surfaces above.

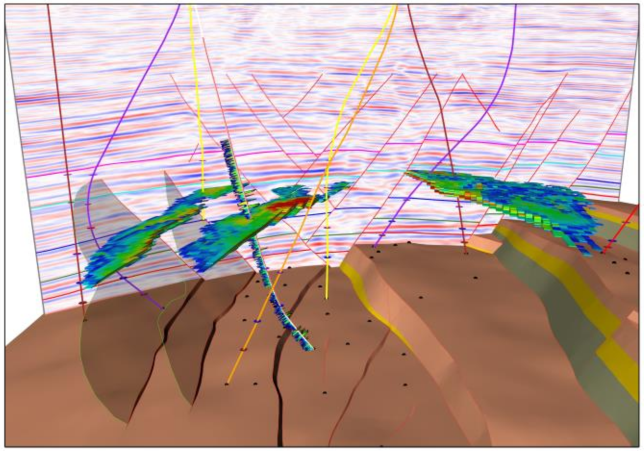
Depth to surface defined as sum of intervals

- **Improved precision**
- **All surfaces are dependent!**
- Observation of one surface carry information on all other surfaces
- **Correct uncertainties**



Well targets

- Mature fields are complicated
- Where to place next well
- Which one is best
- What about risk
- Which to choose first
- Can we drill it



General approach

- Understanding of Reservoir drainage
- Unwept areas seen on 4D Seismic
- Identify remaining oil
- Identify well targets
- Select the best
- Optimize the well path