A stochastic structural model

B. F. Nielsen, L. Holden, P. Mostad,
A. Skorstad, A. Vazquez
C. Townsend (Statoil) and S. Ottesen (Statoil)

Norwegian Computing Center

Outline

- Problem.
- Fault operators.
- Building structural models.
- An example.
- Conclusion.

Problem

- Structural model;
  - A set of horizons.
  - A set of faults.
- Framework for 3D models.
  - Facies & petrophysics.
- Framework for simulation grids.
  - reservoir simulation.

Problem

- Make a common consistent model of the horizons and the faults.
- Model the uncertainties in both the horizons and the faults.

Problem, continued ...

- Input;
  - Seismic data $\rightarrow$ horizons and faults.
  - Well observations.
  - Faults not well represented in the horizons.
  - Large uncertainties.
- Output;
  - Number of consistent structural models.
  - Conditioned on the well observations.

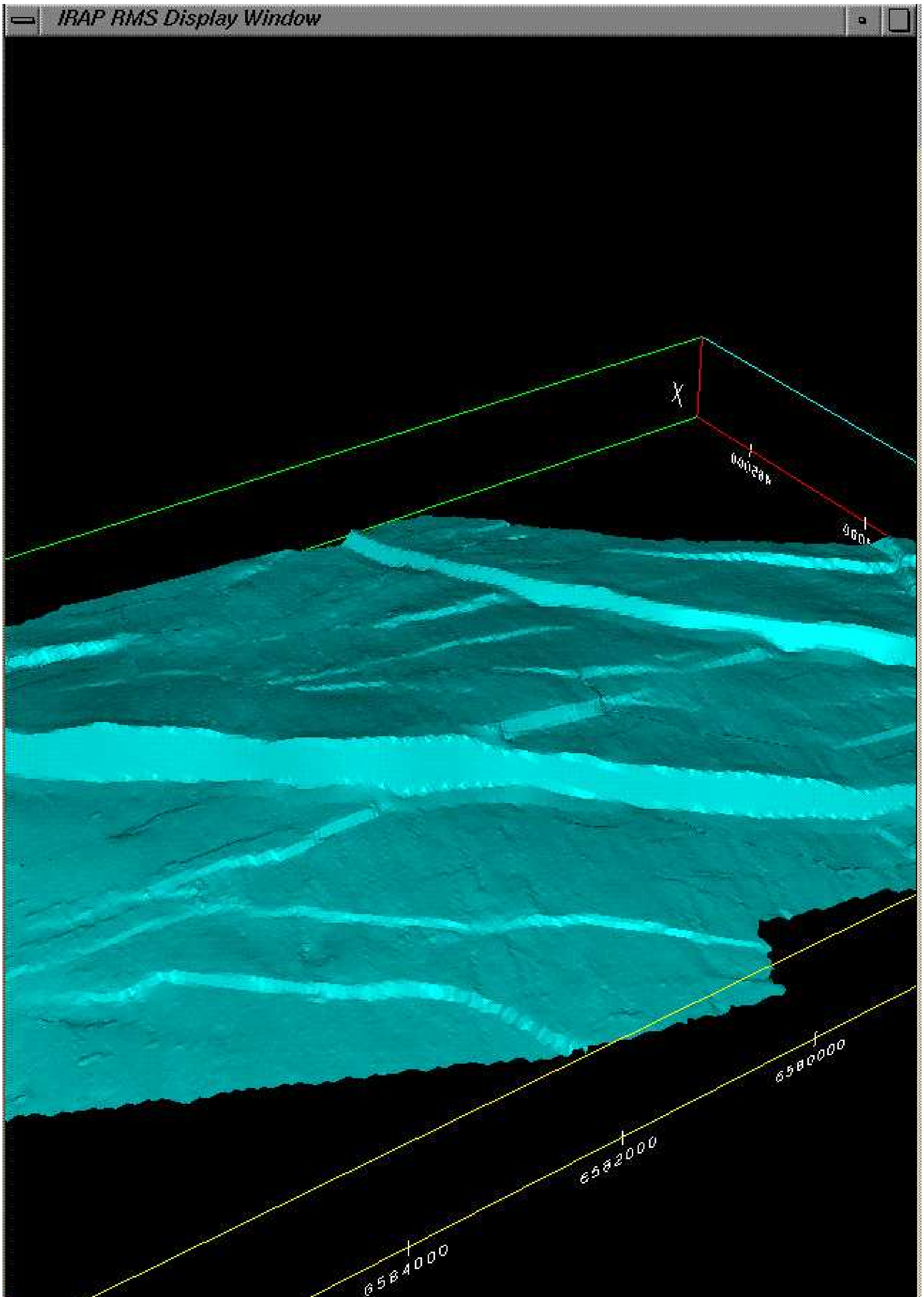
Problem, continued ...

- Basic tools;
  - Faults: flexible, invertible operators
  $$\mathbb{R}^3 \to \mathbb{R}^3.$$
  - Software package *Horizon* $\to$ model uncertainties in the horizons.
- New structural model in the software package *Havana*.

Fault operators

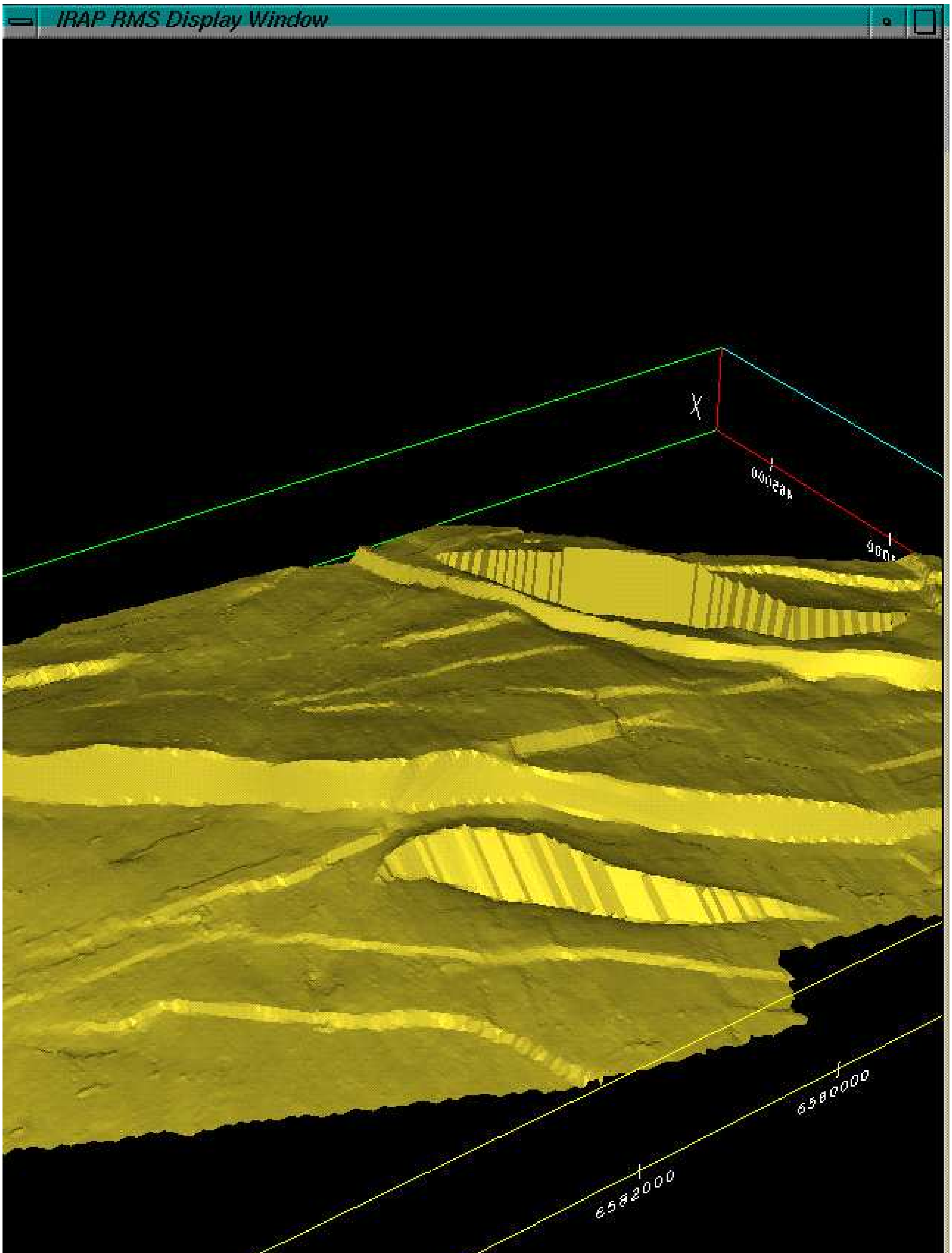
- Invertible operators, $F : \mathbb{R}^3 \to \mathbb{R}^3$.
- Discontinuous along the fault surface. Elsewhere continuous.
- Fault surface: sequence of truncated bilinear surfaces.
- Specify displacement along the fault surface.
- Specify the reverse drag.
- Fault truncations.

Fault operators, continued ...

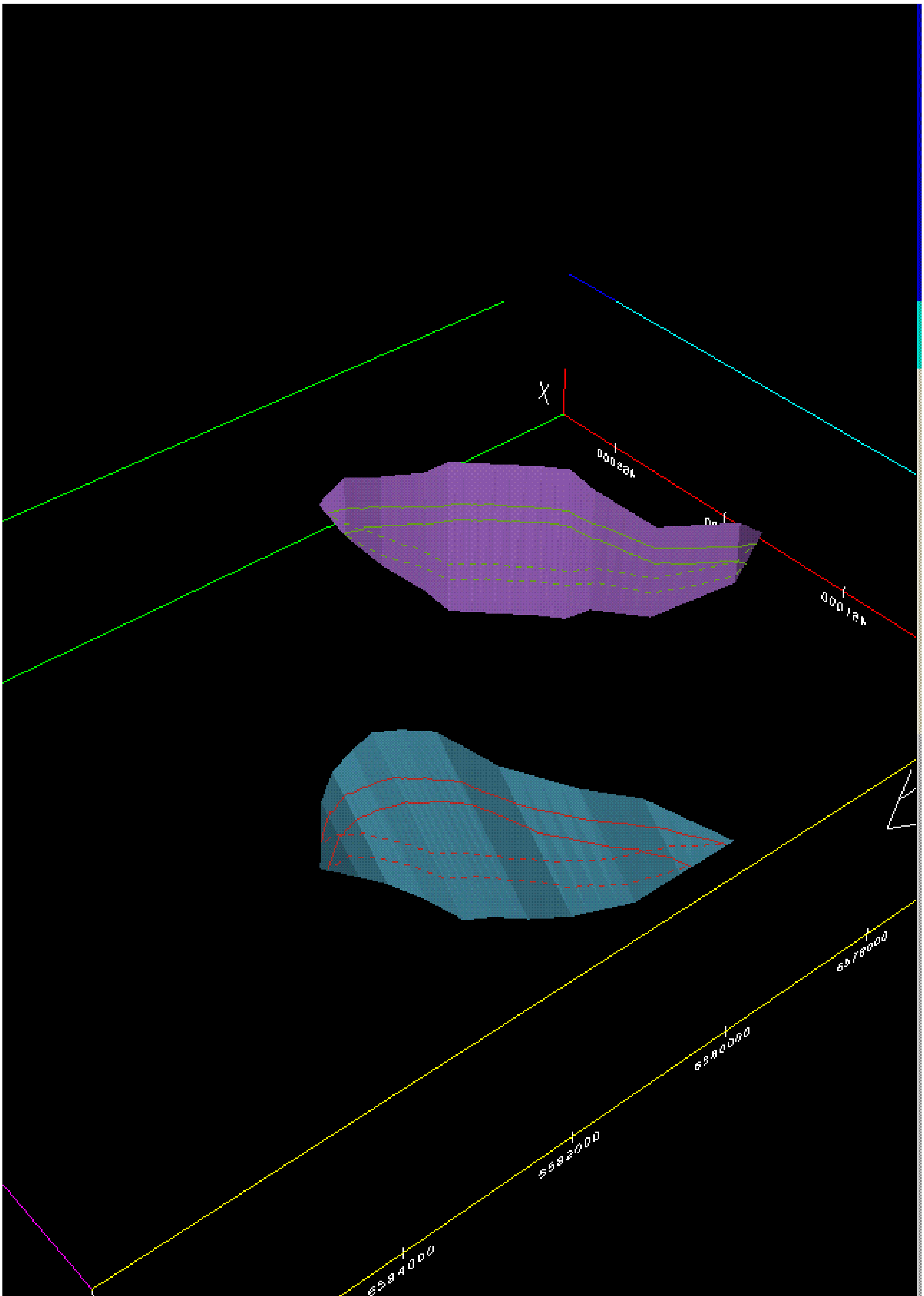


Fault operators, continued ...

2 extra faults



Fault operators, continued ...



Building structural models

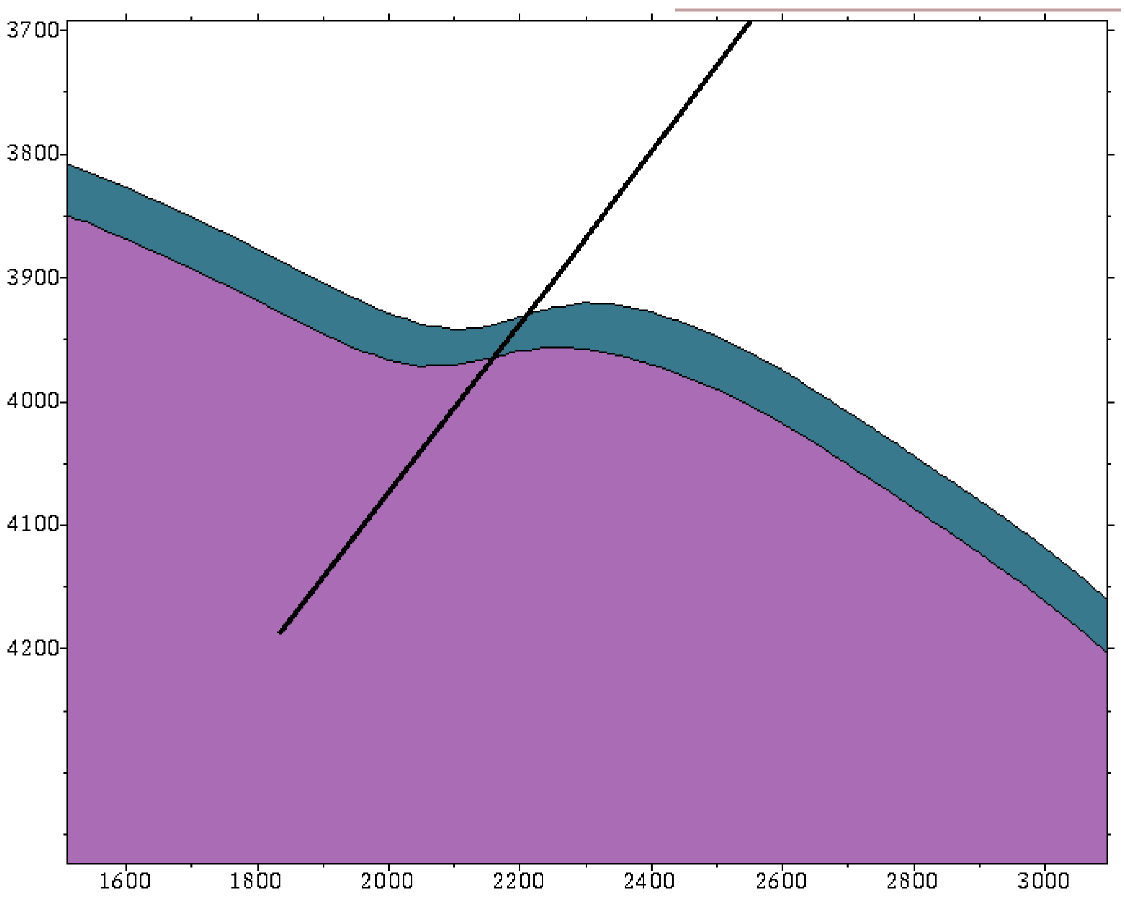
- Input;
  - Seismic data $\rightarrow$ horizons and faults.
  - Well observations.
  - Faults not well represented in the horizons.
  - Large uncertainties.

Building structural models, continued ...

- User specifies the uncertainty level.
- Basic steps;
  1. Draw a set of faults (uncertainty).
  2. Inverse fault the horizons (apply F^{-1}).
  3. Smooth horizons.
  4. Add noise to the horizons (uncertainty). Condition on well data.
  5. Fault the horizons (apply F) .
- $\rightarrow$ a realization.

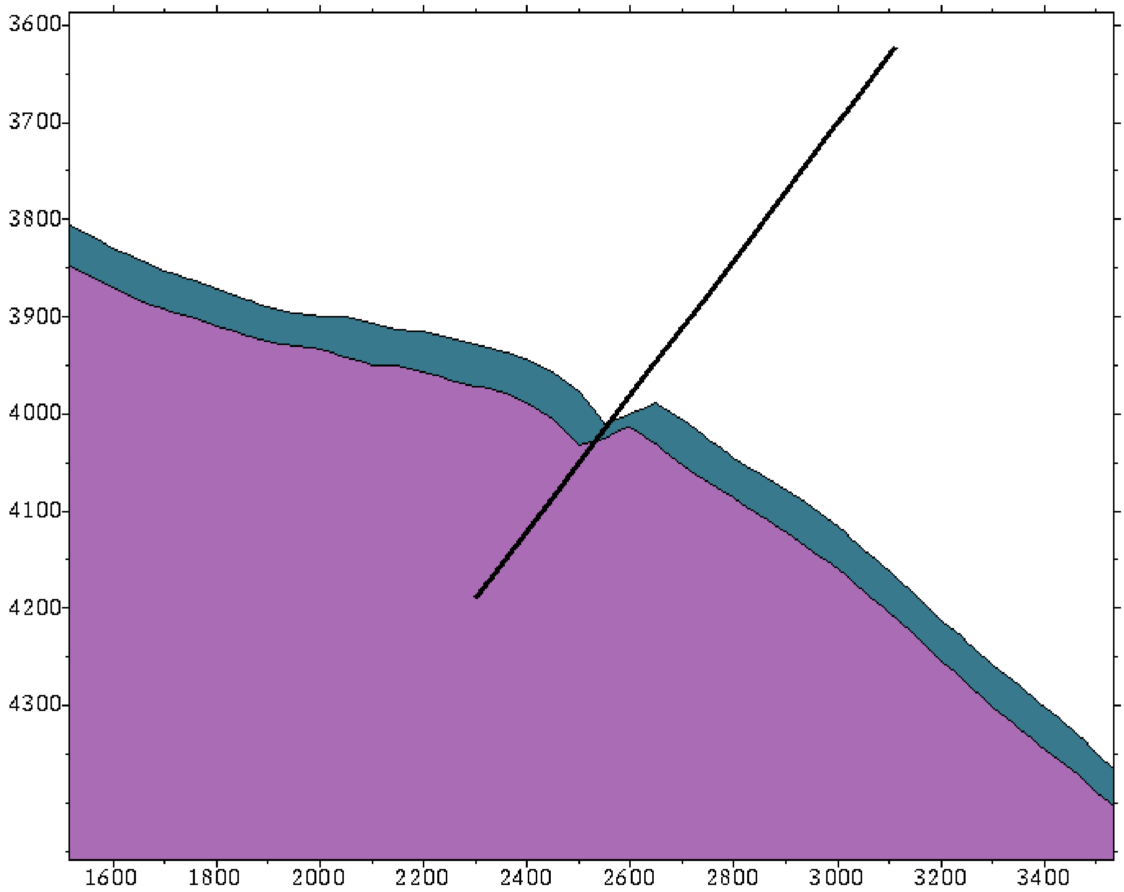
Building structural models, continued ...

Input.



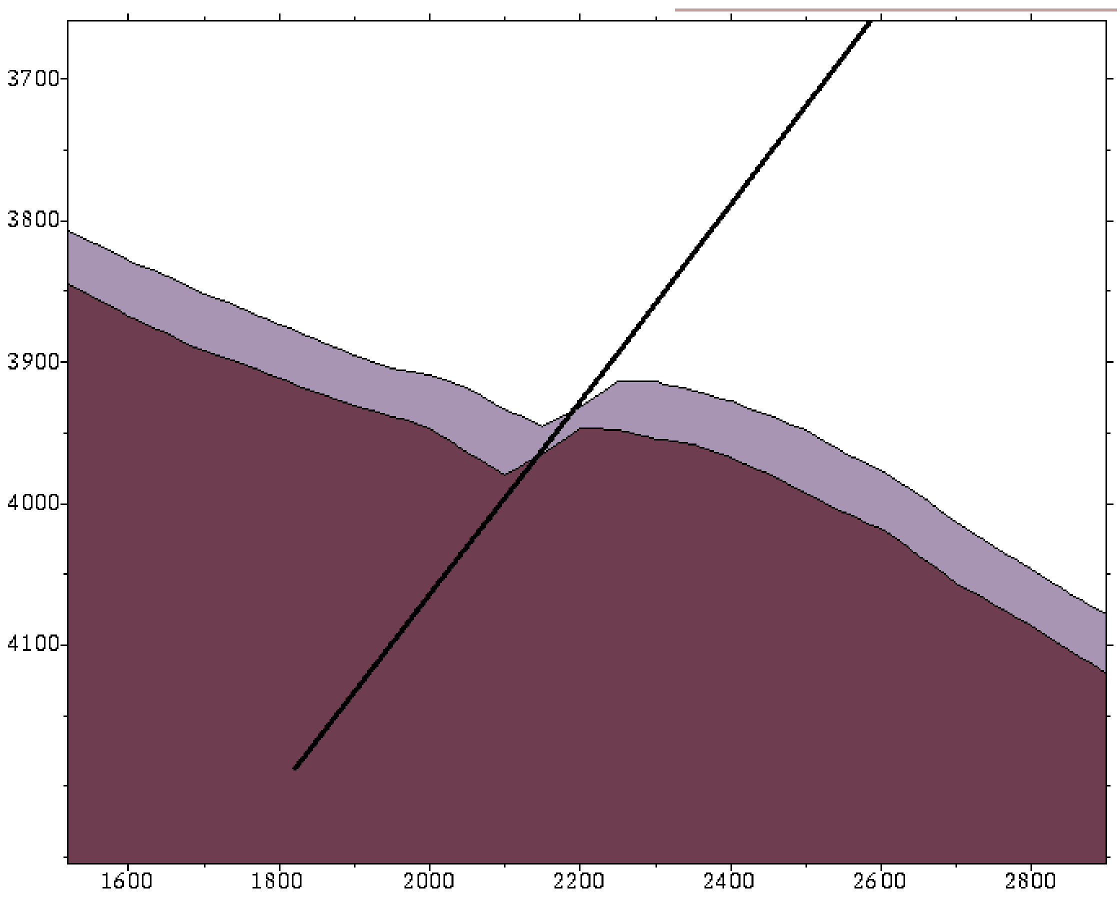
Building structural models, continued ...

Realization I.



Building structural models, continued ...

Realization II.



An example

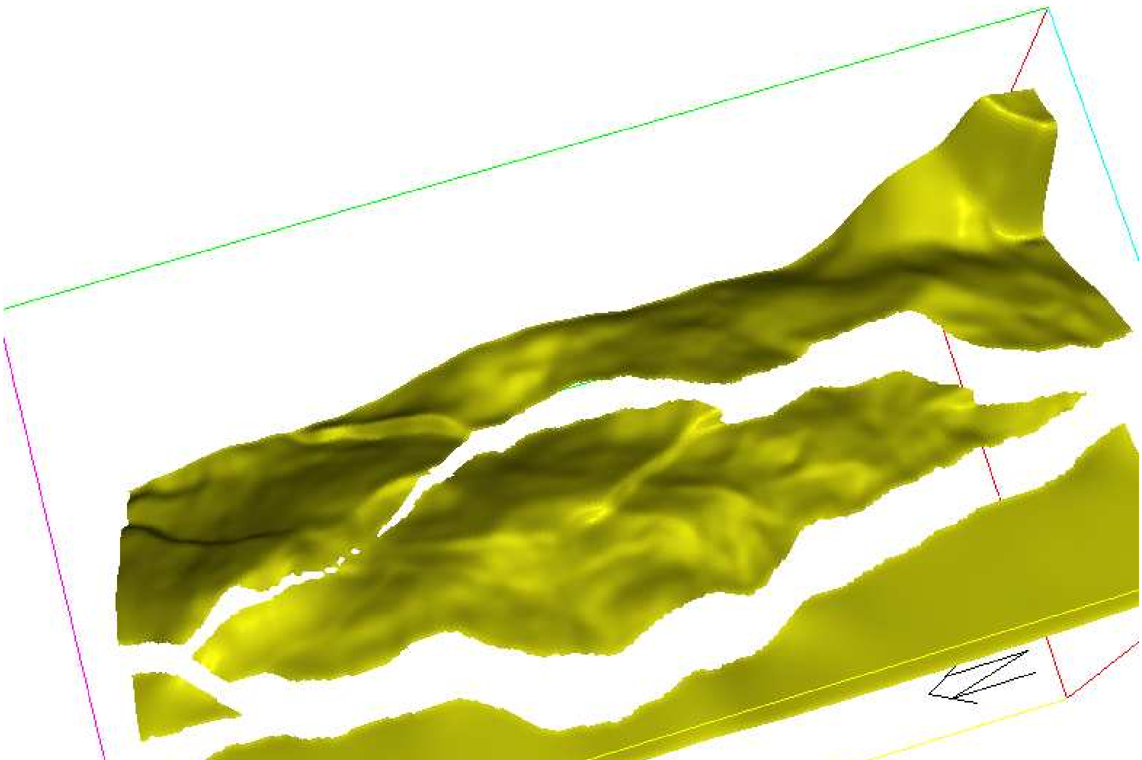
A field containing 18 faults.

- Input.
- Draw 18 faults.
- Inverse fault and smooth.
- Add noise to the horizons.
  Condition on well data.
- Apply the fault operators.

$\rightarrow$ new realization.

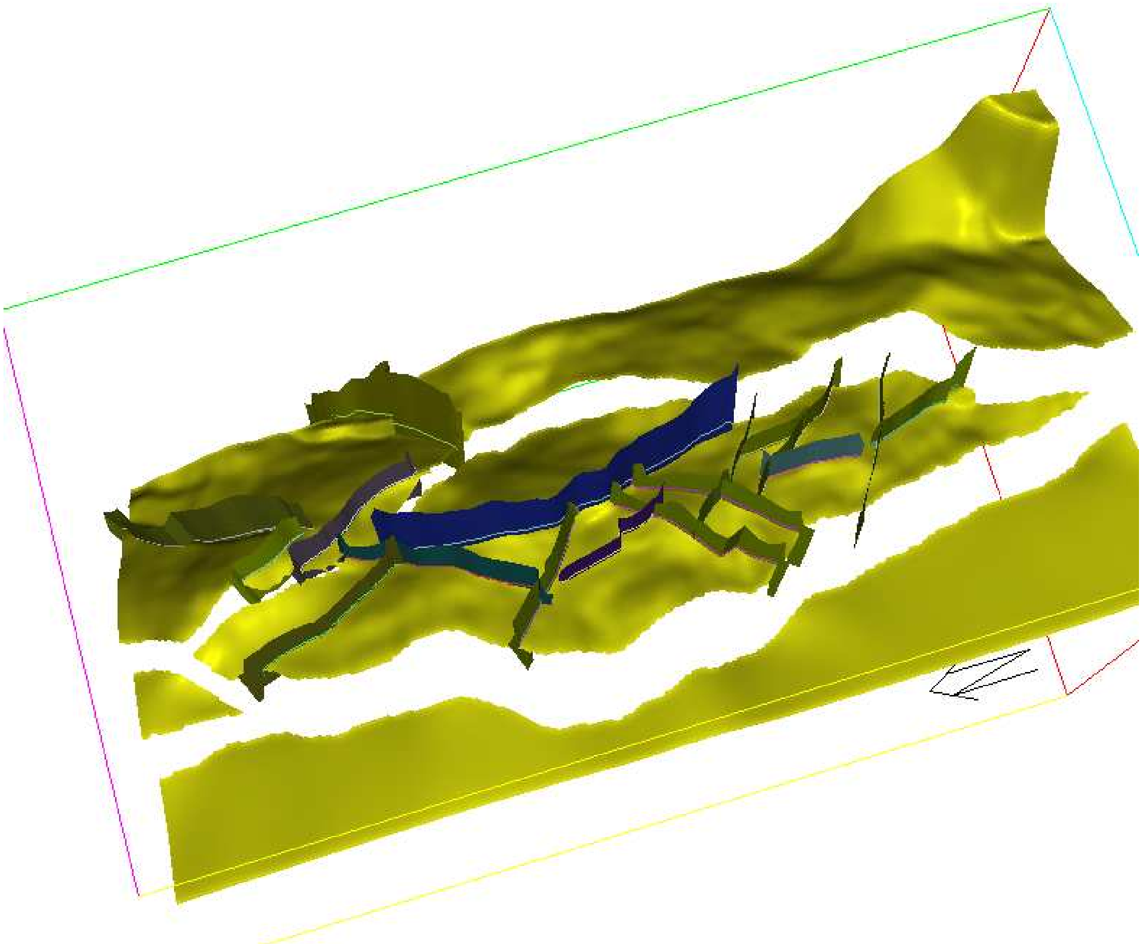
An example, continued ...

Input horizon.



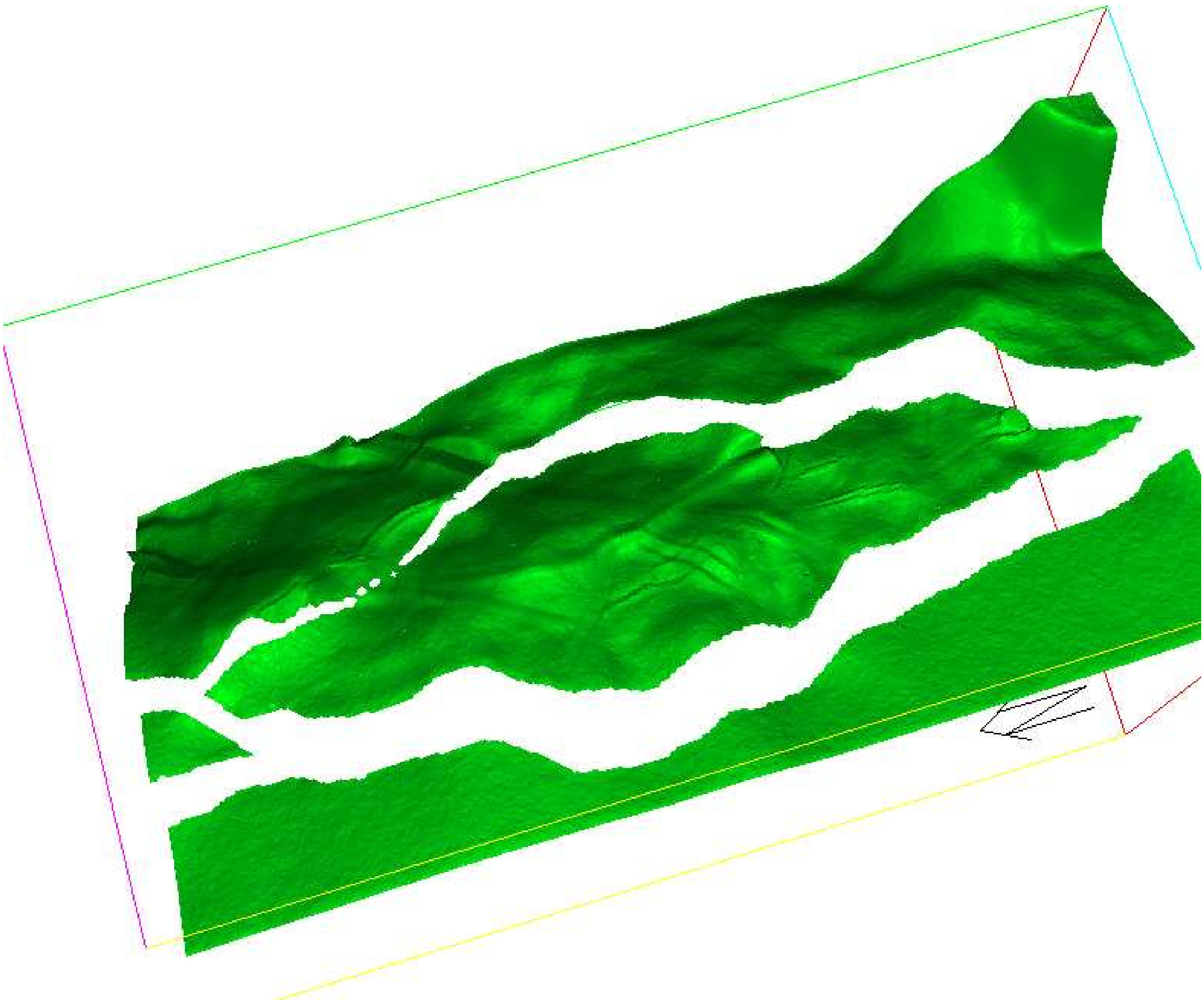
An example, continued ...

Input. 18 faults.



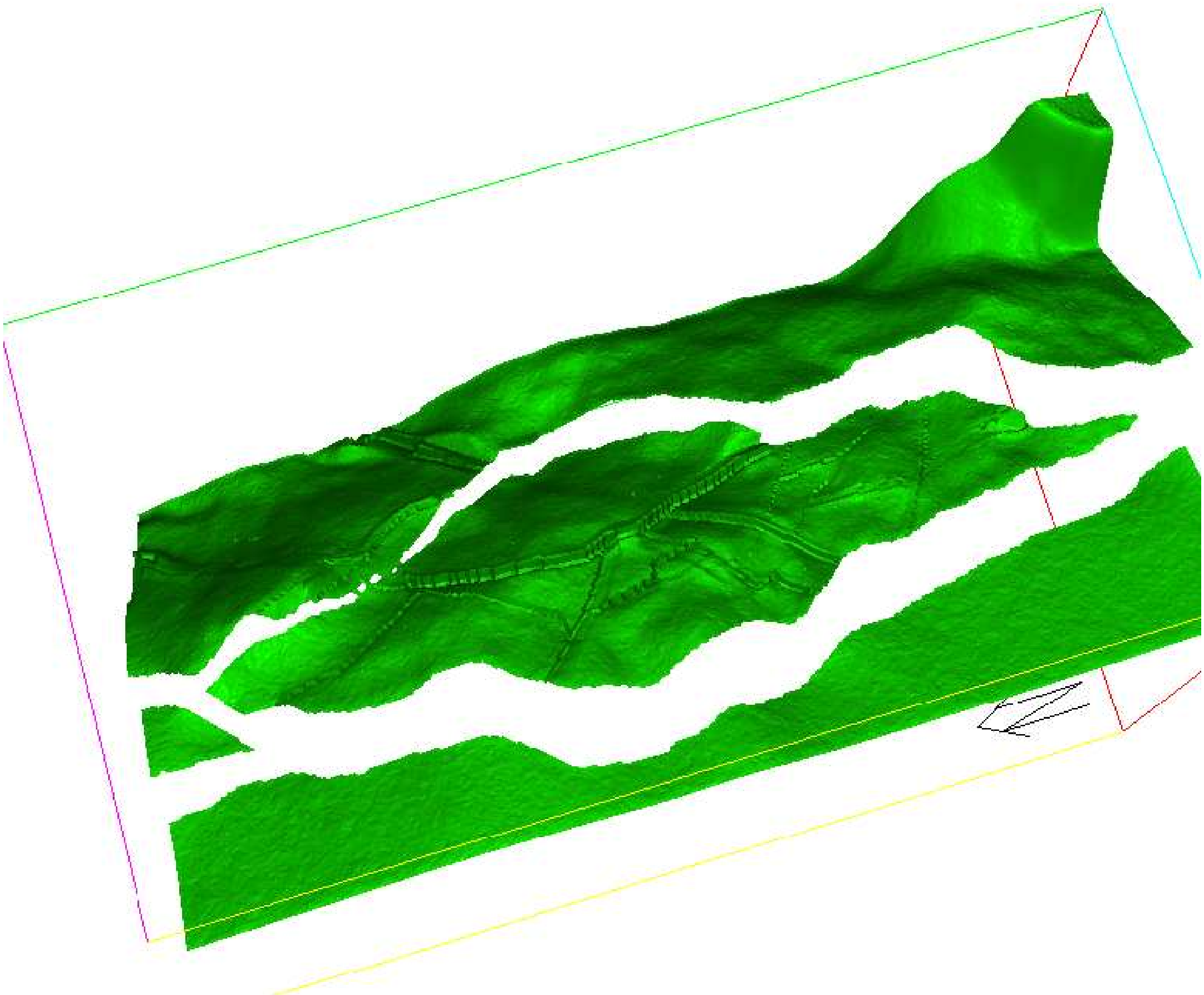
An example, continued ...

Inverse faulted and smoothed.



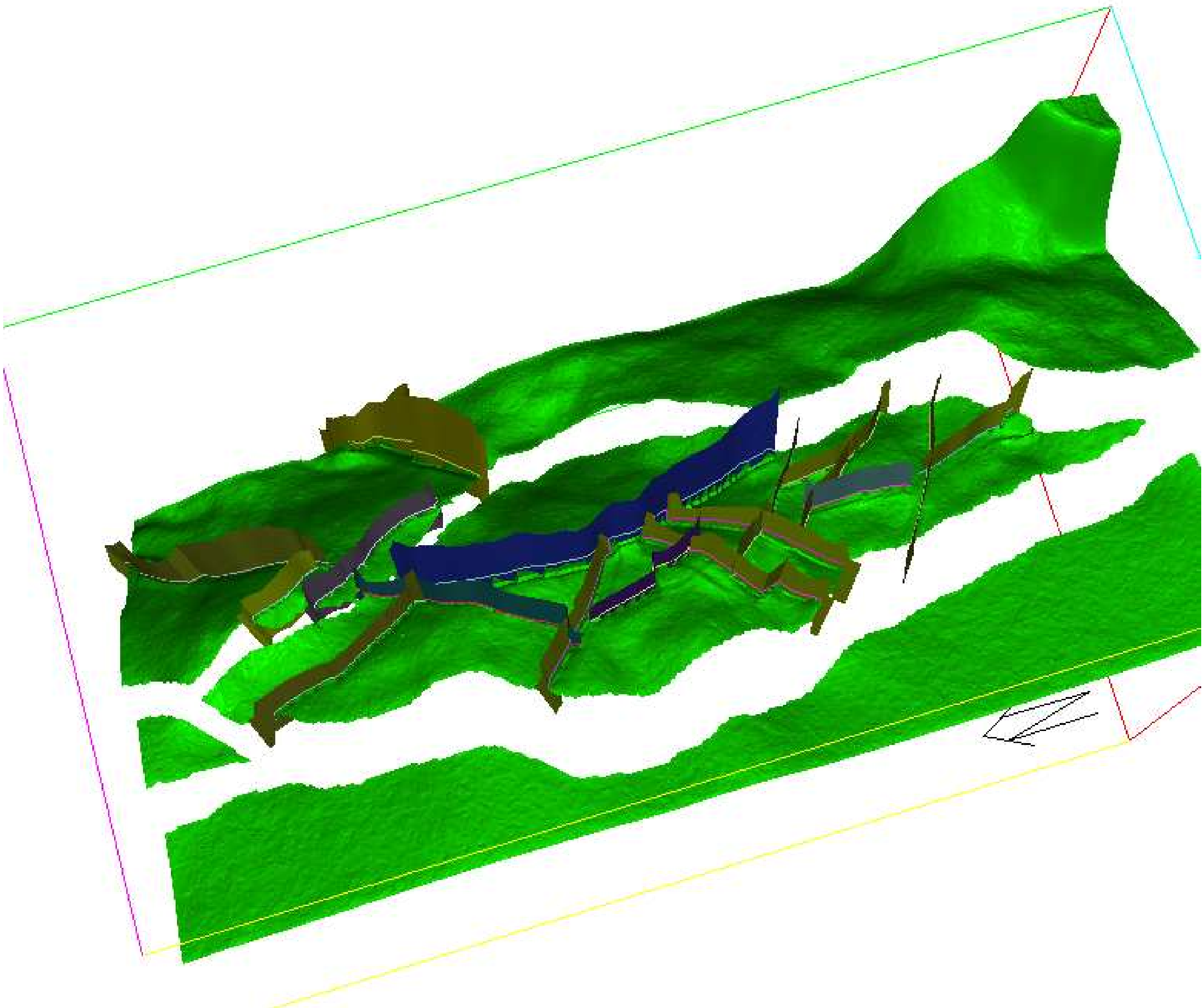
An example, continued ...

New realization. Horizon.



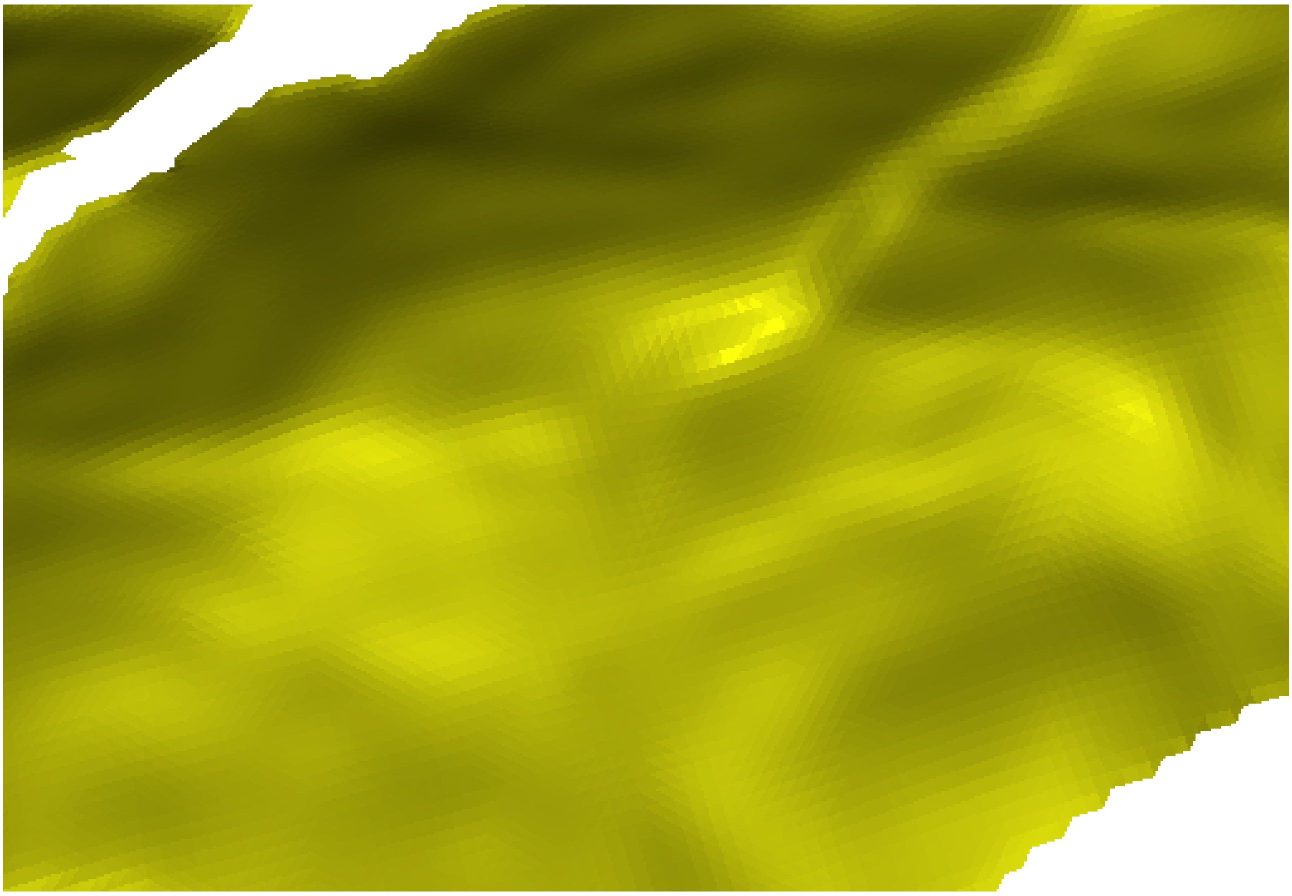
An example, continued ...

New realization.



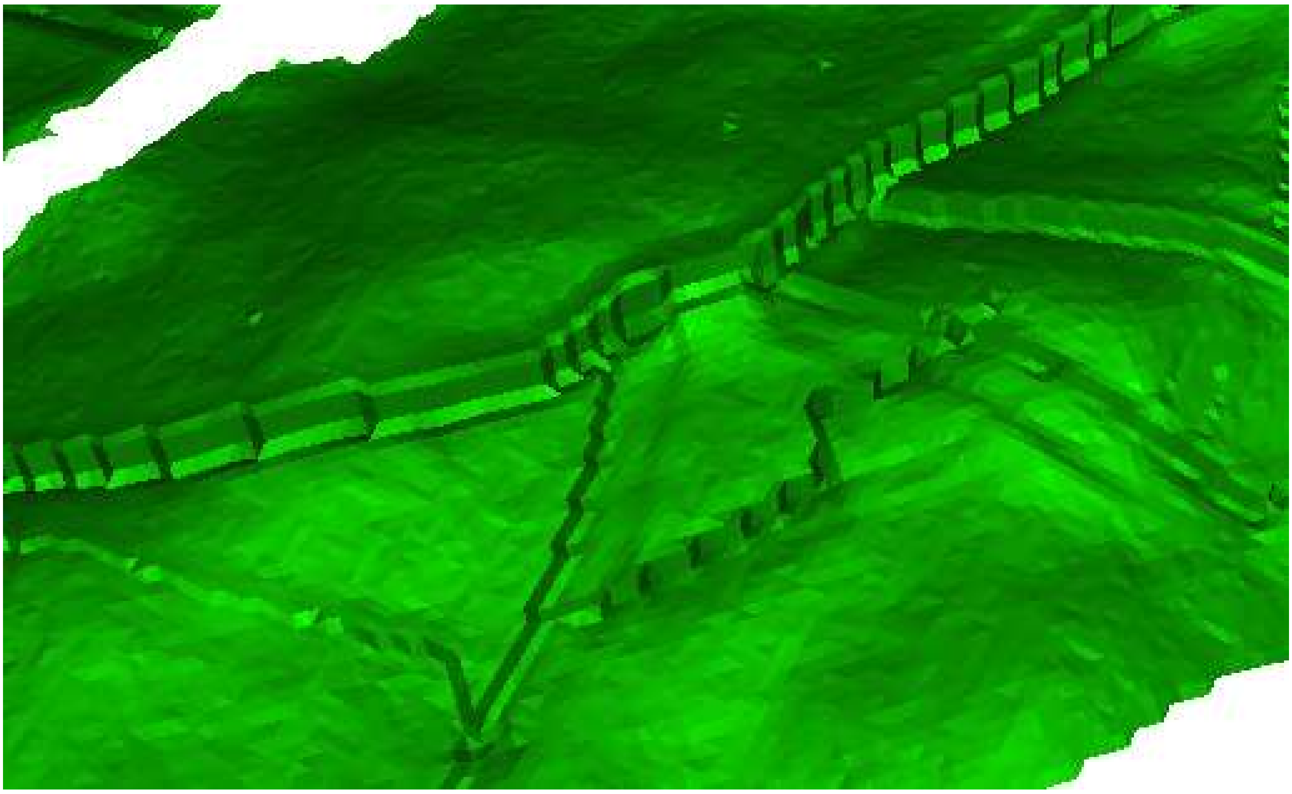
An example, continued ...

Zoom. Input horizon.



An example, continued ...

Zoom. New realization.



Conclusion

Building structural models.

- Consistency for faults and horizons.
- Uncertainty in faults and horizons.
- Basic tools;
  - Faults, invertible operators, $F : \mathbb{R}^3 \rightarrow \mathbb{R}^3$.
  - Uncertainty in horizons. Program package *Horizon*.
- Easy & efficient.
- Implementation. Program package *Havana*.