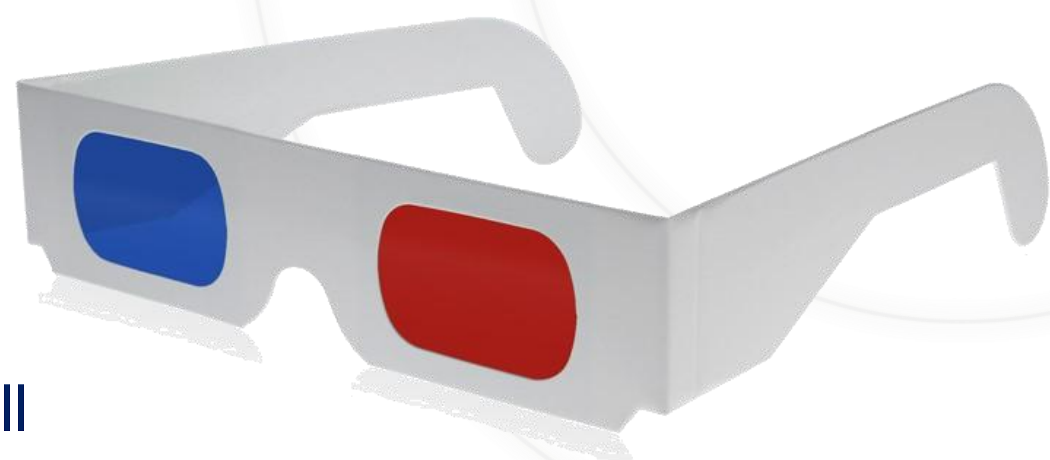
Next Generation 3D Modelling & Inversion:

what you don't know can help you



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Mark Lindsay, Florian Wellmann (CET UWA)

3D Interest Group

Aims of 3DIG

- Non-denominational interest group focussing on 3D modelling methods and applications
- All modelling scenarios (Mine, Basin, Hard rock, Lithosphere)
- Geological, Petrophysical and Geophysical

Next Meeting June 10th 15:00 CET/UWA

Speakers from the Monash Structural Geophysics Group

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Plan

1. Why 3D?
2. Uncertainty in 3D
3. Better use of geological constraints
4. Integrated Inversion

1. Why make 3D Models?

1. The act of making the model teaches you something about the internal consistency of your ideas

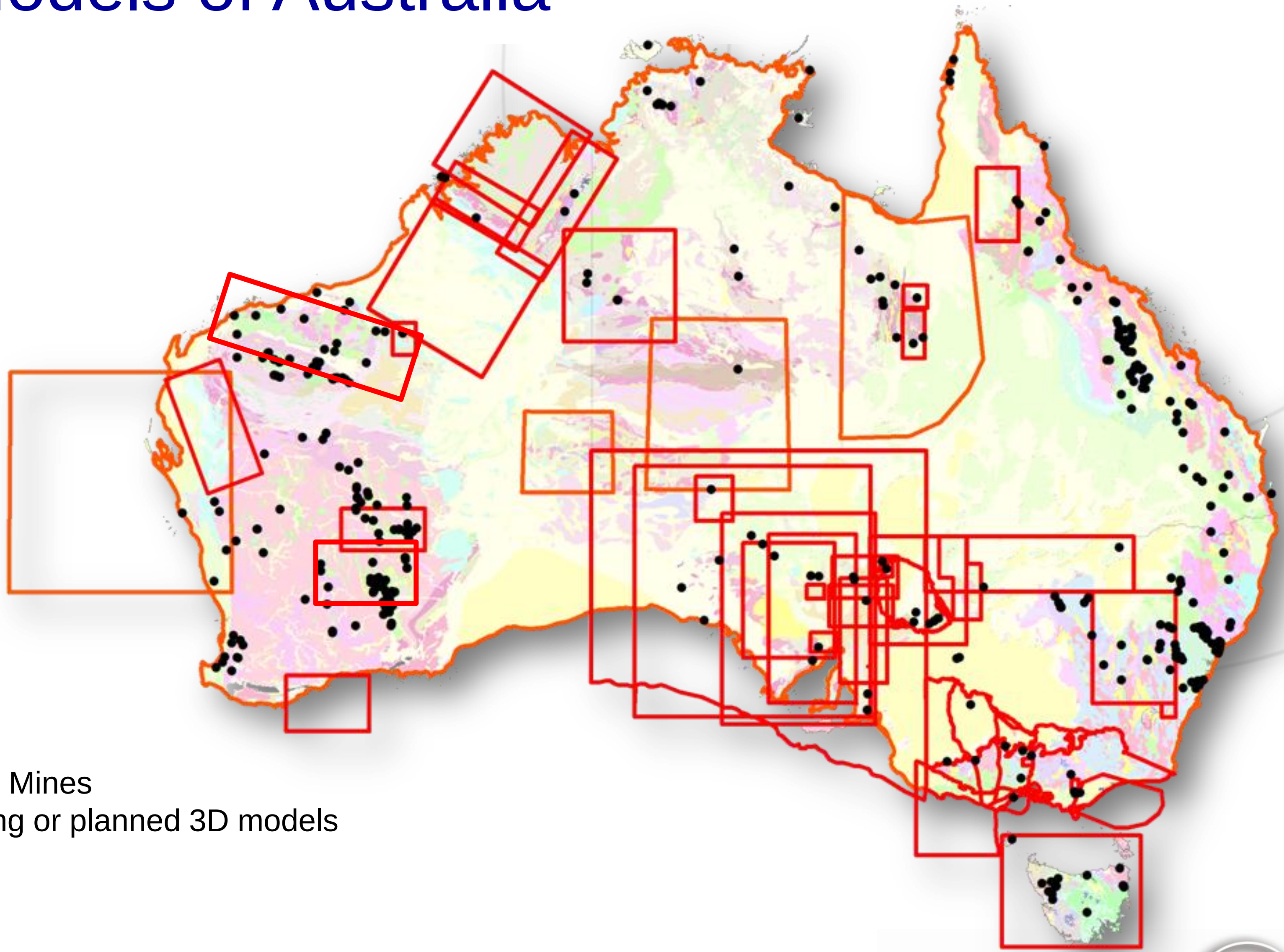
2. As 3D maps, for the communication of ideas

3. As inputs to n-dimensional process modelling (groundwater flow, thermo-metallo-tectonic modelling)

4. As prior models for geophysical inversion

To reduce the geological risk associated with exploration

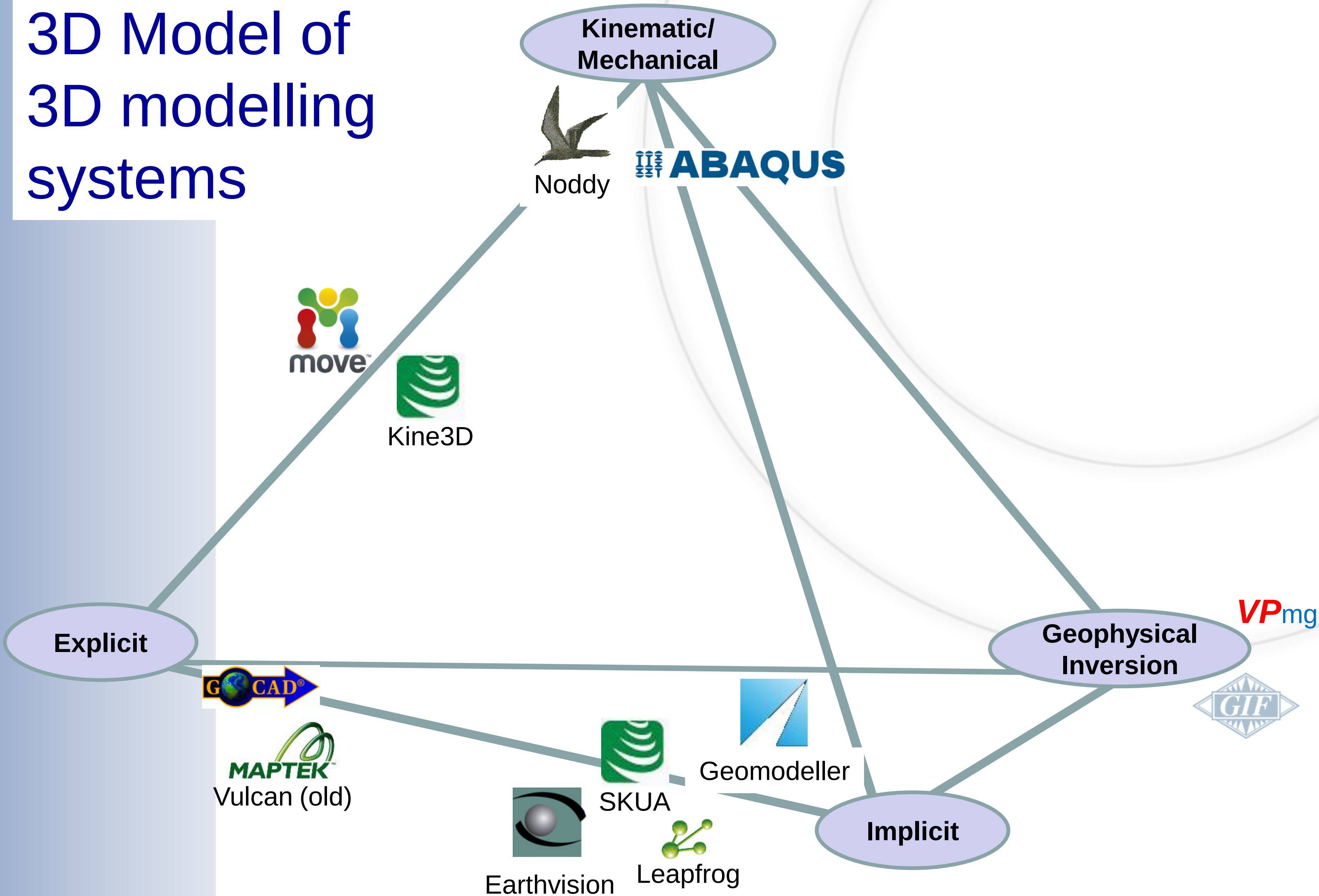
3D Models of Australia



- ● Active Mines
- Existing or planned 3D models

Centre for EXPLORATION TARGETING

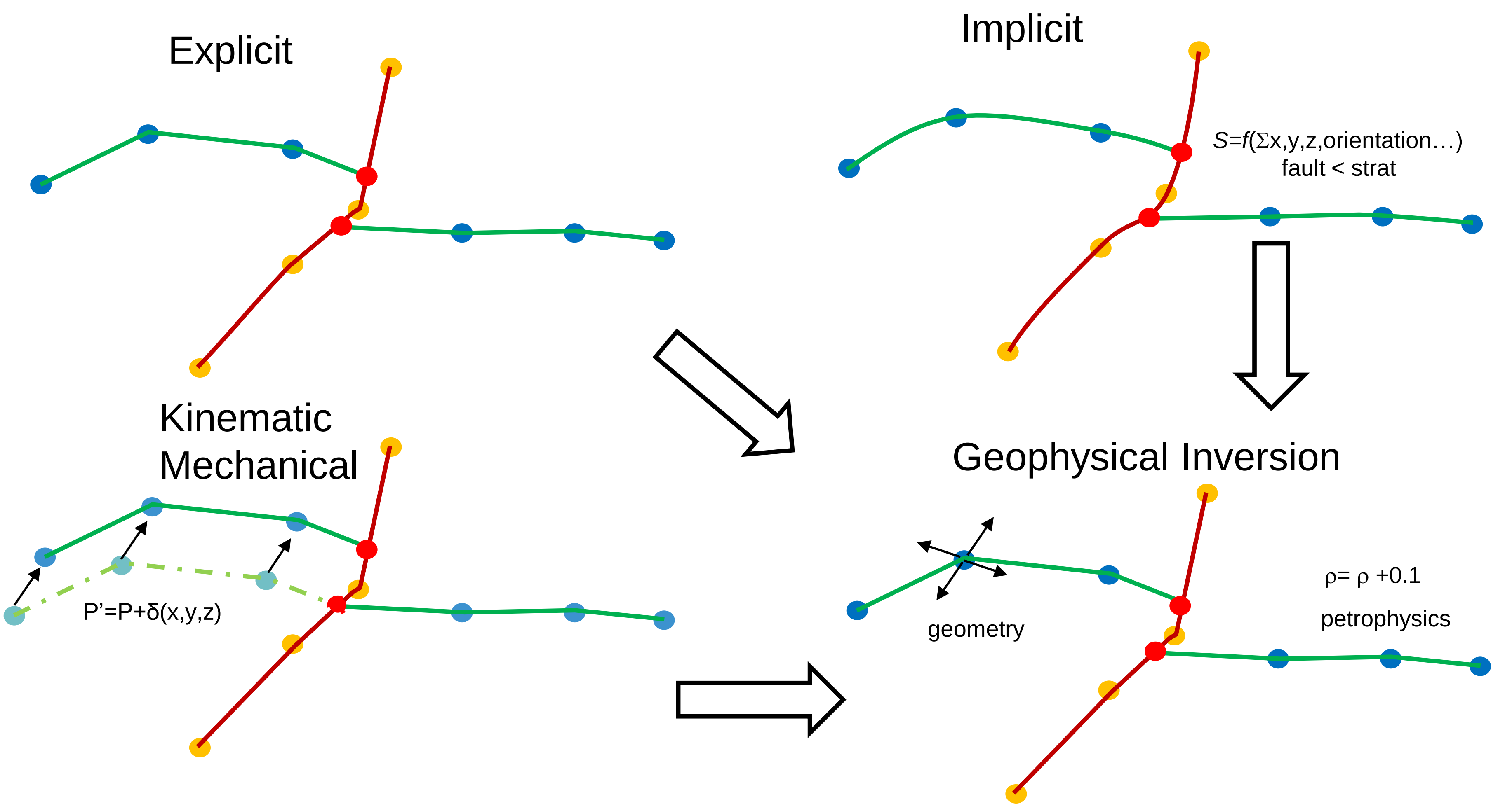
3D Model of 3D modelling systems



Vulcan (old)

Modelling Schemes

Geomodeller Leapfrog Earthvision SKUA

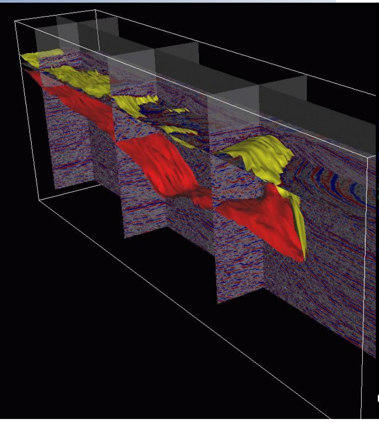


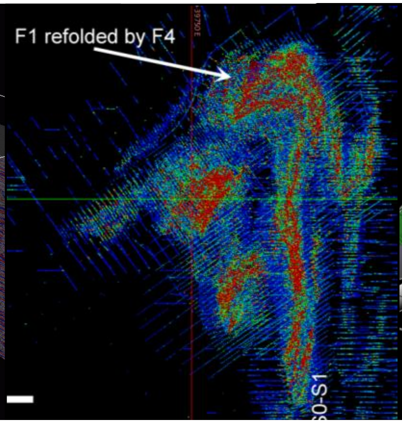
Noddy move Kine3D ABAQUS

Geomodeller VPmg

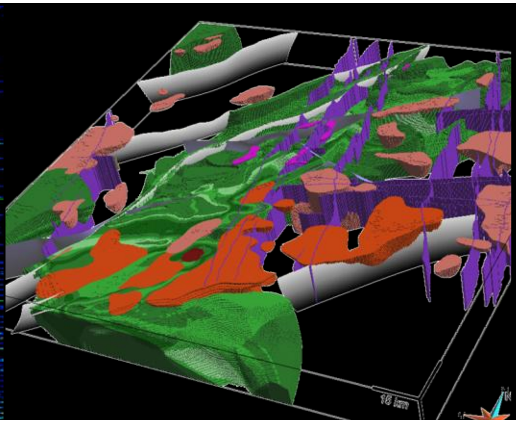
When I say 3D modelling, I mean…

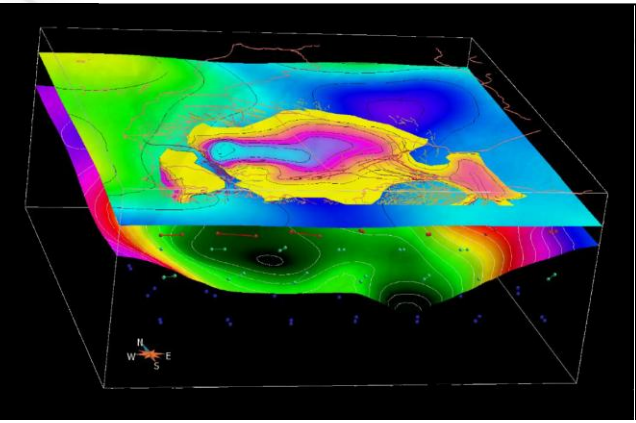
	Sedimentary Basins	Mines	Regional Hard Rock	Lithosphere
3D Constraints	**RICH** (3D seismic, deep boreholes, gravity)	**RICH** (dense boreholes, magnetics, seismic, electromagnetics)	**SPARSE** (rare boreholes, surface outcrops, gravity, magnetics)	**RICH** (Teleseismic, seismic, gravity, MT)
Structural Complexity	**SIMPLE(R)**	**COMPLEX**	**COMPLEX**	**SIMPLE(R)**
Dedicated Software	Gocad 1989, Geomodeller 1999…	MicroMine 1986, Leapfrog 2003...	Noddy 1981	Gocad 1989

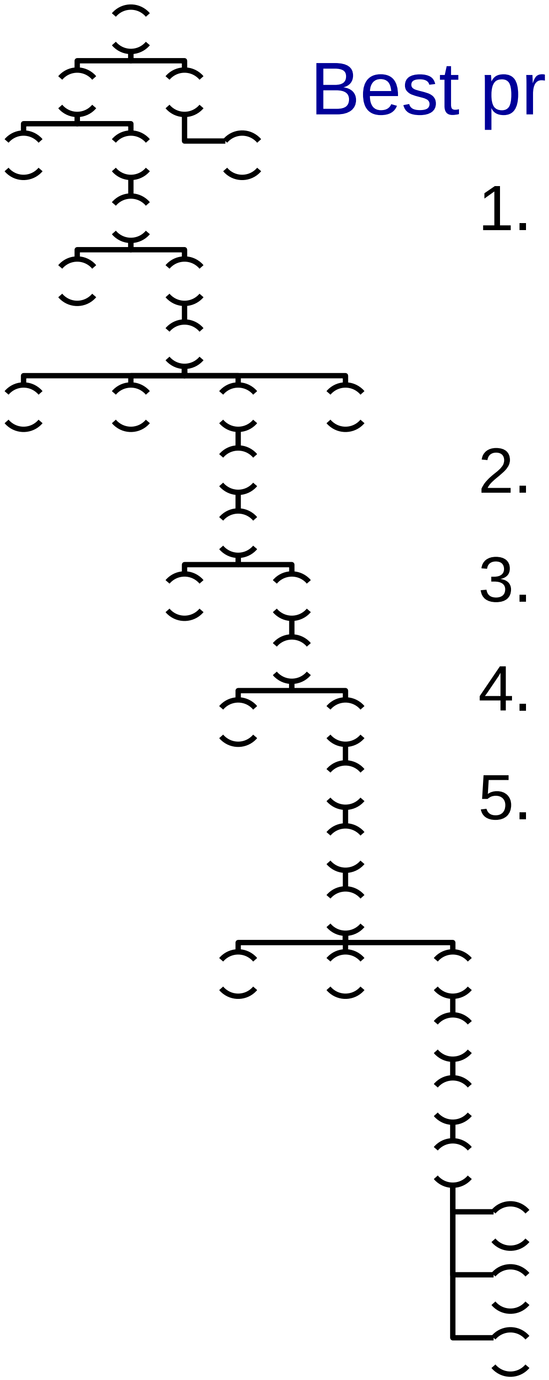

Basin



Mines

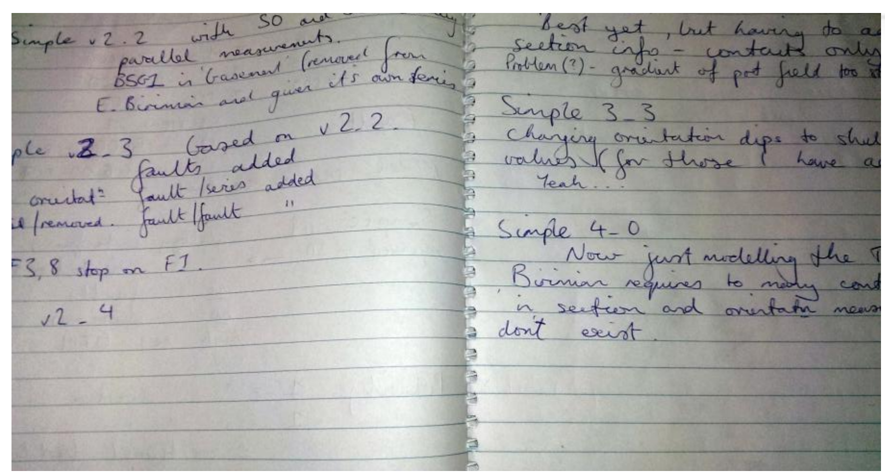

Regional


Lithosphere



Best practice: The single "best guess model"

1. Works for maps, but much lower density of 3D information reduces the value of this approach
2. No separation of data and interpretation
3. No error bars
4. Not reproducible
5. Fixed geometry & topology of inputs for process modelling and geophysical inversion



3D geology is an under-constrained problem
-Sampling Error

- We do not have sufficient geological and/or geophysical data to define a unique 3D model

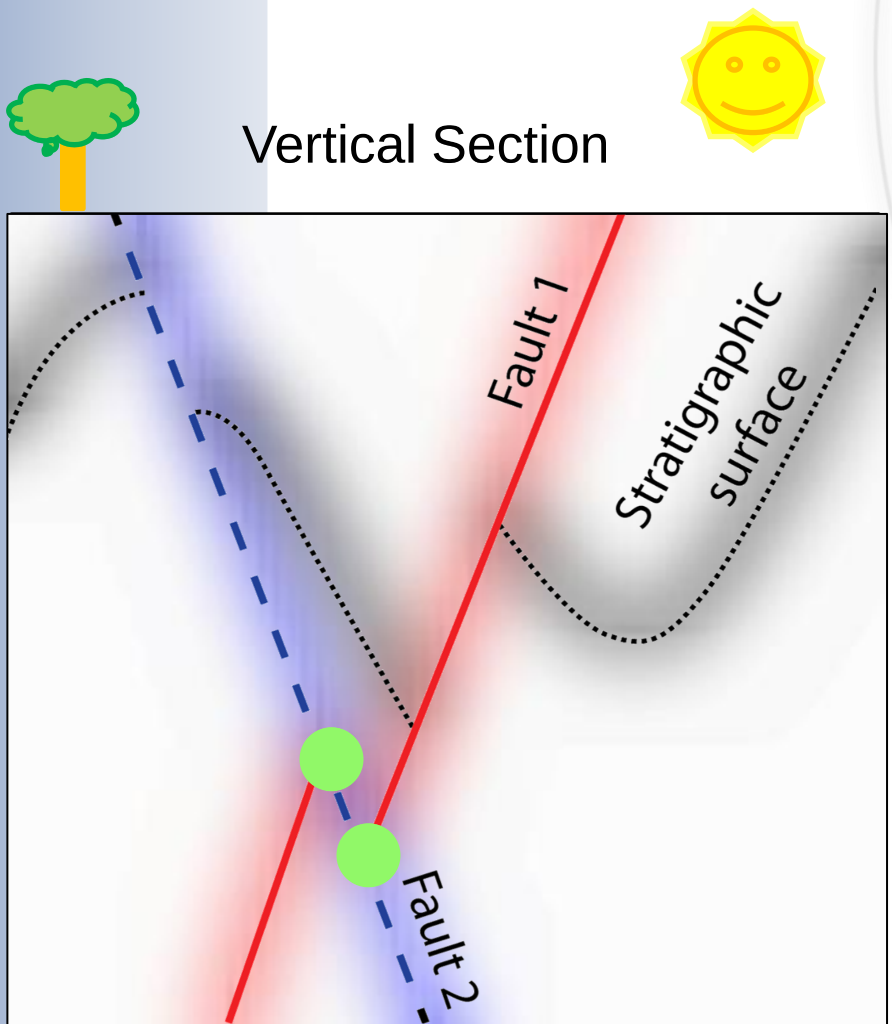
$$\Downarrow$$

- Therefore we shouldn't restrict ourselves to a single model (error bars, just like a real science)

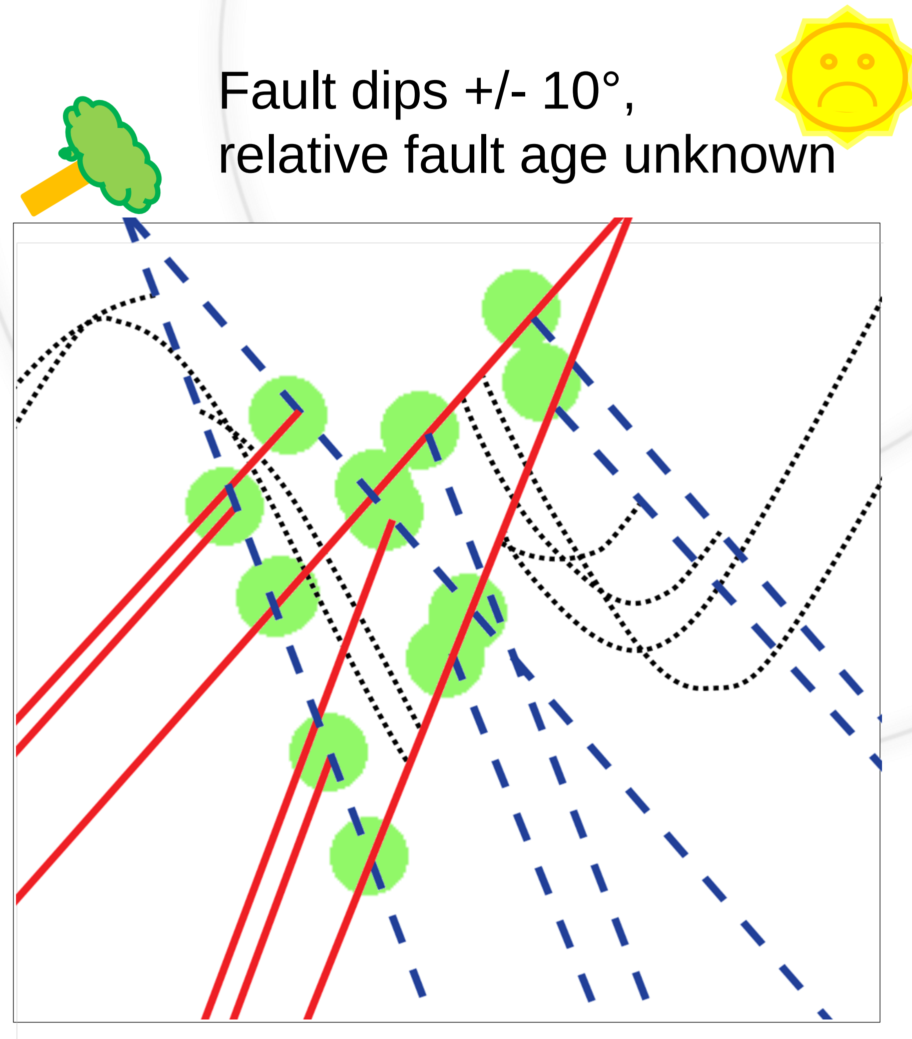
$$\Downarrow$$

The conclusion is that 3D Modelling tools that require continual manual intervention are a dead end

2) Geometric vs geological uncertainty

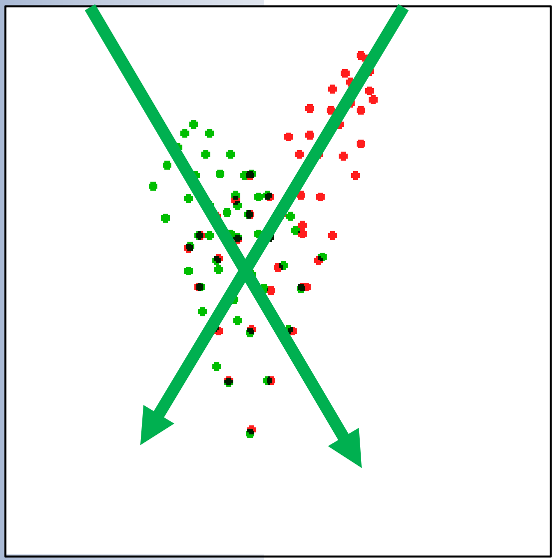


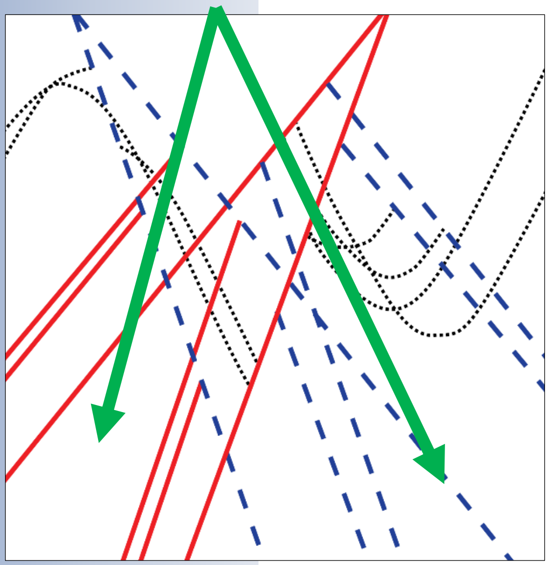
***Geometric** Uncertainty*



***Geological** Uncertainty*

Which Targeting Strategy?





Short term:
drill where most likely to hit intersection

≠

Long term:
drill where you are most likely to understand system

≠

Optimal:
maximise stable share price increase

Uncertainty & Simulation

Original Inputs — 45

Perturbed Inputs 1 — 44

Perturbed Inputs 2 — 43

Perturbed Inputs 3 — 47

Perturbed Inputs 4 — 41

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•
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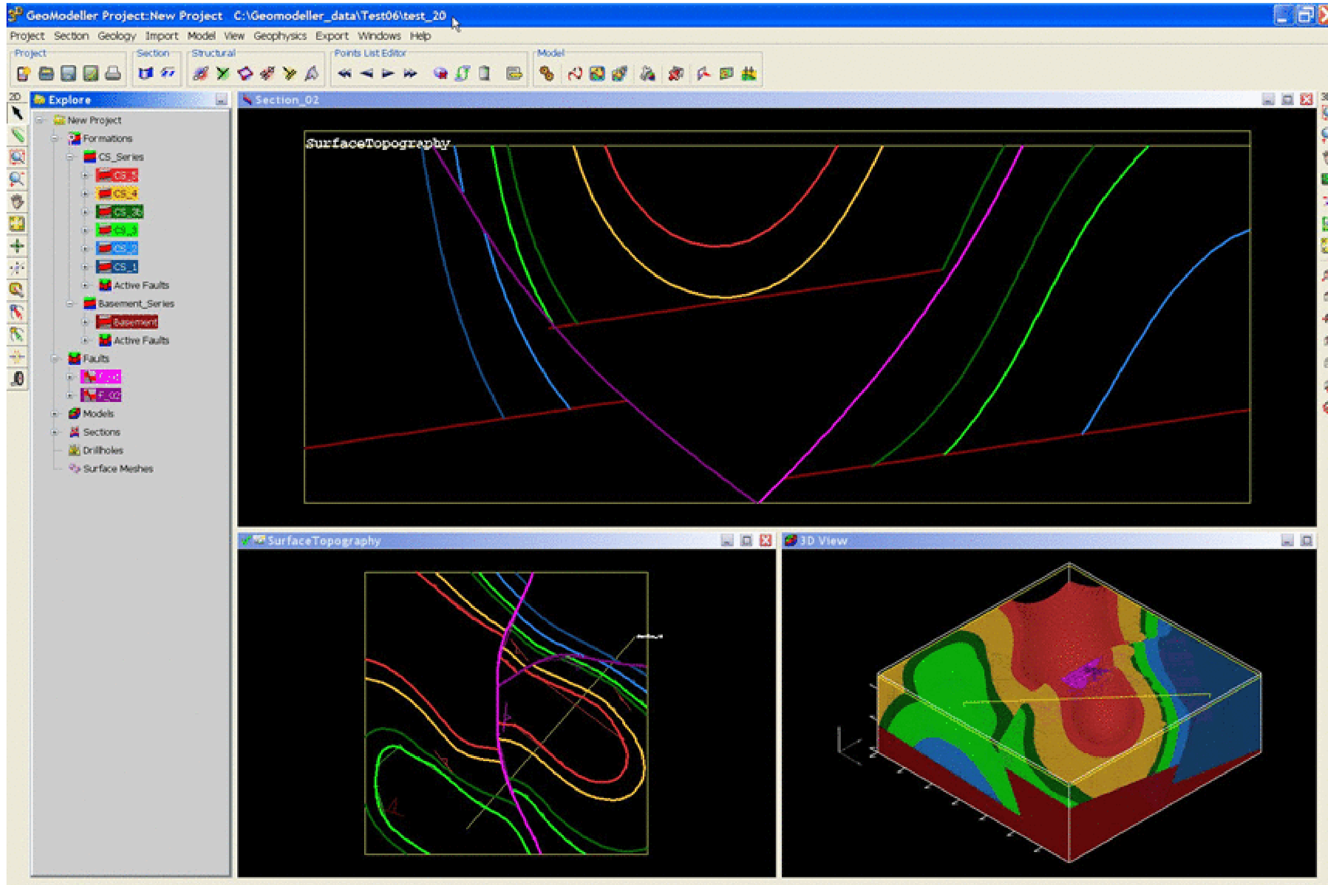
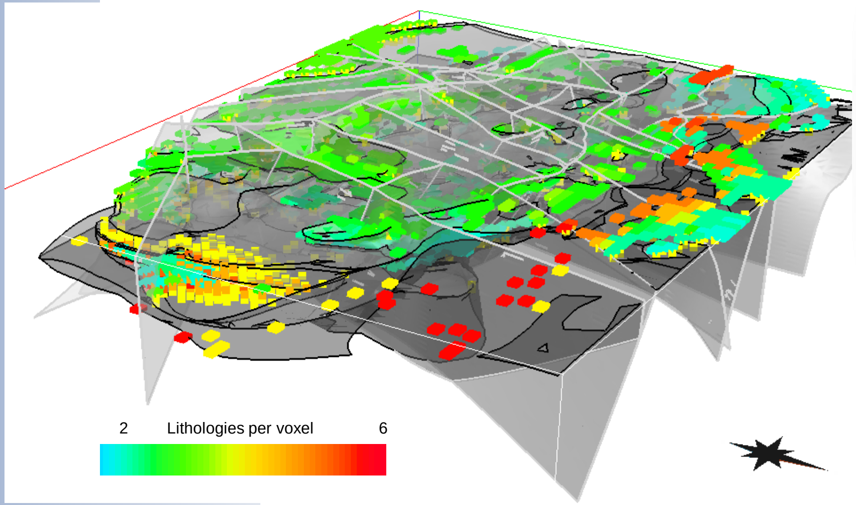
Perturbed Inputs N — 45

Implicit Modelling Engine

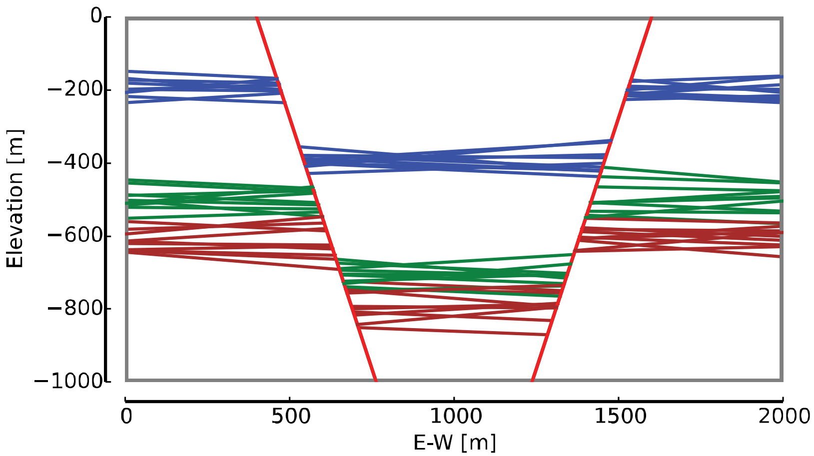


Wellman et al., 2010, 2011
Jessell et al., 2010
Lindsay et al., 2012,2013

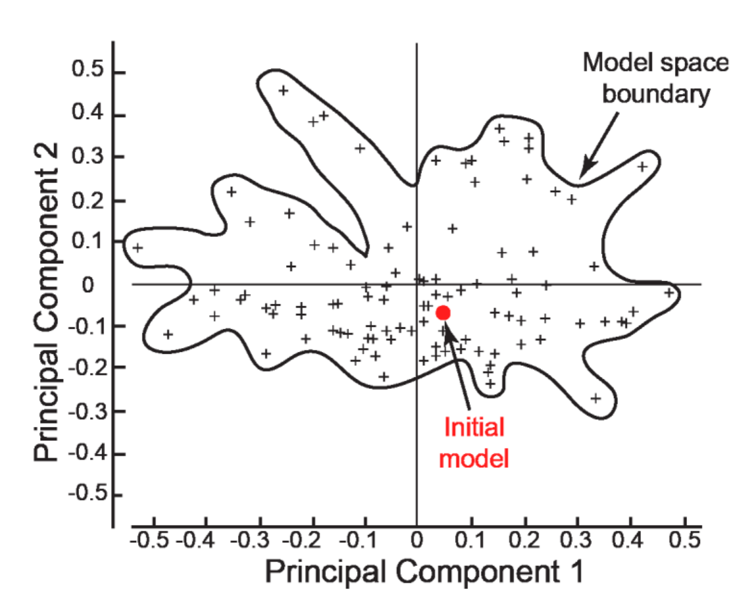
Uncertainty



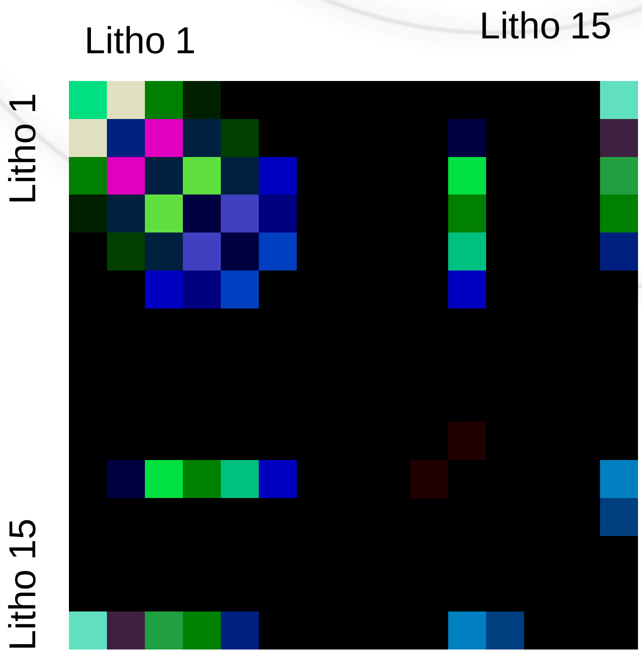
Stratigraphic Variation



Geometric Variation



Geodiversity



Topological relationships

Why is geological uncertainty important?

1. It allows us to assess reliability of subsequent predictions, which leads to reduction of technical risk
2. Provides improved sampling strategies (drill-hole, mapping, geophysics…)
3. Gives us pathways to integrated inversion

3) Increasing Geological Content

-Errors of the mathematical evaluation of geological data

- Current implicit systems stop mid-way to producing “geologically reasonable models”

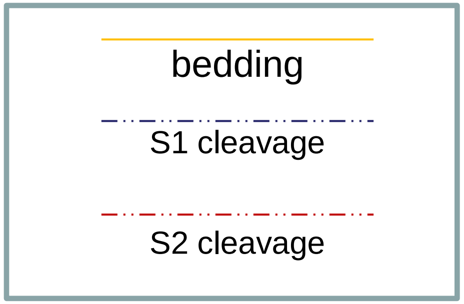
$$\Downarrow$$

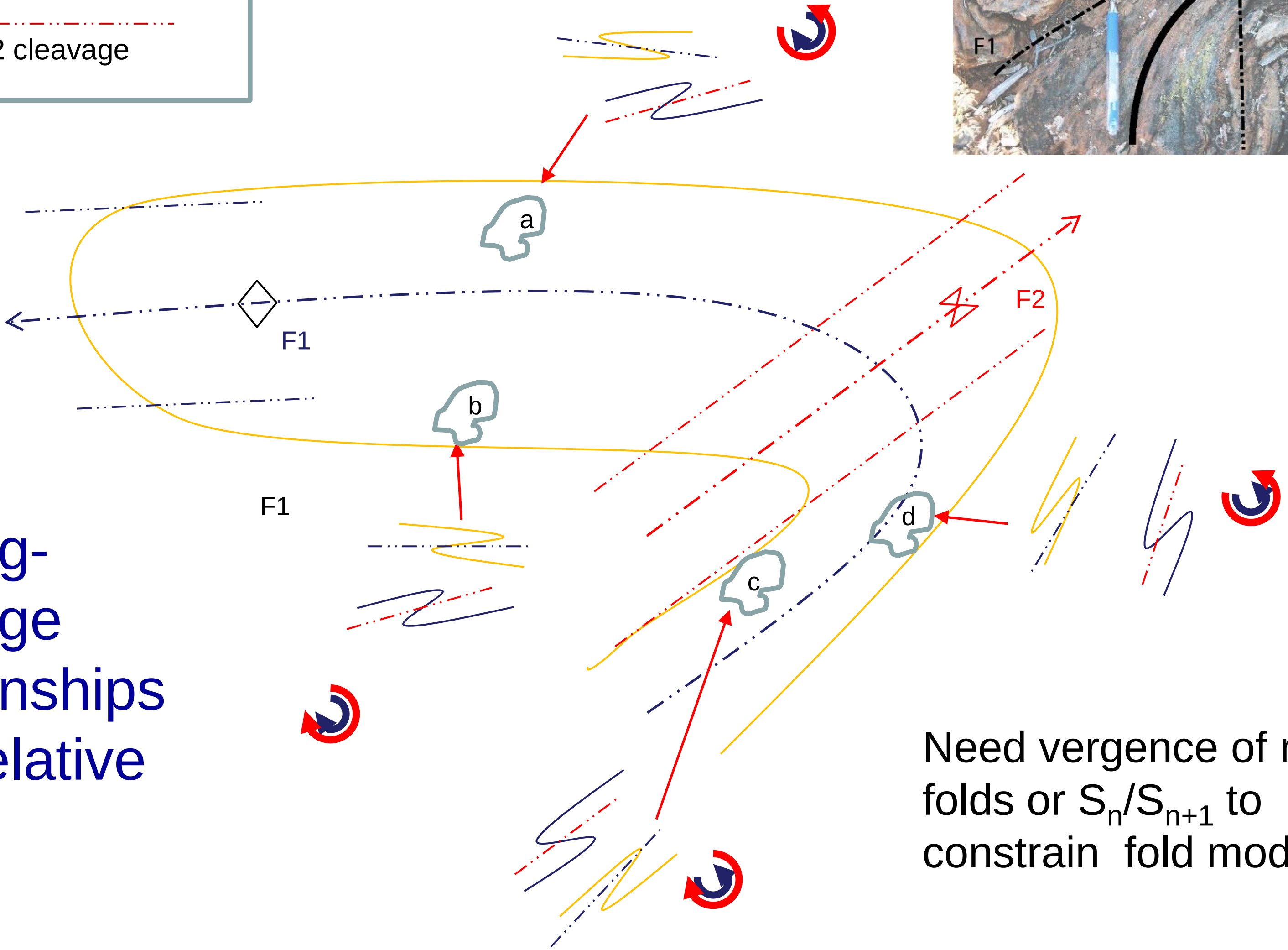
- Implicit schemes do not incorporate sufficient geological data or knowledge to fill in the gaps

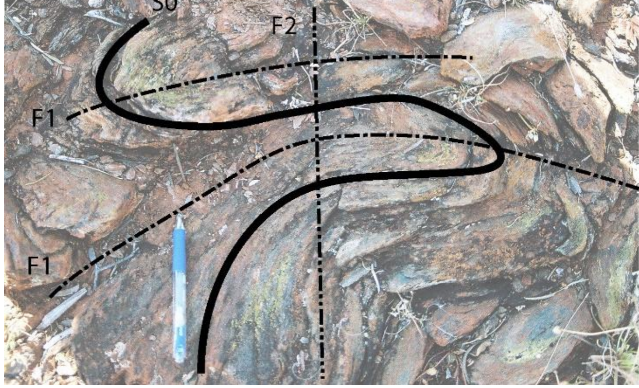
$$\Downarrow$$

- A major task is to make implicit schemes honour our geological data and knowledge in hard rock environments

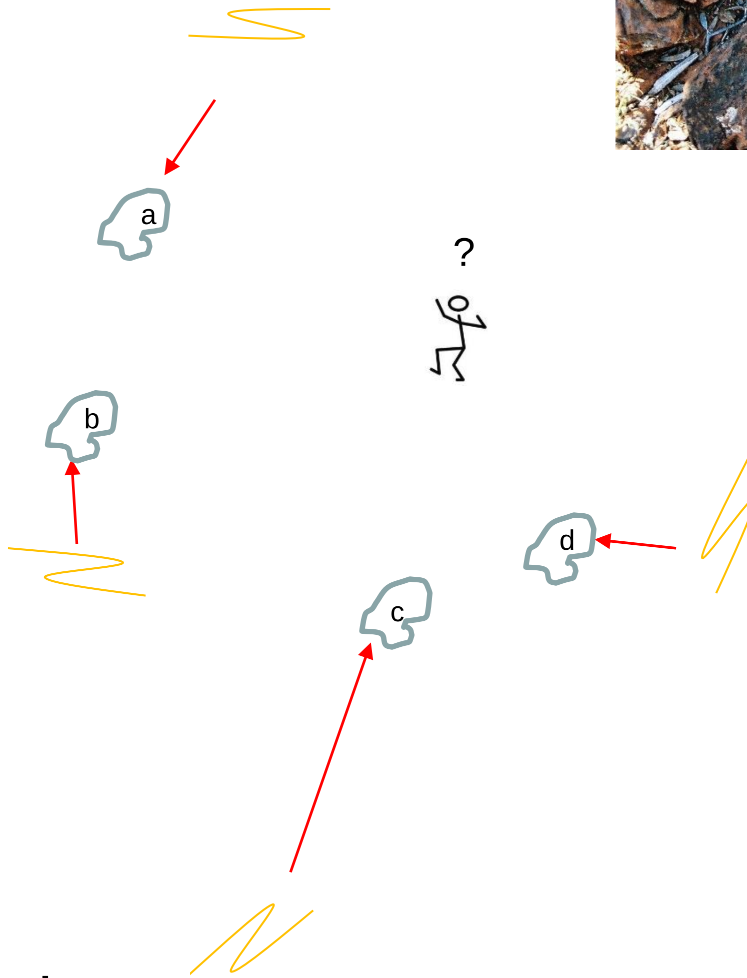
Bedding-Cleavage Relationships with Relative Timing







Need vergence of minor folds or S_n/S_{n+1} to constrain fold model bedding



Bedding Only

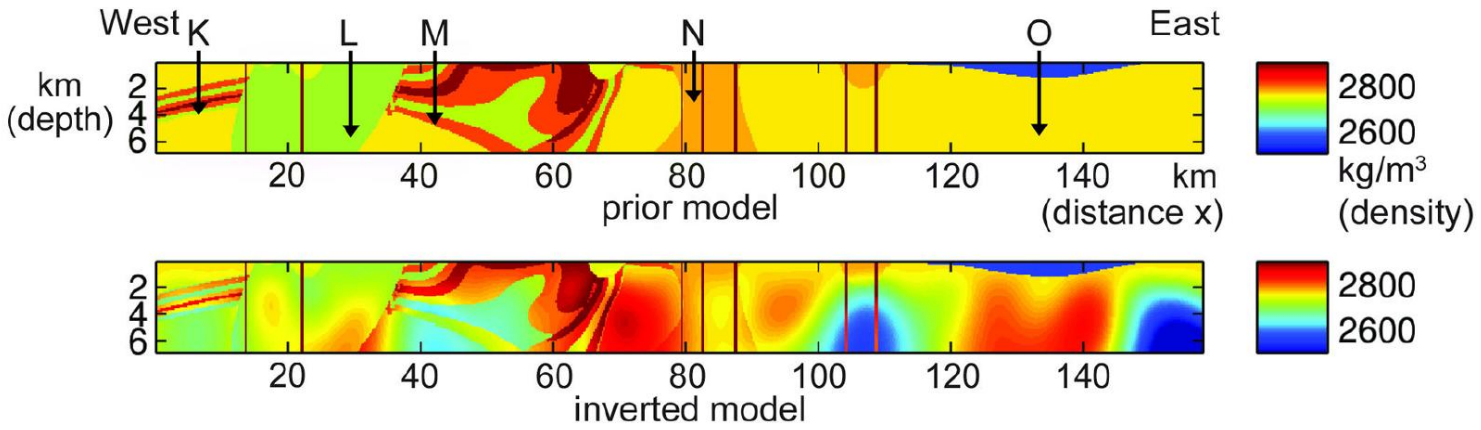
Without additional data (cleavages) and knowledge (vergence relationships) this problem is unsolvable

4) An outcrop (or borehole) is worth a thousand voxels

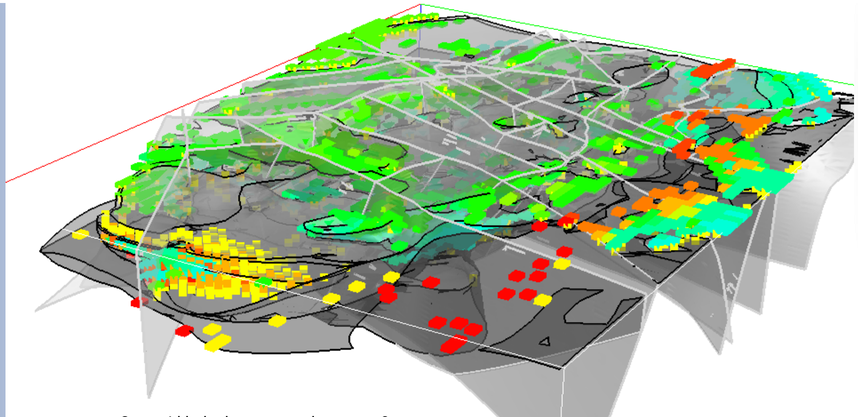
- Geophysics is absolutely essential, BUT we need…
- inversion schemes that retain geological meaning through the inversion process
- to be able to test the results against both the original geophysical AND geological data

Prior Model

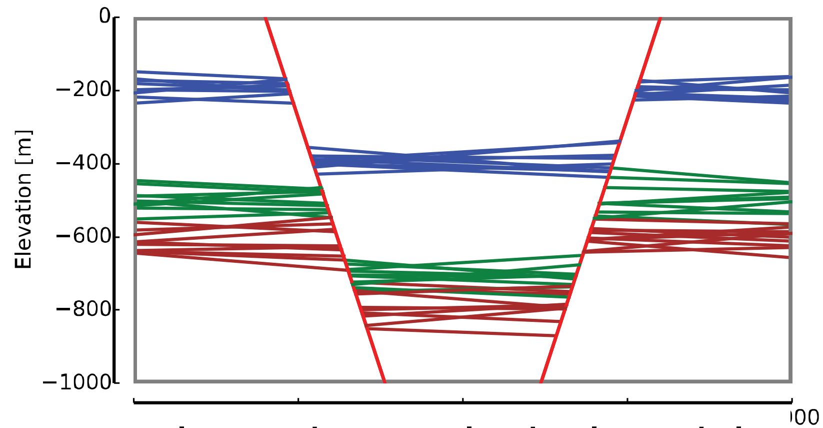
Inversion



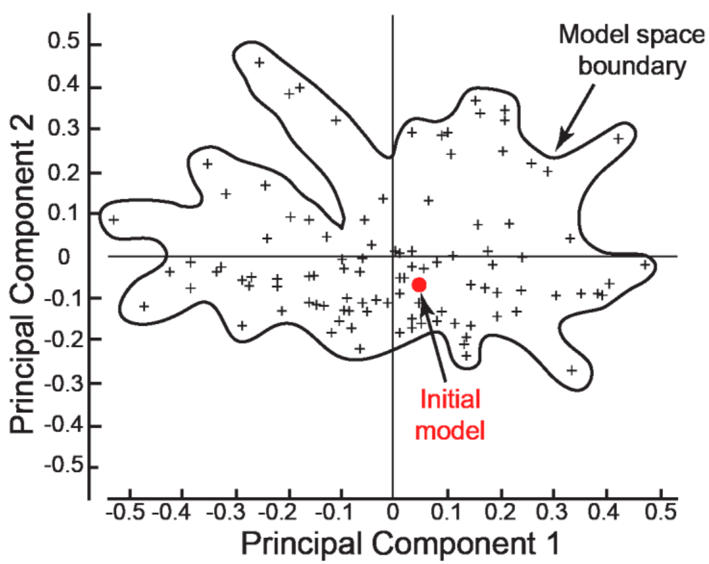
Geological constraints on geophysical inversion



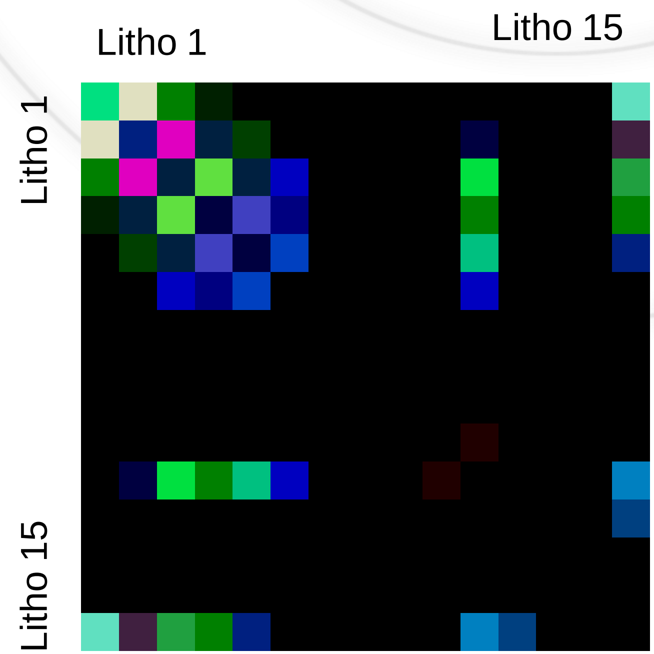
Constraints on petrophysical properties



Alternative geological models

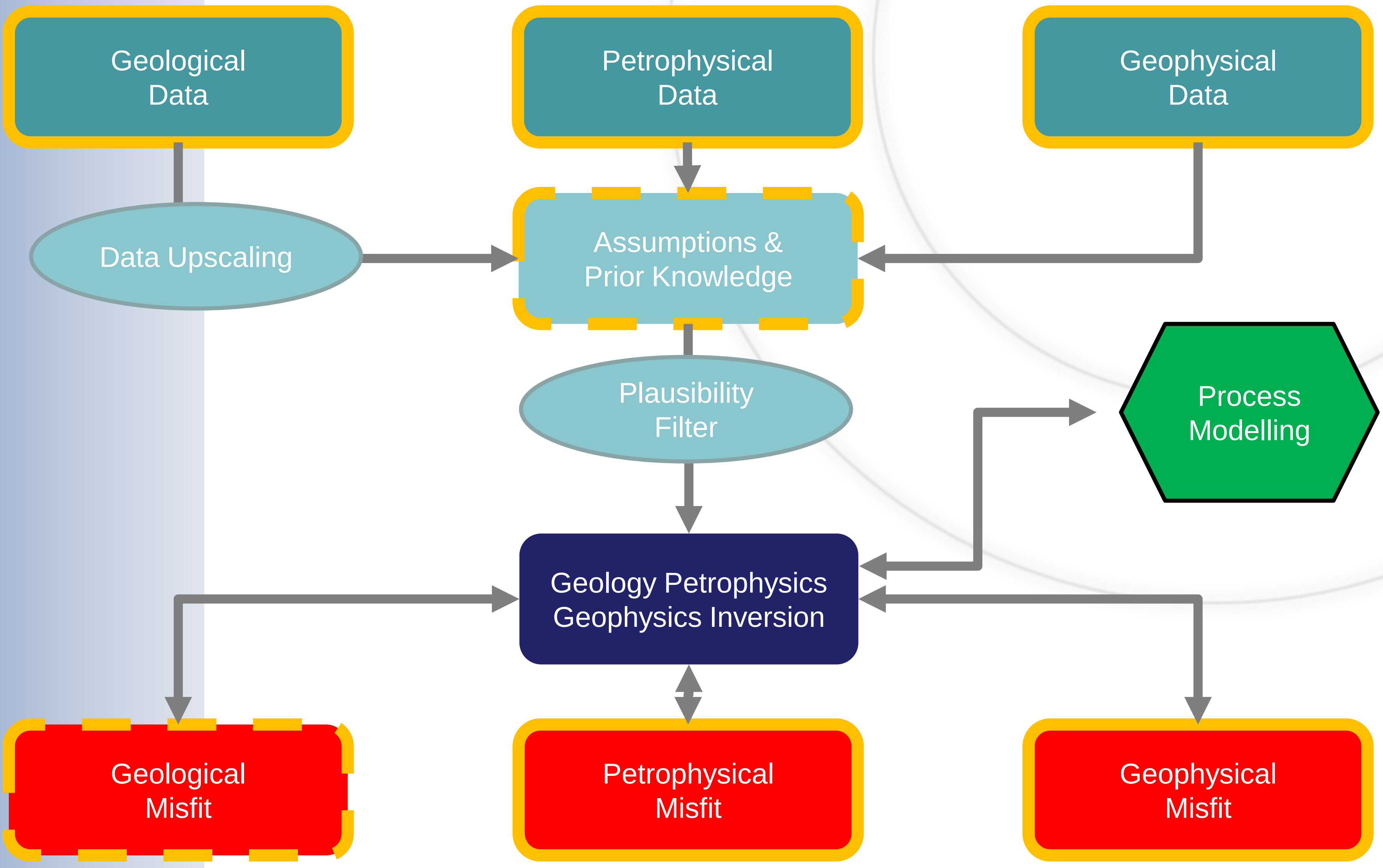


End-member geological models



Topologically distinct geological models

Goal


Geological
Data
Petrophysical
Data
Geophysical
Data
Data Upscaling
Assumptions &
Prior Knowledge
Plausibility
Filter
Process
Modelling
Geology Petrophysics
Geophysics Inversion
Geological
Misfit
Petrophysical
Misfit
Geophysical
Misfit

Conclusions

1. Uncertainty analysis helps transform 3D models from physcho-kinetic art to scientific tools

2. We need to use implicit schemes so we can explore geological uncertainty

3. We need to improve implicit schemes to maximize use of both geological data and knowledge as constraints

4. The use of uncertainty metrics provides several pathways to improved integrated geophysical inversion

Challenge

Improving 3D geological modelling in an exploration context represents a significant challenge…

but Australia has the research groups that in collaboration are ideally placed to to tackle the problem.

Questions?