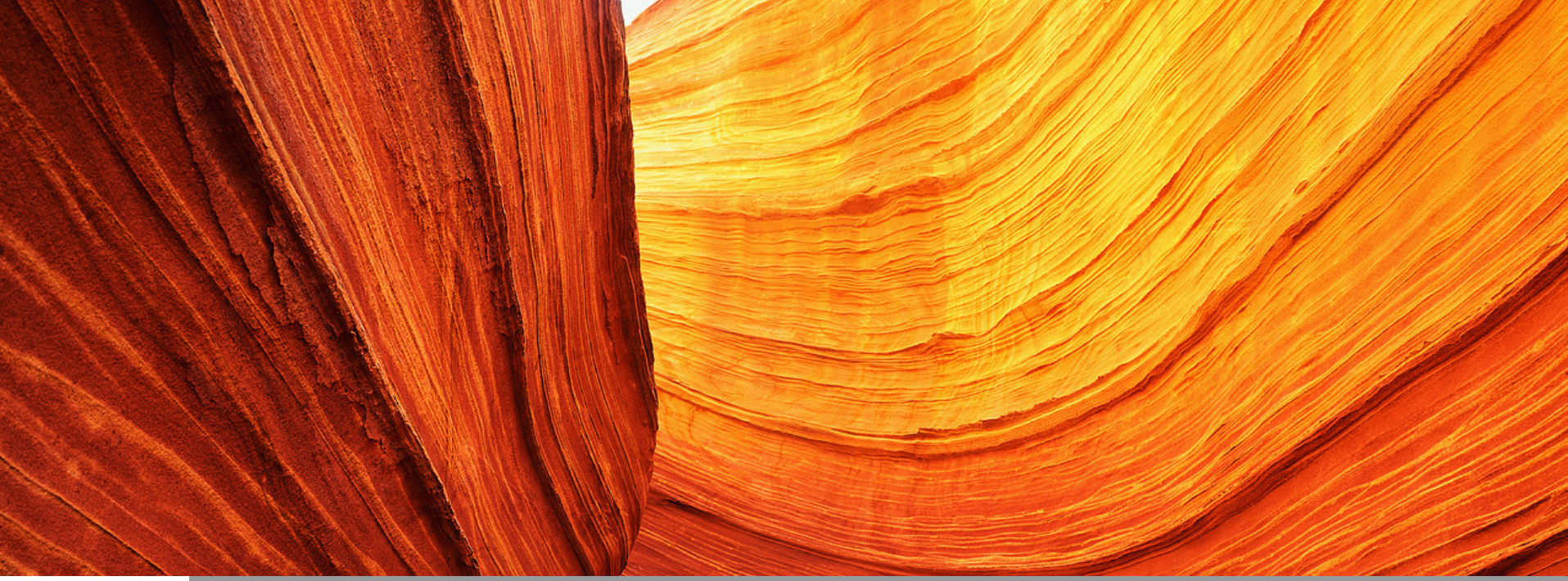

Application of interactive geological inversion techniques

Thomas Poulet

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Division of Exploration and Mining

Outline

- **Geological Numerical Modelling in exploration**
- **Interactive Geological Inversion**
- **Grid computing**
- **Visualisation**
- **The missing parts…**

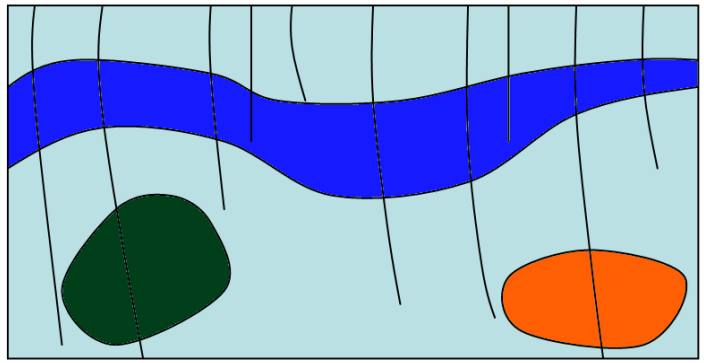
Geological Numerical Modelling in Exploration

- **Goal: what processes produced the current geology?**
- **First question: what is the current geology?**

intuition

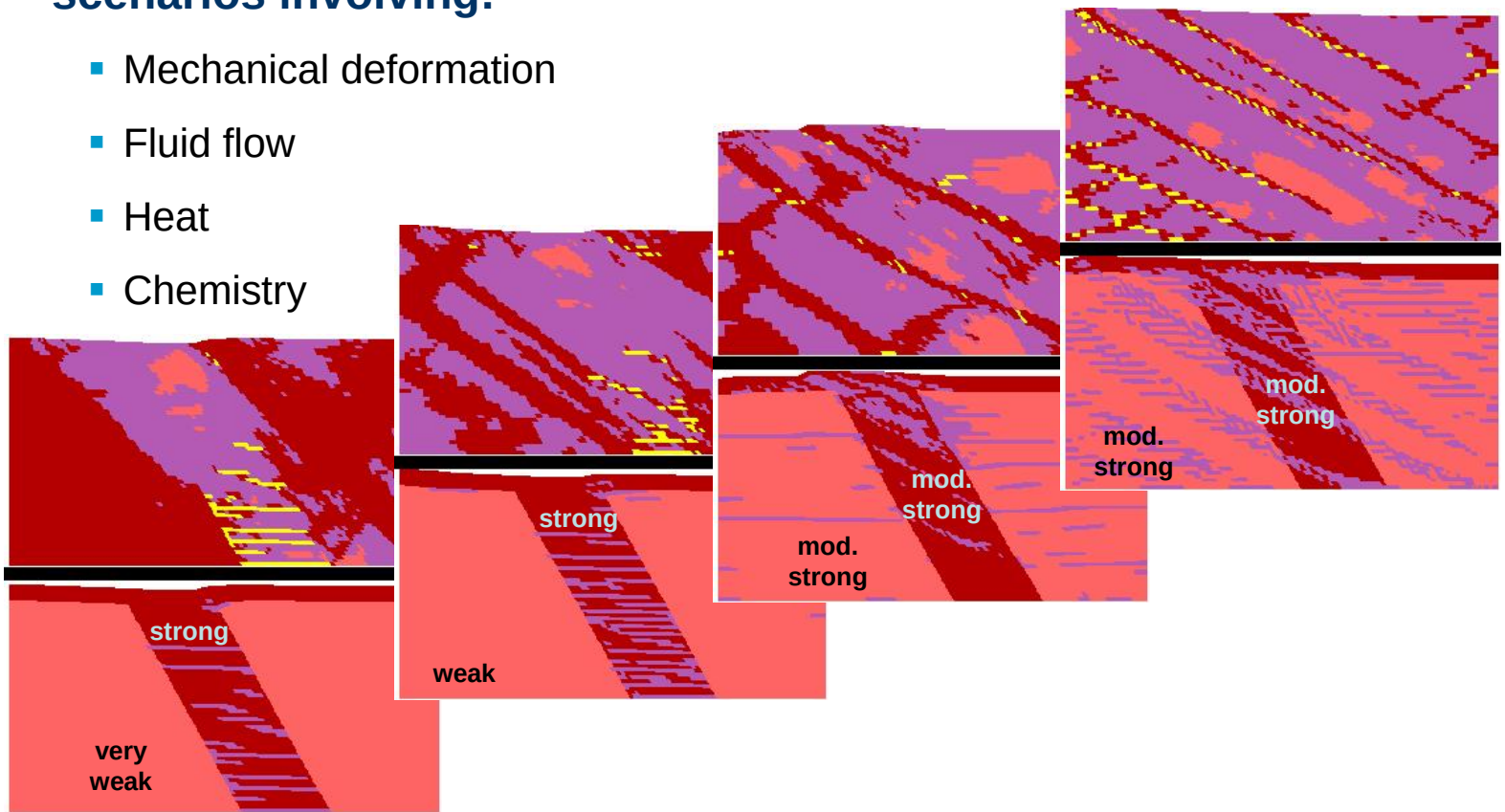
drill holes

- data collection
- experience



Geological Numerical Modelling in Exploration

- **Goal: what processes produced the current geology?**
- **First question: what is the current geology?**
- **Using numerical modelling to investigate different scenarios involving:**
  - Mechanical deformation
  - Fluid flow
  - Heat
  - Chemistry



Geological Numerical Modelling in Exploration

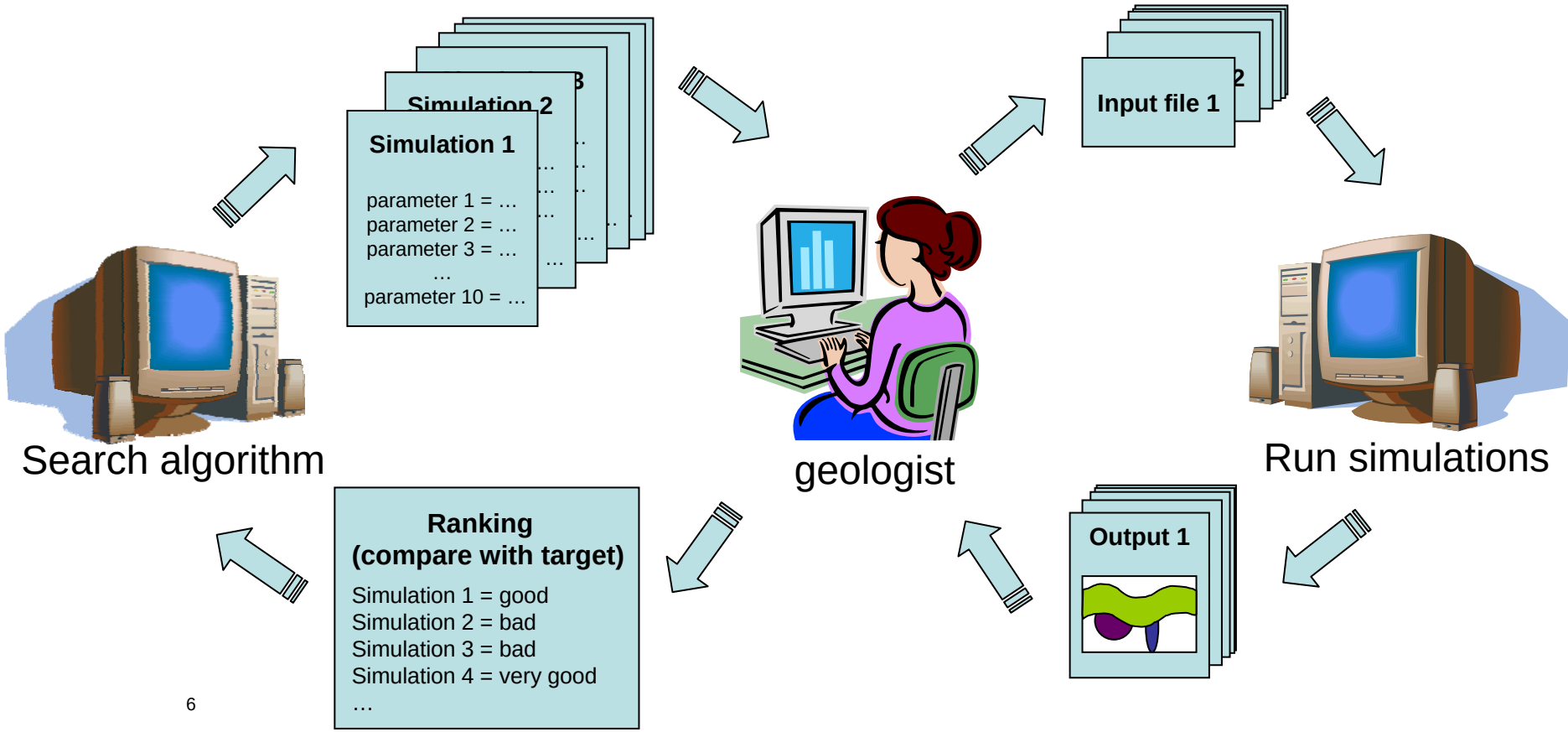
- **Goal: what processes produced the current geology?**
- **First question: what is the current geology?**
- **Using numerical modelling to investigate different scenarios involving:**
  - Mechanical deformation
  - Fluid flow
  - Heat
  - Chemistry
- **Many parameters influence the result of the simulation:**
  - Initial geometry
  - Physical properties
  - Boundary conditions

Interactive Geological Inversion

- **10 parameters with 5 values each**

  $5^{10} = 9{,}765{,}625$ **We need a better way to search the parameter space!**

- **Interactive Geological Inversion:** finding the best parameters to match a target



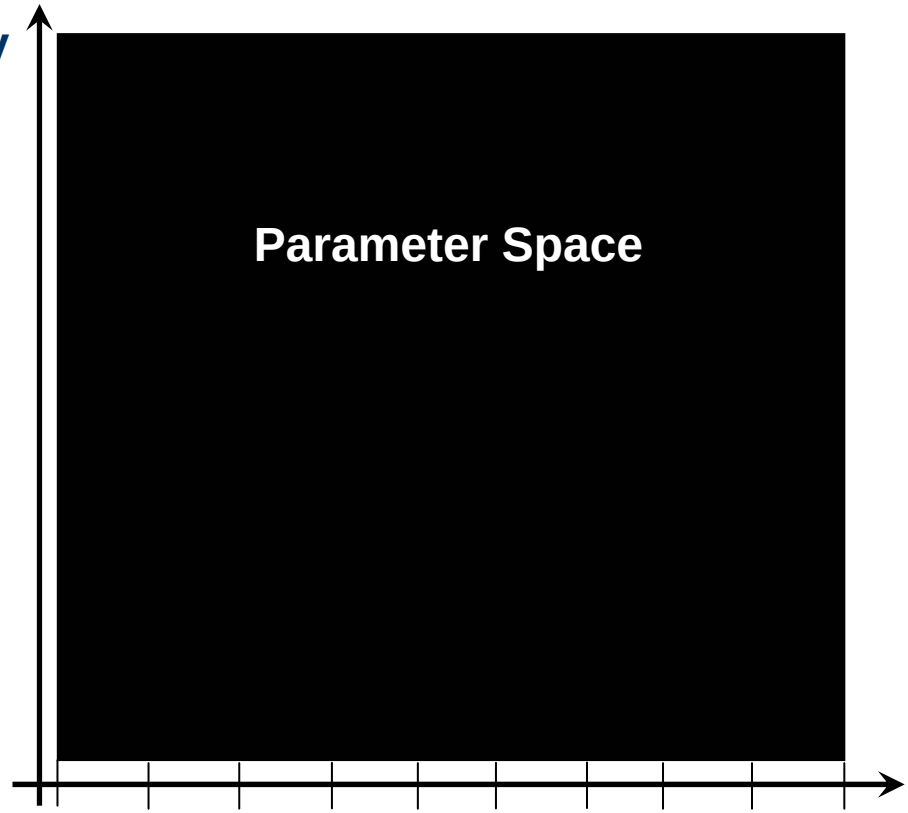
The core: Global Optimisation

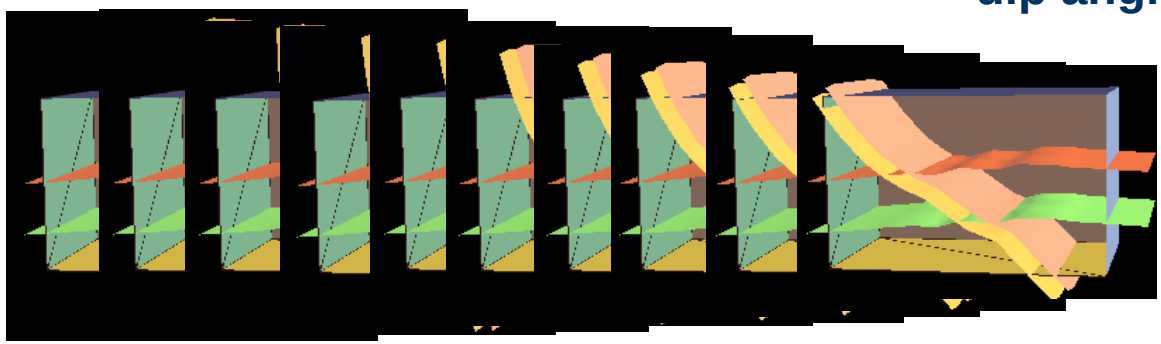
Global optimisation problem

- Parameterised model
- Target in mind

We want:

- Numerical values of parameters to match the target





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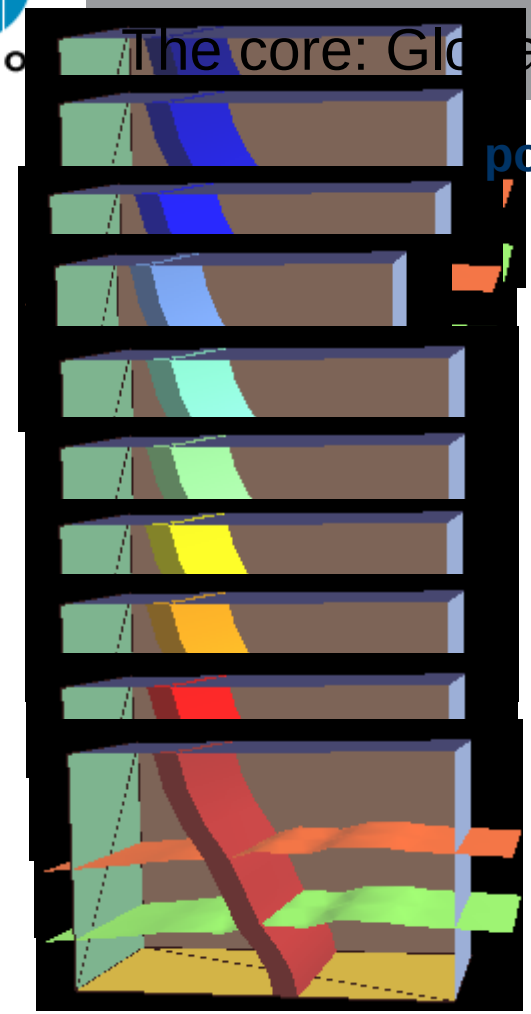

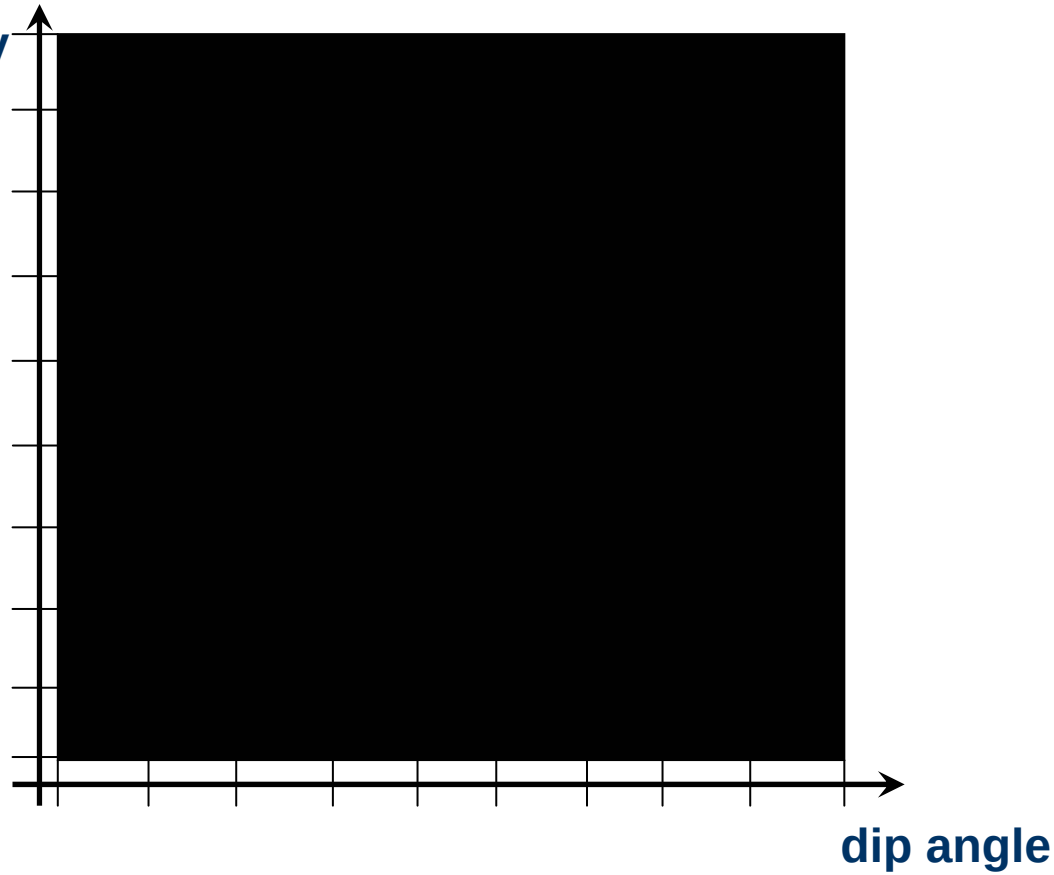

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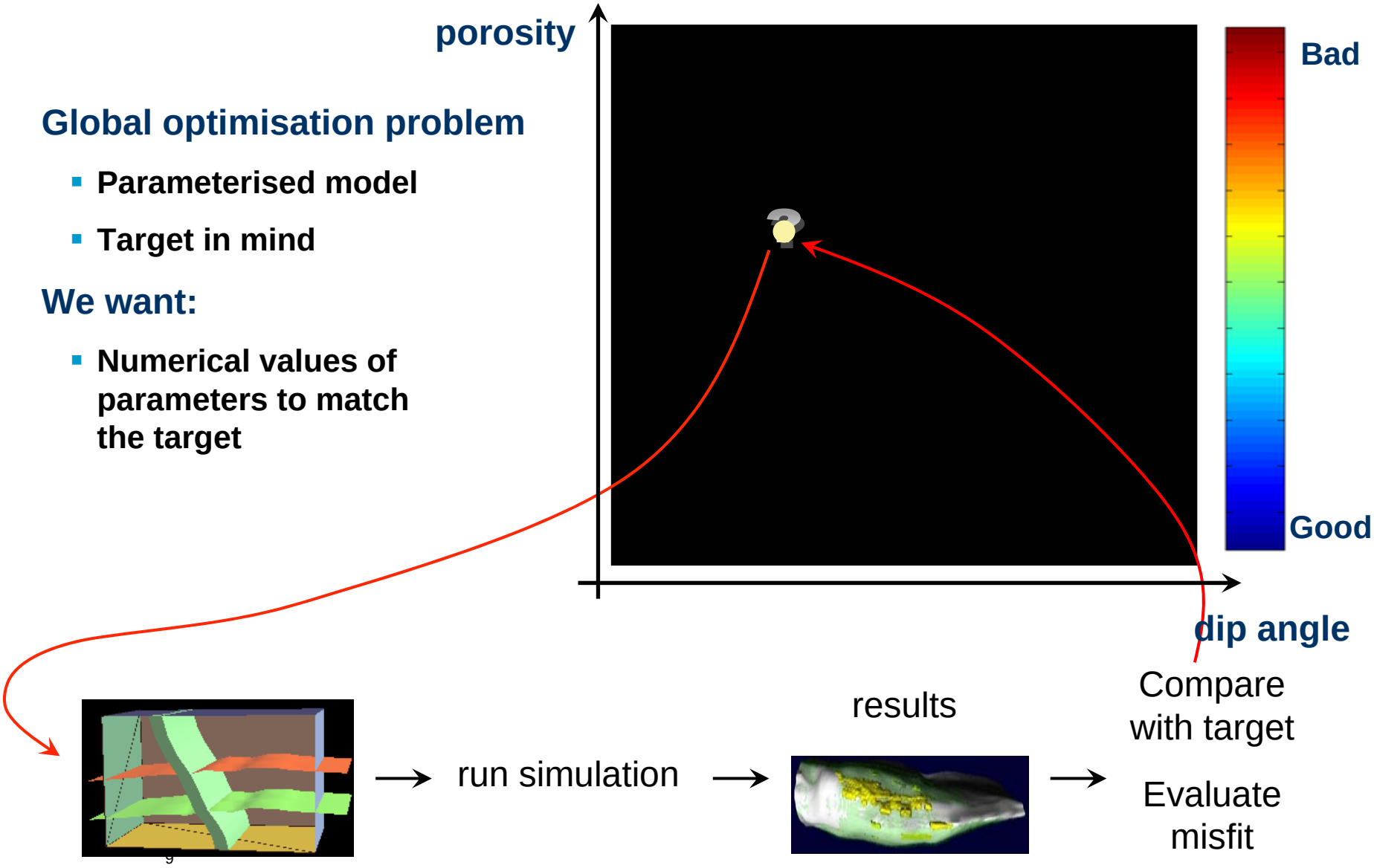

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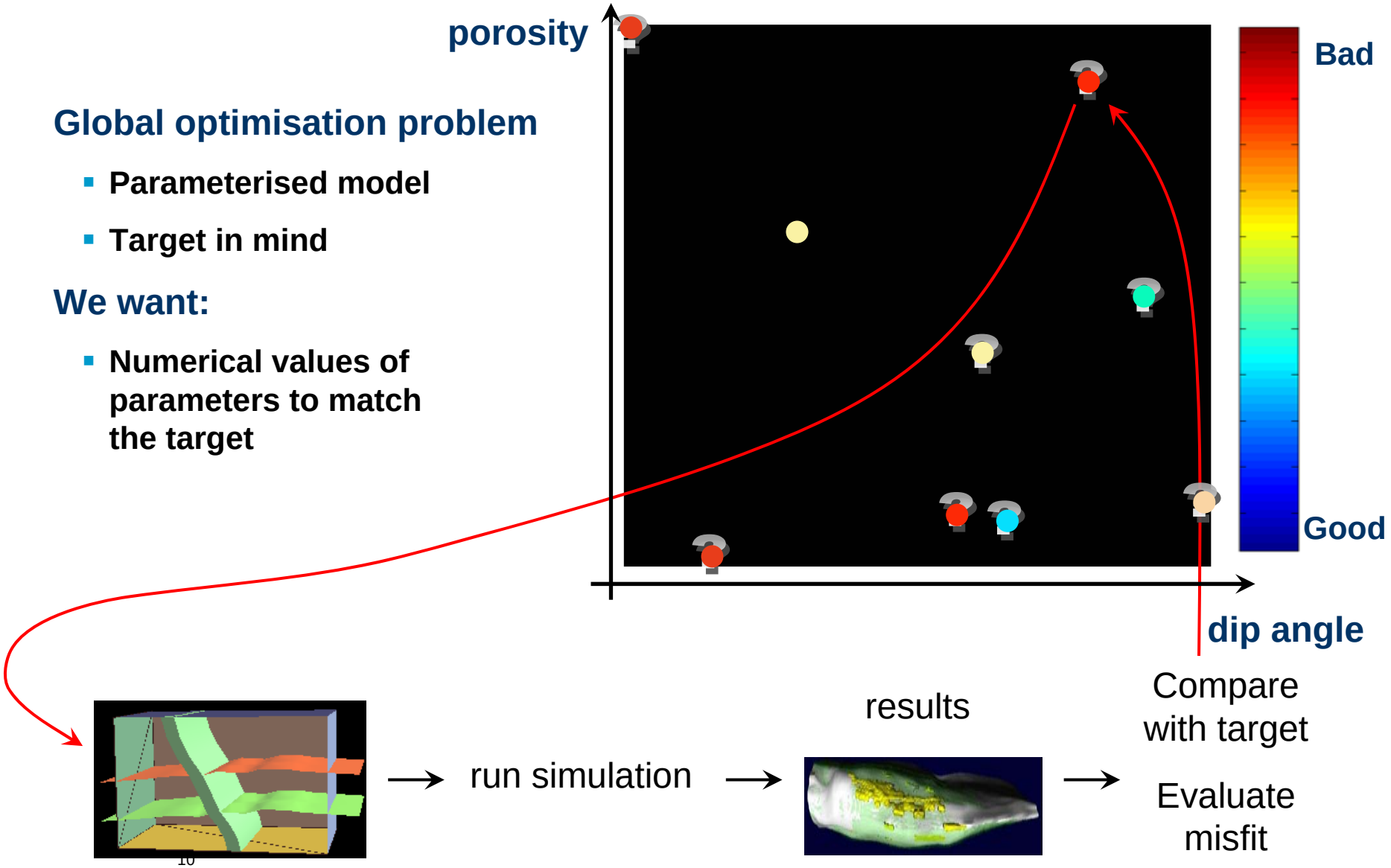

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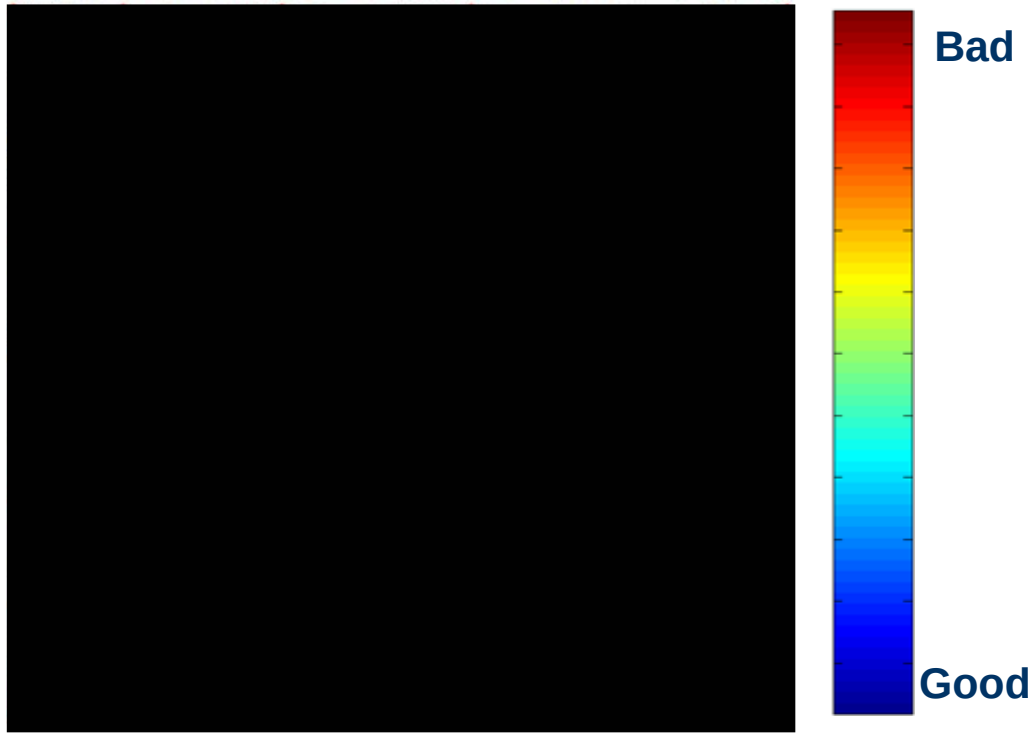


Solution?

Lipschitz algorithm: global minimum found in 52 tries

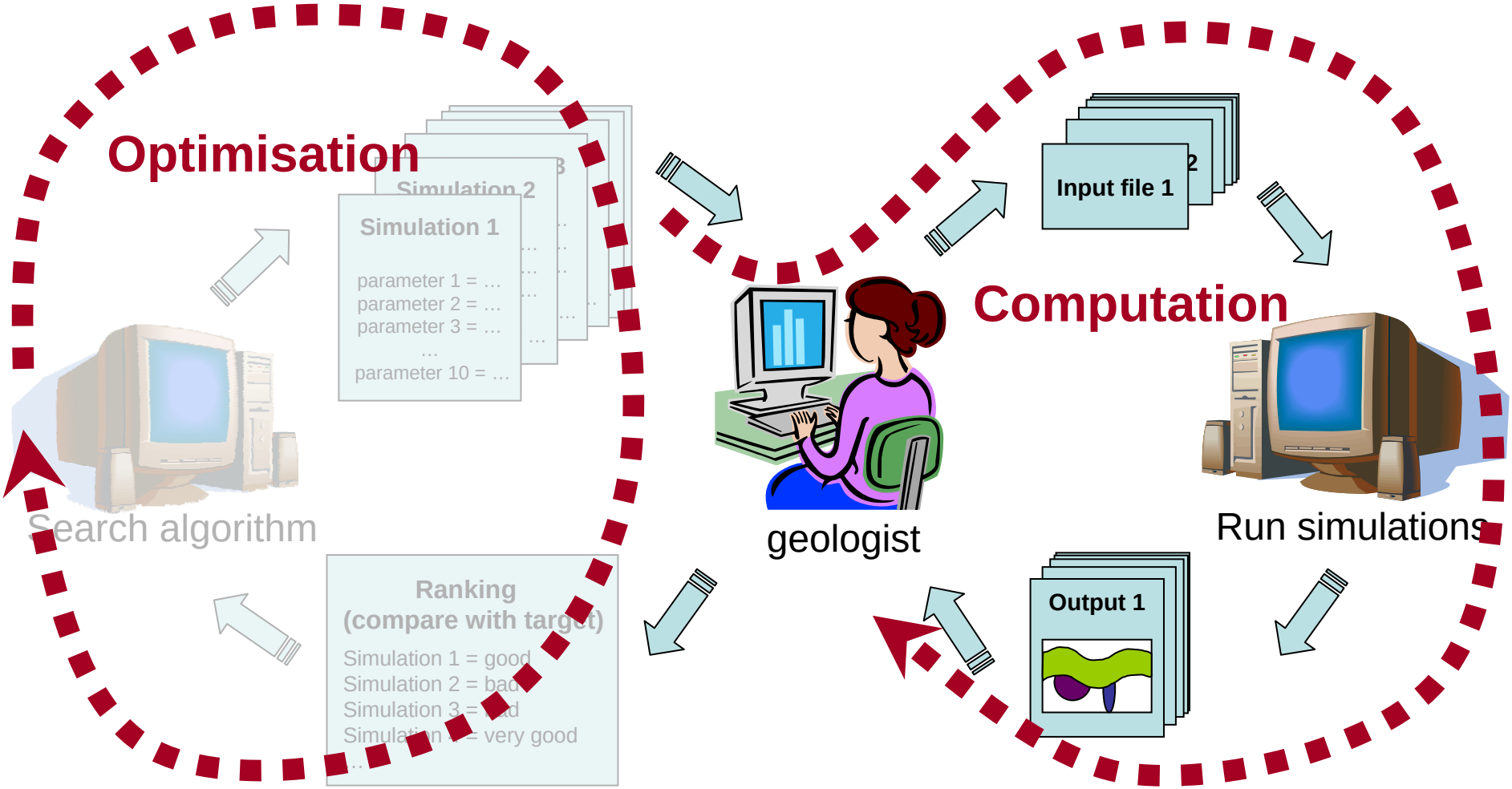
Global Optimisation: which search algorithm?

- **Different algorithms for different classes of problems.**
- **Evolutionary algorithms:**
  - **Genetic Algorithms** (GA) use techniques inspired by evolutionary biology such as inheritance, mutation, natural selection, and recombination (or crossover).
  - **Particle swarm optimization** (PSO) is a technique based around the study of collective behaviour of a swarm of insects or a school of fish.
- **Other methods:**
  - **Lipschitzian methods** denote techniques assuming there is a Lipschitz coefficient to the underlying function to optimise.
- **What does a geological cost function look like?**

Tests on a real geological problem:

- 4 parameters with 8 values each = 4096 possibilities.
- We ran and ranked them all (what a crazy idea!) to test our algorithms.
- Converge in average in 80 tries!

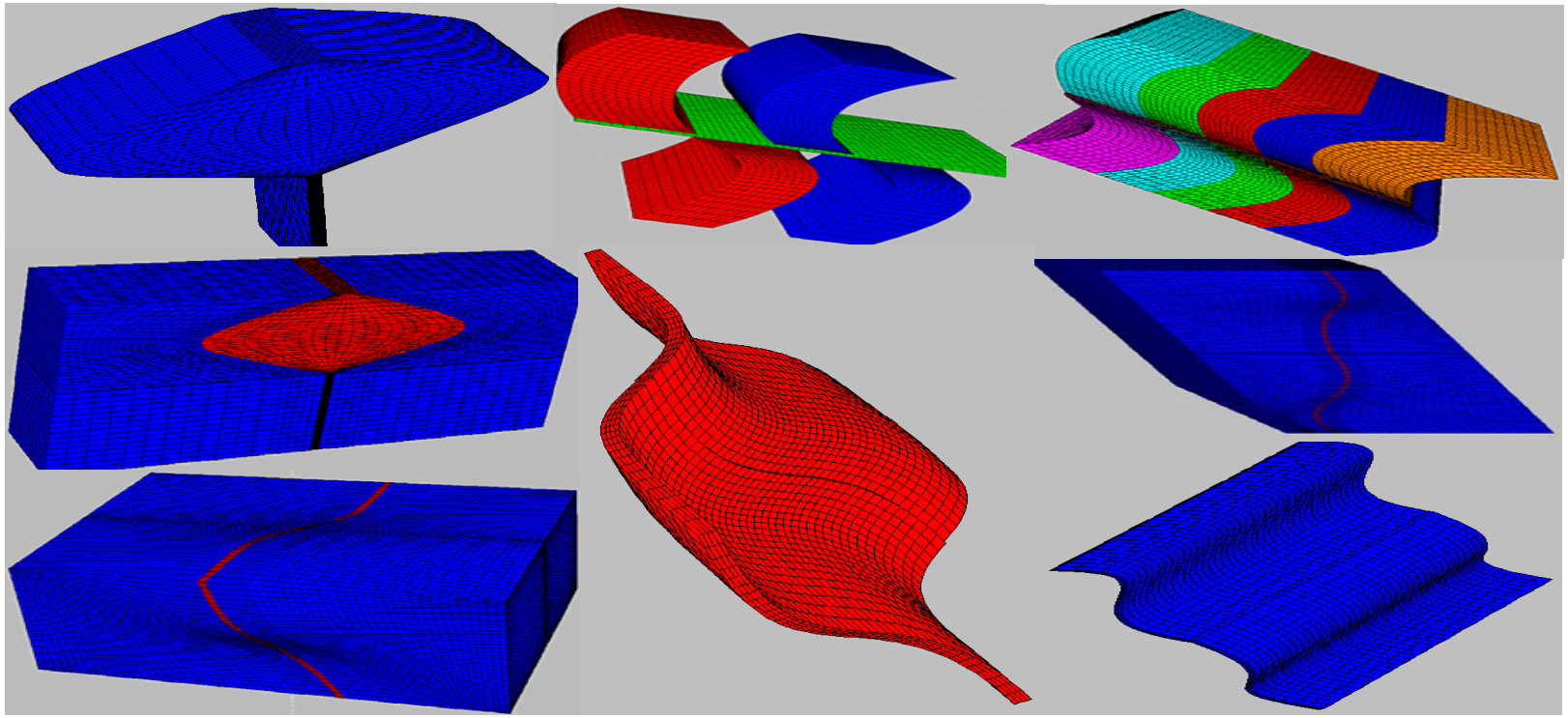
In practise: running all simulations



In practise: running all simulations

1. Creating input files from parameters

- Changing physical properties → trivial
- Automated scripts for parameterised geometries in different CAD packages (GOCAD, FLAC, Gmsh, PATRAN)



In practise: running all simulations

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2. Running all simulations on computer clusters

- CSIRO HPSC (**H**igh **P**erformance **S**cientific **C**omputing)
- Grid computing: APAC grid (**A**ustralian **P**artnership for **A**dvanced **C**omputing)
  A standardized way to submit jobs through a gateway.

3. Storing results

- 10s of MB for a save file **x** keeping 10-50 save files per simulation **x** 100s of simulations per project **=** 100s of GB of data per project!
- SRB (**S**torage **R**esource **B**roker): connecting to heterogeneous data resources over a network and accessing replicated data sets.
- Gigabit link between Perth and Melbourne

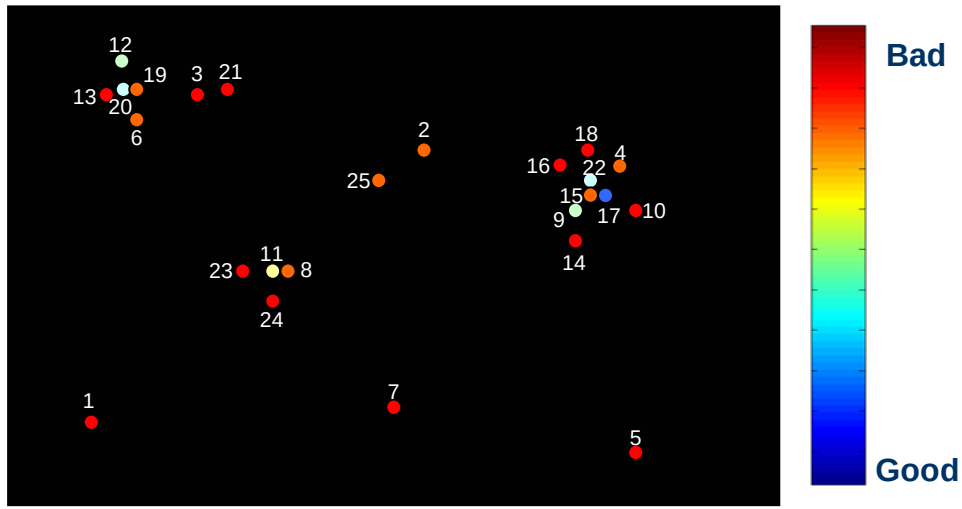
4. Post processing

- Format conversion, creation of pictures/movies on the fly

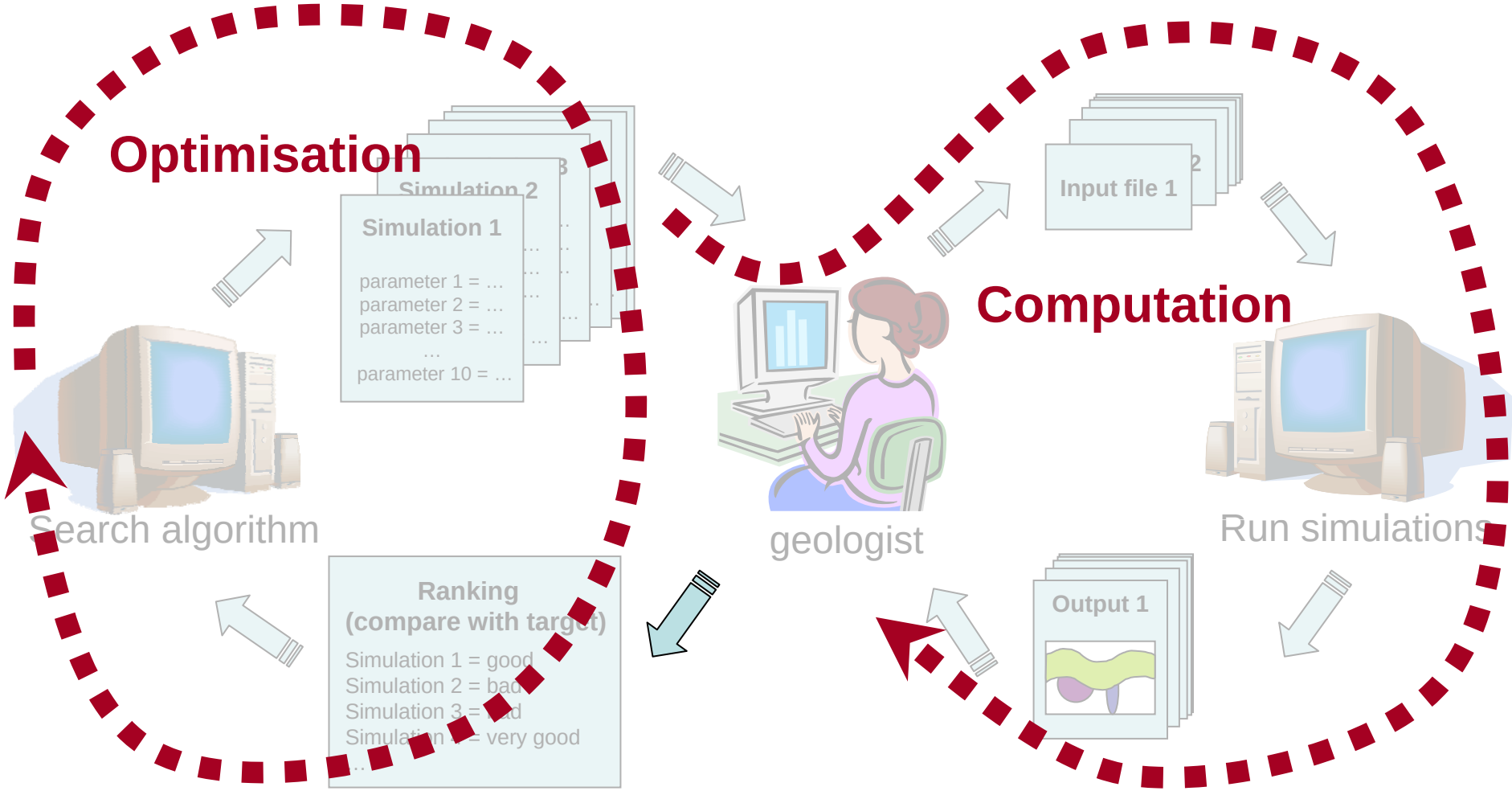
Visualisation

2 types of visualisation:

- **3D time-varying volume visualisation**
  - MayaVi
- **Parameter space visualisation**
  - Statistical analysis: Principal Component Analysis, Projection Pursuit, Alternating Conditional Expectation, Sliced Inversion Regression, Principal Hessian Direction, Inverse Third Moment, …
  - Sammon's map, Multi Dimensional Scaling
  - Self Organising Maps (SOM)
  - …



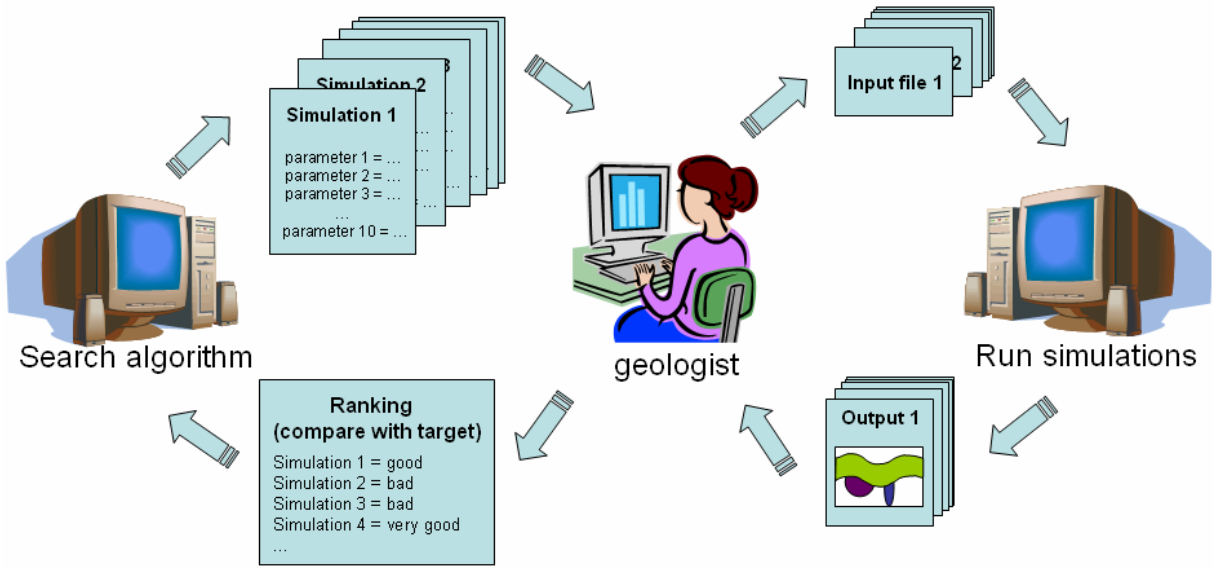
The missing parts…



Conclusion

Effective framework to more quickly:

- **search parameter space**
- **produce parameterised geometries**
- **run a large amount of simulations in parrallel**
- **manage huge result files (storage, backup, transfer)**
- **automate as much as we can the post-processing**



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Thank You

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