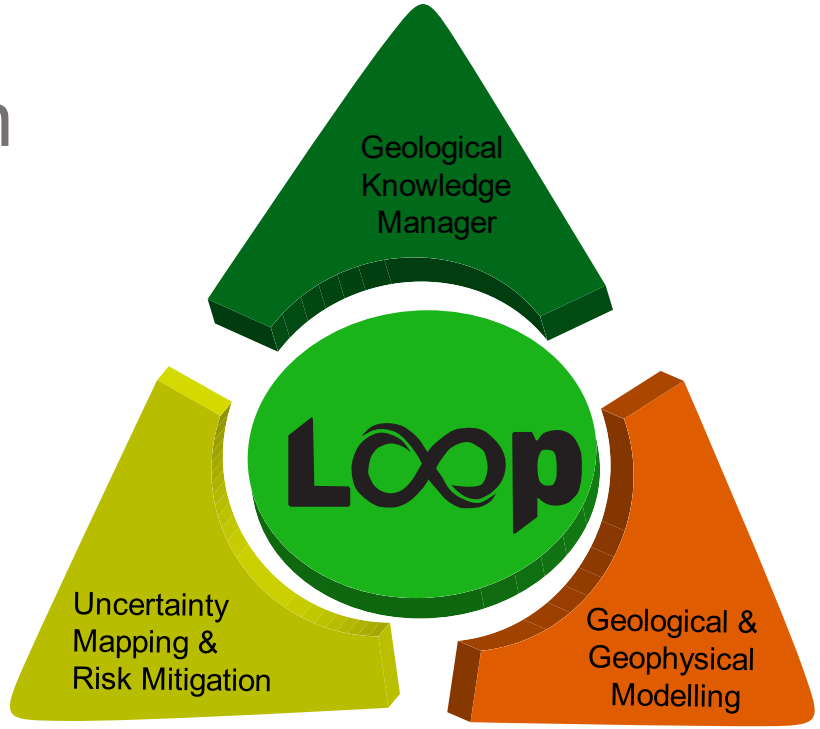
Loop

An integrated and interoperable platform enabling 3D stochastic geological modelling

The Loop project: Three-dimensional Bayesian Modelling of Geological and Geophysical data

Presented by: Laurent Aillères

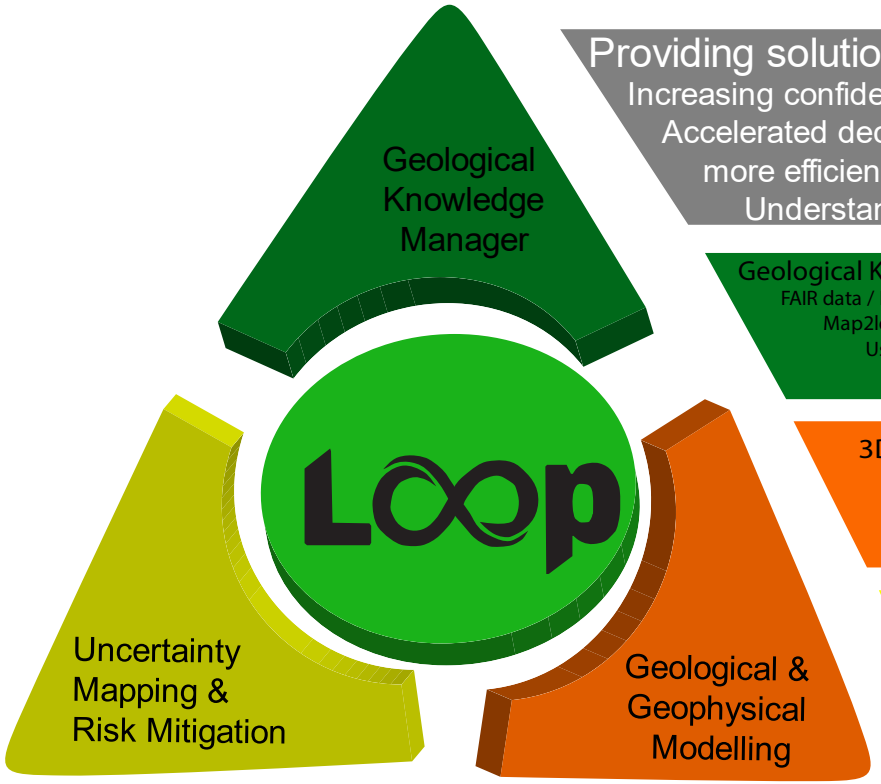
for and on behalf of the entire Loop development team



MONASH University
The University of Western Australia — Centre for Exploration Targeting
Australian Government — Australian Research Council
Australian Government — Geoscience Australia
Tasmanian Government
Government of Western Australia — Department of Mines and Petroleum
Northern Territory Government
Government of South Australia — Department of State Development
Victoria State Government
Queensland Government — Business Queensland
South Australia
NSW Government — Regional NSW
AuScope
RING — Université de Lorraine
CSIRO
RWTH Aachen University
Université d'Orléans
ISTO
British Geological Survey — Natural Environment Research Council
Canada Geological Survey
USGS — science for a changing world
MinEx CRC
AngloAmerican
100 Years
BHP
Government of Western Australia — Department of Mines and Petroleum
NE Geology — Providing geoscience data globally

Loop

An integrated and interoperable platform enabling 3D stochastic geological modelling



Providing solutions for subsurface resources management:

Increasing confidence in subsurface resources & materials management

Accelerated decision making and testing (the ability to make quicker, more efficient decisions and to test them early)

Understanding and reducing risk in resources management

Geological Knowledge Manager

FAIR data / FAIR software *

Map2loop: automated knowledge/data extraction from digital maps

Use more knowledge / use knowledge more

Encoding geological rules

3D Geological and Geophysical Modelling

Encoding structural geological rules

Developing new geologically and petrophysically constrained inversion methods

Developing joint geology/geophysics inversions

Uncertainty Mapping & Risk Mitigation

Geological simulations

Bayesian modelling

Value of information

Decision making enabler

* Findable, Accessible, Interoperable, Reusable

Loop3d.org

Open-source is the future

github.com/Loop3D/

Lead-CI

Dr Laurent Ailleres

Monash University

MONASH University

THE UNIVERSITY OF WESTERN AUSTRALIA — Centre for EXPLORATION TARGETING

VICTORIA State Government

AuScope

RING — Université de Lorraine

British Geological Survey — Natural Environment Research Council

MinEx CRC

Australian Government — Australian Research Council

Australian Government — Geoscience Australia

Tasmanian Government

Queensland Government — Business Queensland

CANADA — Geological Survey — Commission Géologique

AngloAmerican

100 YEARS

BHP

Government of Western Australia — Department of Mines and Petroleum

NORTHERN TERRITORY GOVERNMENT

Government of South Australia — Department of State Development

SOUTH AUSTRALIA

CSIRO

RWTH AACHEN UNIVERSITY

Government of Western Australia — Department of Mines and Petroleum

NSW Government — Regional NSW

UNIVERSITE D'ORLEANS

Earth Sciences Institute of Orléans — ISTO

USGS — science for a changing world

ONE Geology — Providing geoscience data globally

Loopers? Who are we?

Government of Western Australia
Department of Mines and Petroleum

Government of Western Australia
Department of Mines and Petroleum

AuScope

$150K

ARC Linkage

$1,700K + $1,550K

EGF 3D fault model

$67K

Loop Portal

$200K

GSC Knowledge Manager

$400K

P6 & OP6

$2,100K

Loop & Thin Geology modelling

$200K

VOI DECRA

$1,000K

GeoMos

$300K

DARE Data Analytics

$600K

Providing geoscience data globally

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Business Queensland

VICTORIA
State Government

CSIRO

AuScope

RWTH AACHEN UNIVERSITY

Loop – Why a new platform?

Providing solutions for subsurface resources management:

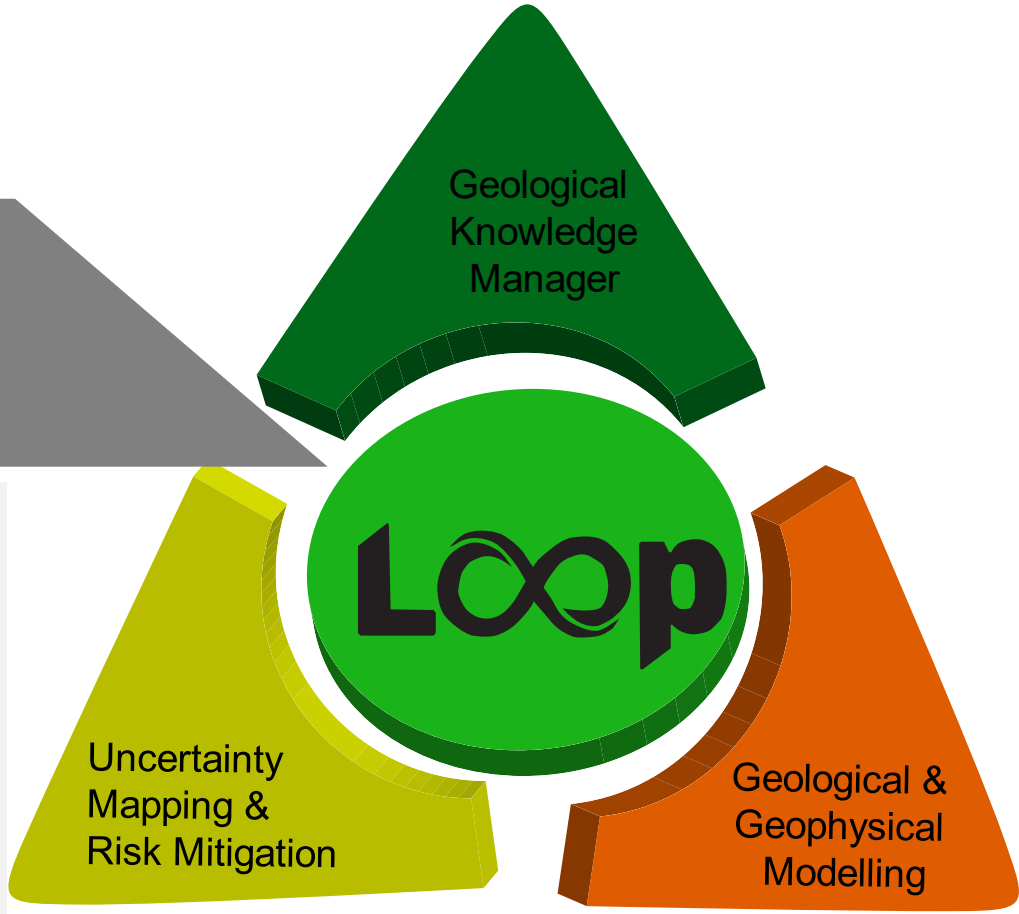
Increasing confidence in subsurface resources & materials management

Accelerated decision making and testing (the ability to make quicker, more efficient decisions and to test them early)

Understanding and reducing risk in resources management

- Current technology does not allow for modelling of poly-deformed terranes in a reproducible sense
  -> structural geology based modelling algorithm
- Need for uncertainty characterisation
- Need for better geophysical integration
- Maximisation of 3D geology uncertainty reduction

This can only happen through automatisation of the modeling workflow



Open-source is the future

github.com/Loop3D/

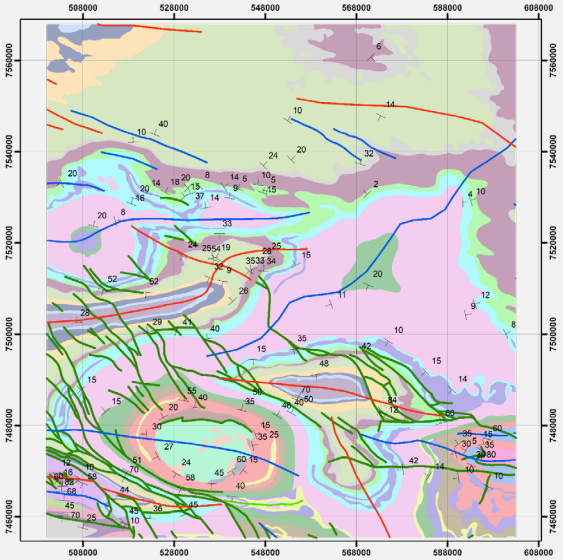
map2loop - Data Pre-Processing & input

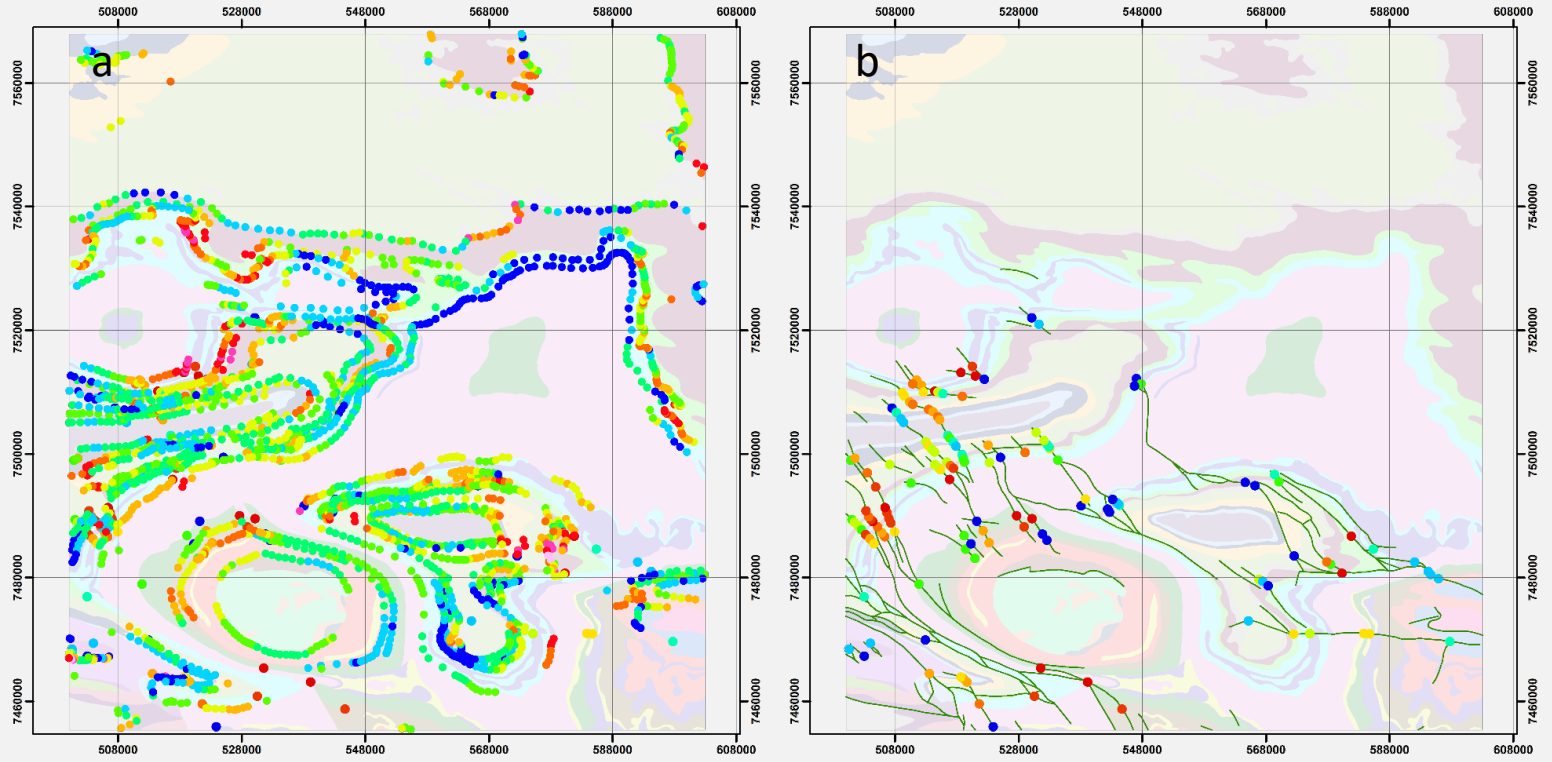
Automated geological map deconstruction for 3D model construction using *map2loop* 1.0 and *map2model* 1.0

Mark Jessell[1], Vitaliy Ogarko[2,6], Yohan de Rose[3], Mark Lindsay[1], Ranee Joshi[1], Agnieszka Piechocka[1,4], Lachlan Grose[3], Miguel de la Varga[5], Laurent Ailleres[3], and Guillaume Pirot[1]

Geosci. Model Dev., 14, 5063–5092, 2021
https://doi.org/10.5194/gmd-14-5063-2021

- Automation of data input for Loop's modelling methods (LoopStructural)
- Geometrical analysis of geological maps provides Fms thickness estimates and estimation of apparent fault offsets
- Topological analysis of the geology map provides fault network relationships, fault formation relationships, intrusive and unconformable relationships





Secondary geological information automatically derived from maps. a) Normalised local formation thickness (hotter colours show thicker formations) b) Apparent fault throw (hotter colours show larger throw)

Geological Knowledge Manager
Uncertainty Mapping & Risk Mitigation
Geological & Geophysical Modelling
Loop

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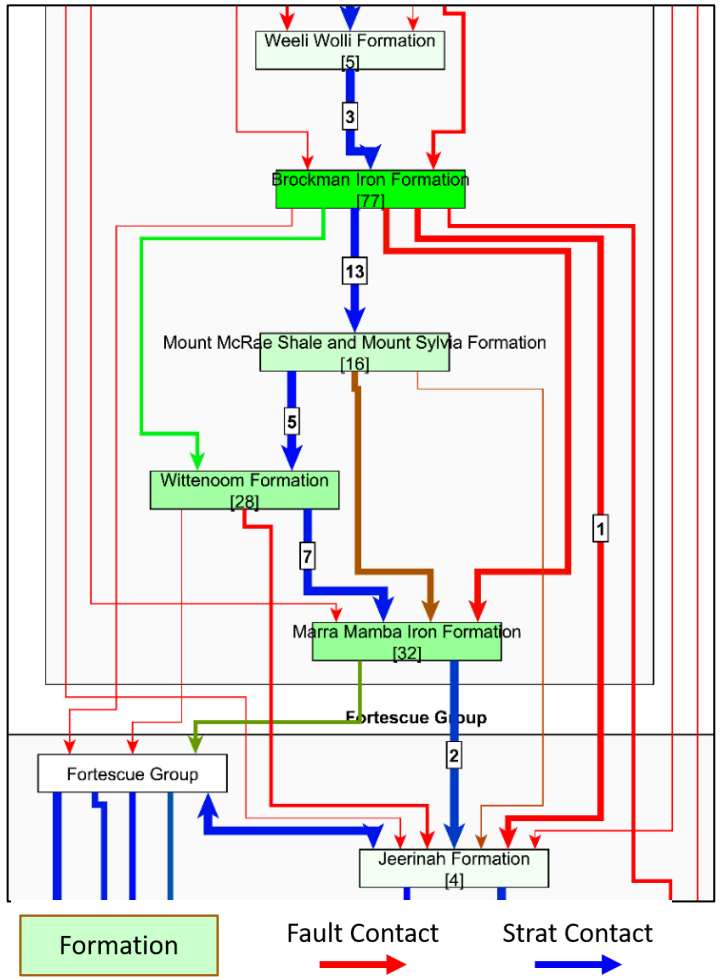

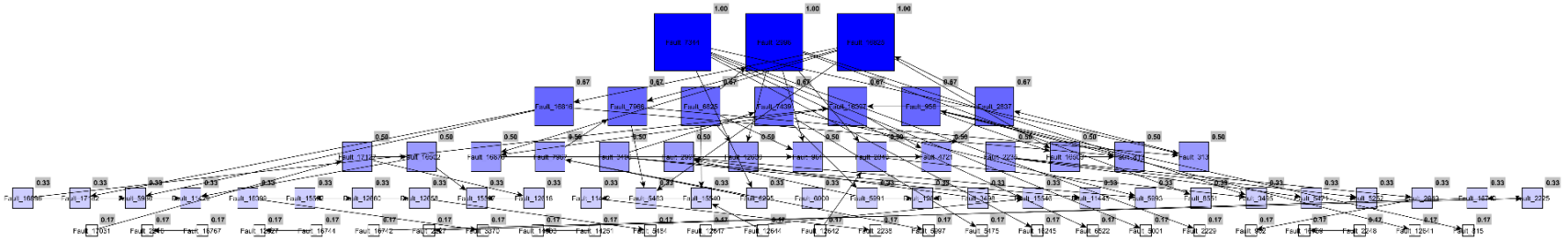

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P_-HAw-fr	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
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P_-TKo-stq	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
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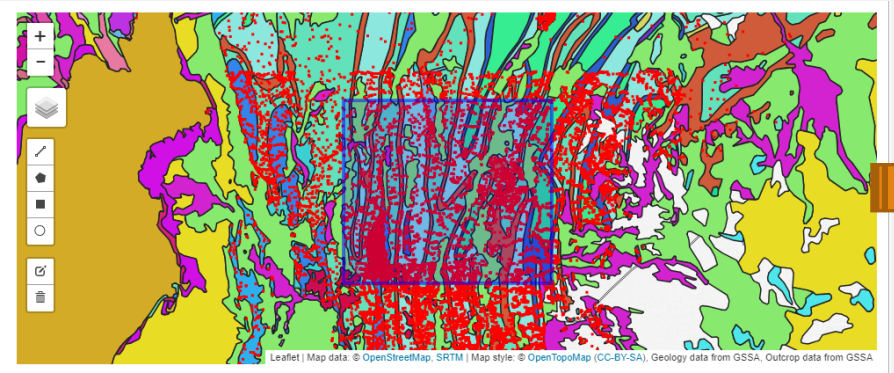
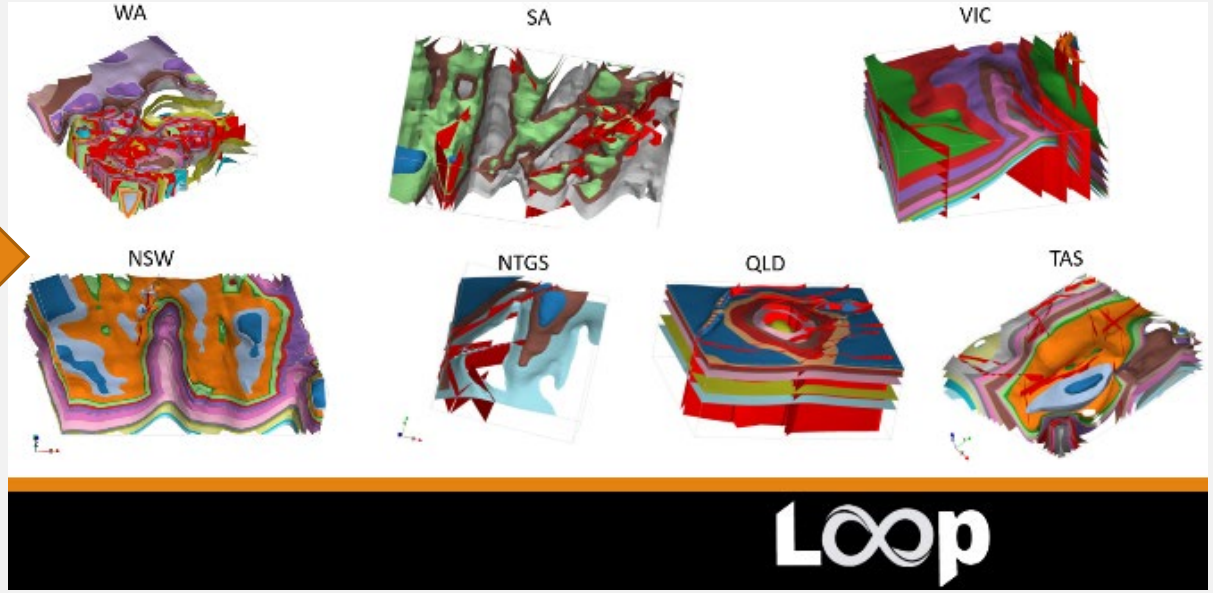
Automation of Geological Digital Twin(s)

Automated 3D model creation with the link: map2loop -> LoopStructural



Data served by Geological Surveys in Australia

m2l analysis and data augmentation



EGU European Geosciences Union **Geoscientific Model Development**

Special issue

The Loop 3D stochastic geological modelling platform – development and applications

Editor(s): GMD topical editors | Coordinator: Laurent Ailleres

LoopStructural models calculated in a few minutes (inc. map2loop and loopstructural time) on a "normal" laptop

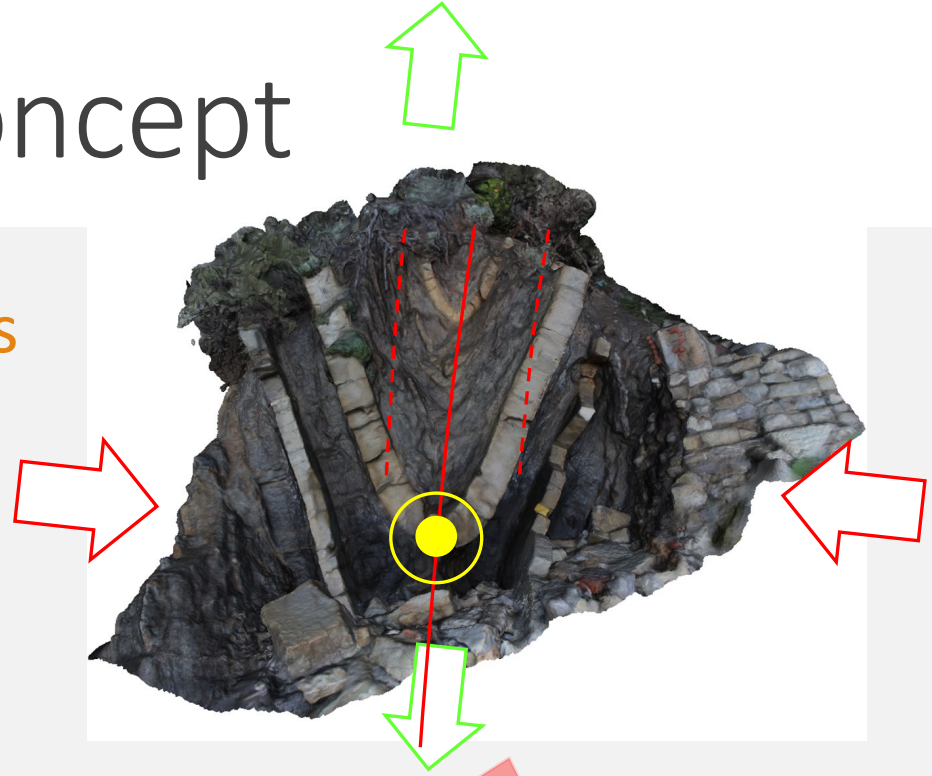
E.g. Flinders ranges: 10K+ orientation data points; overall time ~11 minutes (Dell Inspiron 15).

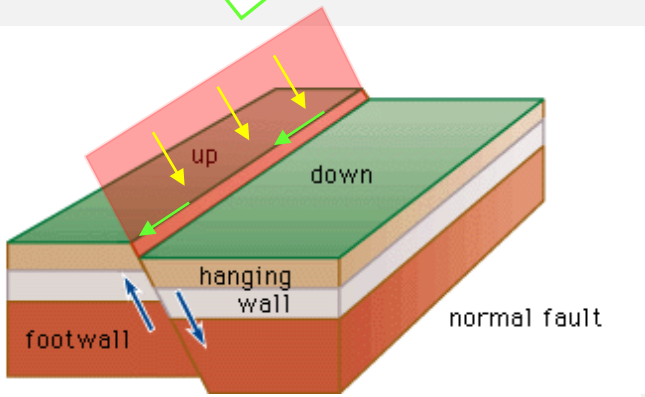
Loop

The Structural Frame concept

Three coordinates – three scalar fields

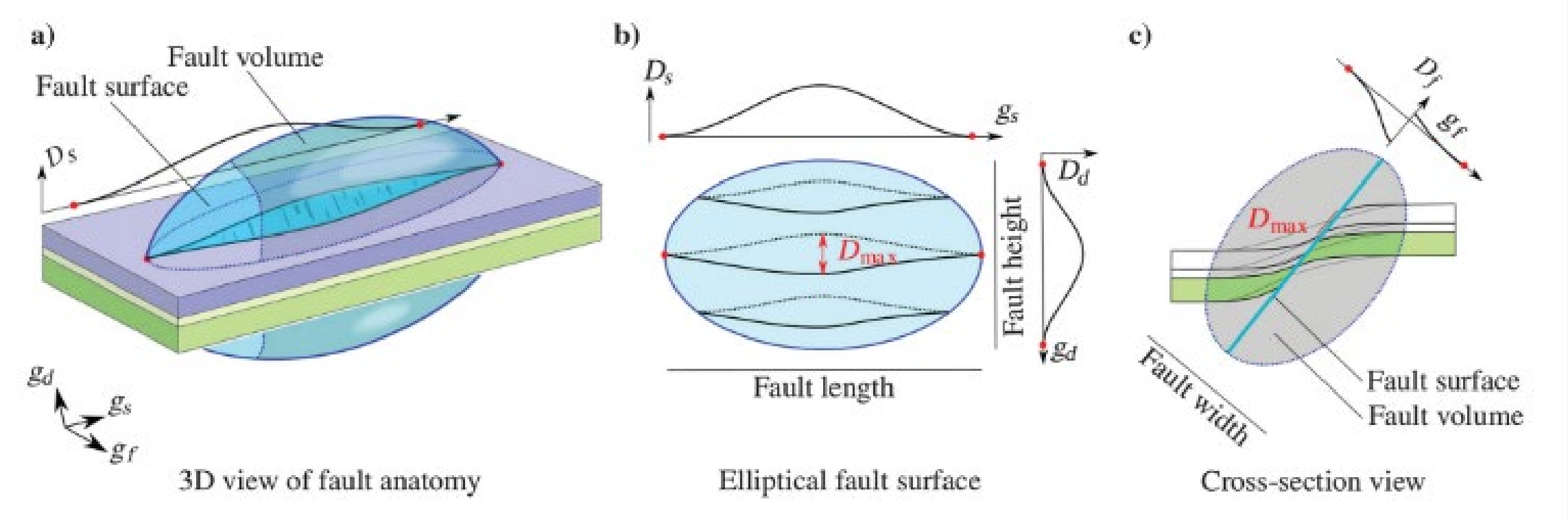
1. **Major structural feature**
   - fault surface
   - fold axial surface
   - intrusion major axis
2. **Structural direction**
   - fault slip direction
   - fold axis
   - intrusion flow direction
3. **Additional direction (if required)**
   - Fault , e.g. fault extent





LoopStructural 1.0: time-aware geological modelling
Lachlan Grose[1], Laurent Ailleres[1], Gautier Laurent[2], and Mark Jessell[3]
Geosci. Model Dev., 14, 3915–3937, 2021
https://doi.org/10.5194/gmd-14-3915-2021

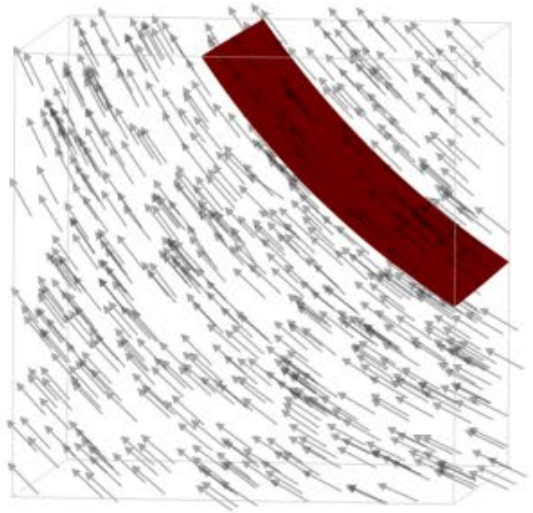
The Fault Frame



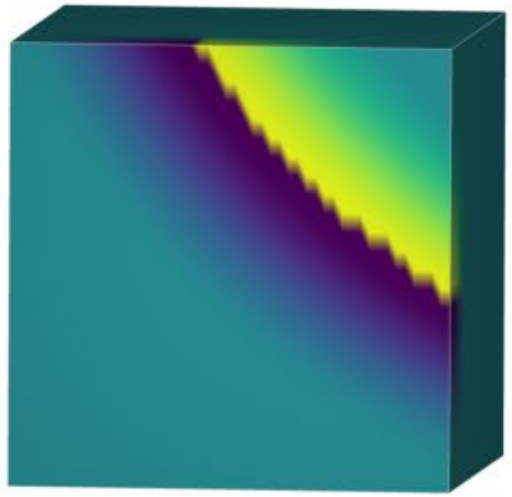
Godefroy et al 2018

The Fault Frame

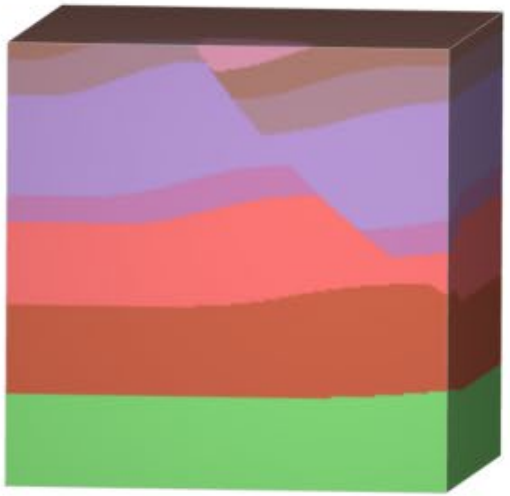
A. Fault surface and fault vector



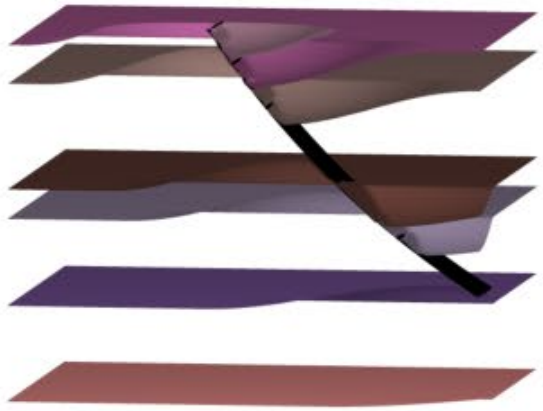
B. Fault displacement field



C. Geological model



D. Basal contact surfaces

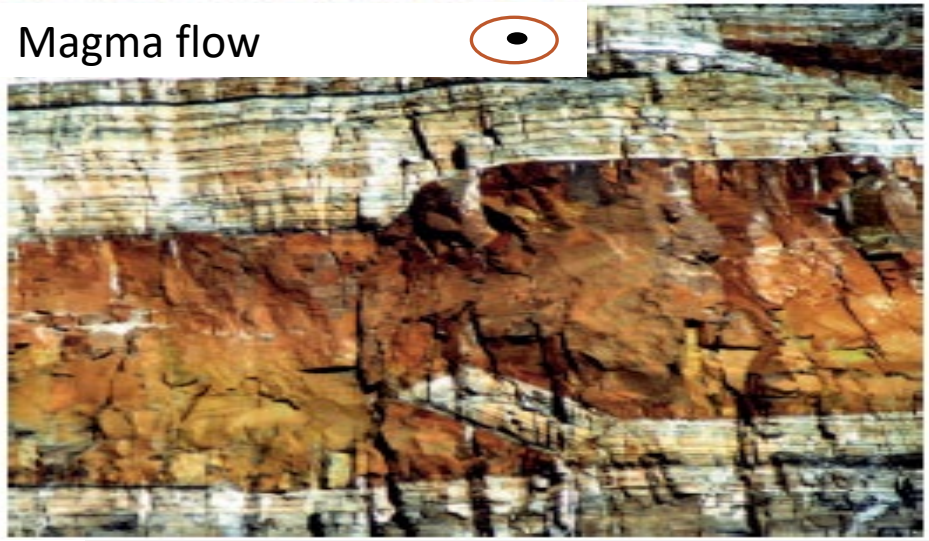


Realistic modelling of faults in LoopStructural 1.0

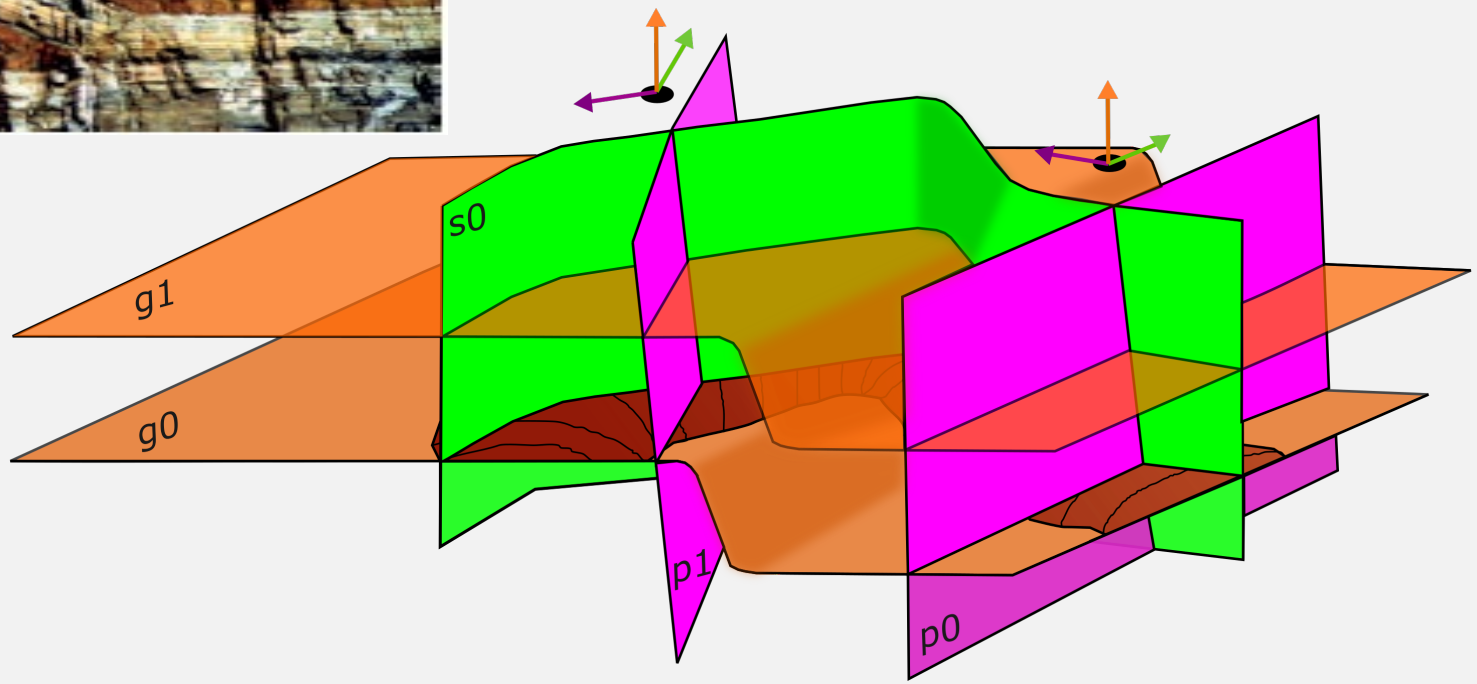
Lachlan Grose[1], Laurent Ailleres[1], Gautier Laurent[2], Guillaume Caumon[4], Mark Jessell[3], and Robin Armit[1]

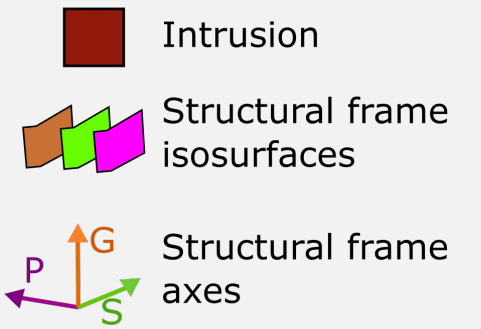
https://doi.org/10.5194/gmd-2021-112 Preprint

Intrusion Structural Frame



Step geometry, sill (Hutton, 2009)

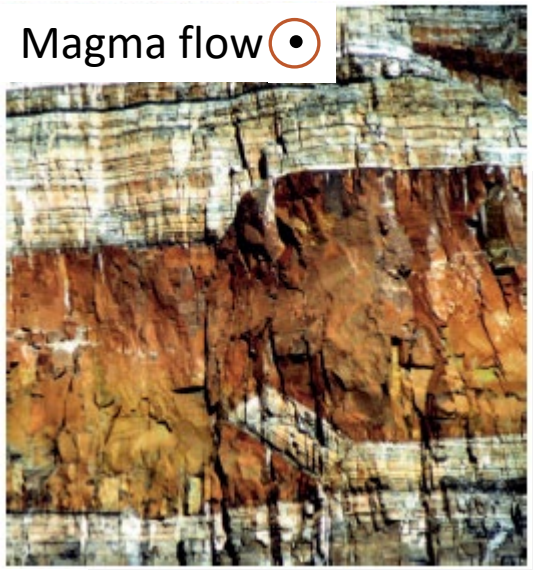




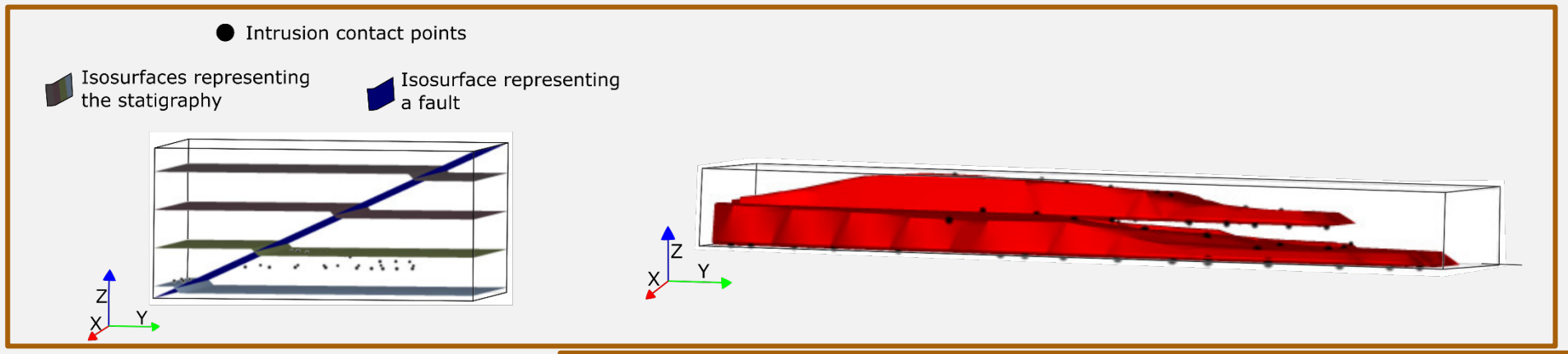
Fernanda Alvarado-Neves (PhD candidate, Monash University

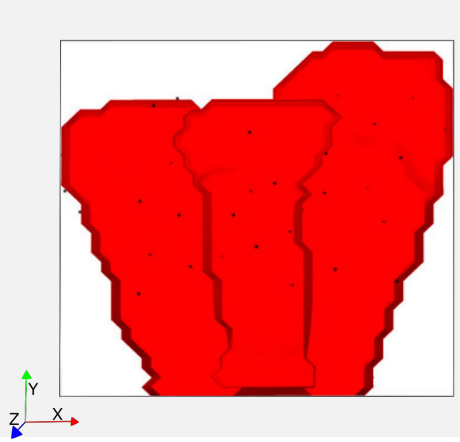
Intrusion Structural Frame

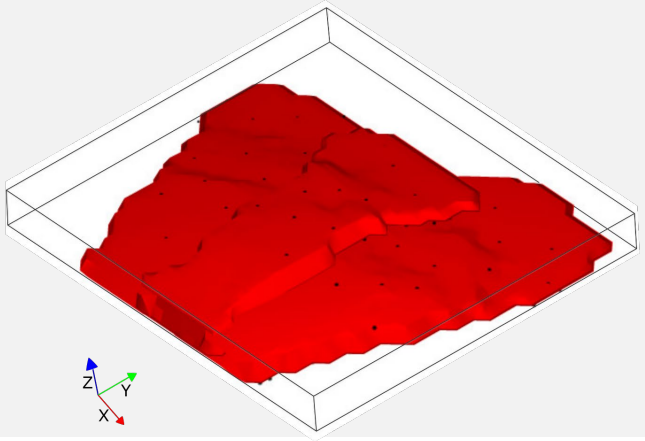
Fernanda Alvarado-Neves (PhD candidate, Monash University

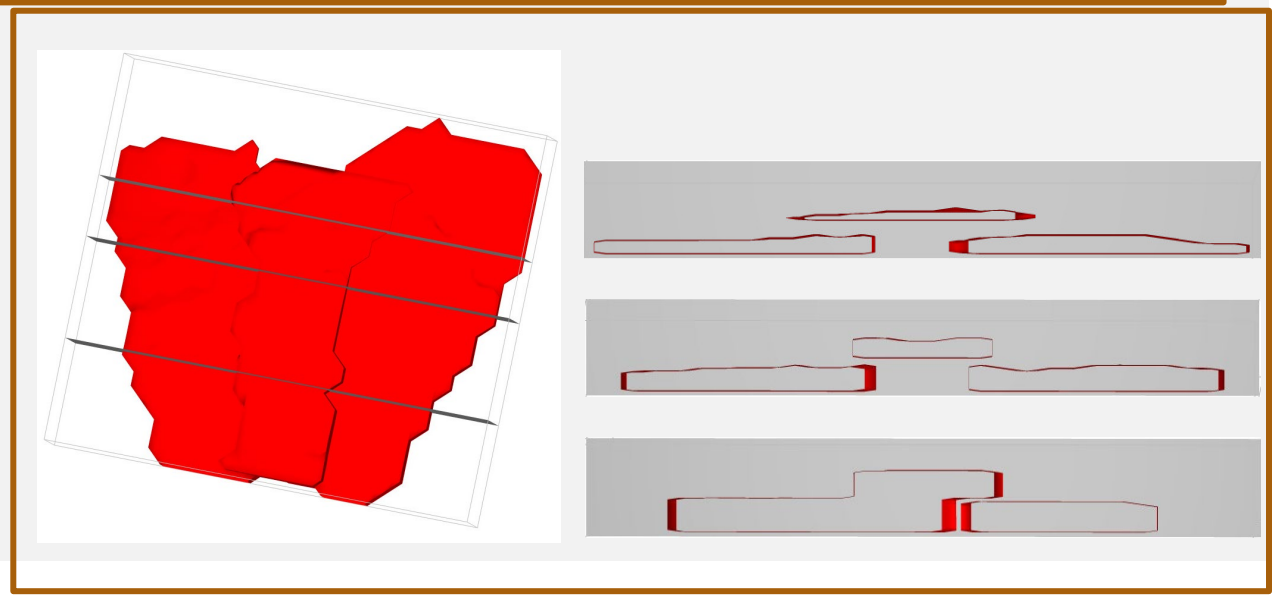


Step geometry, sill (Hutton, 2009)



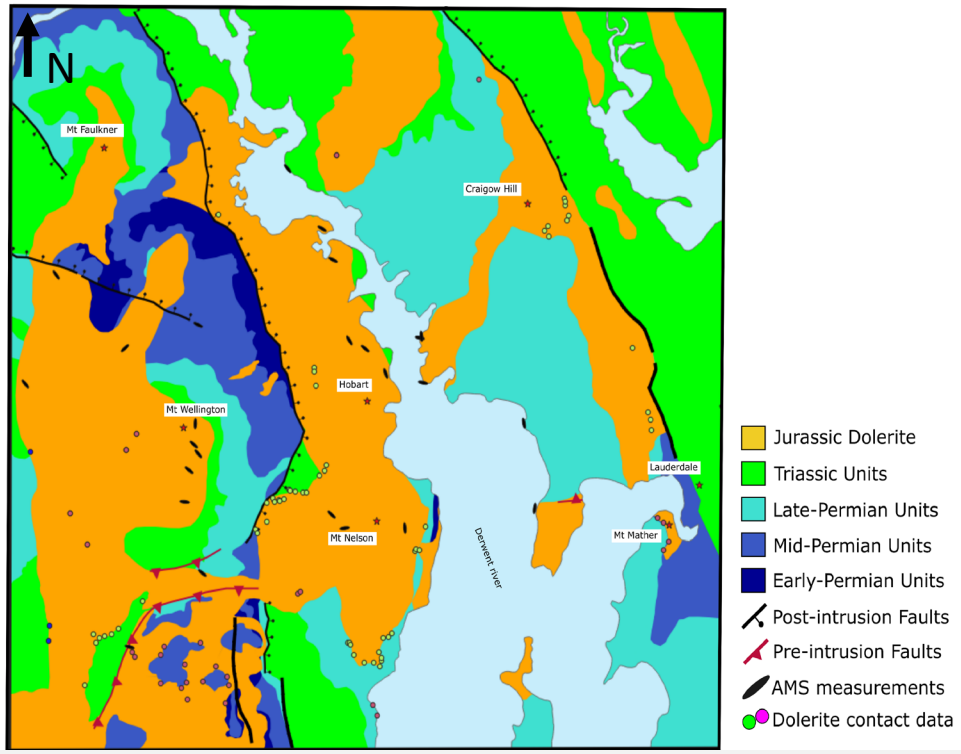


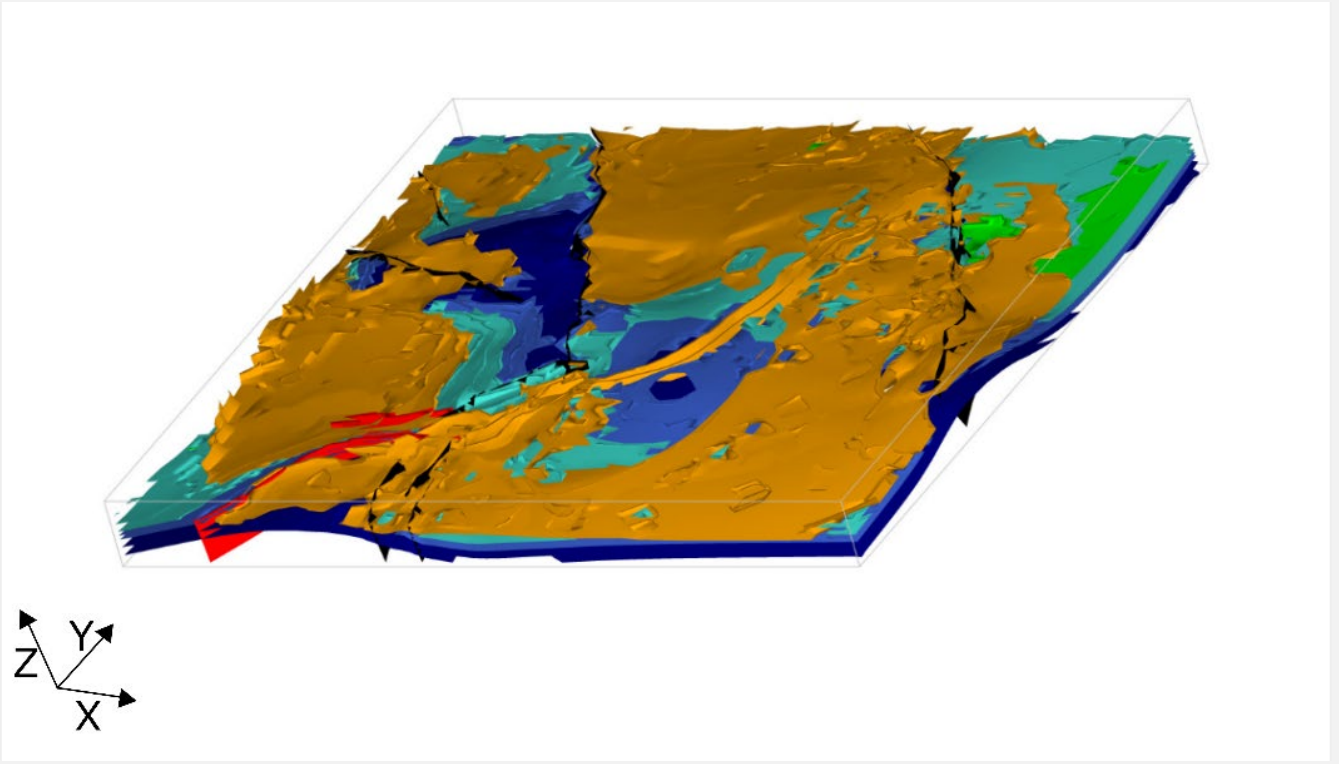




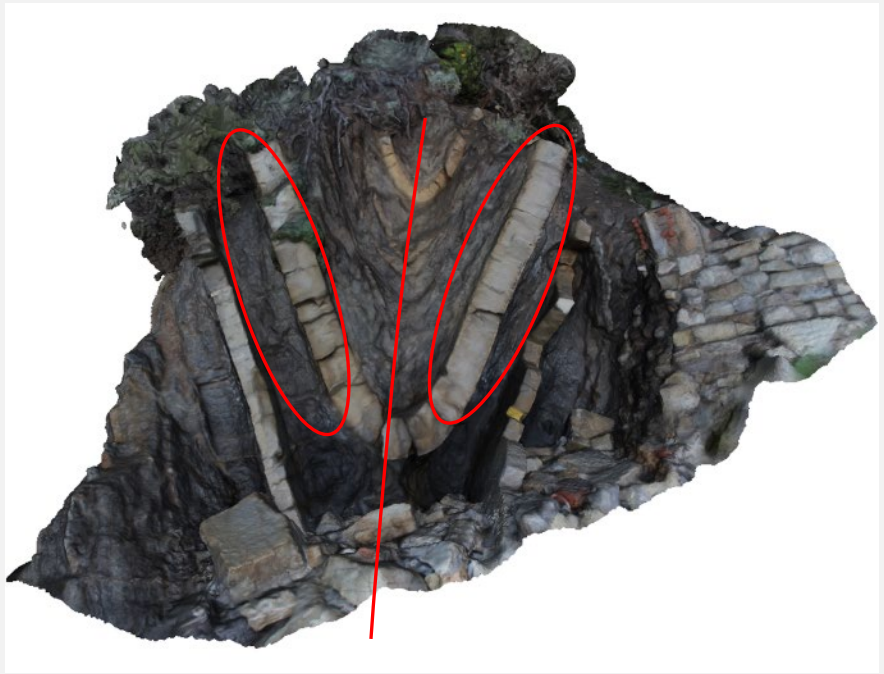
Intrusion Structural Frame

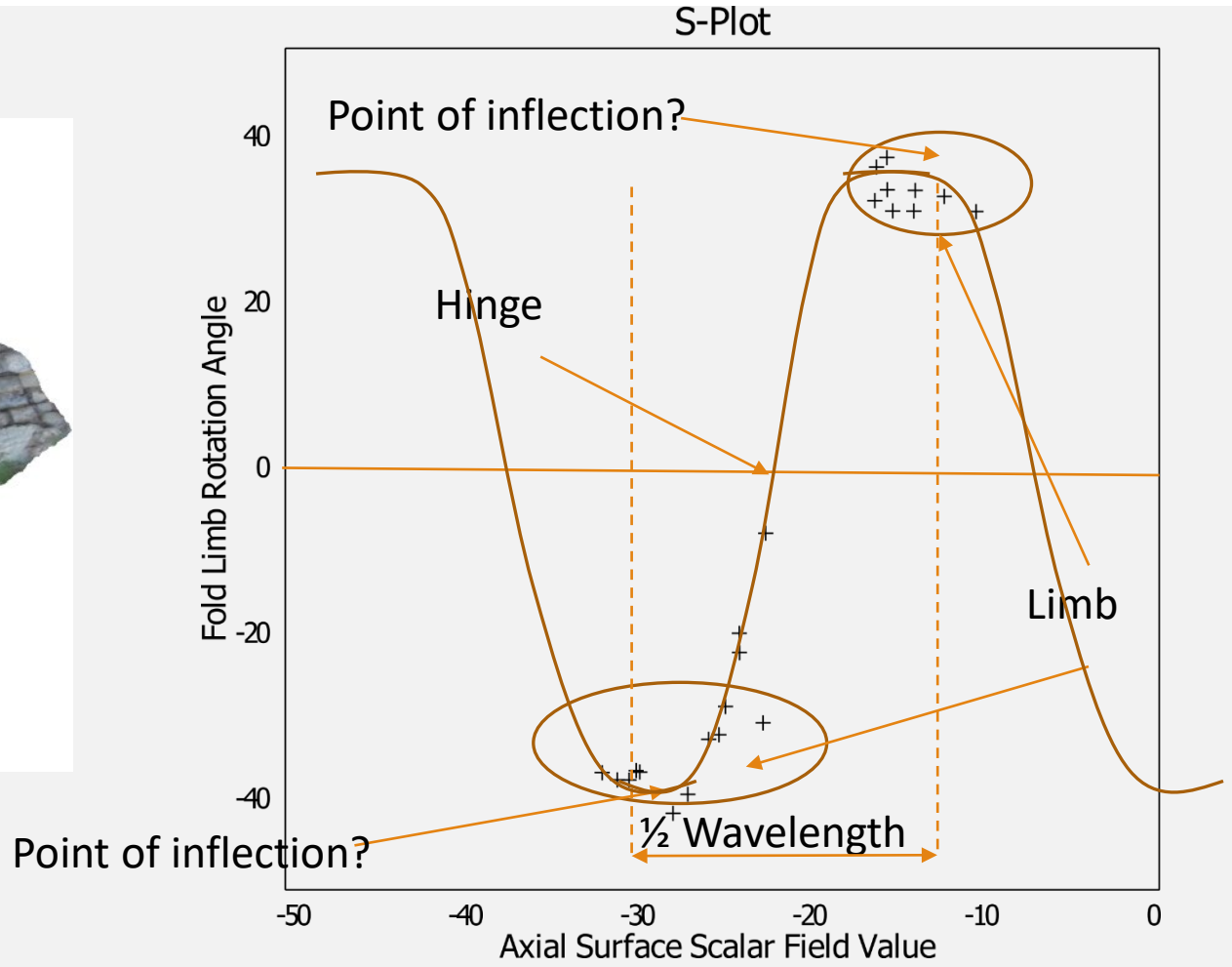
Fernanda Alvarado-Neves (PhD candidate, Monash University





Fold structural frame





Time-aware Geometrical modelling – combining structural frames

Poly-deformation:

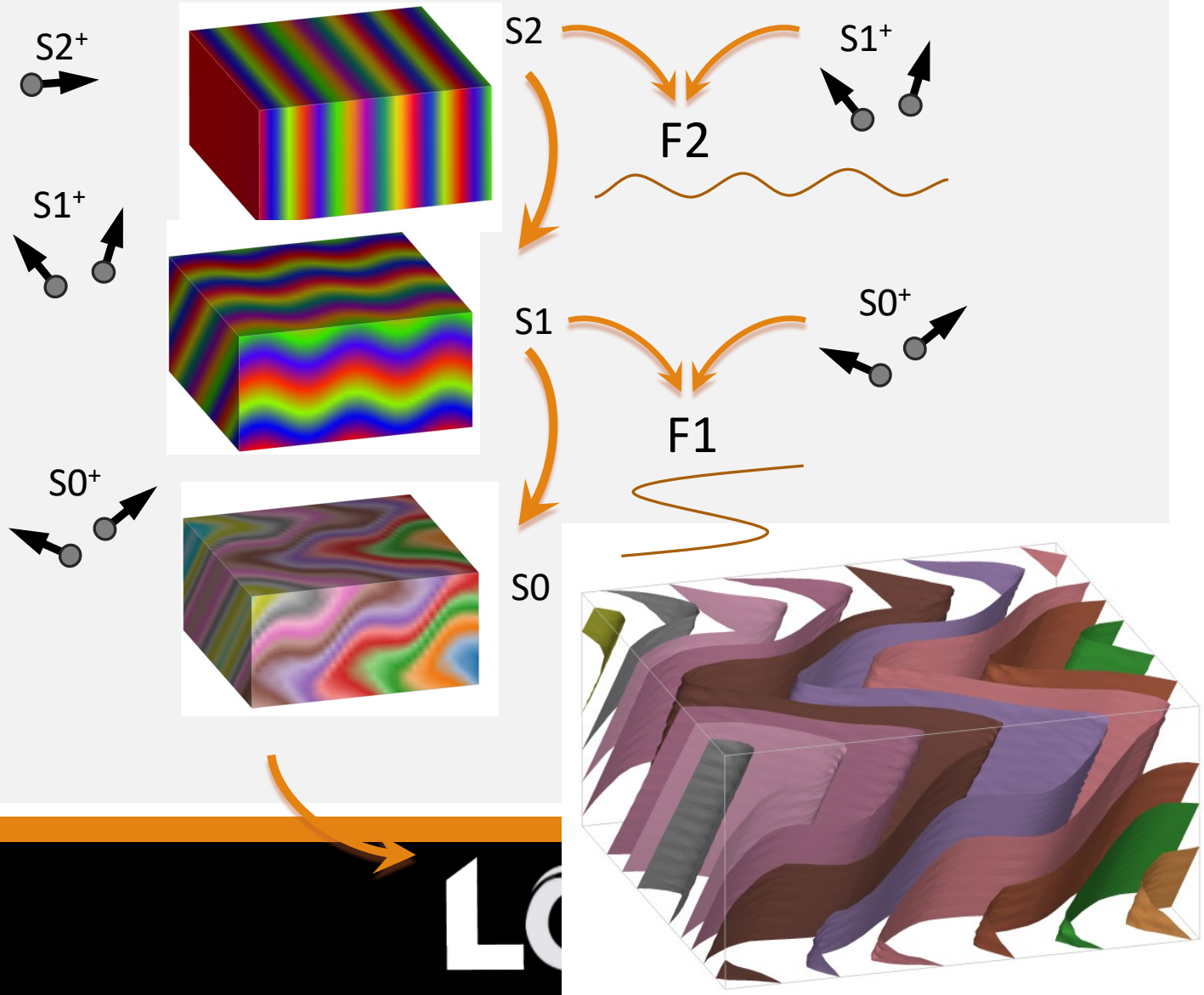
- Modelling events step by step
- Time-aware process: youngest event is modelled first, then the second youngest, etc… until the primary foliation (most often bedding) is modelled

Modelling is geometry based (not mechanical)

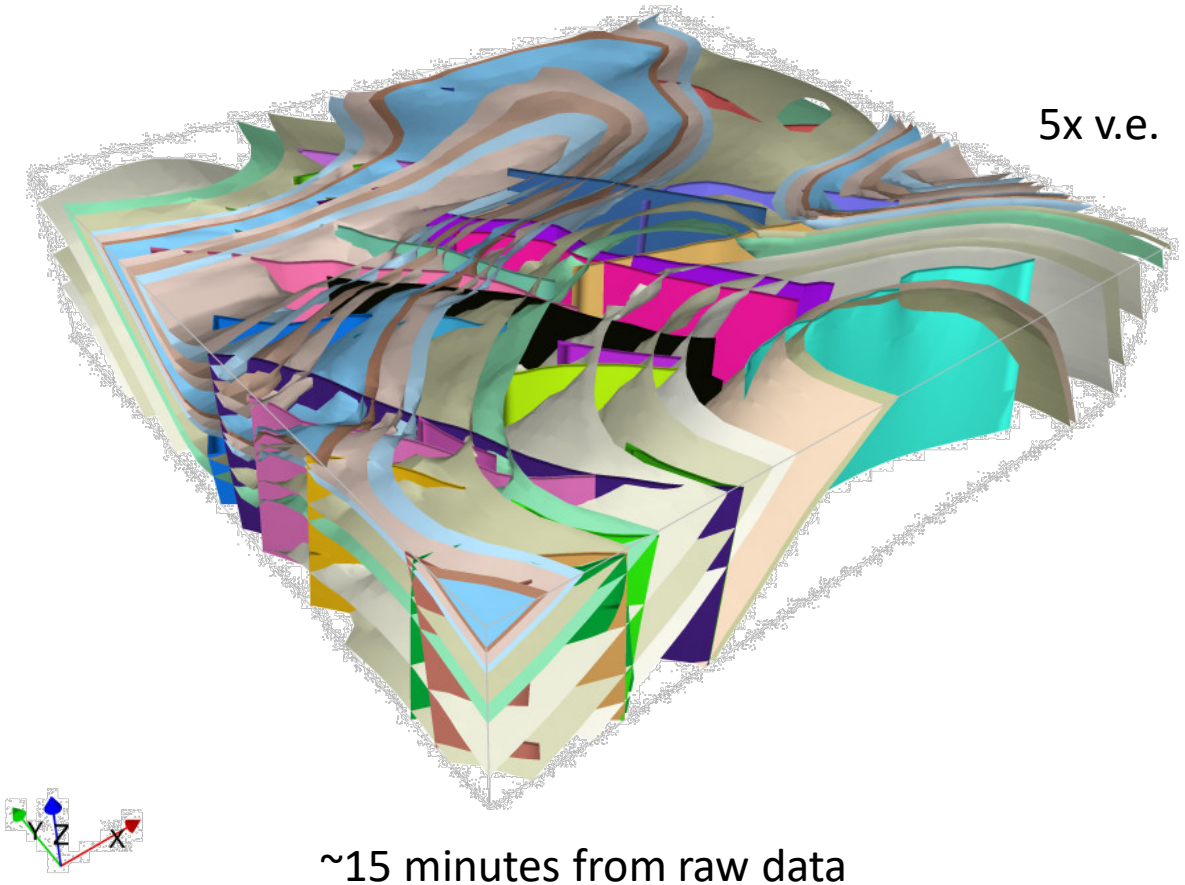
Event types:

- each fault or family of faults
- Folding event
- Unconformity
- Intrusions

Laurent et al., 2016, EPSL

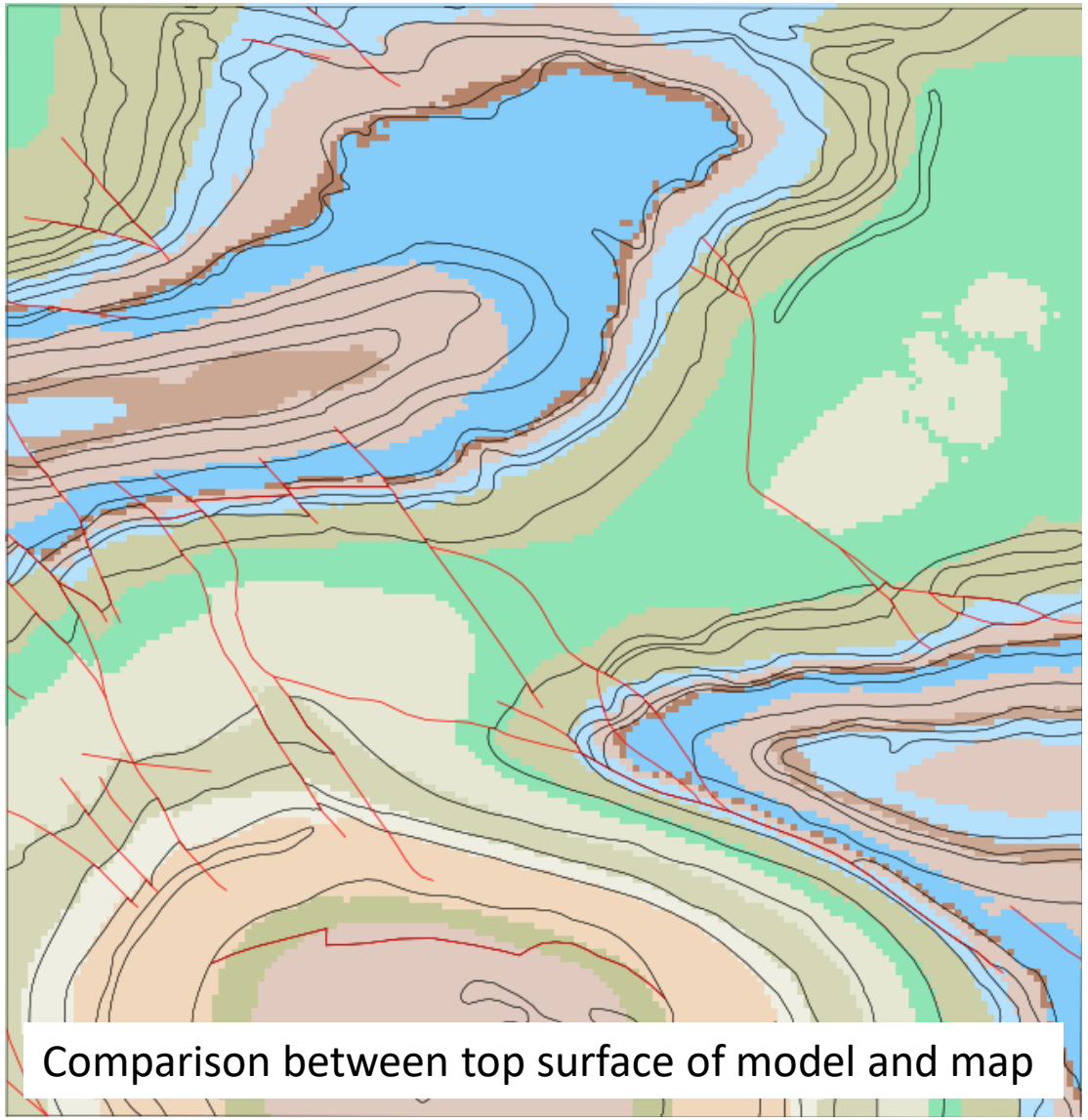


LoopStructural



5x v.e.

~15 minutes from raw data
(6 mins *map2loop*, 9 mins *LoopStructural*)



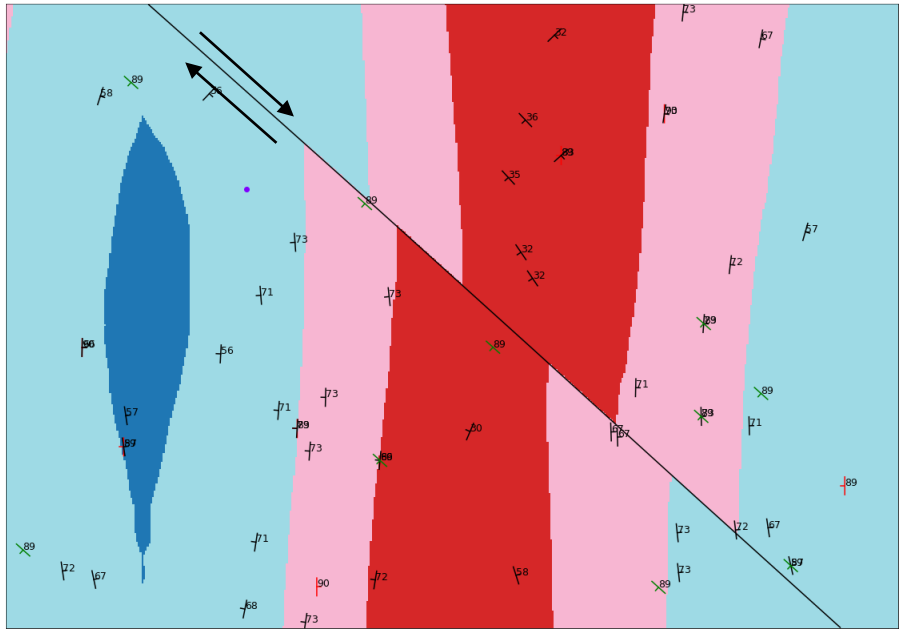
Comparison between top surface of model and map

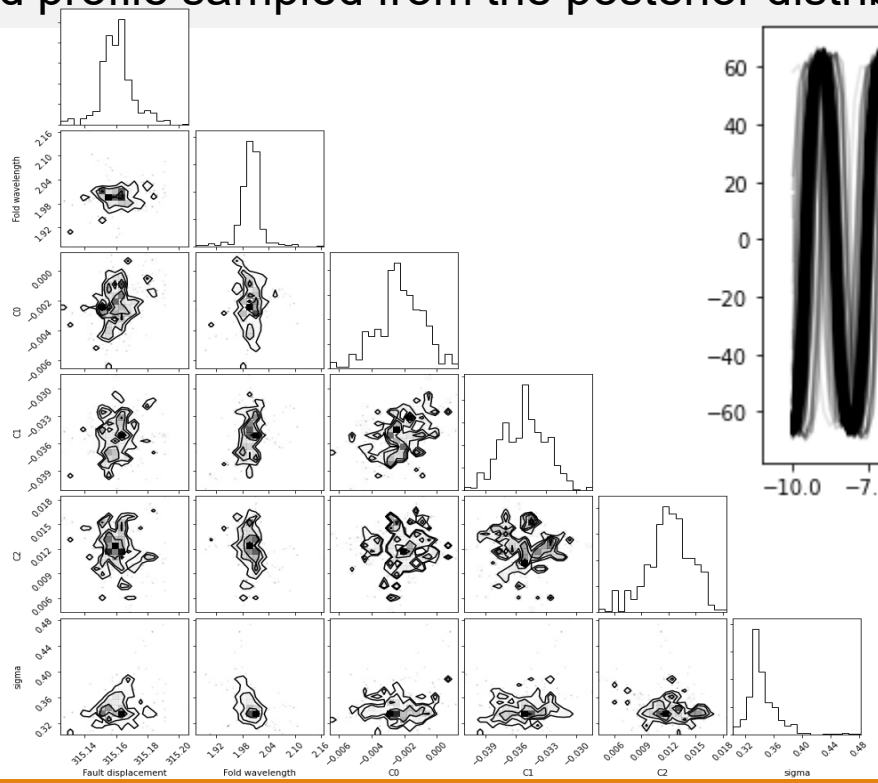
LoopStructural 1.0: time-aware geological modelling
Lachlan Grose[1], Laurent Ailleres[1], Gautier Laurent[2], and Mark Jessell[3]
Geosci. Model Dev., 14, 3915–3937, 2021
https://doi.org/10.5194/gmd-14-3915-2021

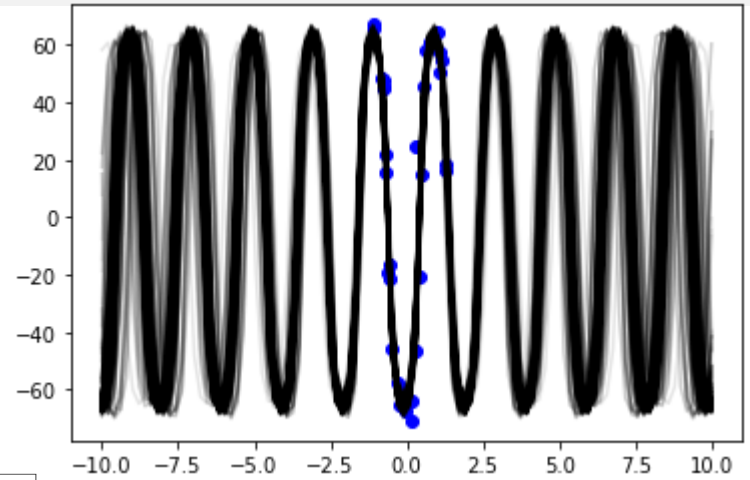
Proof of concept - Bayesian LoopStructural

Bayesian modelling – proof of concept c

a) Faulted fold series
b) Posterior probabilities for displacement and Fourier series coefficients
c) S-Plot showing 1000 realisations of the fold profile sampled from the posterior distribution.



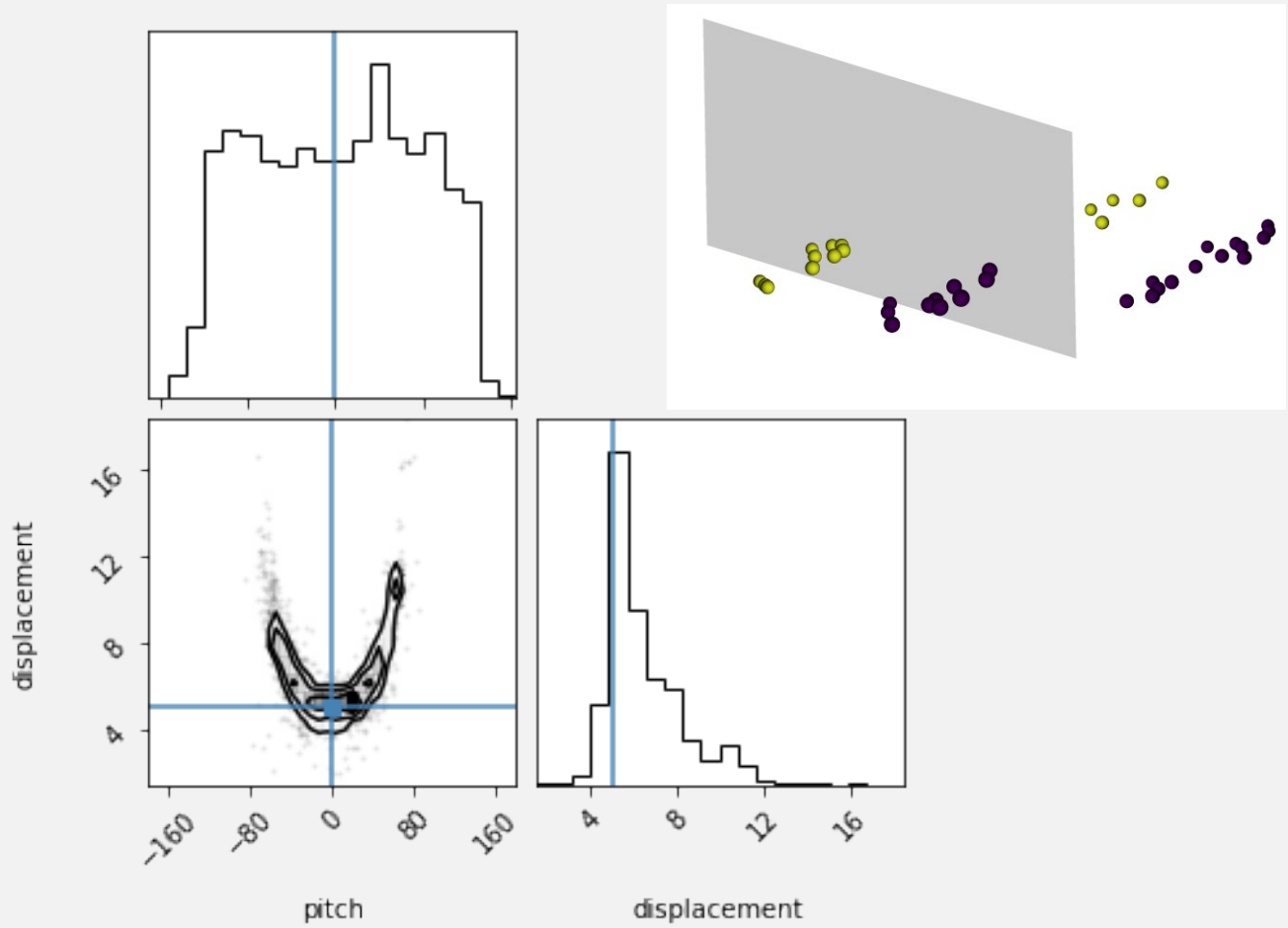




Inverting for geometry

We are building an inversion scheme for geology based on probabilistic (Bayesian) modelling

- Map2loop can provide a-priori probability density functions for some of the parameters.
- Users can also define these pdfs from accumulated knowledge.



Inverting for geometry

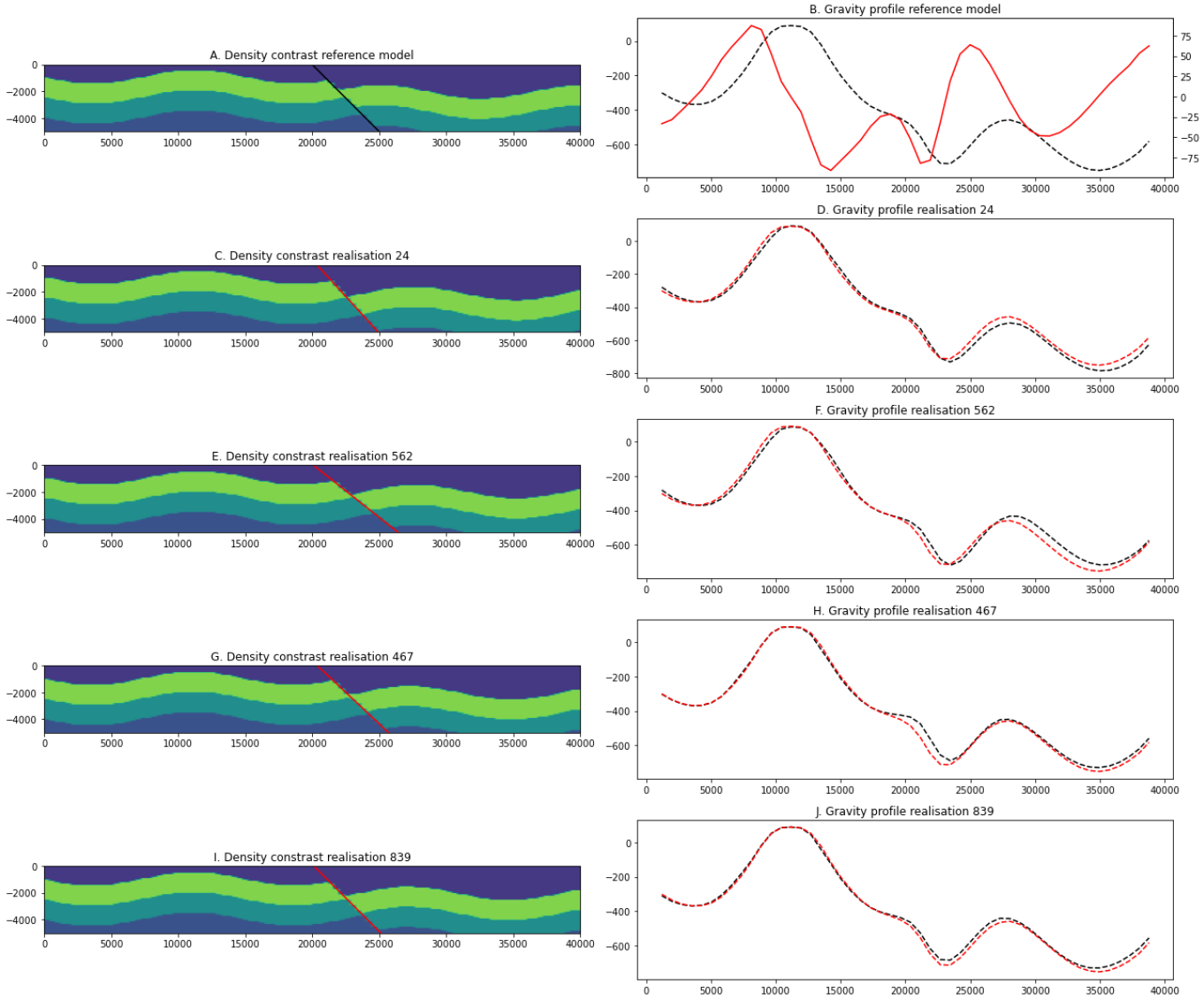
Synthetic example of faulted folded layered model.

Trying to recover fault location, dip and displacement from a gravity profile.

Folded layered model with known density distributions

Likelihood = misfit between observed and calculated gravity

Multiple mcmc chains



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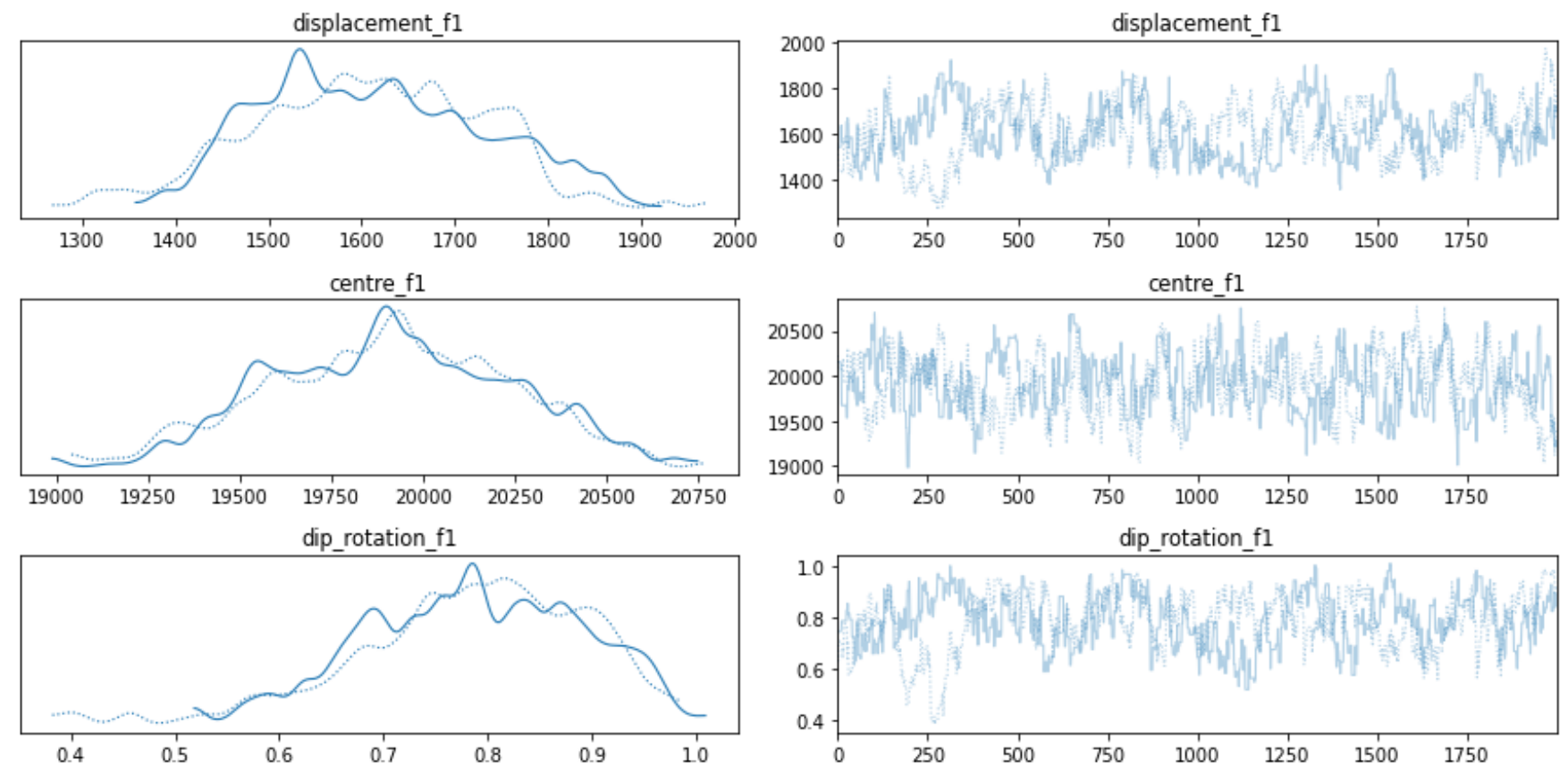
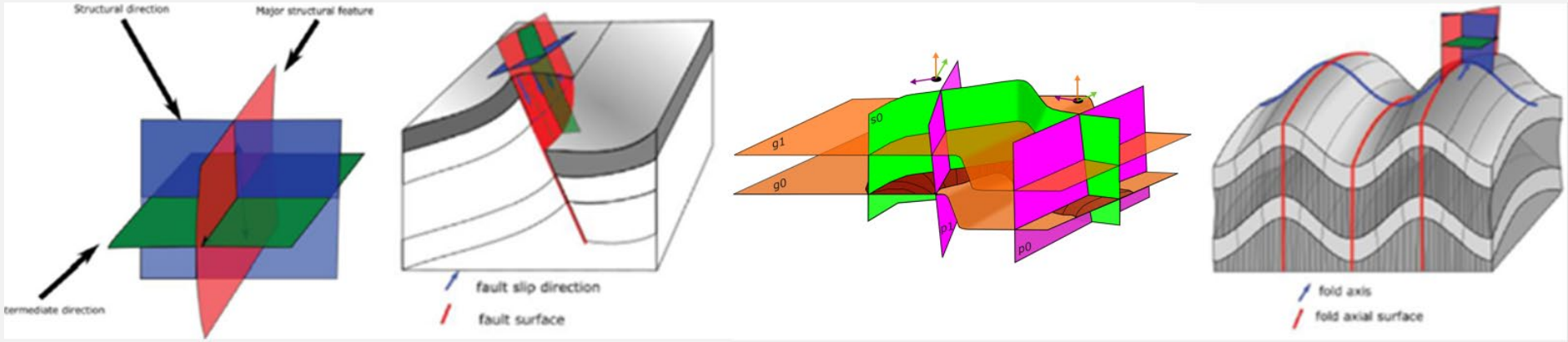


LoopResources Reducing the Mining Footprint

- an automated, reproducible, update-able, workflow to model geology based on structural geological rules
- integration with geophysical modelling (early piecewise inversions or late level-set inversions)

a characterisation of uncertainty that will guide further data acquisition (where and what)

AND a framework using structural frames to model ore body properties including: lithology, alteration, mineralogy, metallurgy, geotechnical parameters and grades



LoopResources Reducing the Mining Footprint

- The Loop Vision:
  - Create more realistic digital-twin of the geology at all scales
  - Help and optimise decision making related to managing our resources
  - For example, at the mine scale:
    - Optimise drilling from 1st intersection
    - Propagate and consider uncertainty throughout the modelling process, including property modelling
    - Increase recovery rate
    - Decrease the amount of resources needed to extract (less energy for less drilling, optimised crushing and processing chain, less water…

Optimising the extraction of resources for a greener tomorrow