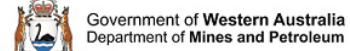


Application of LoopStructural to model the Kalgoorlie area

Angela Rodrigues, Loop team & GSWA team

Overview of the Hannah Lake, Kalgoorlie



Providing geoscience data globally



BHP
100
YEARS



Government of Western Australia
Department of Mines and Petroleum

Outline

- A brief introduction
- Study Area
- Datasets
- Map simplification
- Fault Network Modelling
 1. Defining gradient constraints
 2. Defining topological relationships
 3. Defining abutting relationships
- Stratigraphy modelling
 1. Map de-simplification
 2. Modelling without fold frames
 3. Modelling with fold frames
- Conclusion

Acknowledgements



Lachlan Grose, Laurent Ailleres,
Roy Thompson, Mark Jessel

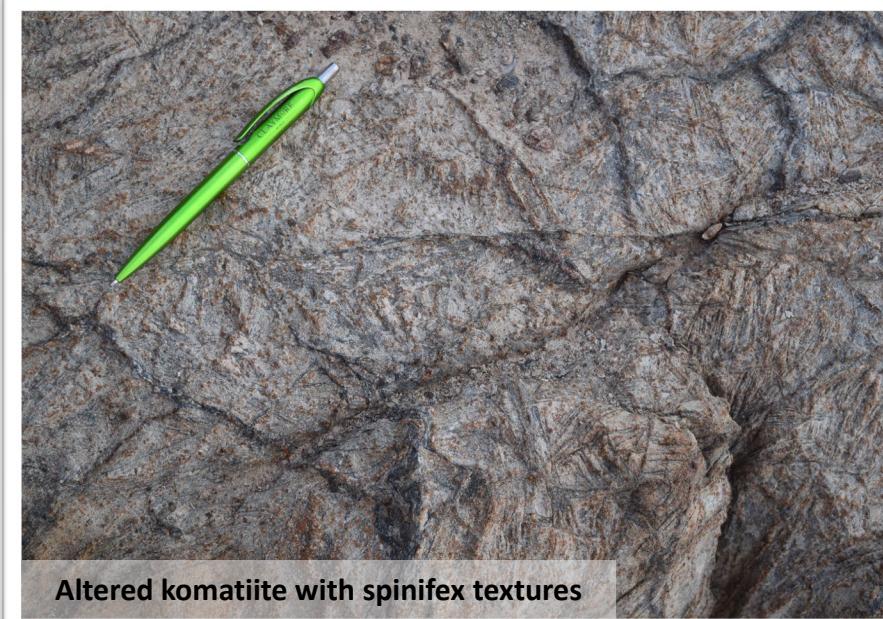
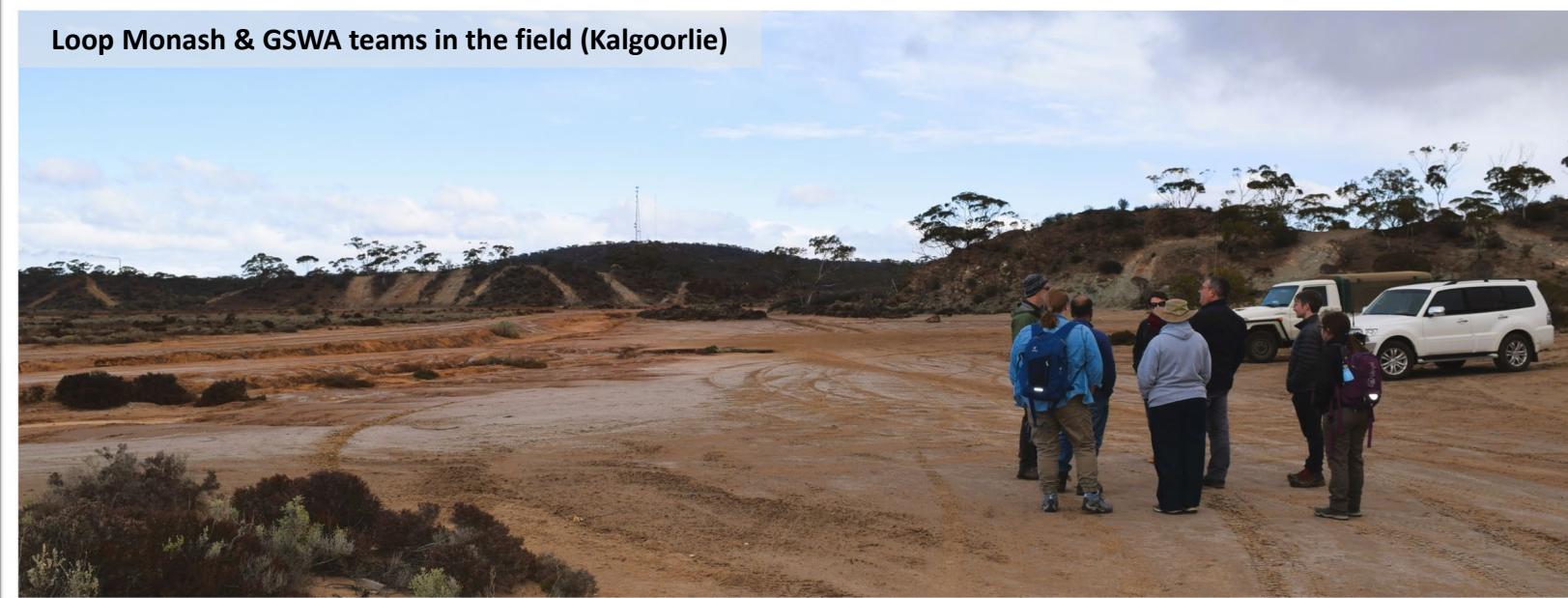


Geological Survey of
Western Australia

Klaus Gessner, Cristina Angheluta,
Hugh Smithies, Jyotindra Saptoka,
Ivan Zibra, Erin Grey,
Melissa Drummond

A brief introduction – Loop & GSWA

Loop Monash & GSWA teams in the field (Kalgoorlie)



Altered komatiite with spinifex textures



Paringa basalt, with variolitic texture

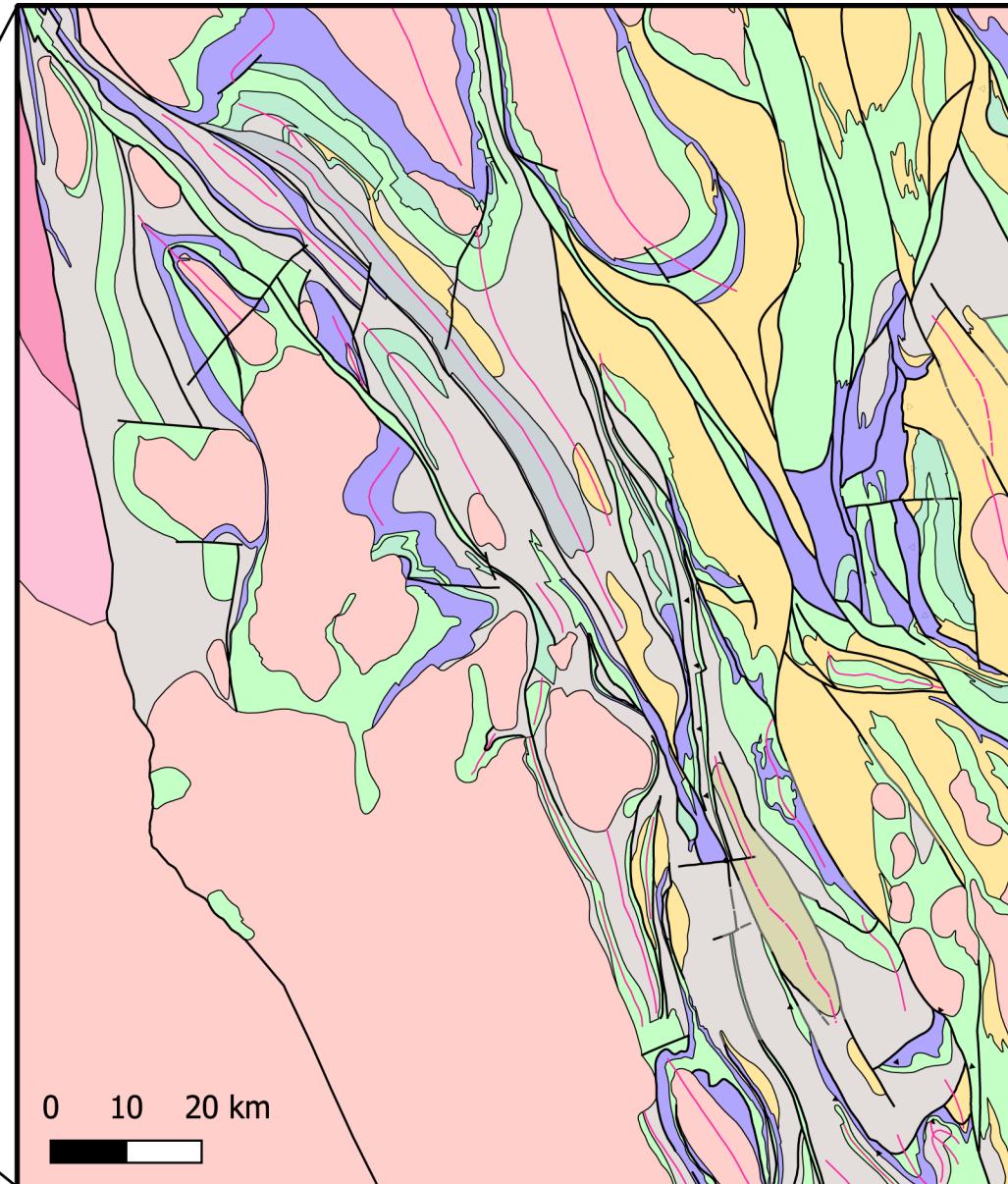


Black Flag Turbidite

Study area



Data from GSWA



Kurrawang Formation
Merougil Formation

Eastern Goldfields Superterrane Greenstones

Siliclastic sedimentary rocks
Volcaniclastic felsic rocks
Mafic
Mafic with minor ultramafic
Ultramafic

Intrusives

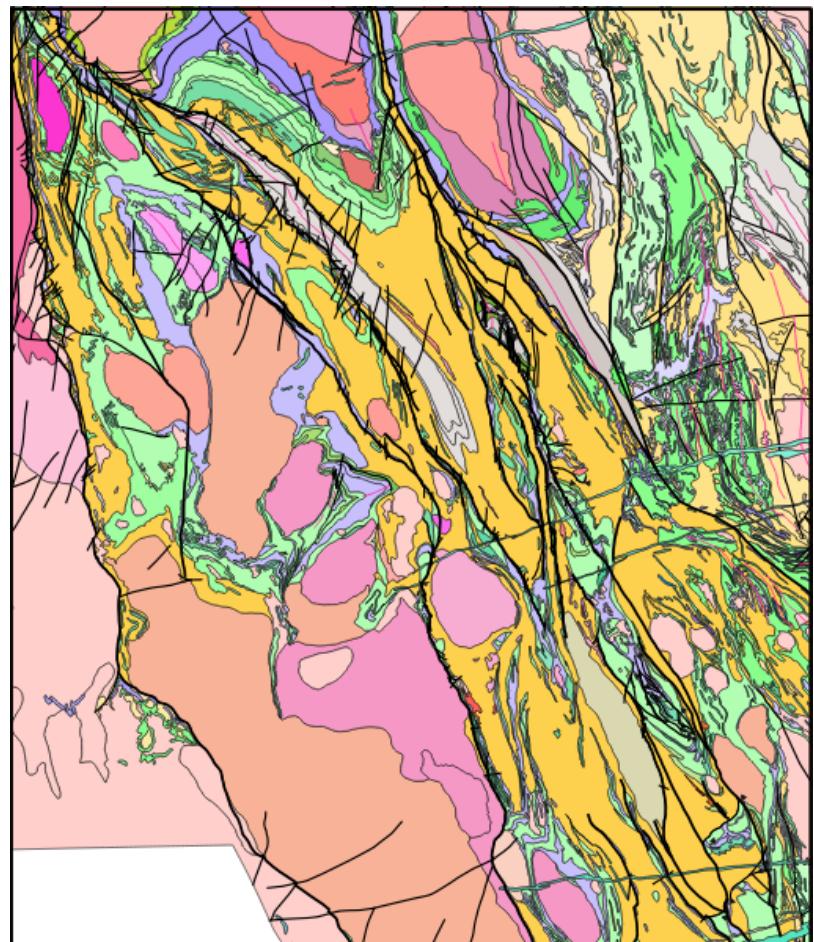
Yilgarn Craton Granites
Walganna Suite
Tuckanarra Suite

Structures

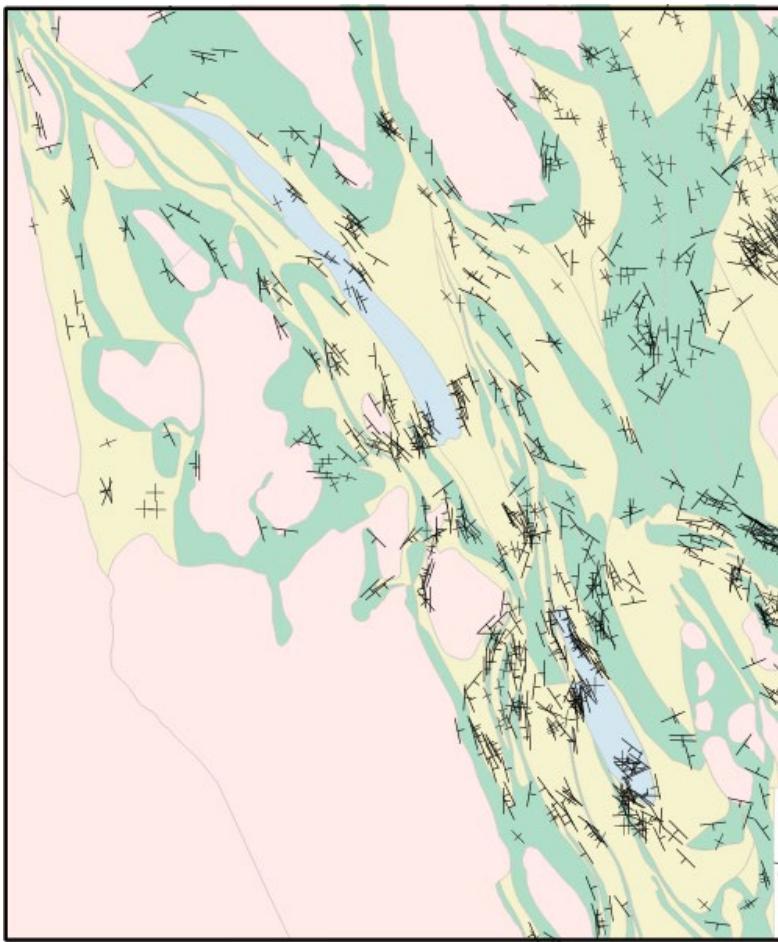
Fault or shear zone
Fold axial trace (antiform or synform)

Datasets

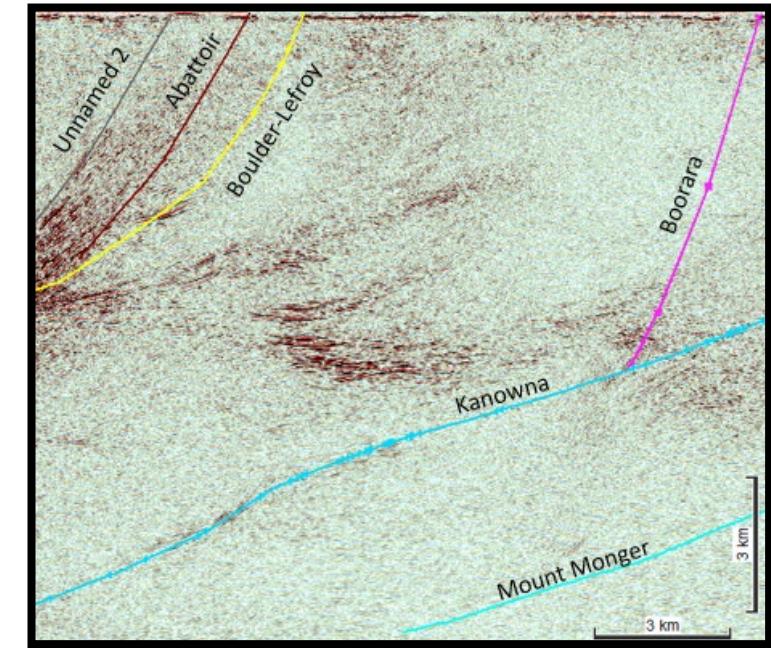
Lithological and structural
spatial information



Field measurements



Seismic data

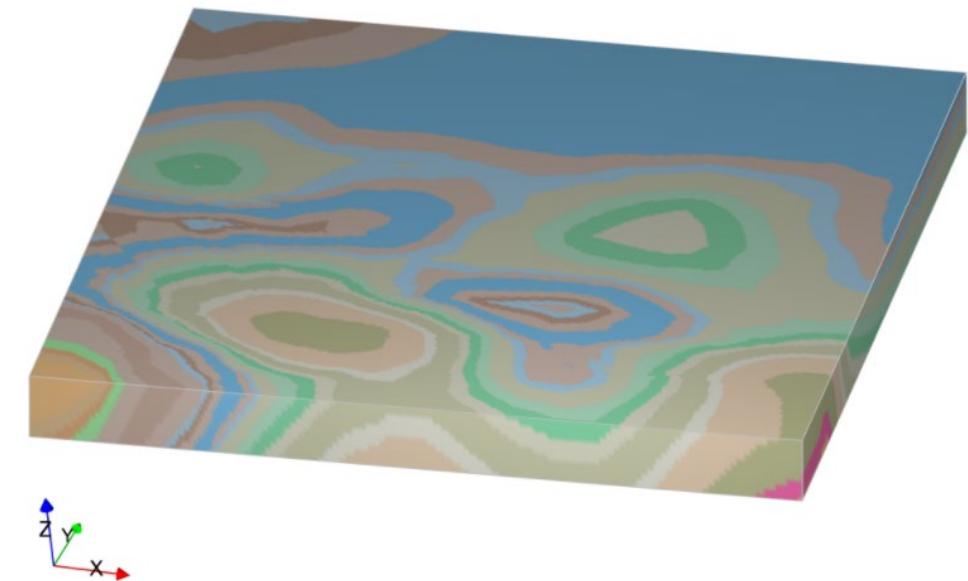


3D points

LoopStructural – a Python library for 3D geological modelling

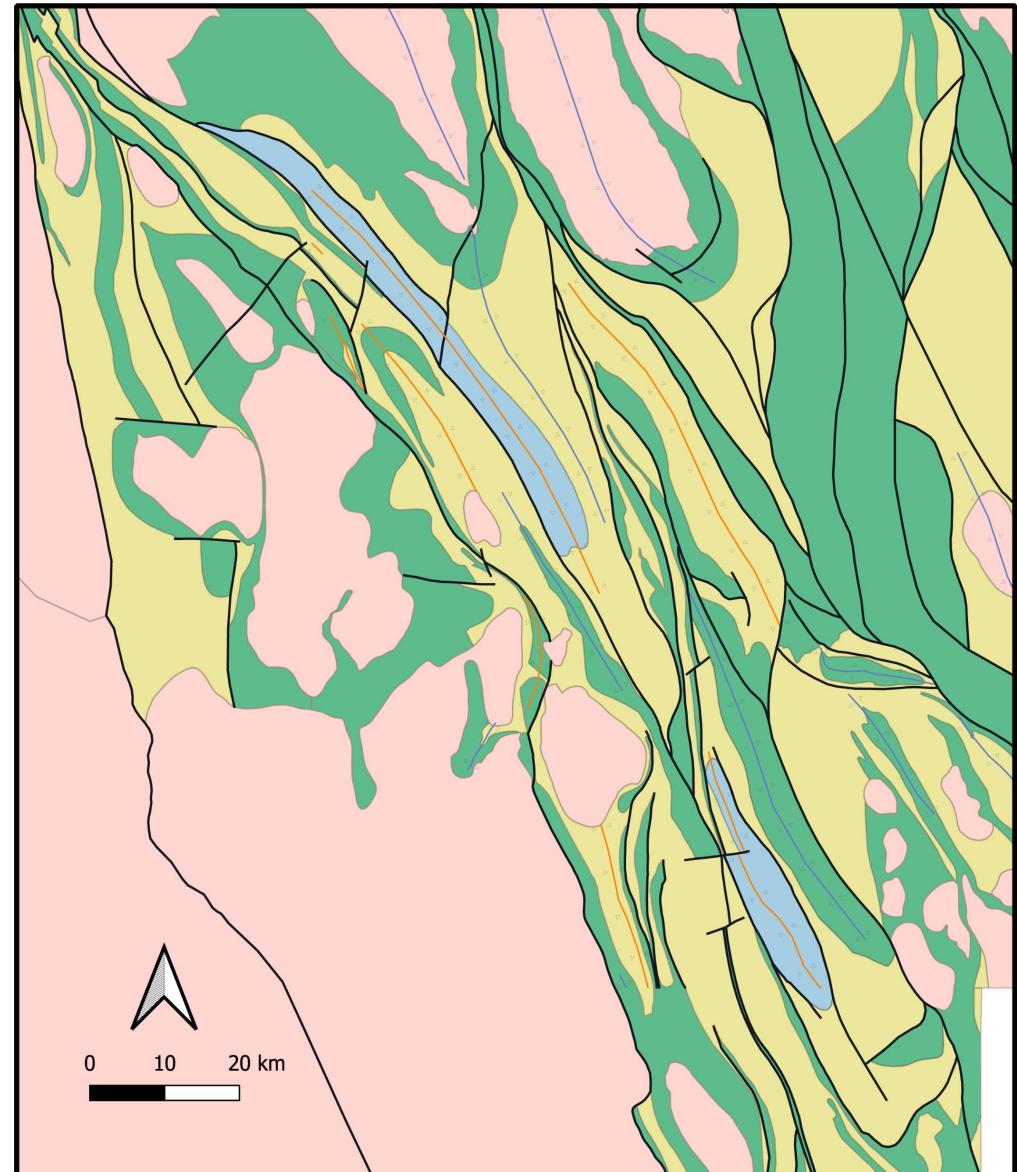
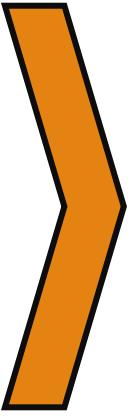
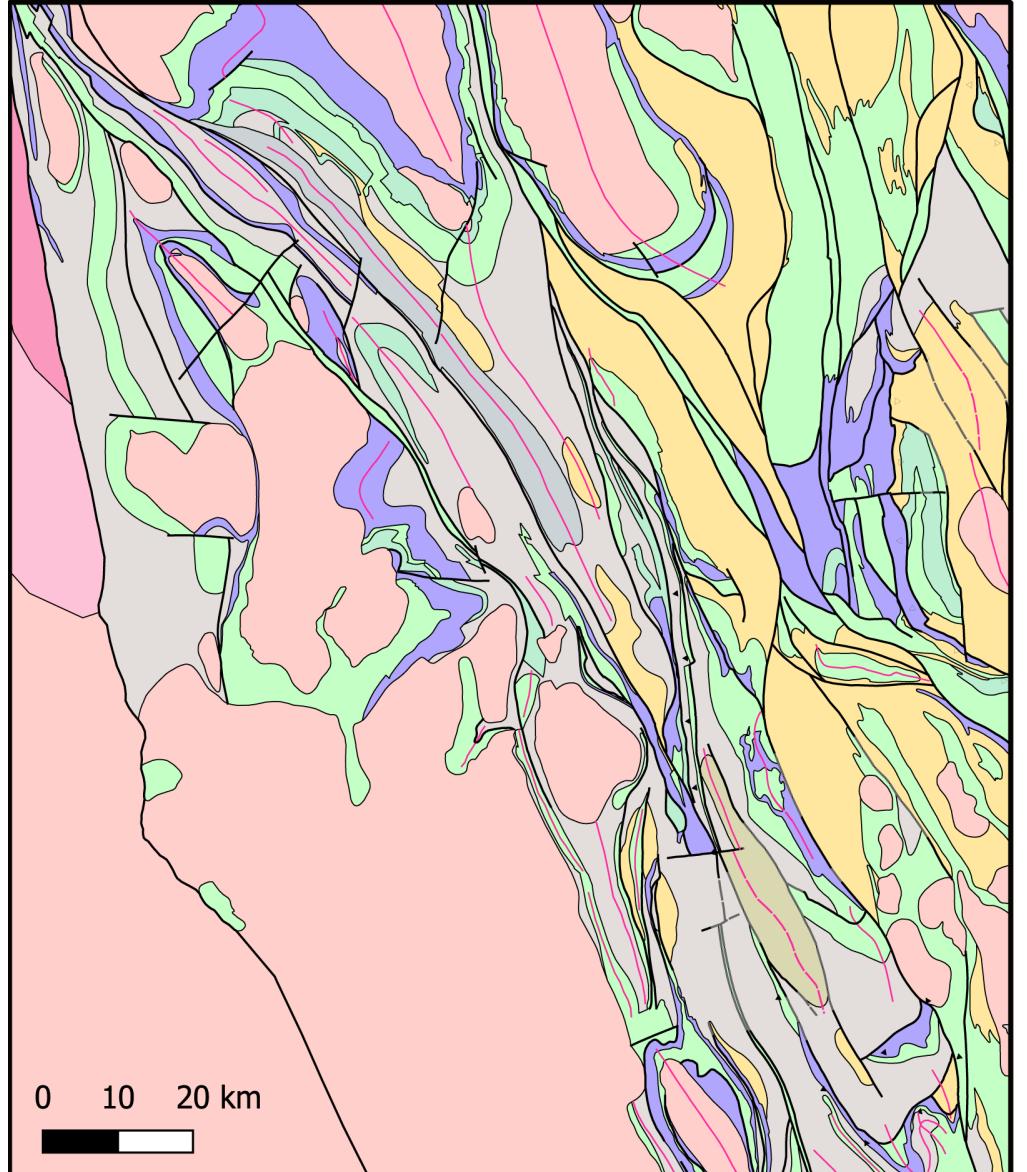
- Core 3D modelling algorithms behind Loop
- Python library for 3D geological modelling
 - Discrete interpolation using finite difference method and piecewise linear method
 - Fold interpolator (Laurent et al., 2016)
 - Implicit fault kinematics (Grose et al, 2021)
 - Intrusion builder (Alvarado-Neves et al., 2022)
- Open source (MIT license)
- Available on PyPI, conda and Github
- Linked with map2loop (Jessel et al., 2021) for automatic model generation
- Export surface meshes as vtk, obj
- [Publication in Geoscientific Model Development](#)

LoopStructural: Loop3D Geological Forward
Modelling Engine



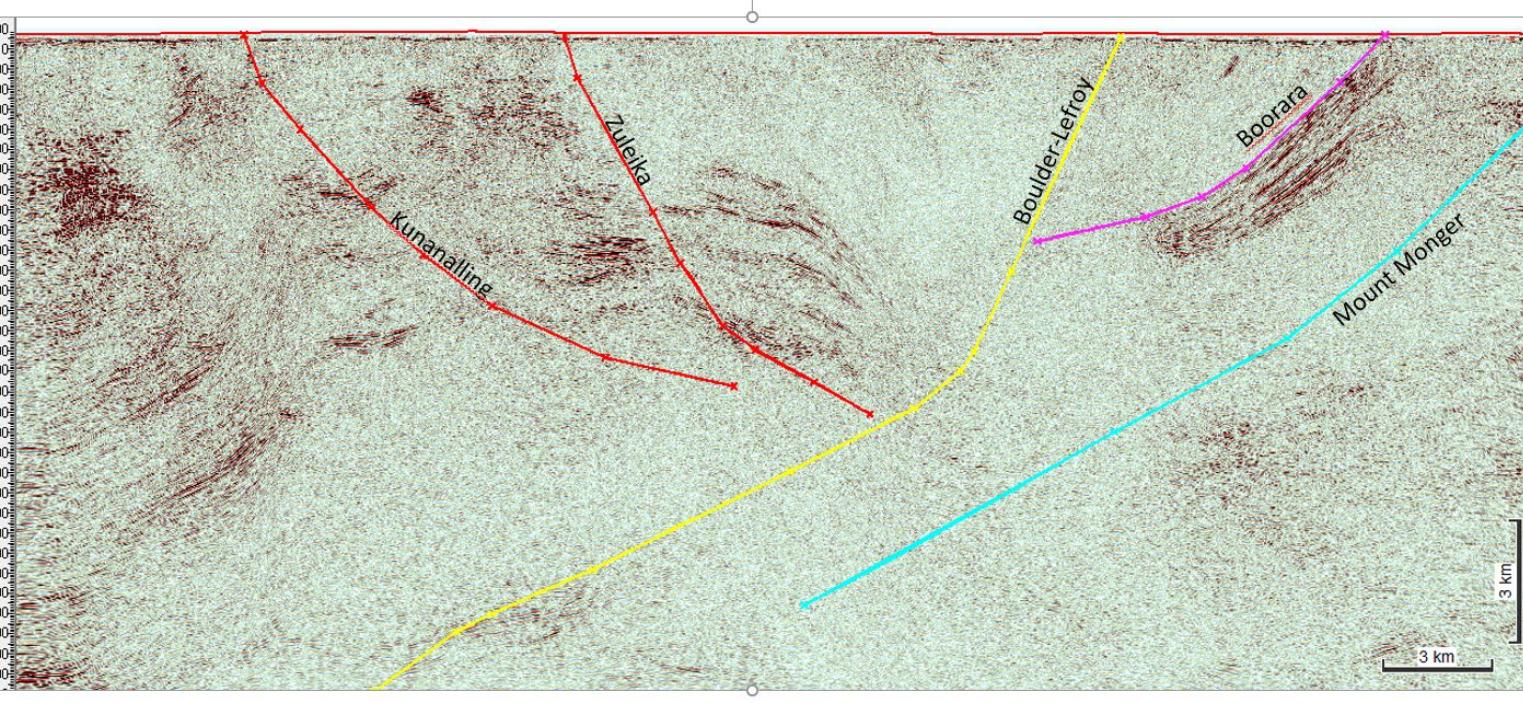
Continuous integration and deployment passing Publish Docker Hub passing pypi package 1.0.89 license MIT docs githubio

Geological map simplification

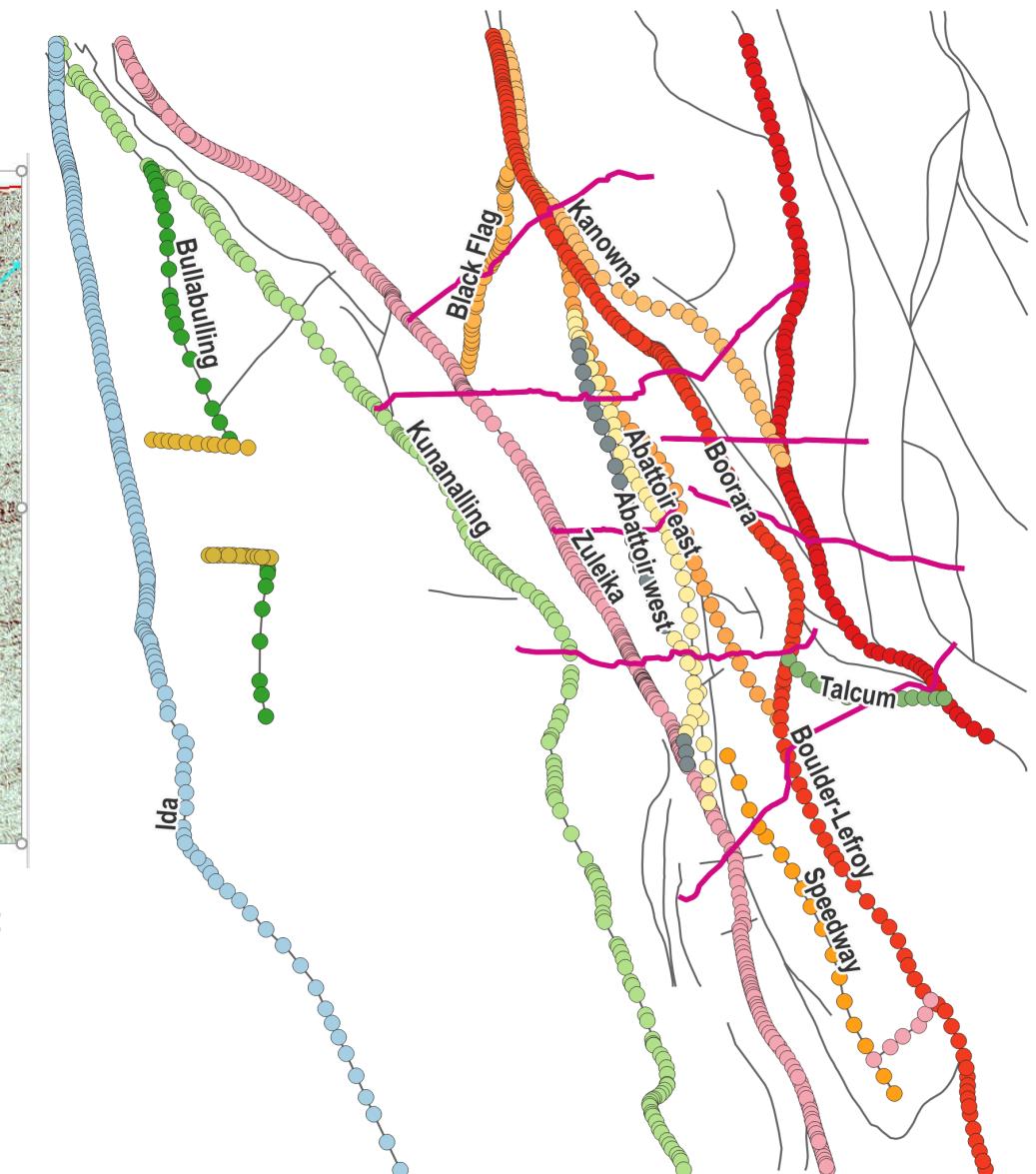


Fault Network Modelling

○ Faults picked in the seismic interpretation



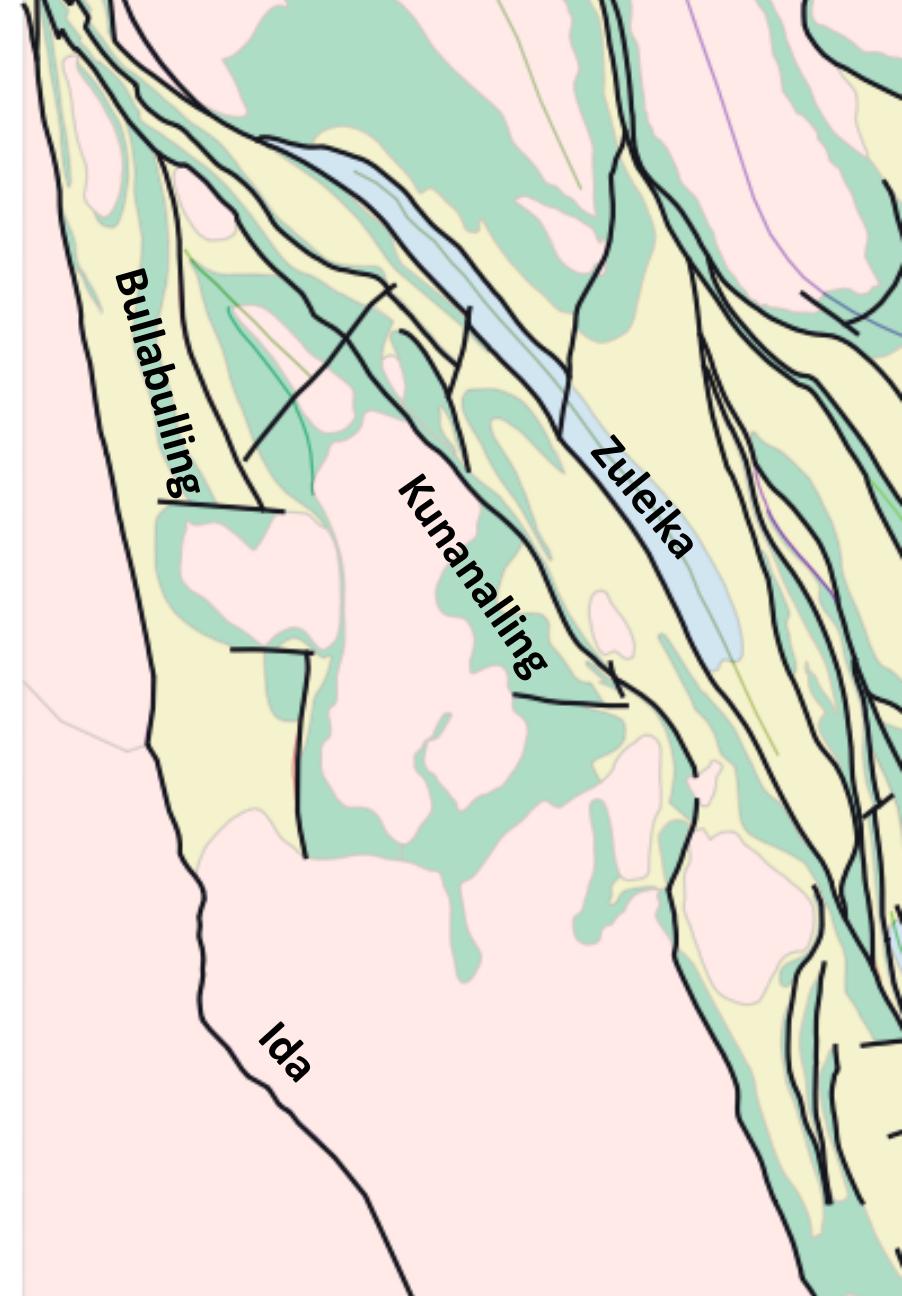
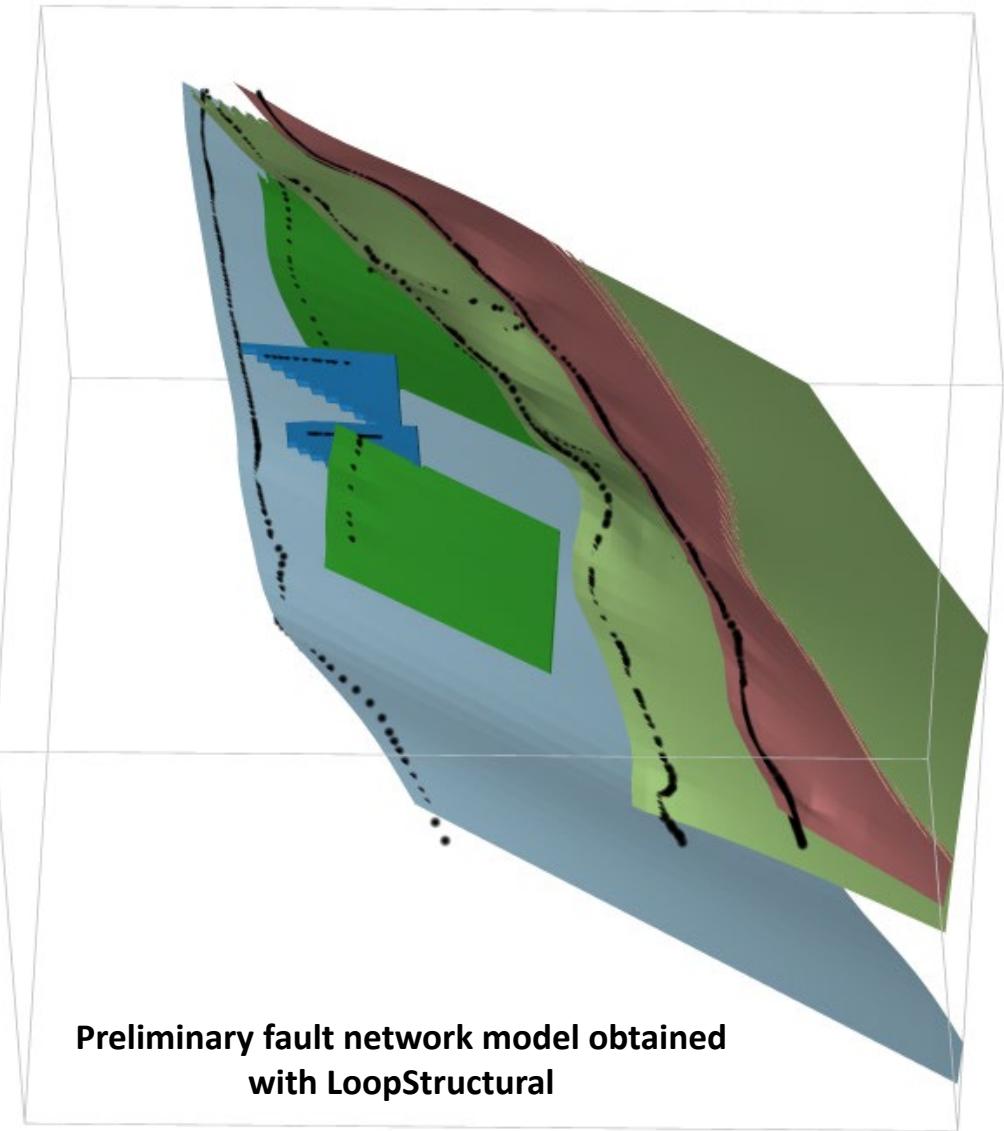
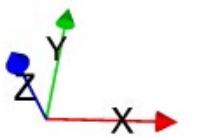
Line 5 from the [Eastern Goldfields high-resolution reflection seismic survey](#);
Example of the seismic interpretation by [Zibra](#) (2020)



Fault Network modelling

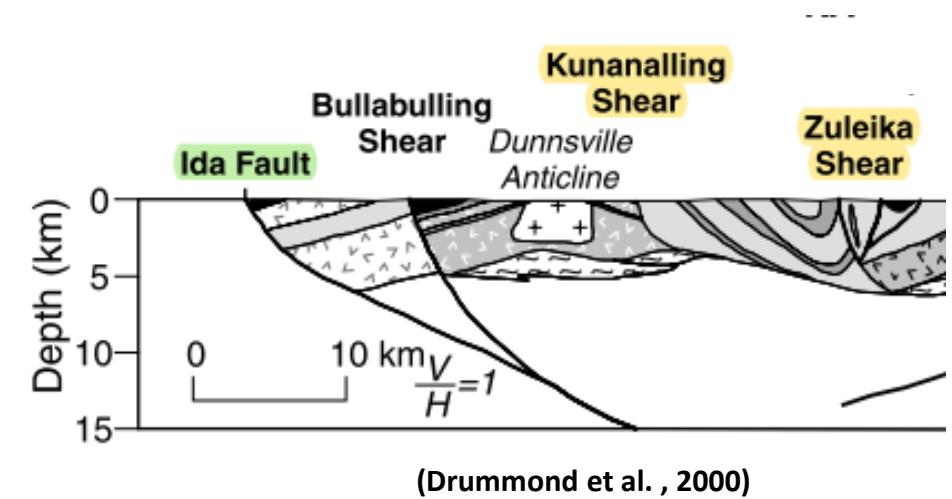
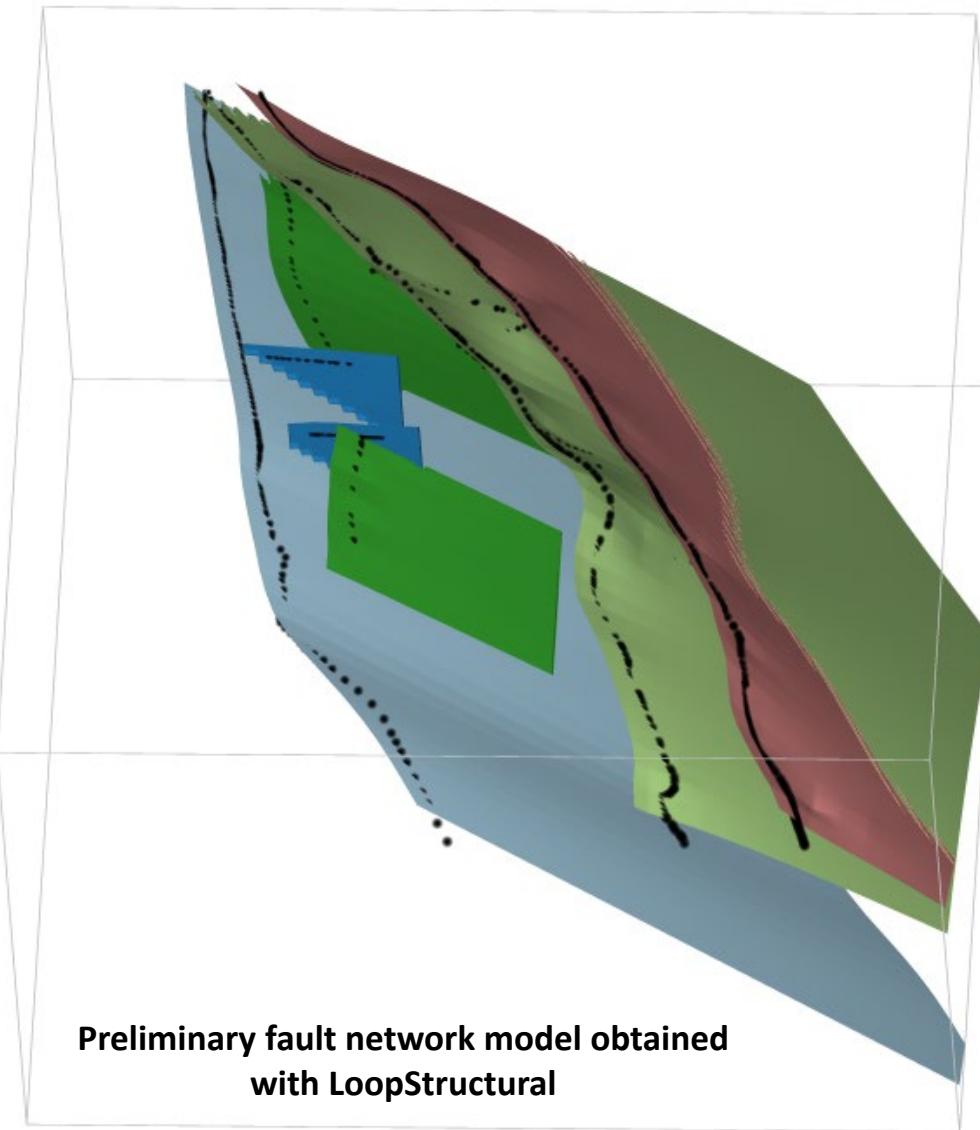
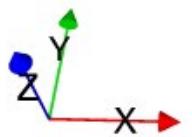
Ida + Bullabulling + Kunanalling + Zuleika

- Ida
- Kunanalling
- Bullabulling
- Zuleika



Fault Network modelling

Ida + Bullabulling + Kunanalling + Zuleika



Fault Network modelling

Ida + Bullabulling + Kunanalling + Zuleika

To model a geological feature, LoopStructural
needs:

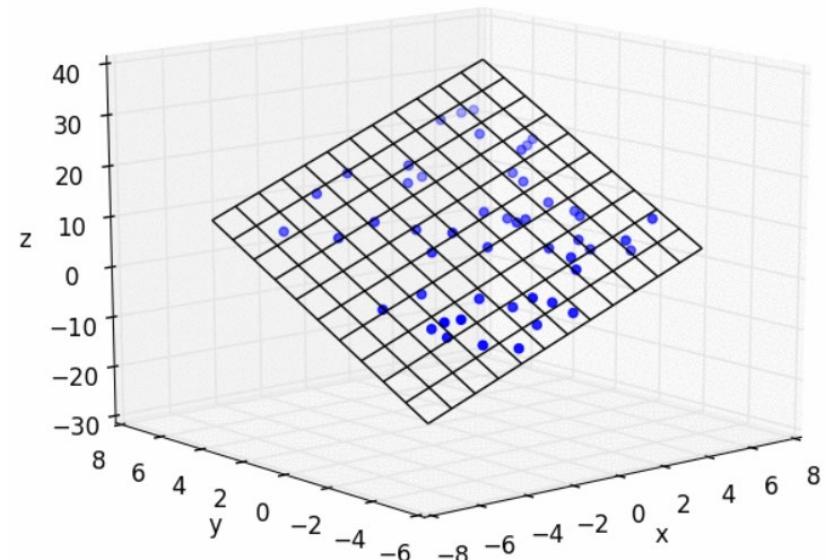
- A set of x, y, z coordinates
- Feature name
- Value observations of a scalar field
- And some constraints, either:
 - Gradient constraints
 - Norm gradient constraints
 - Gradient tangent constraints

[LoopStructural Documentation](#)

Given a set of x, y, z points, we can find the function's coefficients:

$$ax + by + c = z$$

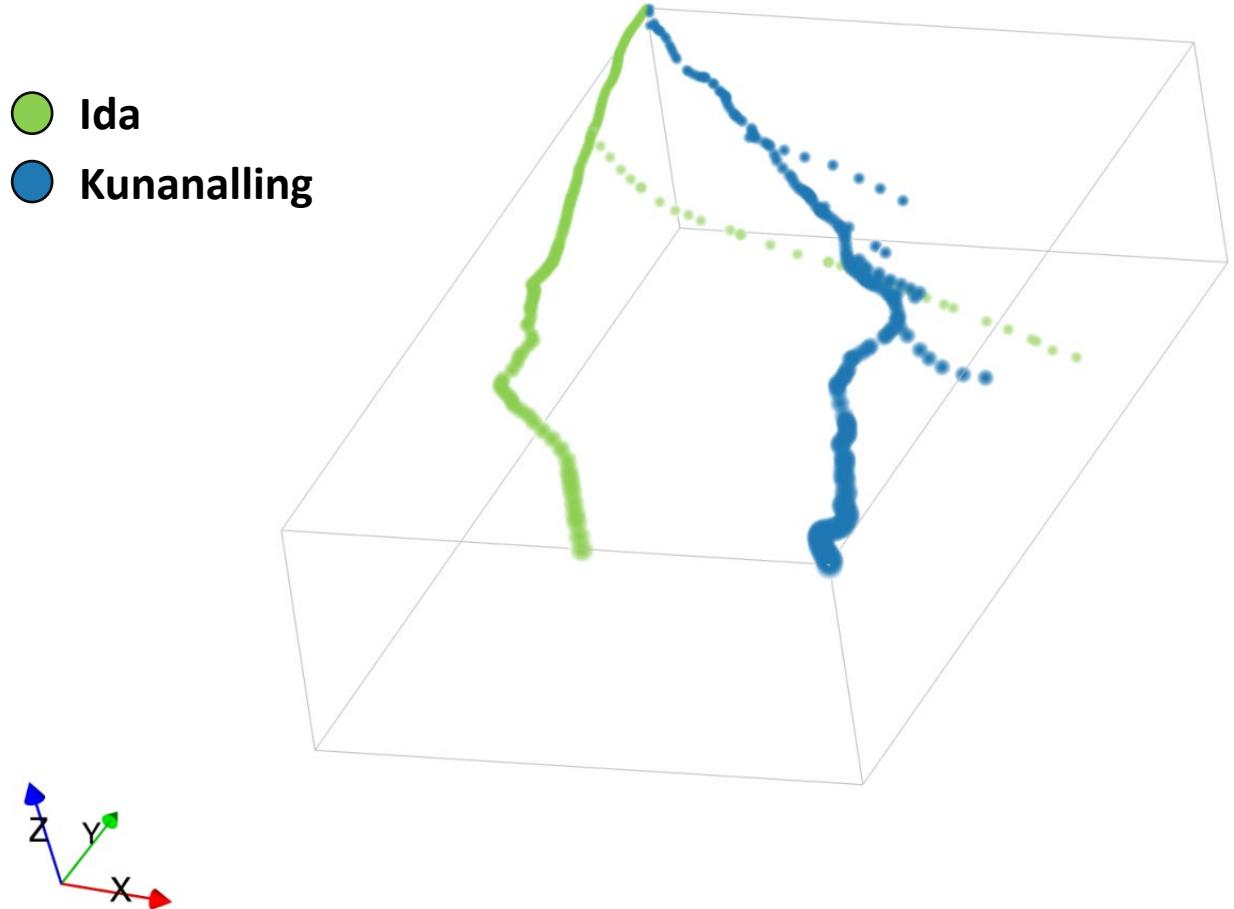
The norm of these coefficients will give us the gradient constraints to input in LoopStructural.



[source](#)

Fault Network modelling

Ida + Bullabulling + Kunanalling + Zuleika

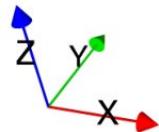
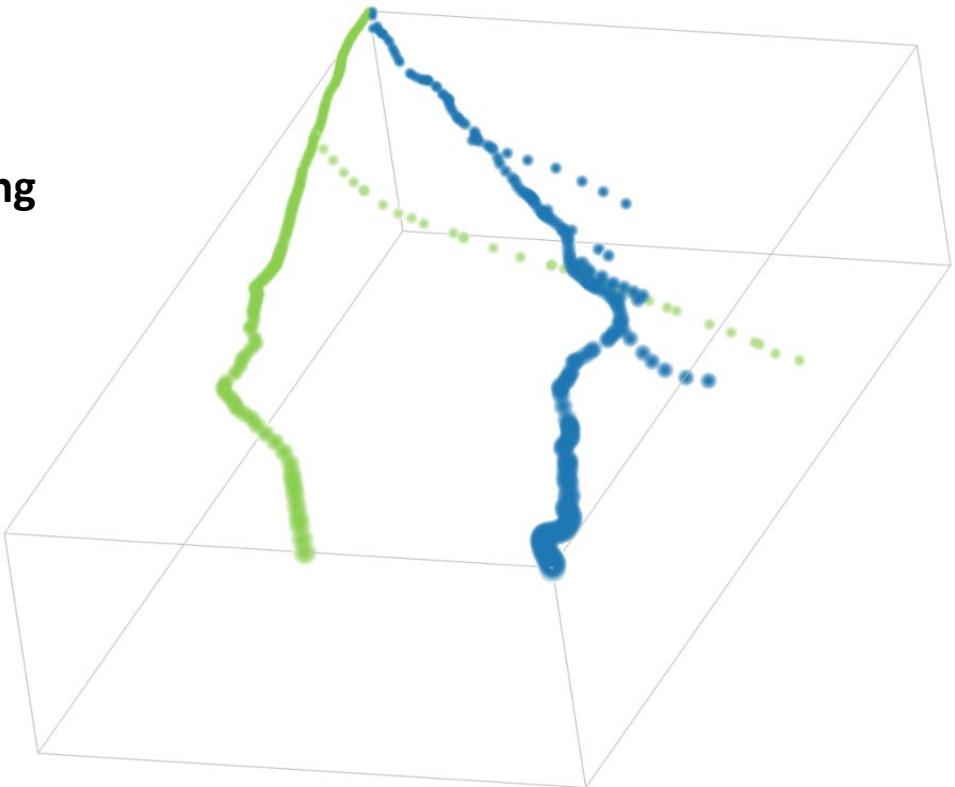


Fault location points in depth from seismic interpretation
& fault surface points from GSWA database

Fault Network modelling

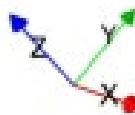
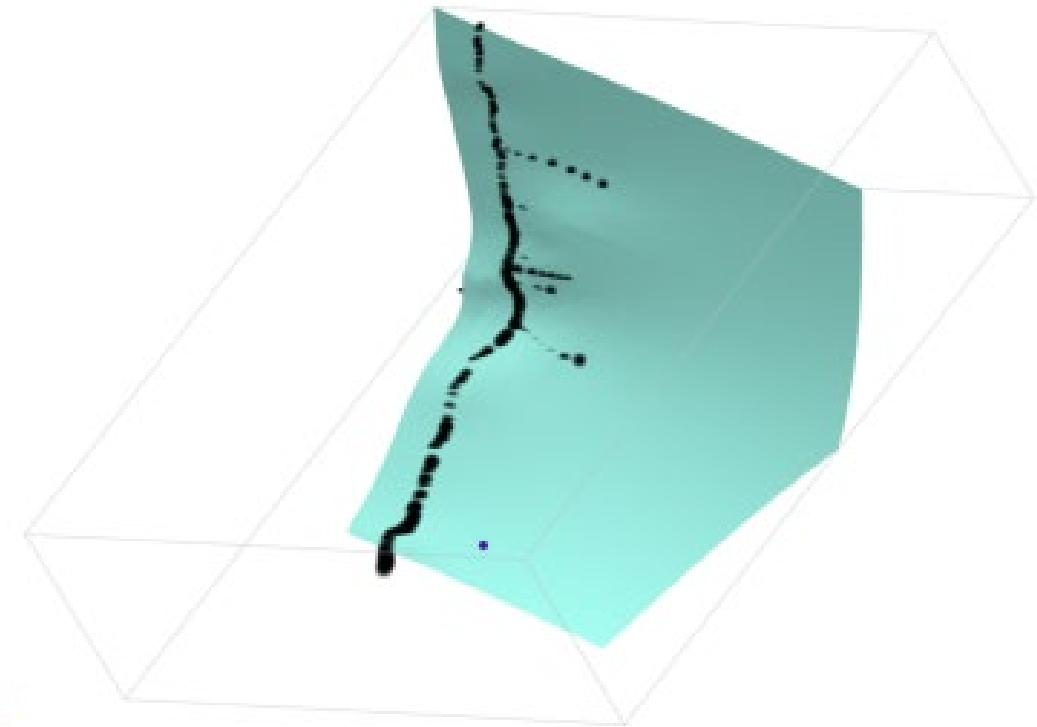
Ida + Bullabulling + Kunanalling + Zuleika

● Ida
● Kunanalling



Fault location points in depth from seismic interpretation
& fault surface points from GSWA database

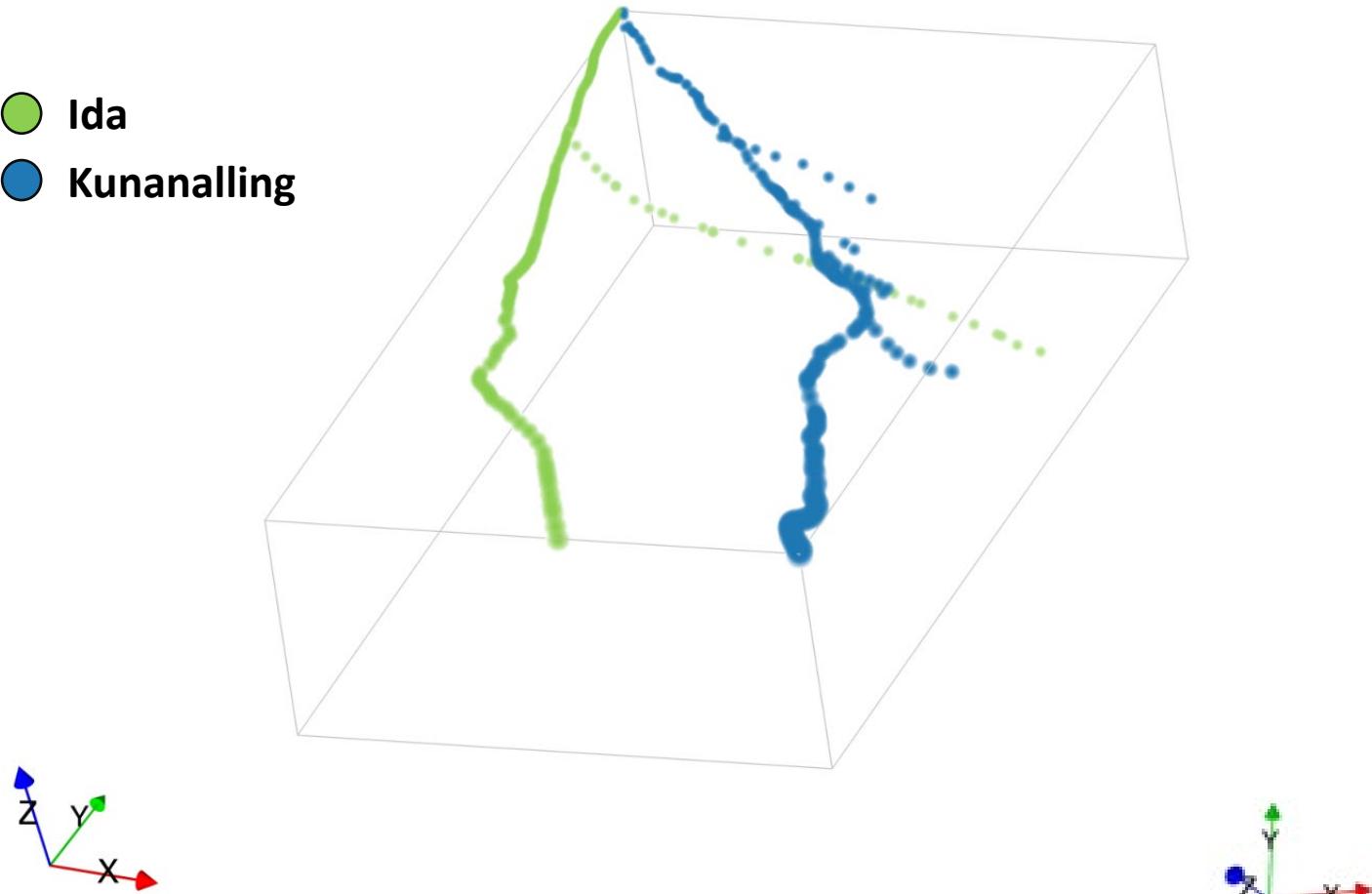
Kunanalling interpolation when using
coefficients as gradient constraints



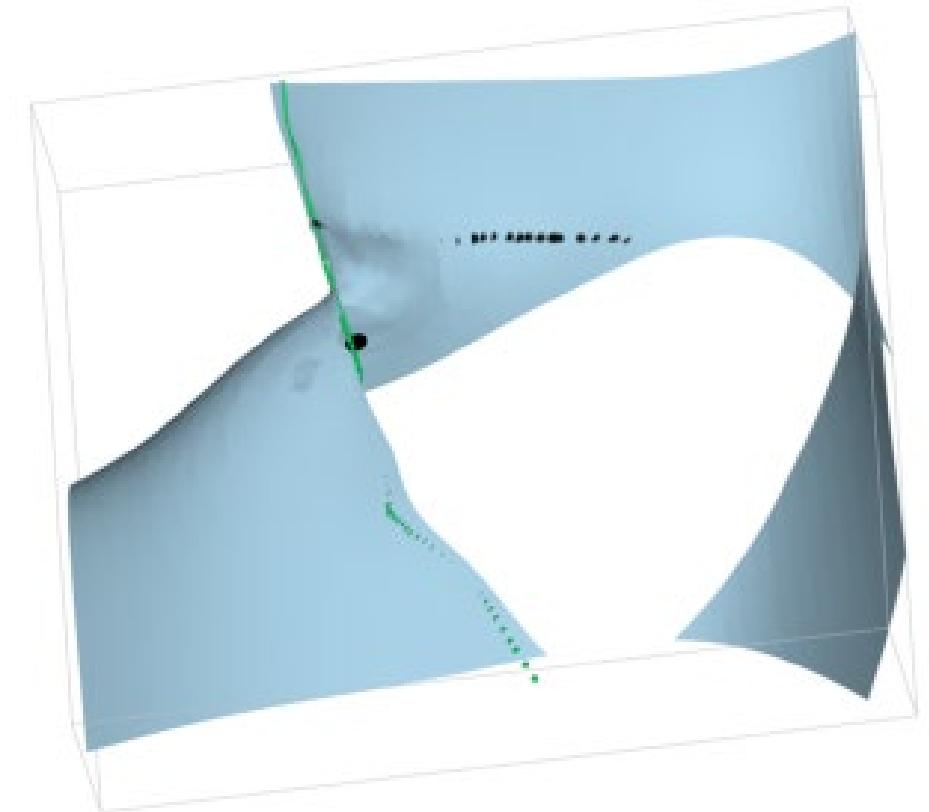
Fault Network modelling

Ida + Bullabulling + Kunanalling + Zuleika

● Ida
● Kunanalling



Ida interpolation when using coefficients
as gradient constraints

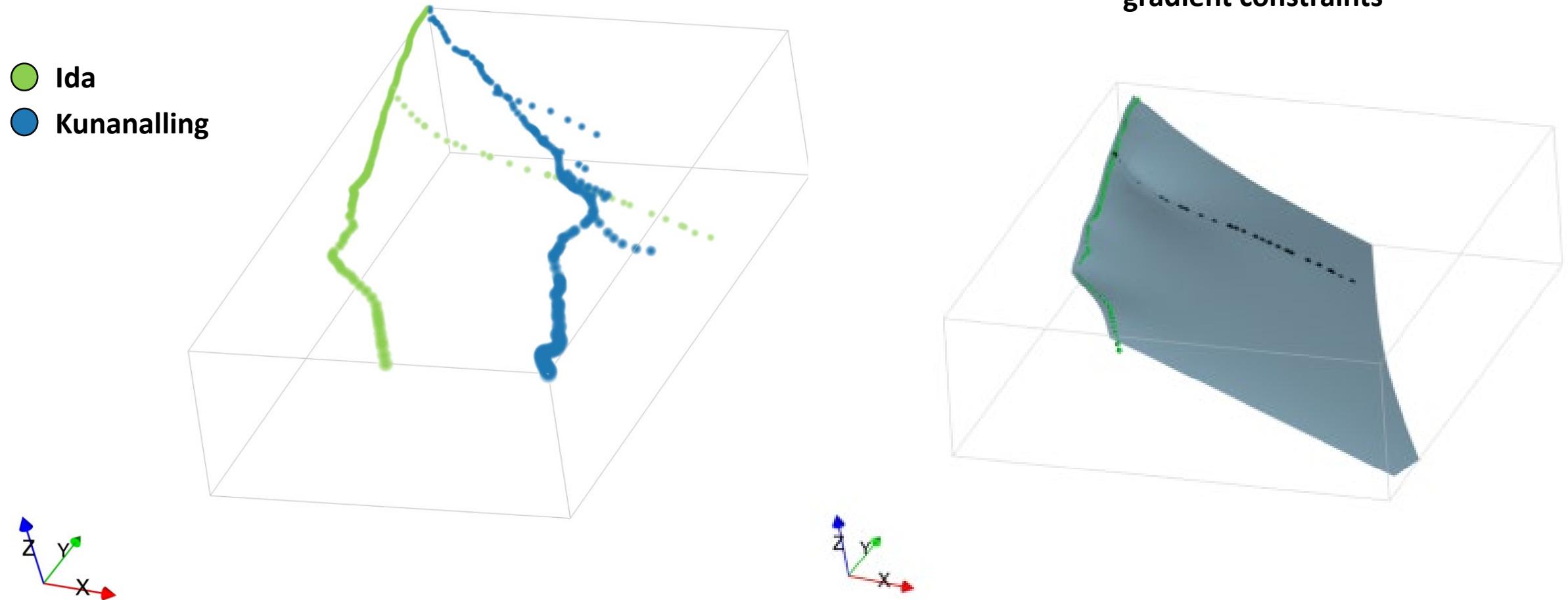


Fault location points in depth from seismic interpretation
& fault surface points from GSWA database

Fault Network modelling

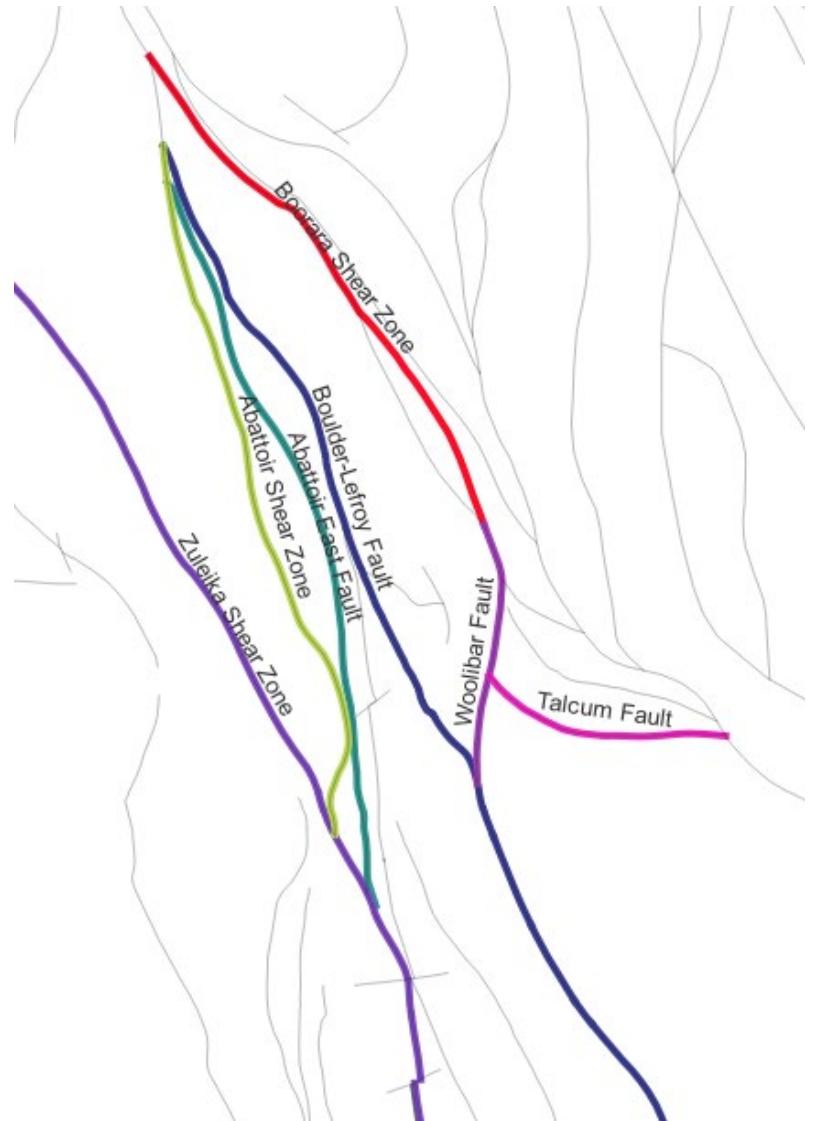
Ida + Bullabulling + Kunanalling + Zuleika

Ida interpolation when using norm gradient constraints



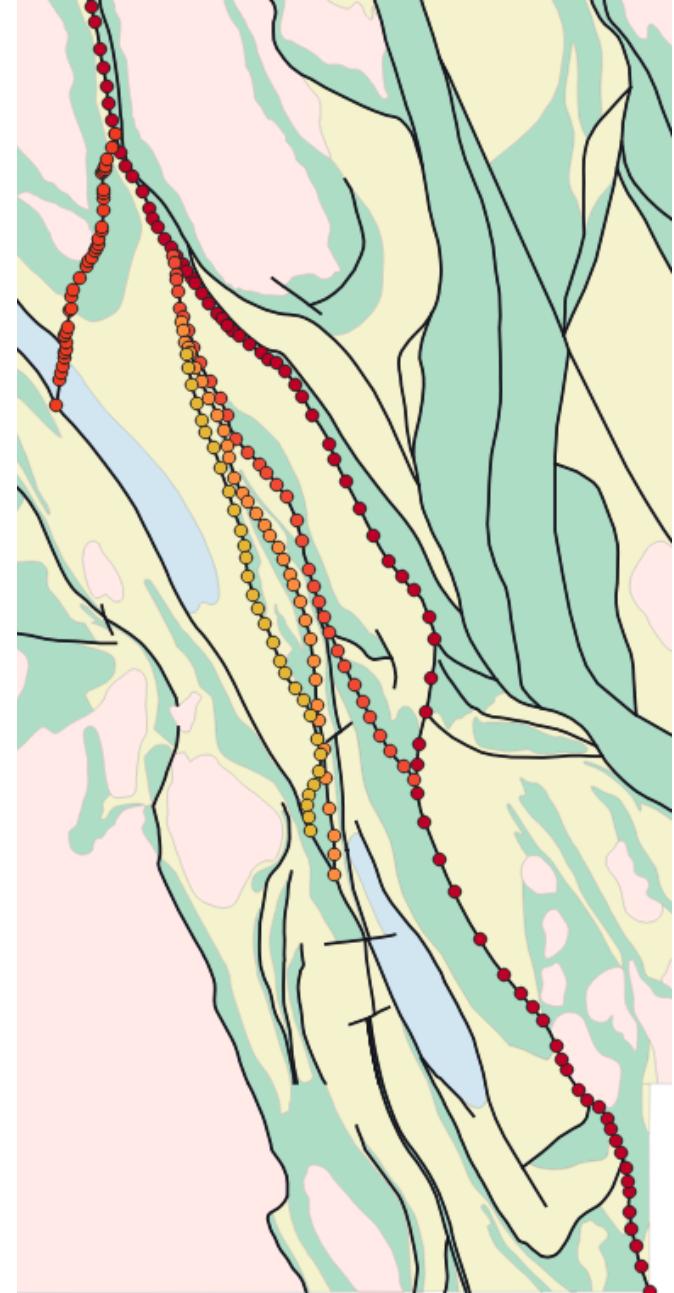
Fault location points in depth from seismic interpretation
& fault surface points from GSWA database

Fault Network modelling

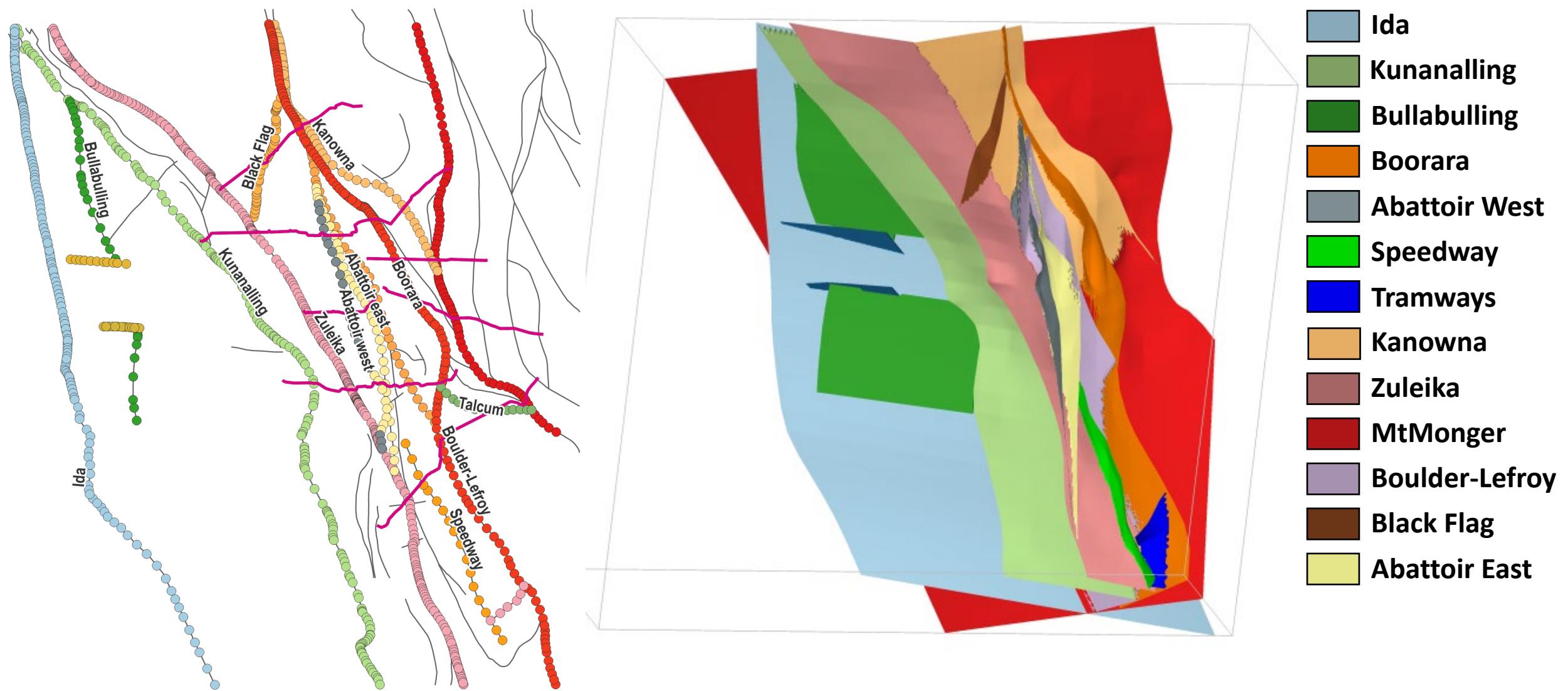


1_2.5M State interpreted bedrock geology structural lines, GSWA 2015

- 1) Boorara SZ
- 2) Black Flag + Boulder Lefroy
- 3) Abattoir East
- 4) Abattoir "West"

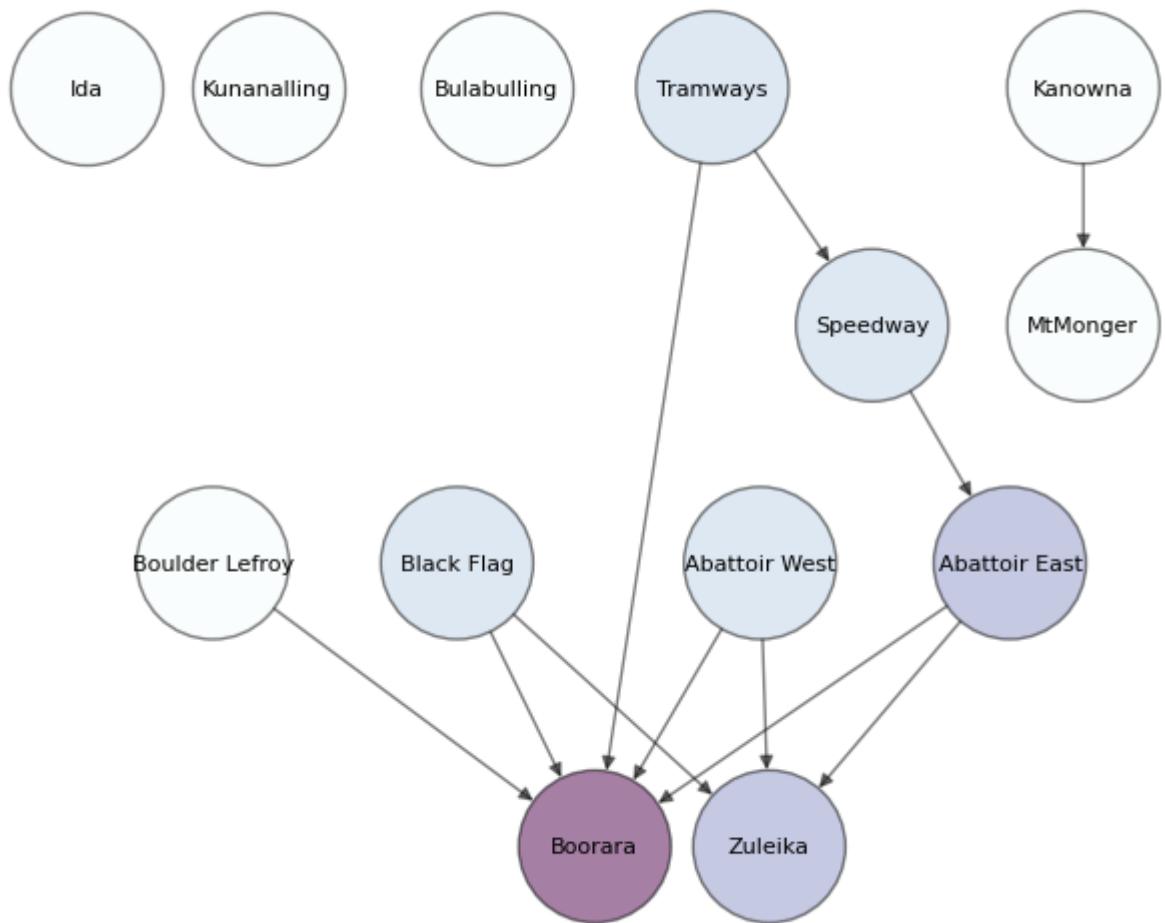


Fault Network modelling

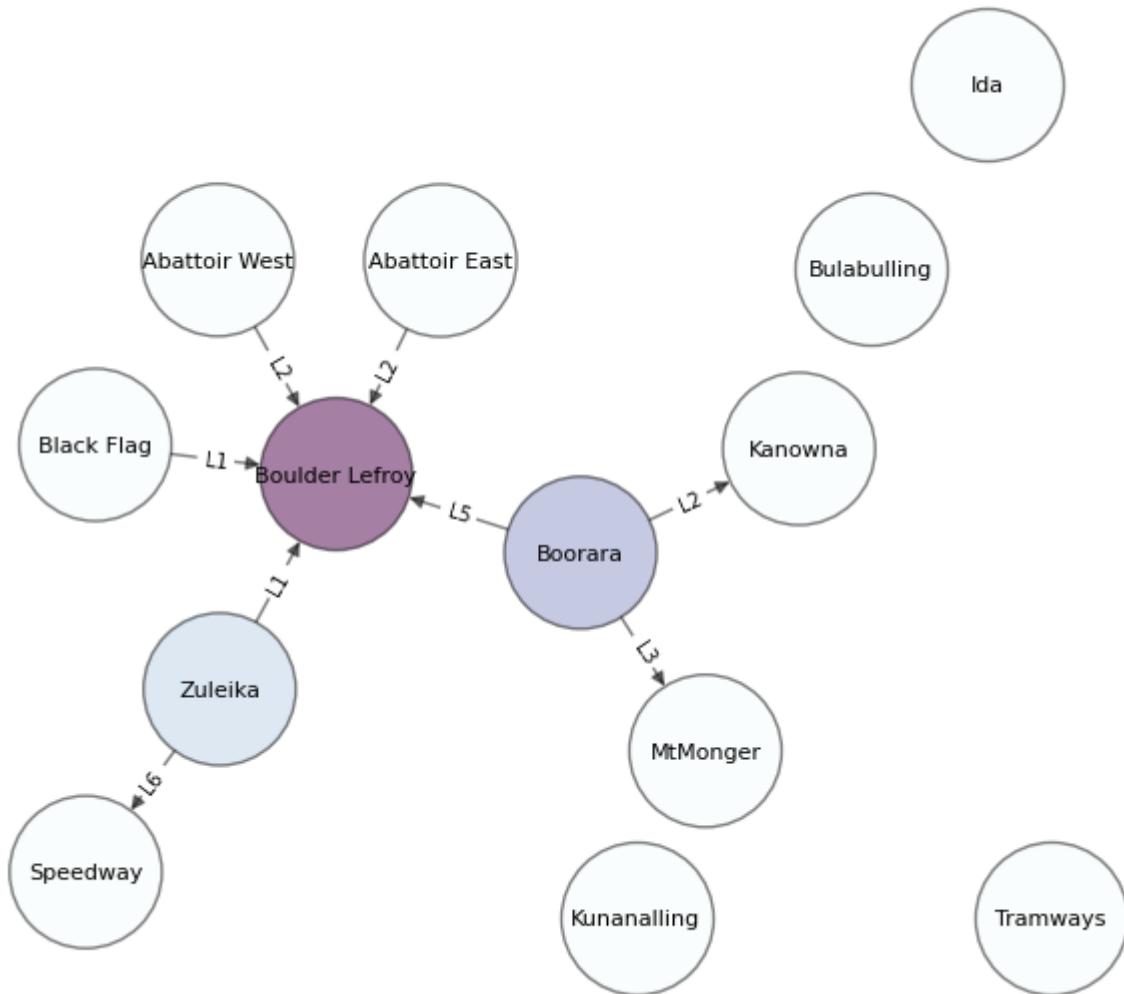


Fault Network modelling – Abutting relationships

From map

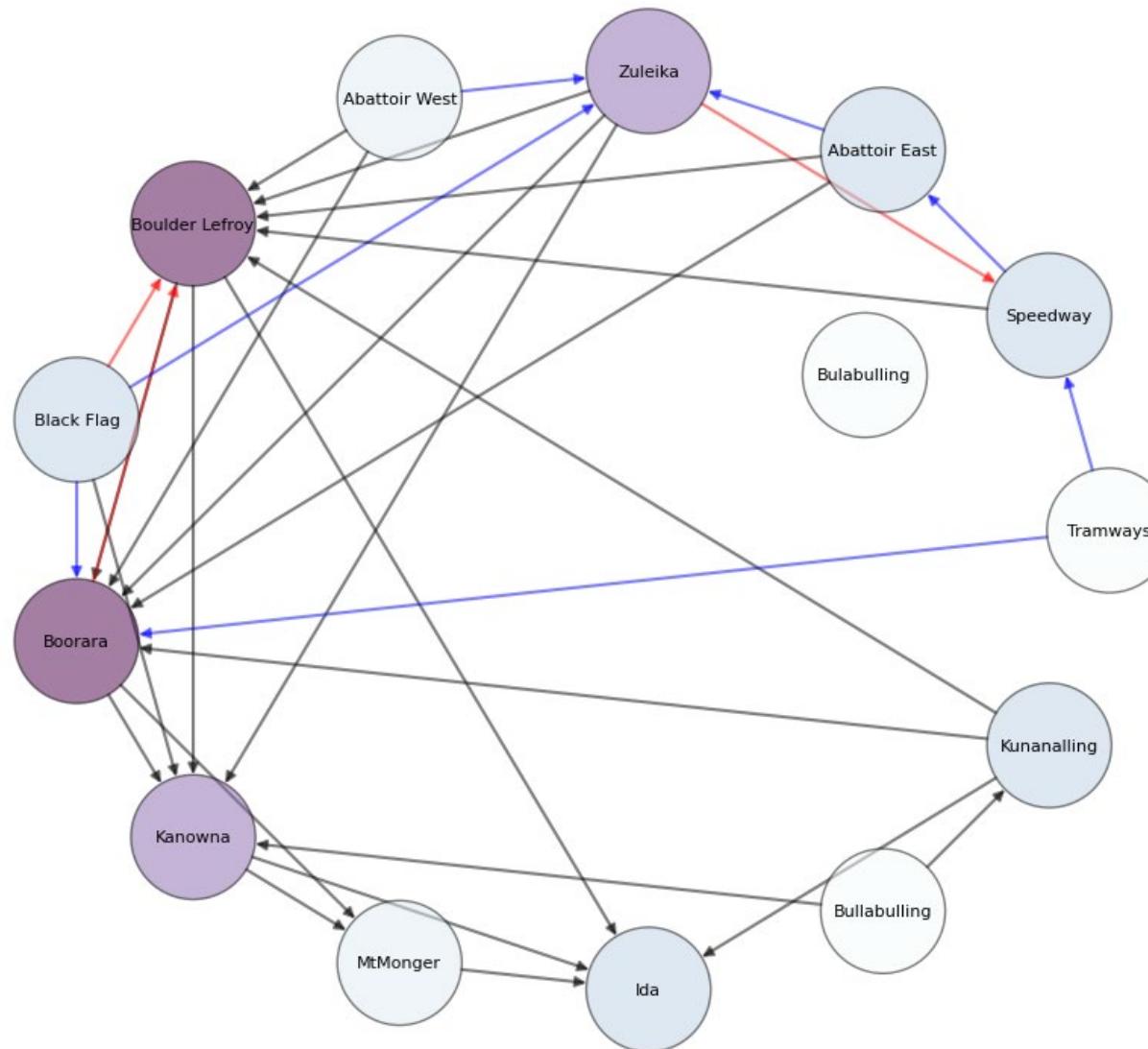


From seismic



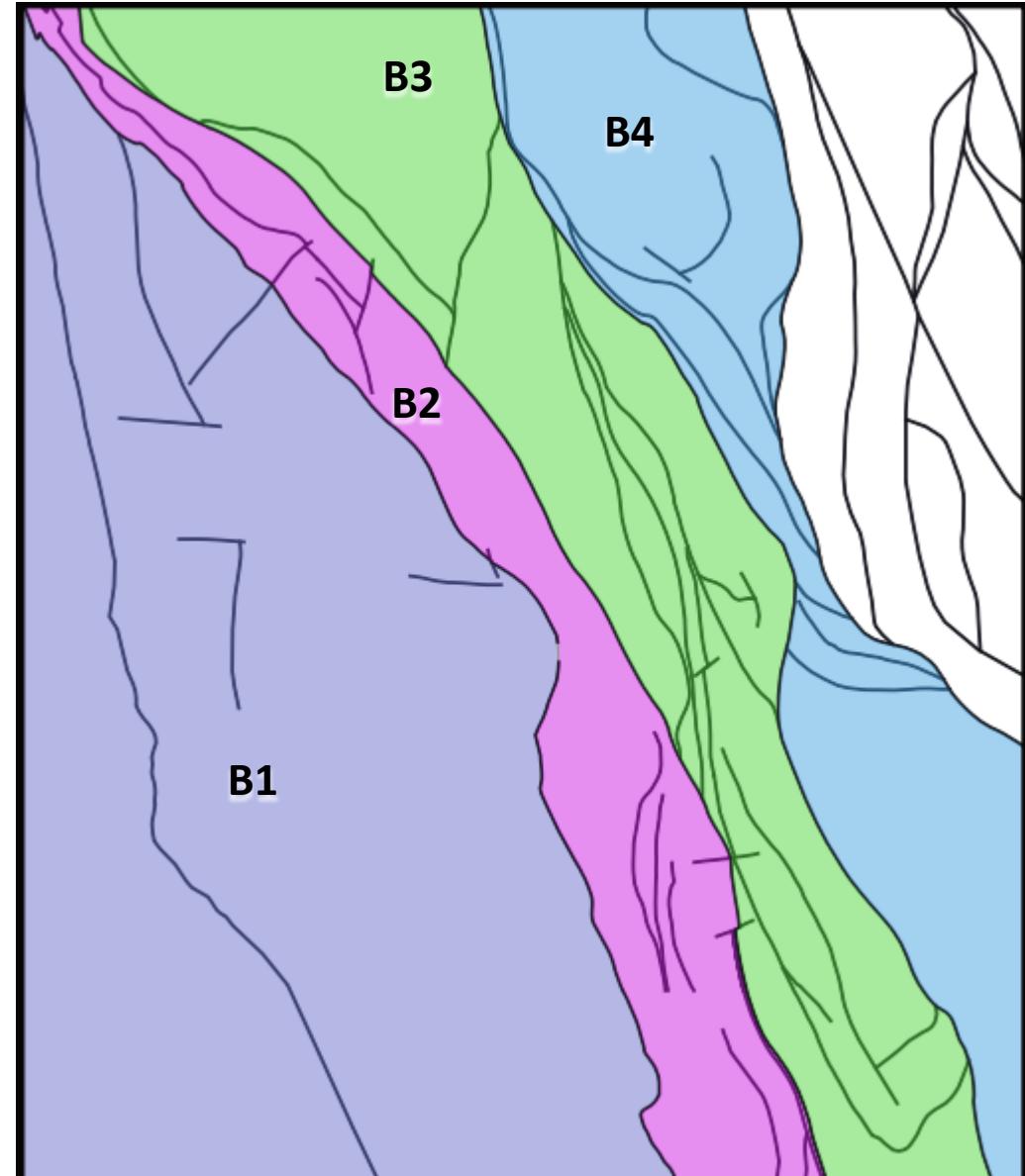
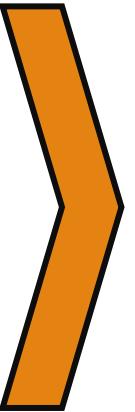
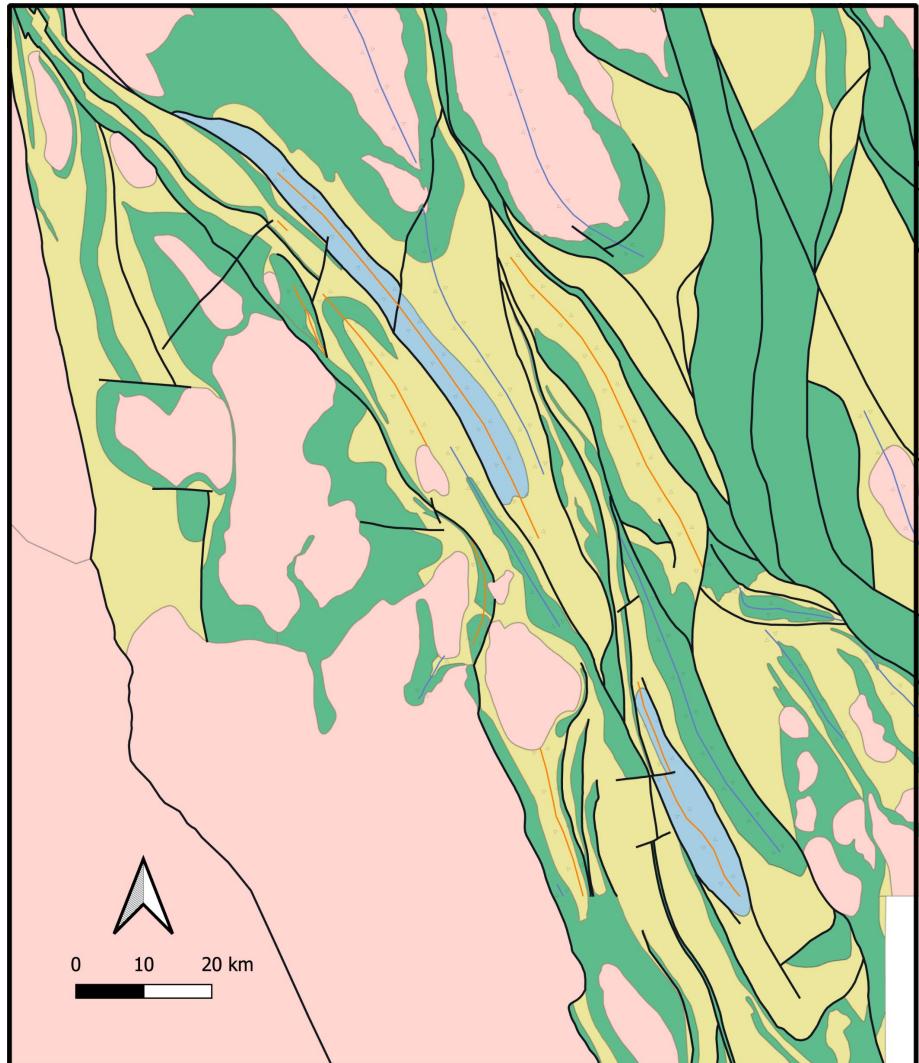
Fault Network modelling – Abutting relationships

- Map
- Seismic
- Inferred at depth



Modelling the stratigraphy

Granitoids Black Flag
Mafics and ultramafics Late Basins

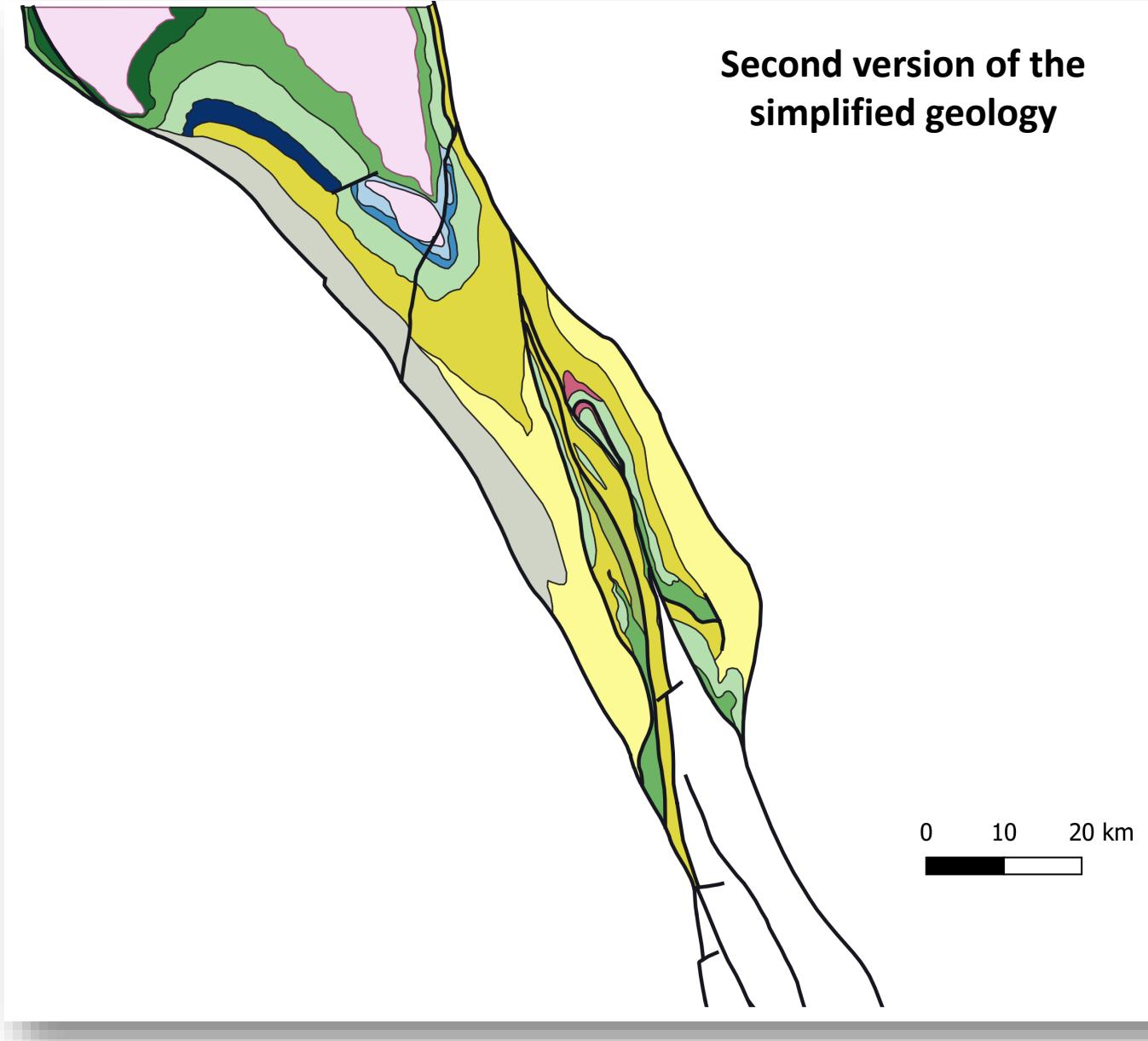


Modelling the stratigraphy

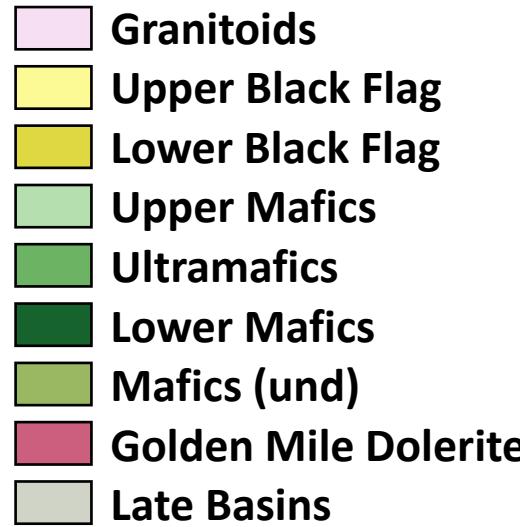
- Granitoids
- Upper Black Flag
- Lower Black Flag
- Upper Mafics
- Ultramafics
- Lower Mafics
- Mafics (und)
- Golden Mile Dolerite
- Late Basins

Gabbros

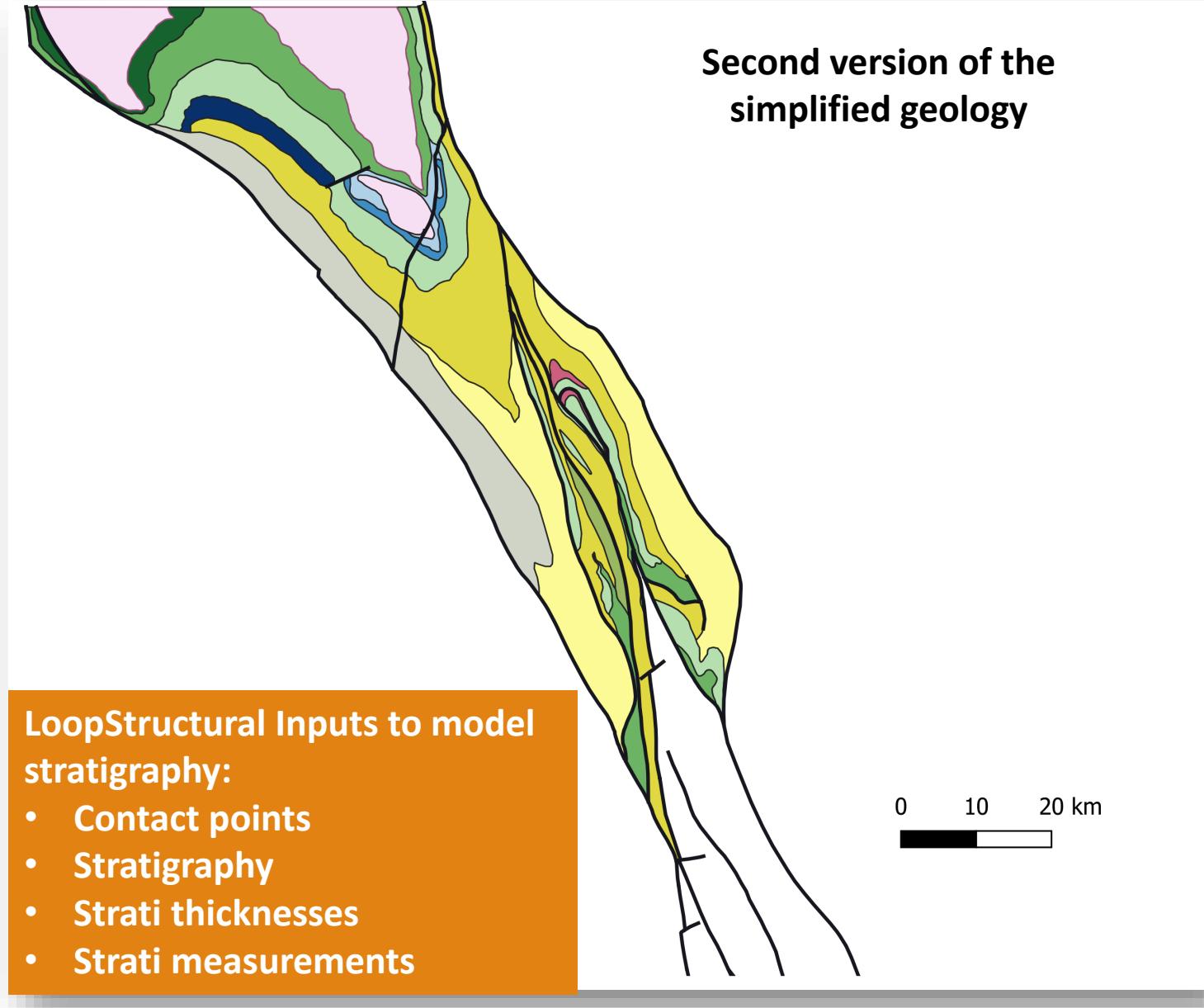
- Mt Ellis Gabbro
- Mount Pleasant Gabbro
- Ora Banda Gabbro



Modelling the stratigraphy



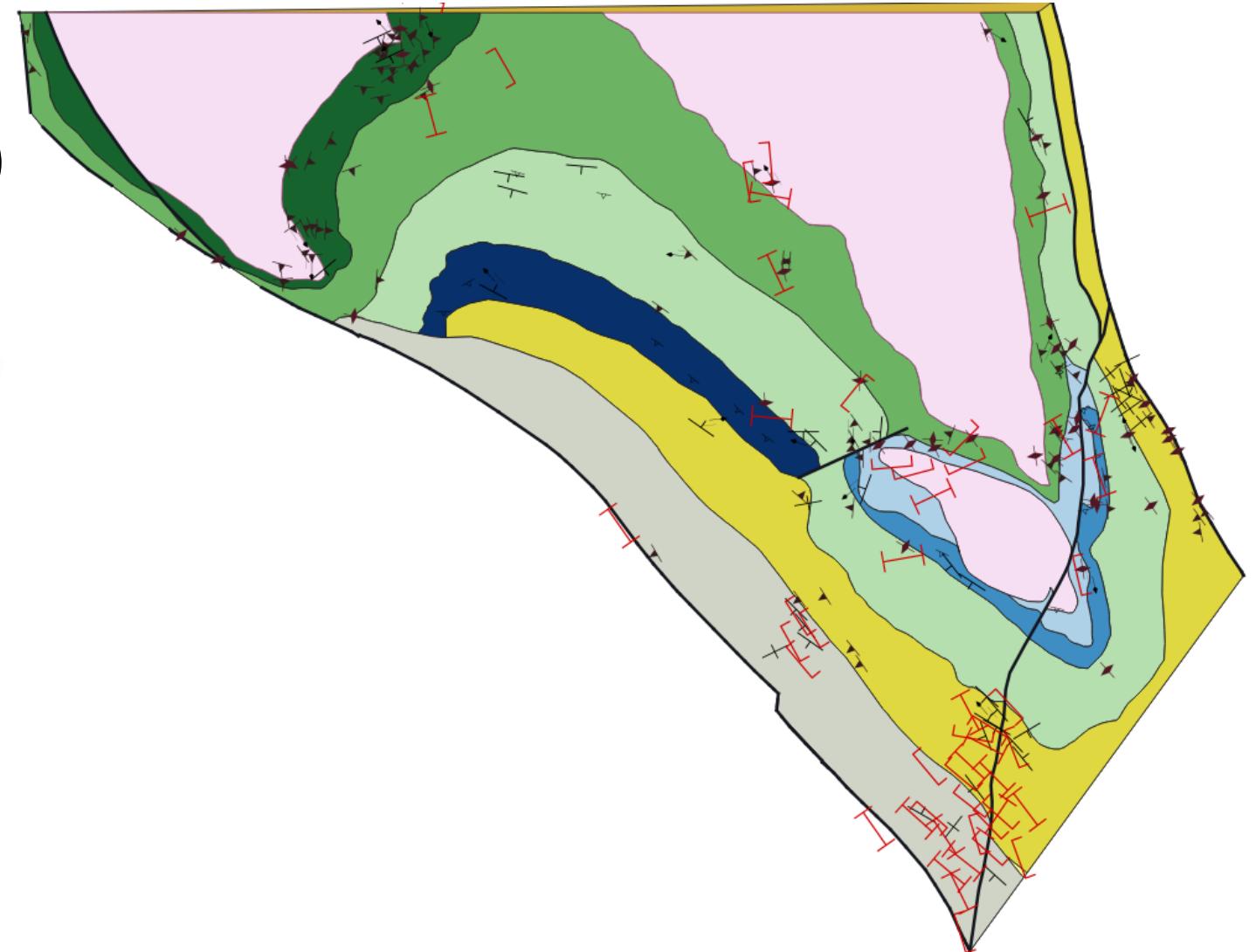
Gabbros



Modelling the stratigraphy

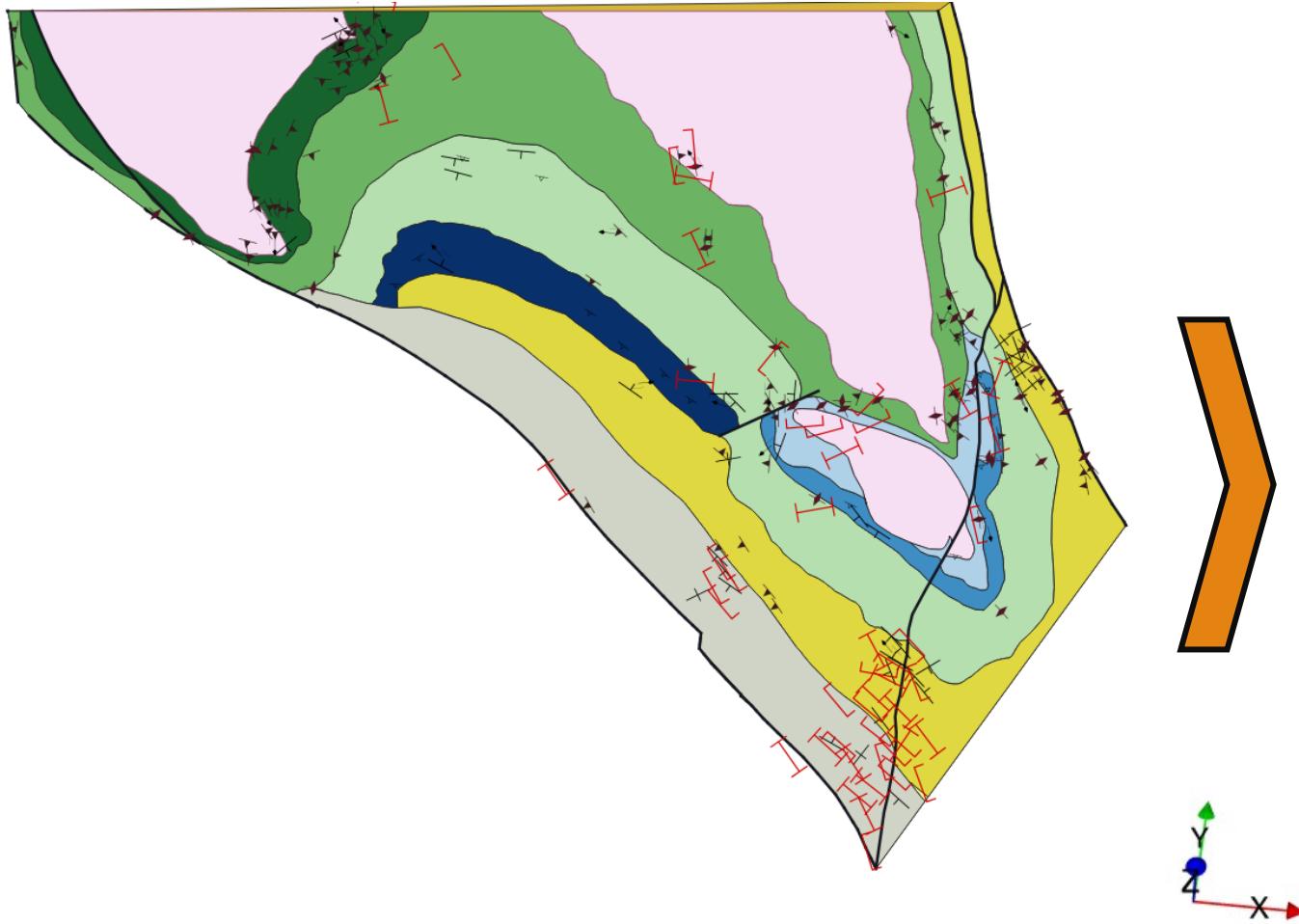
Extract from WAROX DB (2020)

- Mineral Lineations
- Cleavages
- Metamorphic Foliations
- Beddings
- Igneous Layering

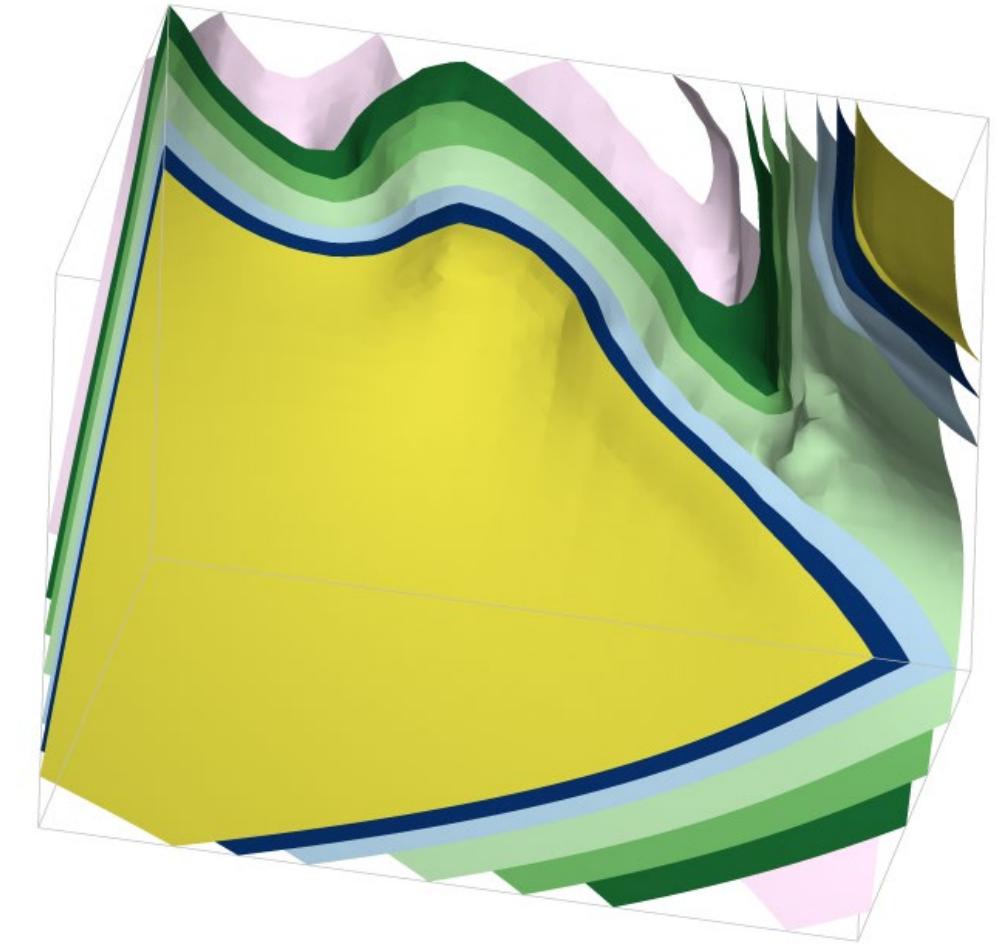


Goongarrie-Mount Pleasant Anticline

Modelling the stratigraphy

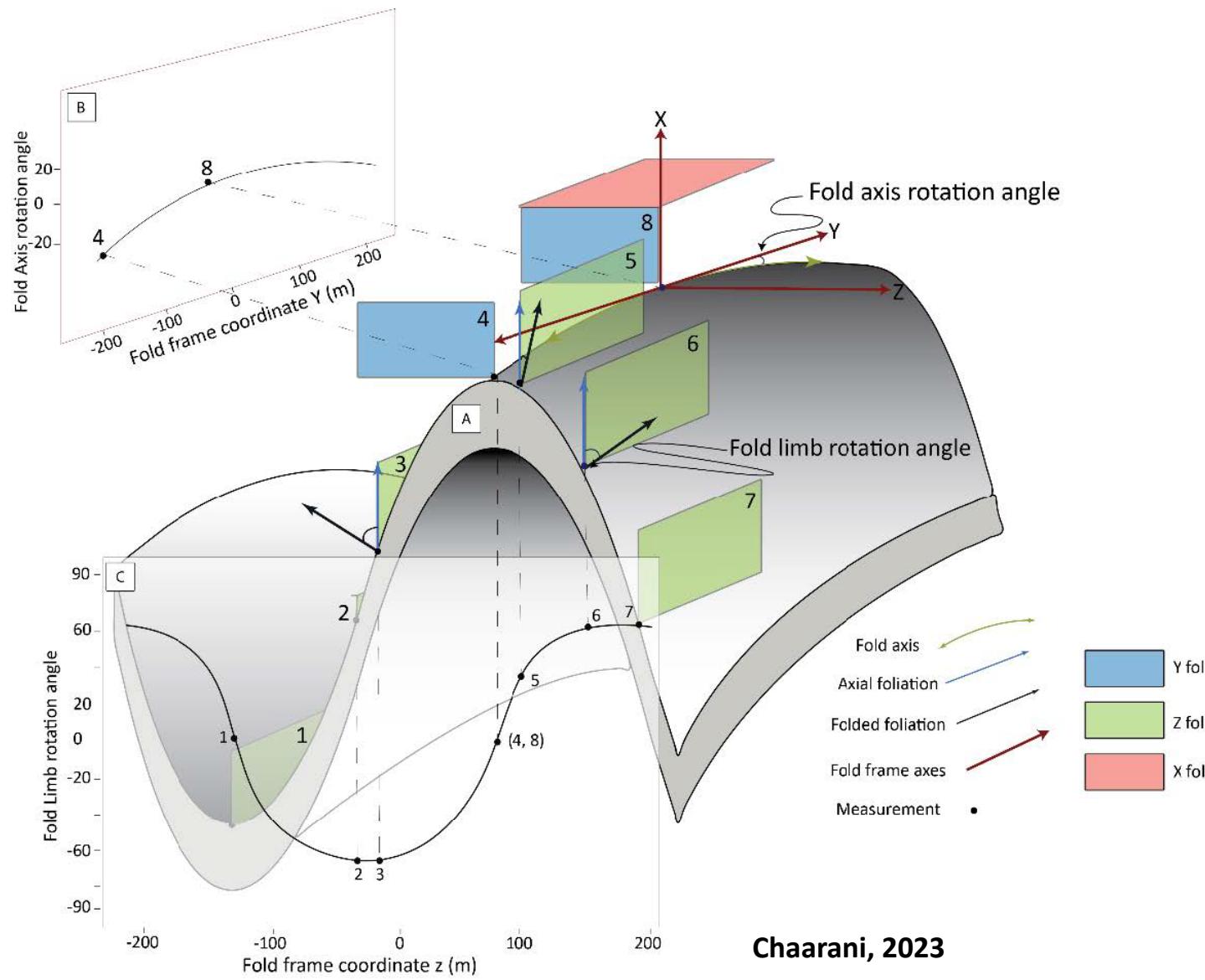


Map data utilised for a preliminary model
- Goongarrie-Mount Pleasant Anticline

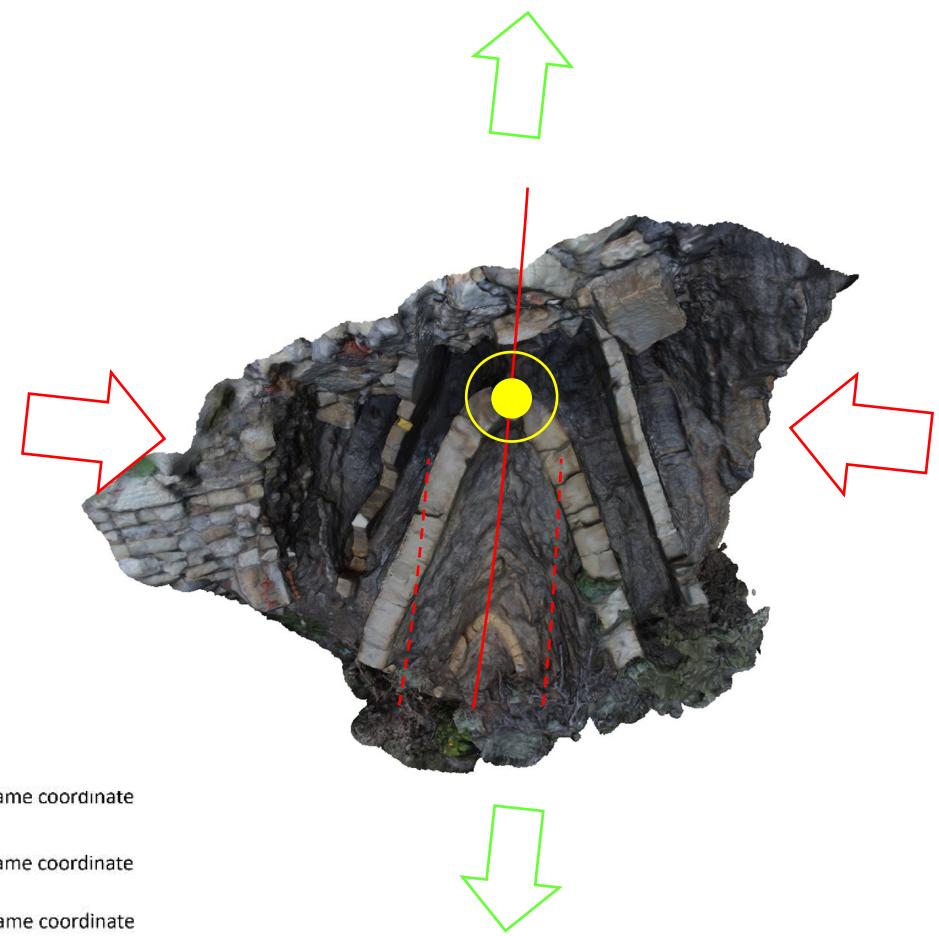


Model obtained using LoopStructural

Modelling the stratigraphy – including a fold frame

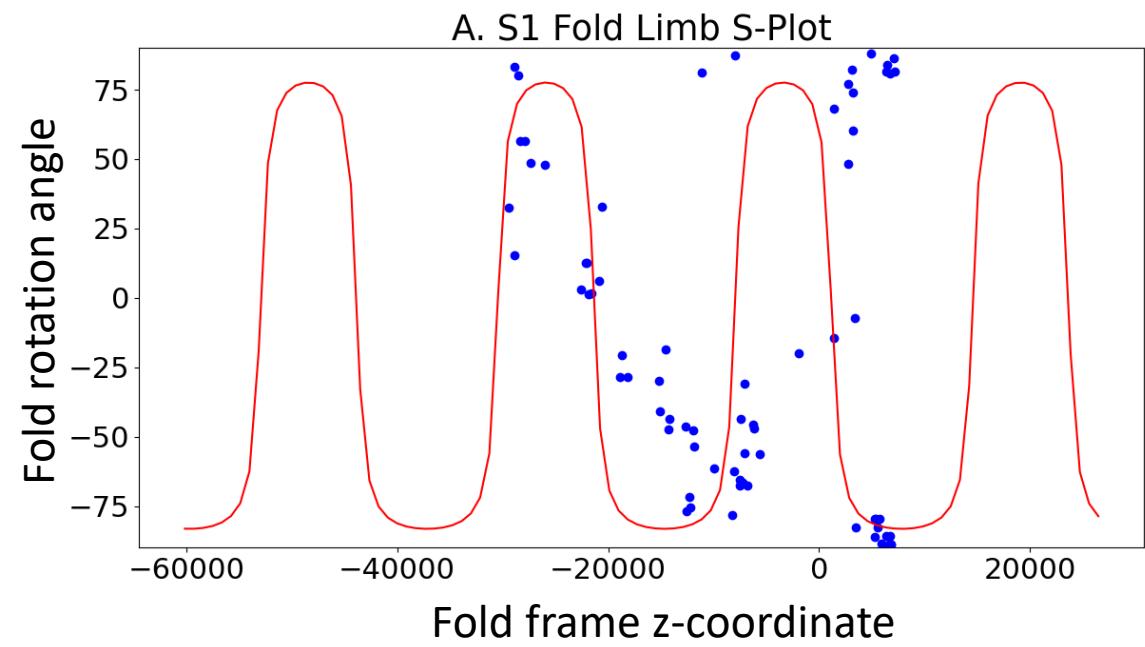


Chaarani, 2023

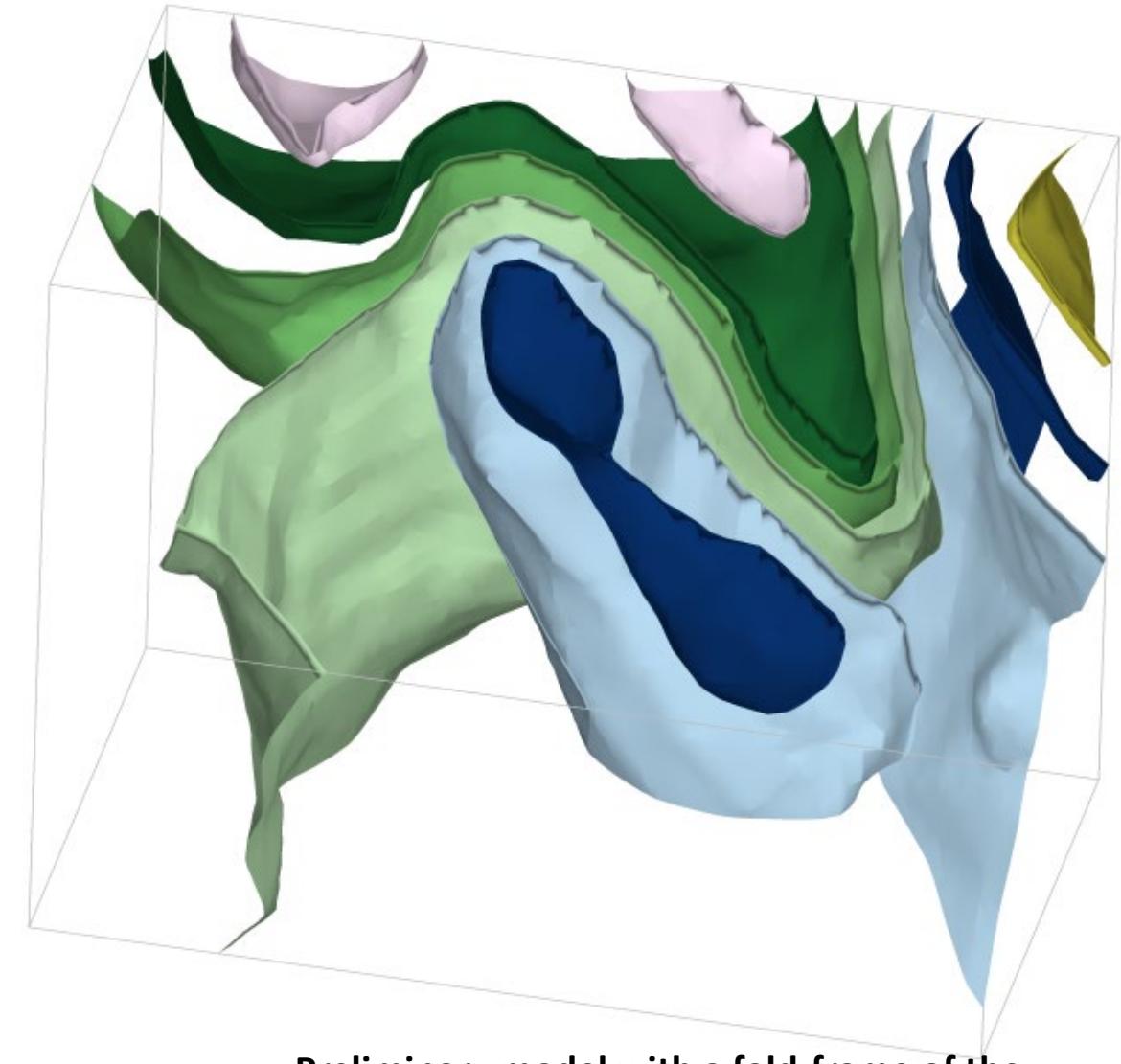
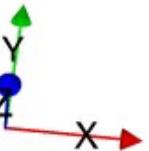


Grose, 2020

Modelling the stratigraphy



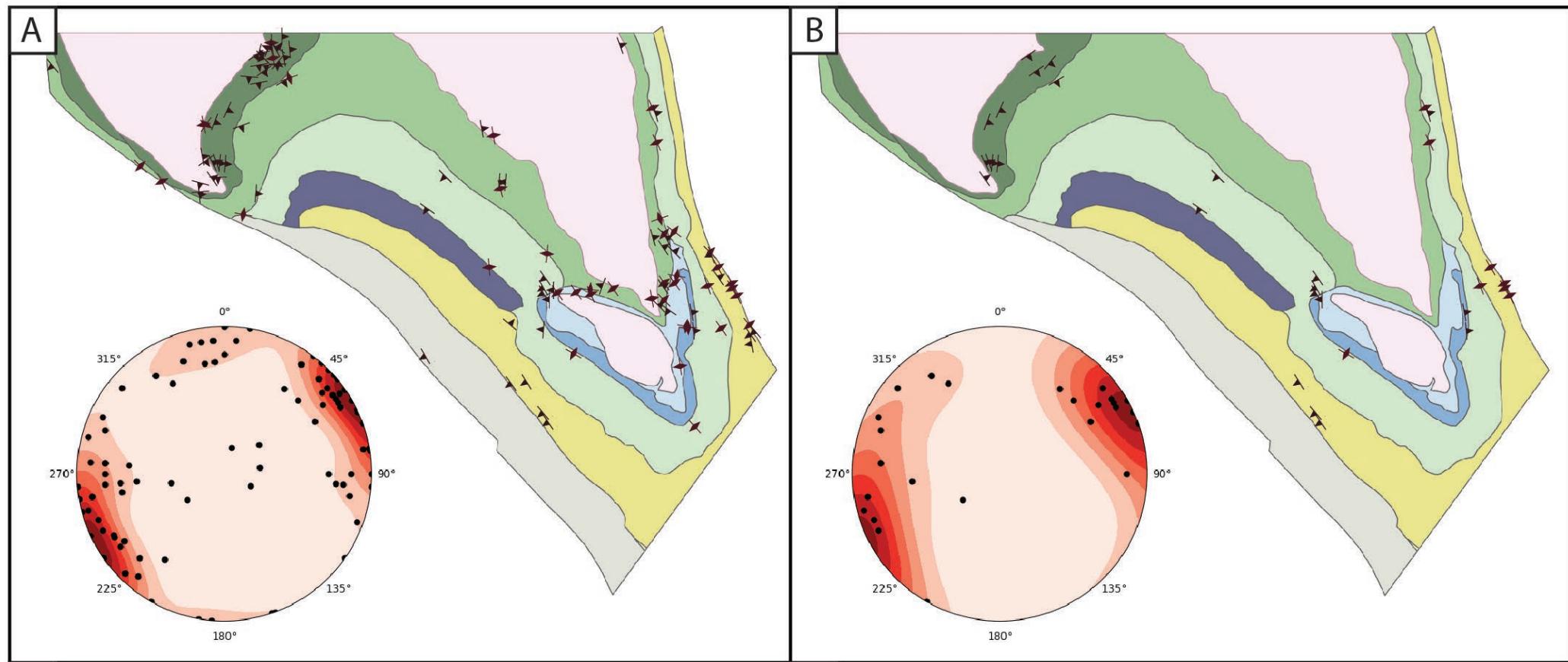
S-plot - Grose et al. (2017)



Preliminary model with a fold-frame of the
Goongarrie-Mount Pleasant Anticline

Modelling the stratigraphy

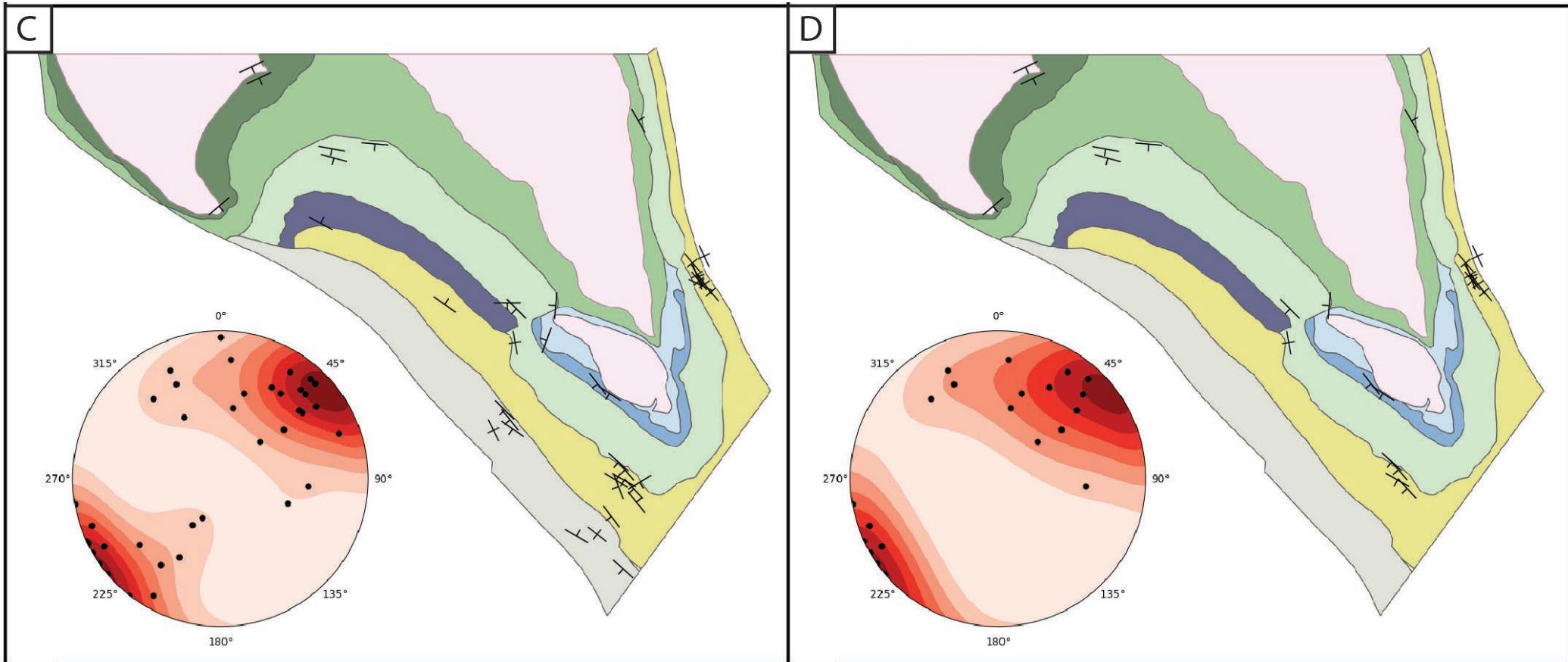
Removing extra measurements in the database



Metamorphic foliations structural measurements from the WAROX database used in this study (on the left is the full dataset; on the right are the measurements manually selected to be representative of S0).

Modelling the stratigraphy

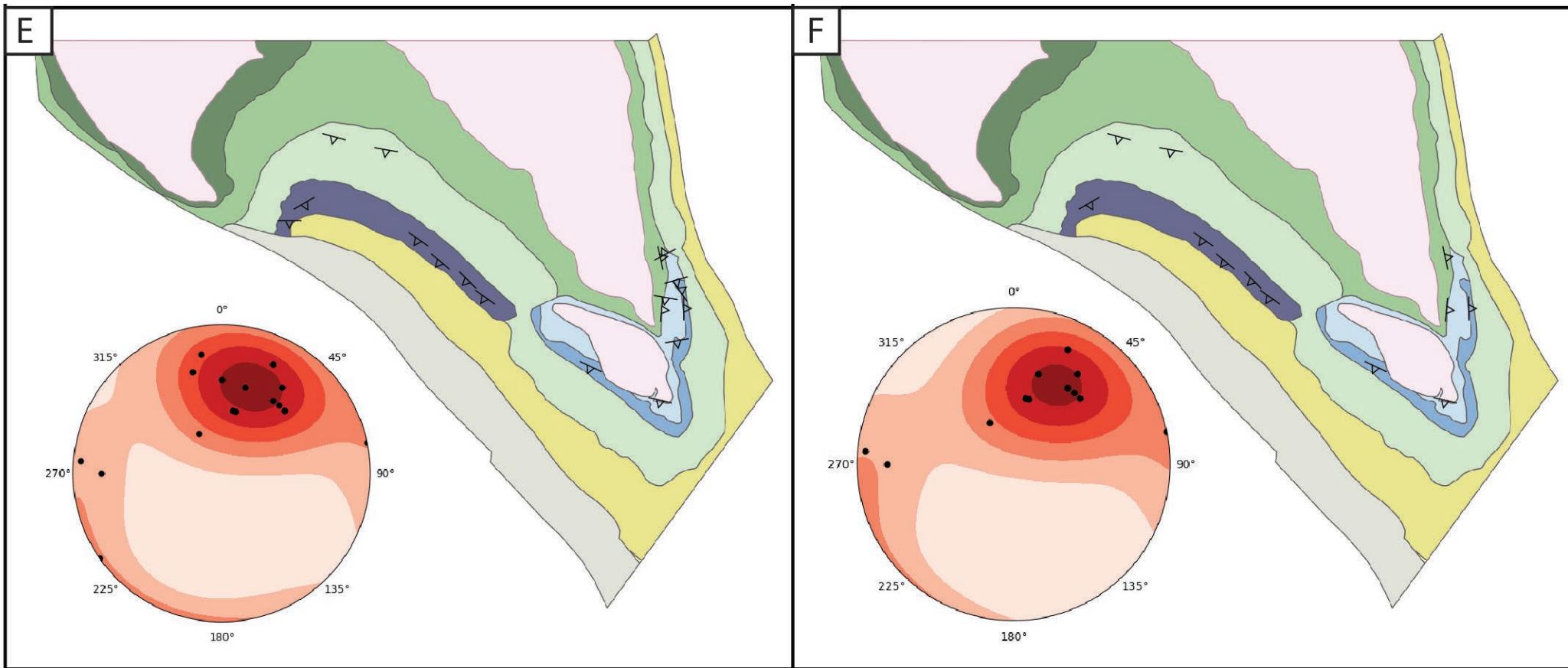
Removing extra measurements in the database



Bedding structural measurements from the WAROX database used in this study (on the left is the full dataset; on the right are the measurements manually selected to be representative of S0).

Modelling the stratigraphy

Removing extra measurements in the database

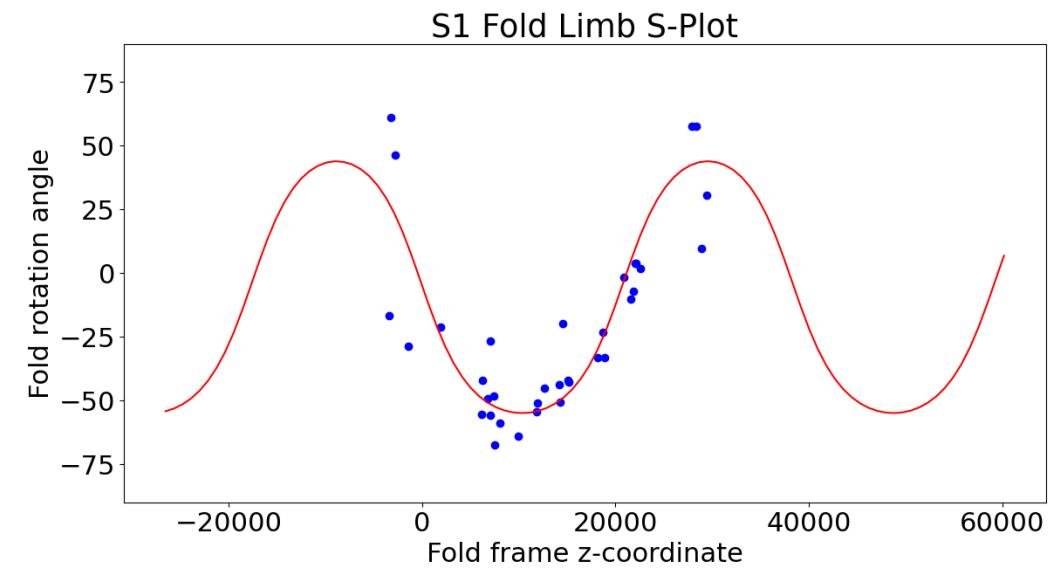


Igneous Layering structural measurements from the WAROX database used in this study (on the left is the full dataset; on the right are the measurements manually selected to be representative of S0).

Modelling the stratigraphy



“Final” model with a fold-frame of the
Goongarrie-Mount Pleasant Anticline



Conclusions

- LoopStructural is an effective tool to model geological features.
- Advantageous for poly-deformed terranes:
 1. Time-aware approach
 2. Structural frames
- Geological data & inputs should be representative of the geological features to model
- Pre-processing is required to ensure proper modelling
- Topological relationships between geological features can be included in the modelling process



Black Flag outcrop, Kambalda East, over Lake Lefroy



Lakewood, Kalgoorlie

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- Grose, 2020, pers. comm.
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- Laurent, G., et al., Implicit modeling of folds and overprinting deformation. *Earth and Planetary Science Letters*, 2016. 456: p. 26-38.

Loop



Find us on Github!



Kalgoorlie modelling

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LoopStructural
(Grose et al., 2021)