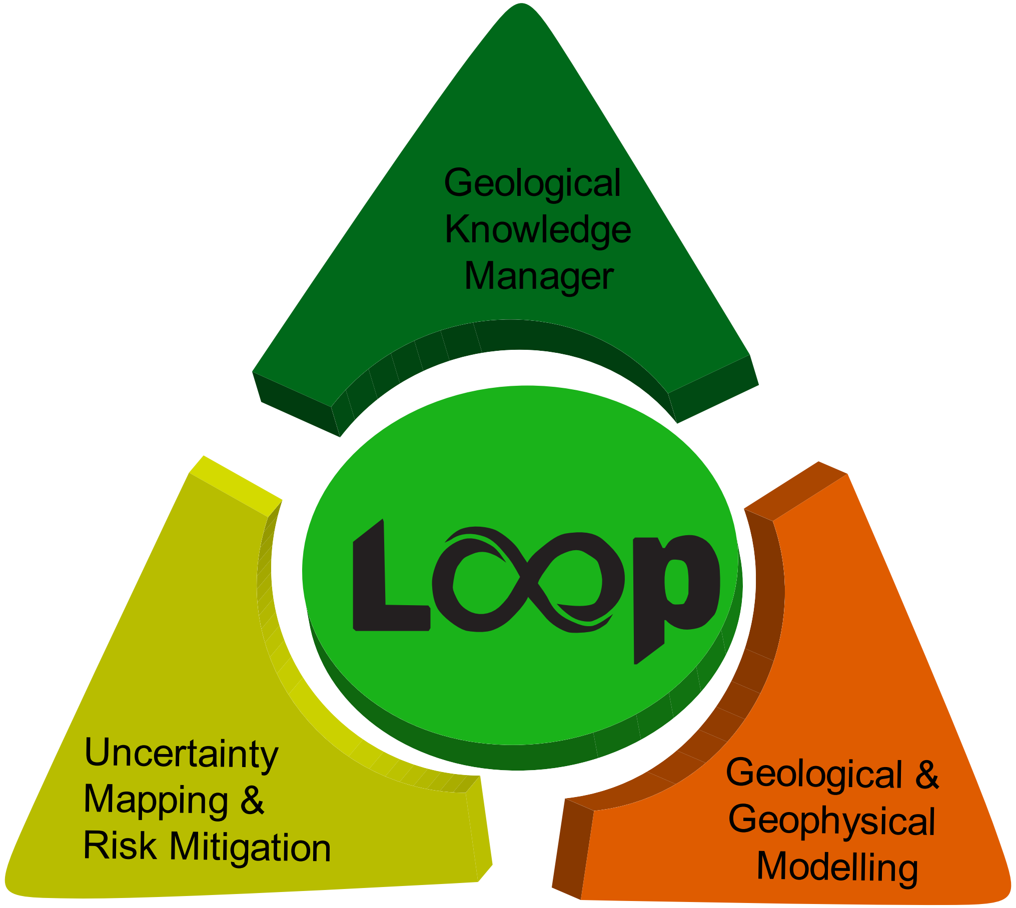
Loop

An integrated and interoperable platform enabling 3D stochastic geological modelling

Quarterly Report #7
Aug2020

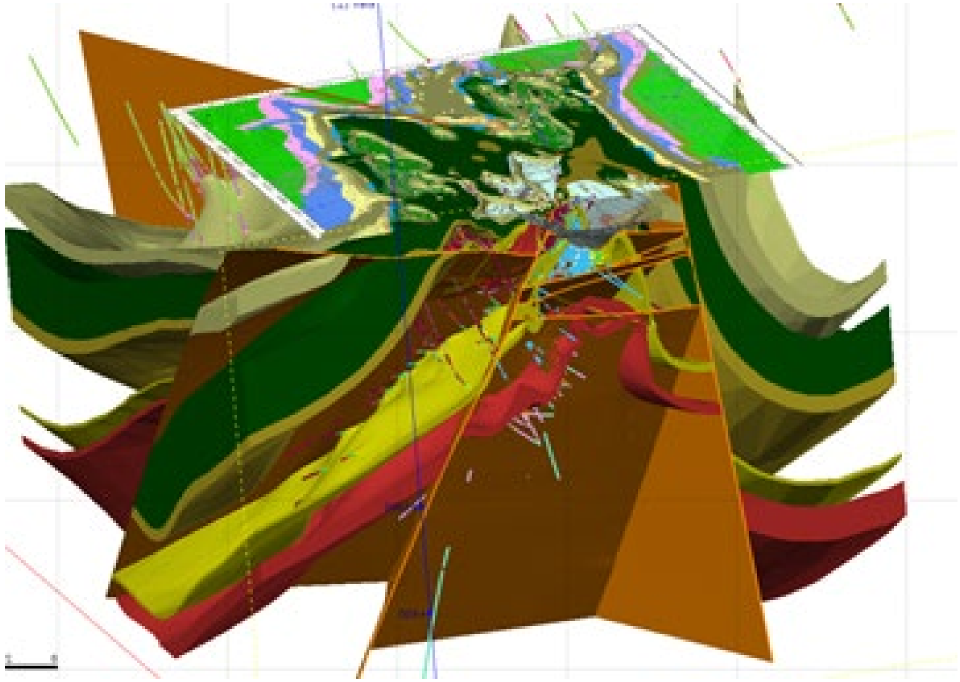


MONASH University
RING Université de Lorraine
Australian Government Australian Research Council
Australian Government Geoscience Australia
Government of South Australia Department of State Development
SOUTH AUSTRALIA
British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL
MinEx CRC
AngloAmerican
The University of Western Australia
Centre for Exploration Targeting
RWTH AACHEN UNIVERSITY
AuScope
OneGeology Providing geoscience data globally
Government of Western Australia Department of Mines and Petroleum
NORTHERN TERRITORY GOVERNMENT
NSW Government Regional NSW
brgm
Geological Survey of Canada
MICROMINE
BHP

Loop – Why a new platform?

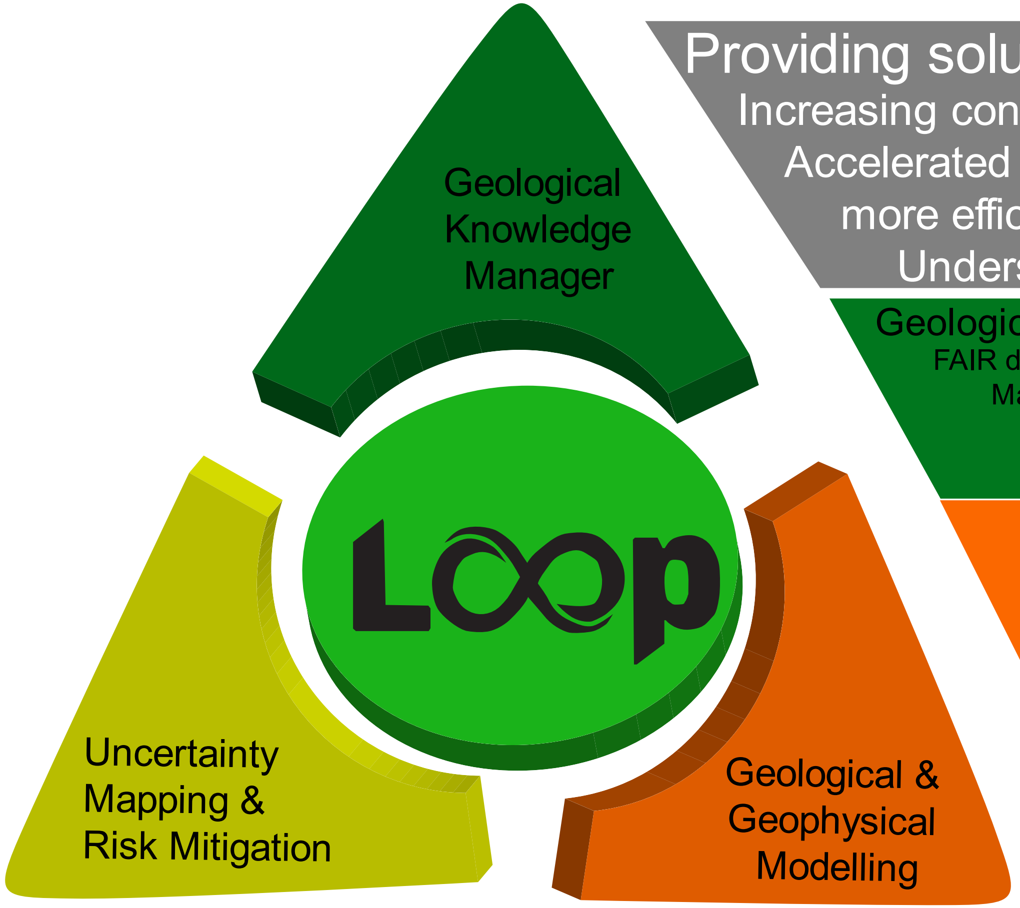
- Current technology does not allow for modelling of poly-deformed terranes in a reproducible sense
- Need for uncertainty characterisation
- Need for better geophysical integration
- Maximisation of 3D geology uncertainty reduction
- **Open-source is the future**

https://github.com/Loop3D/LoopStructural



A complex model like this would have to be hand-drawn

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

* Findable, Accessible, Interoperable, Reusable

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

Lead-CI
Dr Laurent Ailleres
Monash University

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Research Organisations

MONASH University

THE UNIVERSITY OF WESTERN AUSTRALIA

RING

RWTH AACHEN UNIVERSITY

UNIVERSITÉ TOULOUSE III PAUL SABATIER

British Geological Survey
Expert | Impartial | Innovative

Geological Survey of Canada – Commission Géologique du Canada 1842

Australian Government
Geoscience Australia

brgm
Geoscience for a sustainable Earth

AuScope

Funding Organisations (cash & in-kind)

Australian Government
Australian Research Council
ARC LP170100985

MinEx CRC

Geological Survey of Western Australia

BHP

Australian Government
Geoscience Australia

Geological Survey of Western Australia

AngloAmerican

MICROMINE

NORTHERN TERRITORY GOVERNMENT

NSW GOVERNMENT
Department of Industry
Resources & Energy

Government of South Australia
Department of State Development

SOUTH AUSTRALIA

Partner Organisations

Loop

Governance

One Steering Committee:

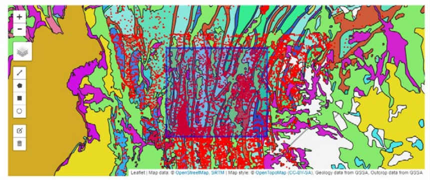
- Chair:
  - Carina Kemp (Aarnet)
- Members:
  - Laurent Ailleres (Monash / lead-CI)
  - Mark Jessell (UWA / rep. MinEx CRC)
  - Tim Rawling (AuScope)
  - Steve Hill (Geoscience Australia)
  - Klaus Gessner (GSWA / representing the state and territory surveys)
  - Matthew Harrison (BRGM / rep. OneGeology)

Research and Development team:

- Lead-CI:
  - Laurent Ailleres (Monash)
- Senior software architect:
  - Roy Thomson (Monash)
- Knowledge Manager:
  - Boyan Brodaric (Geological Survey of Canada)
- Map2Loop / Pre-processing:
  - Mark Jessell (UWA)
- LoopStructural:
  - Lachlan Grose (Monash)
- Geophysical Integration:
  - Jeremie Giraud (UWA)
- Uncertainty and value of information:
  - Guillaume Pirot and Mark Lindsay (UWA)
- Knowledge transfer and community:
  - Robin Armit (Monash)

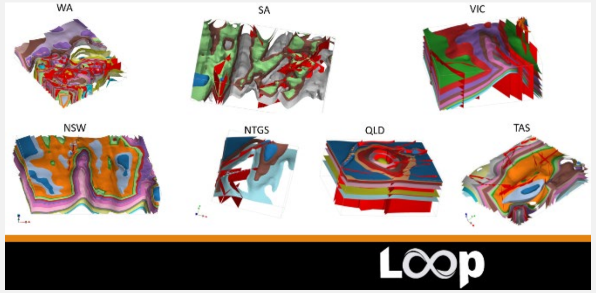
Highlights this Quarter

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



Data served by Geological Surveys in Australia

m2l analysis and data augmentation



LoopStructural models calculated in a few minutes (inc. m2l and loopstructural time) on a “normal” laptop

E.g. Flinders ranges: 20K+ orientation data points; overall time <5 minutes (Dell Inspiron 15).

- Loopinars and LoopExe meetings delivered for GSWA, NTGS, GSNSW and partially GA (awaiting confirmation from other states)
- Loop mentioned multiple times in the Auscope 5-year Investment Plan
- Sessions proposed/accepted at AGU Fall meeting(a), AESC 2021(a) in Hobart and SGA2021(p) in Rotorua. Abstracts have been/will be submitted
- Grant application with GNS to investigate urban geology modelling in NZ – Loop to provide software expertise.

Funding and Resources

Current Funding

Project 6- Automated 3D geological modelling

$1.2M Project 6 - CRC
Project 6 Leaders **Mark Jessell** & **Mark Lindsay**
1: week for uncertainty-characterised model suites

Loop Consortium

$3M OneGeology/ARC Linkage Consortium
Project Leader **Laurent Ailleres**
Make a better world for 3D modellers

Data Analytics in Resources and the Environment ARC

ARC Industrial Transformational Training Centre
$10M Multi-institutional Graduate School in applied Data Analytics (15 PhD & 3 Postdocs)
Centre Director: Prof **Sally Cripps**, Co-Director of Centre of Translational Data Science Sydney University
Lead Minerals Exemplar: Dr **Mark Lindsay**, ARC DECRA Fellow

DECRA

Value of Information

$1M ARC DECRA
Project Leader **Mark Lindsay**
What (geophysical) data should I collect?

Funding Leverage

- ARC LP + MinEx CRC P6 + DECRA ~= $5.6M research expenditure
- Sponsors investment leverage of between 10:1 to 170:1

Loop in Numbers

- 7 in-kind CI
- 9 in-kind PI
- 4 NEW research positions
- 3 NEW software design/development positions
- 7 non initially named PI's at partner organisations
- 10 NEW PhD candidates
- 4 Universities, 4 National Geological Survey Organisations
- 5 countries, 3 continents
- *Problem: the senior research team is heavily lacking diversity*

The most important resource: People!
CI/PI on the initial ARC LP grant

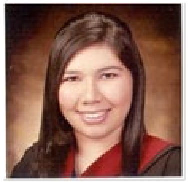
- Monash Uni: Laurent Ailleres, Robin Armit, Peter Betts, Sandy Cruden, Tiangang Cui, Jerome Droniou
- UWA: Mark Jessell, Mark Lindsay (now a DECRA Fellow)
- RING – Nancy, FRA: Guillaume Caumon
- RWTH Aachen, GER: Florian Wellmann
- GS of Canada: Eric de Kemp
- BGS - UK: Matthew Harrison (now with BRGM) & Holger Kessler
- GA Carina Kemp (now at Aarnet // chair of the steering committee)
- Auscope: Tim Rawling
- GSNSW/GSWA Giovanni Spampinato & Klaus Gessner

Loop

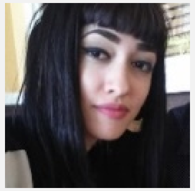
People – leverage of collaborative research in open source

• Monash Uni:	Lachlan Grose – post-doc LoopStructural (ARC LP) Roy Thomson - software architect (ARC LP) Yohan de Rose – software engineer (ARC LP)
• UWA:	Jeremie Giraud – G-Loop "LoopGeophysics" (ARC LP +/- Minex CRC) Guillaume Pirot – value of information (MinEx CRC) Khavita Madaiah – software engineer (MinEx CRC)
• RING – Nancy, FRA:	Francois Bonneau – meshing and algorithmic (in-kind)
• RWTH Aachen, GER:	Miguel de la Varga (PhD RWTH Aachen)
• GS Canada	Boyan Brodaric / Steve Richard – ontology of geology // knowledge manager (In-kind) Michael Hillier – (staff and new PhD @ RWTH Aachen) Interpolant constrained by anisotropy Marion Parquer - post-doc // 3D models consistency checker (new position @ GSC)
• BGS:	Edd Lewis, Russell Lawley, Katherine Royse (CDO BGS)

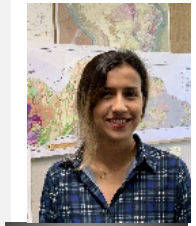
The most important resource: People! (PhD)



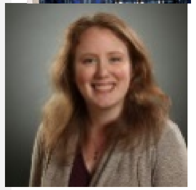
- Multi-scale 3D modelling Yalgoo–Singleton greenstone belt (Ranee Joshi, 21/1/2019) (MinEx CRC scholarship)



- Integrated 3D modelling of the Paterson Orogen (Polyanna Moro, 25/2/2019) (MinEx CRC scholarship)



- Data fusion methodologies for geology-geophysics inversion (Mahtab Rashidi Fard, 1/92019) (MinEx CRC scholarship)



- Factors Contributing to Metal Endowment in the Wabigoon Subprovince (Becky Montsion, Cotutelle with Uni Laurentian & GSC) (Canadian scholarship)

- Integrated 3D modelling in a drilling/Electrical methods (Nuwan Suriyaachchi)(1/10/2019) (MinEx CRC scholarship)

Loop

The most important resource: People! (PhD)

- 3D prospectivity analysis with uncertainty analysis for the Sandstone Greenstone Belt (Sam Davies) (MinEx CRC scholarship)

- The value of structural data (Rabii Chaarani, Mar 2019) (APA)

- Modelling intrusion from field observations (Fernanda Alavarado, Aug 2019) (APA)

- Integrated geophysical and geological 3D modelling: Marina Jeronimo-Zarate (starting in March 2021) (APA)

Detail Progress Report

WP #0 – Infrastructure // Software Development

Is work on track against plan? update all deliverables
Work completed ◯ On track 🟢 Delayed 🟠 Problem 🔴 Will not happen ⚫ New 🔵

◯ 1. Recruit one post-doctoral fellow for structural modelling: completed / Dr Lachlan Grose

◯ 2. Organise and run the kick off meeting – completed and run in Nov 2018

🟢 3. Set up high level infrastructure: GitHub repository / Slack workspace running, website, central GitHub repository with each work package as a sub-module

◯ 4. Recruiting one senior software engineer with knowledge of software architecture: Roy Thomson

◯ 5. Recruiting a software developer: Yohan de Rose

🟢 6. Data structure / API's design by Sept 2019 (was June 2019) : completed – refined and completed python and C++ implementation of data structures for WP 2 and 3 and continuing work on WP1,4,5 components and Fortran versions (ongoing)

WP #0 – Infrastructure // Software Development

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

7. Report on redefinition of the work packages / report of meeting / Distributed via email, google drive and slack
8. Software architecture: (ongoing) First-pass UI design complete and data passing from online sources, re-projected, sampled, used in forward inverse structural modelling and displayed, incorporating new version of map2loop and further WP software modules also adding online data sources (GADDS2, OneGeology)
9. Collate deliverables / milestones of all WP's by start of Feb 2019 (done) and ongoing with updates
10. Engage with Auscope to assess their level of support: ongoing // involved in the current strategic planning meetings and proposals. **Loop mentioned multiple times in the Auscope 5-Year Investment Plan**
11. Manage Quarterly reports (ongoing quarterly)
12. Design and implement mechanism to calculate and display permutations of possible geological event histories with feedback that shows which events contribute to the greatest uncertainty

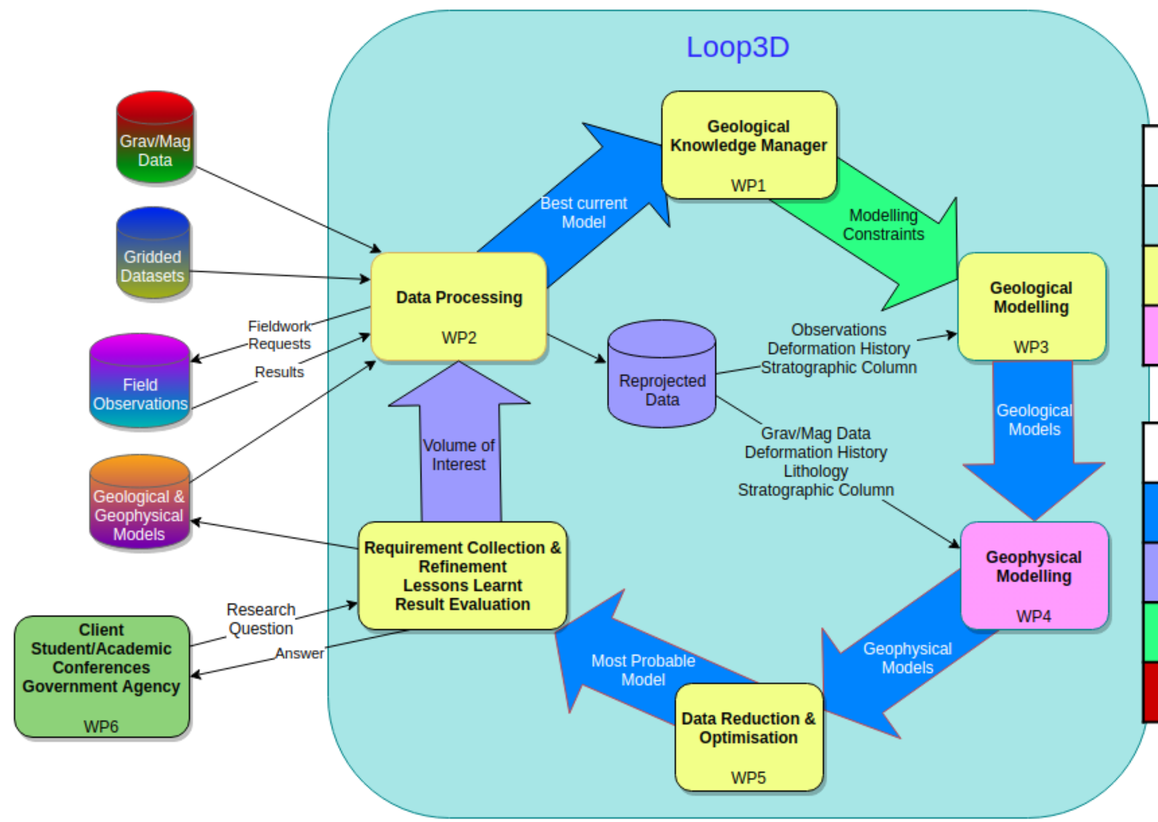
WP #0 – Infrastructure // Software Development

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

13. Adding optional data review procedure into the Loop GUI to fix errors in downloaded and re-projected data (such as mis-classified observations)

14. Rewriting and generalization of map2lopp -> map2loop_v2

WP #0 – Infrastructure // Software Development



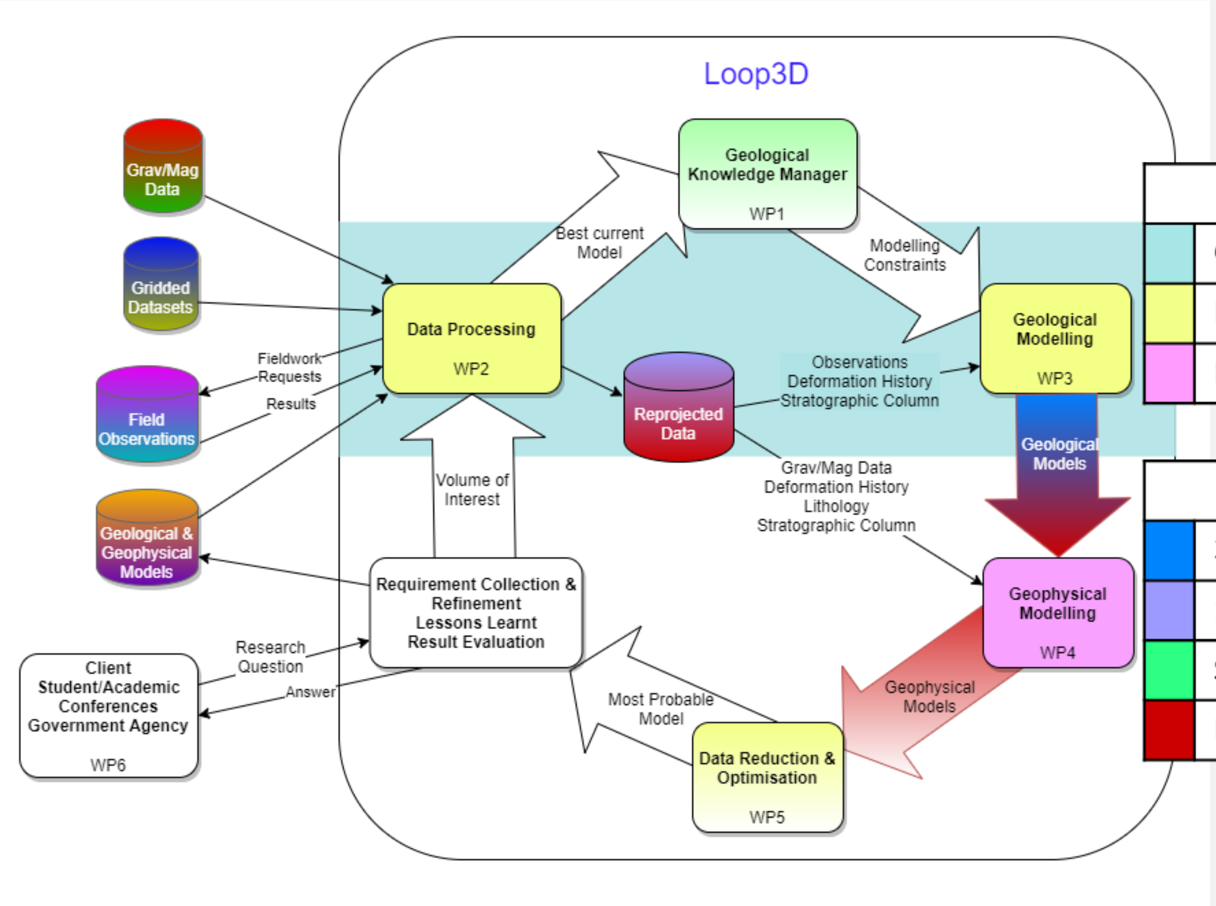
Language	
	C/C++
	Python
	Fortran

Data Type	
	3D
	1D Pointcloud
	SparQL
	Plain Text

Loop Workflow

Data Types are to be encoded in a single netCDF project file (with .loop3d extension)

WP #0 – Infrastructure // Software Development

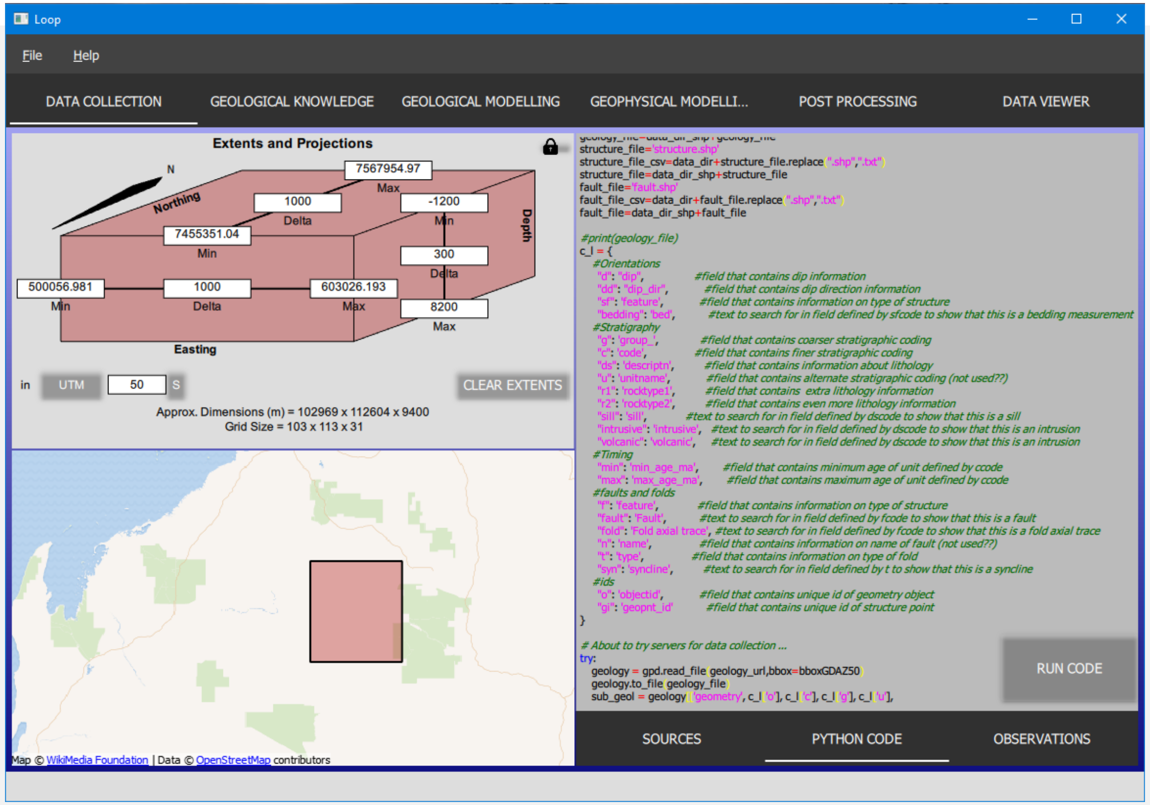


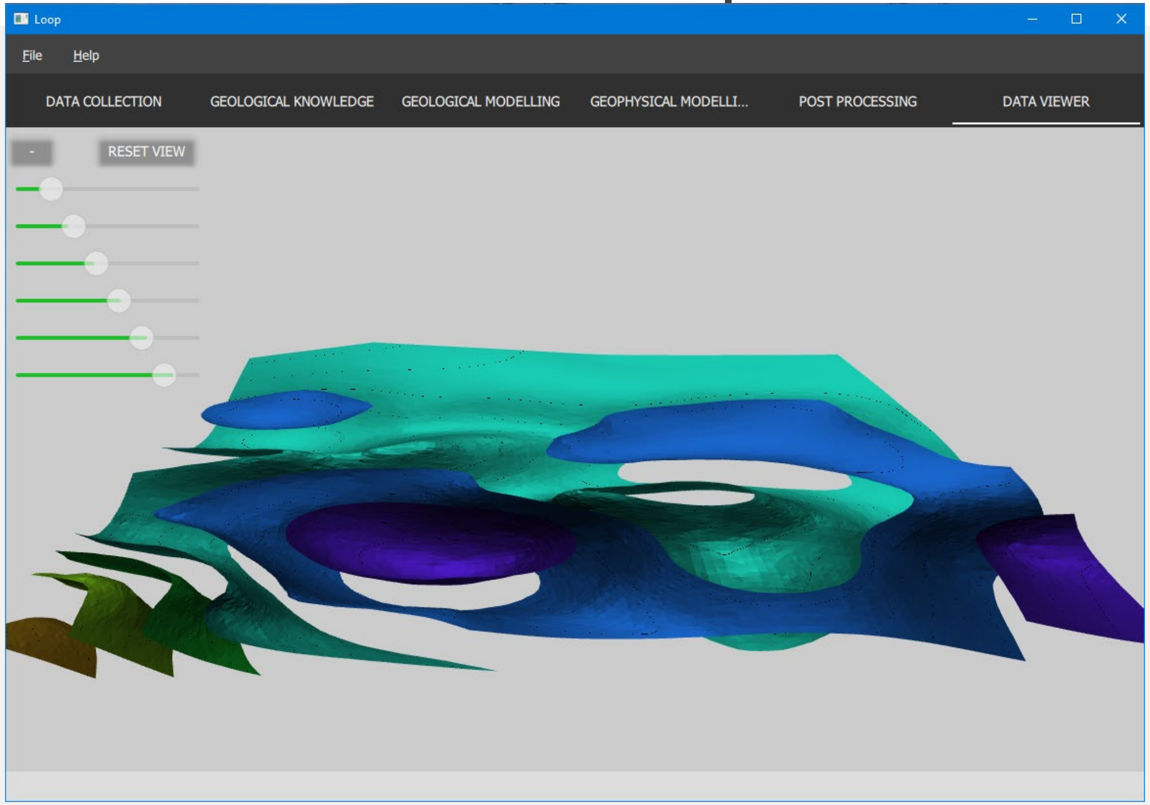
Language
C/C++
Python
Fortran

Data Type
3D
1D Pointcloud
SparQL
Plain Text

Implemented Workflow
Python version of NetCDF data structures completed
Further progress towards inclusion of WP1 & WP5

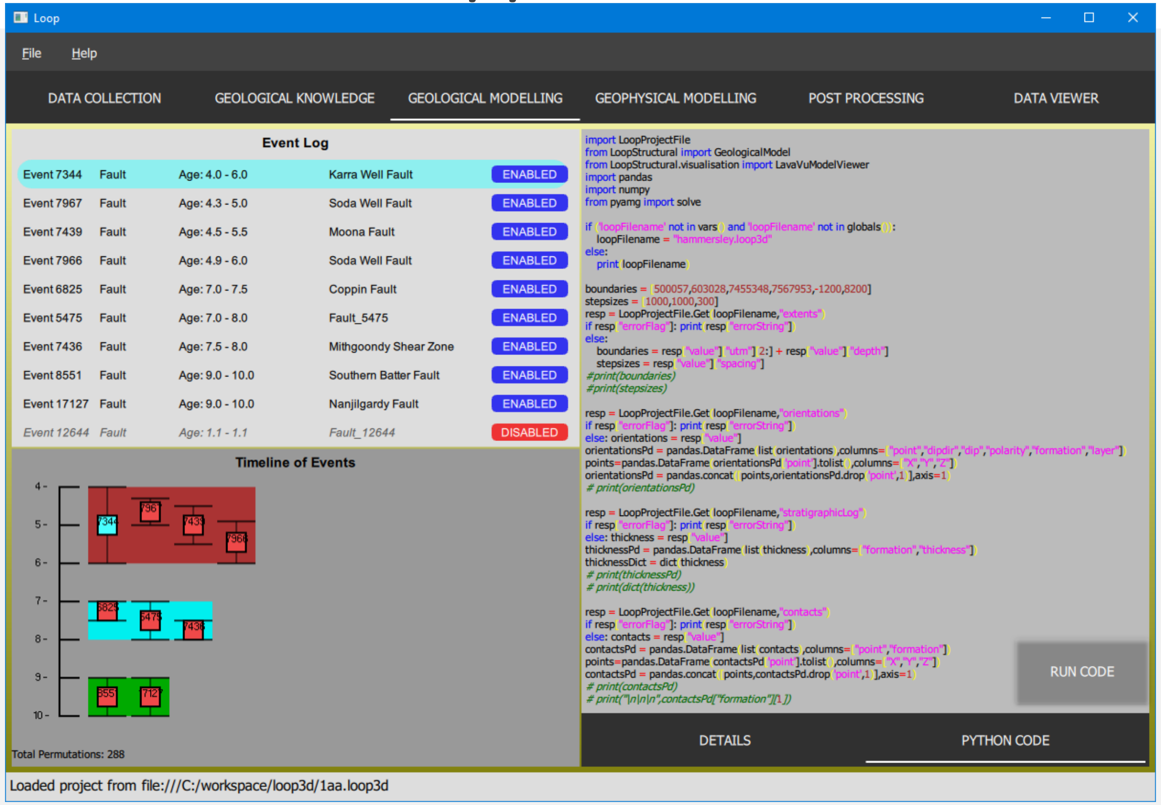
WP #0 – Infrastructure // Software Development





Left – GUI in construction showing the workflow to modelling. First step: setting the model volume of interest and running WP2 map2loop to extract data for modelling (WP #1 & 2).
Right: iso-slices through a first pass LoopStructural model of the Hammersley Group.

WP #0 – Infrastructure // Software Development



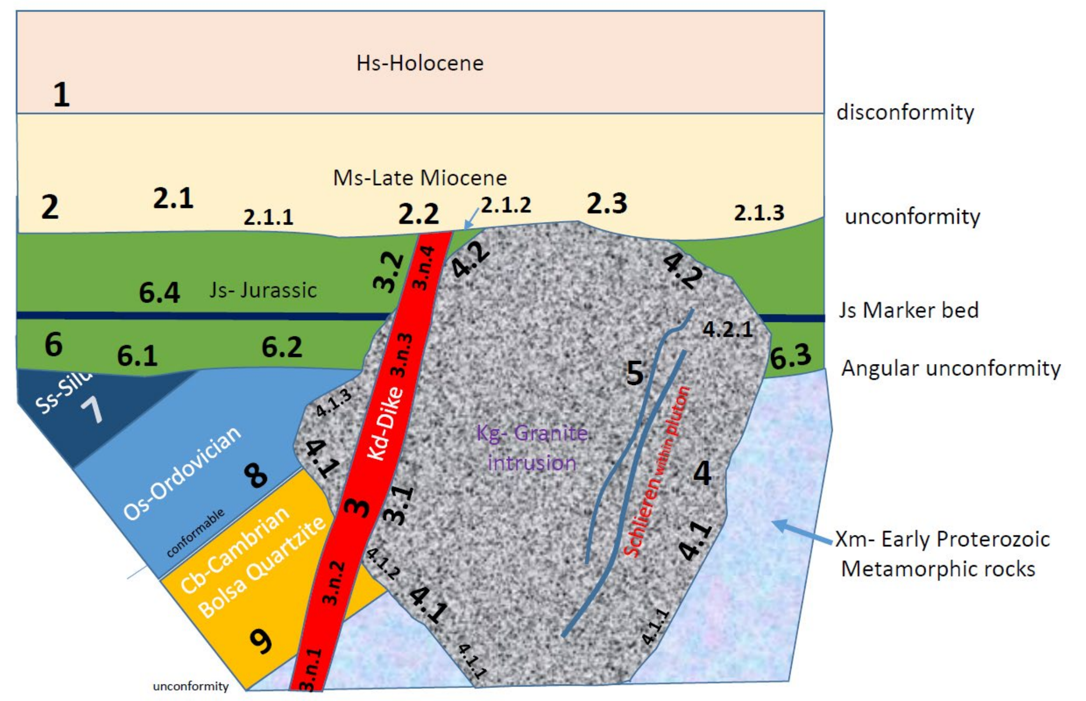
GUI Image showing calculation of total permutations of an event log including basic colouring interface based on the complexity of sub-sections of the event log

WP #1 – Geoscience Knowledge Manager

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

1. **Task:** Establish working group membership and procedures. **Deliverable:** working group membership.
2. **Task:** recruit one knowledge representation geoscientist. **Deliverable:** staffing contract.
3. **Task:** develop draft *geoscience knowledge manager* (GKM) architecture. **Deliverable:** draft GKM implementation.
4. **Task:** develop draft *geoscience knowledge ontology* (GSO). **Deliverable:** draft GSO encoding & notes
5. **Task:** develop *knowledge capture methods*, populate GSO and GKM. **Deliverable:** knowledge (test) in GKM.
6. **Task:** evaluate GKM access and explore *usage scenarios* (with WPs). **Deliverable:** GKM query patterns.

WP #1 – Geoscience Knowledge Manager



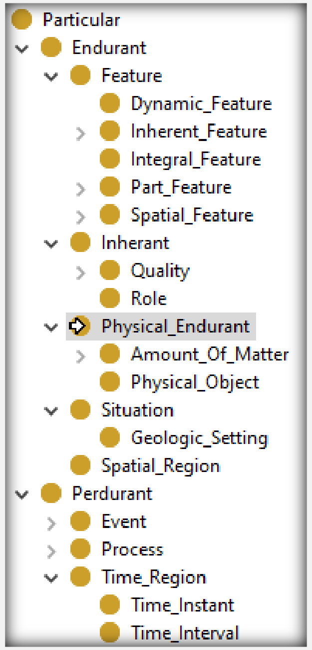

```
ejs:JsFormation
        rdf:type geo:Formation;
        rdfs:label 'Js Formation';
        rdfs:comment 'upper part is massive limestone';
        geo:hasTemporalProperty [
                rdf:type geo:Chronostratigraphic_Age;
                geo:hasYoungerAge
                        tim:Lower_Jurassic_Epoch;
                geo:hasOlderAge
                        tim:Lower_Jurassic_Epoch
                ];
        common:hasPart ejs:JsFormation-lower;
        common:hasPart ejs:baseJs-6;
        common:hasPart ejs:JsFormation-upper;
        common:hasPart ejs:topJs-2;
        common:hasPart con:KdInJsDikeContact-3.2.4;
```

Task 4: progress on GSO development – refinements made post-LOOP workshop Mar 2020; v1 document draft.

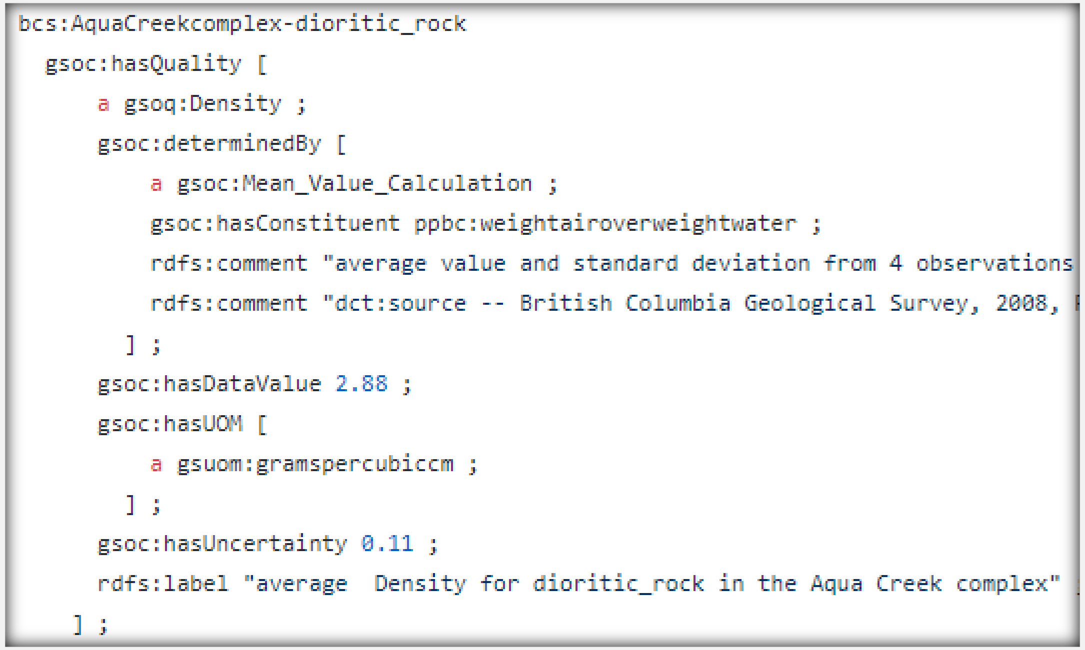
Task 5: progress on GSO content – developed petrophysical examples, with more planned.

Task 6: evaluate GKM access and explore *usage scenarios* – petrophysical testing scenario in progress.

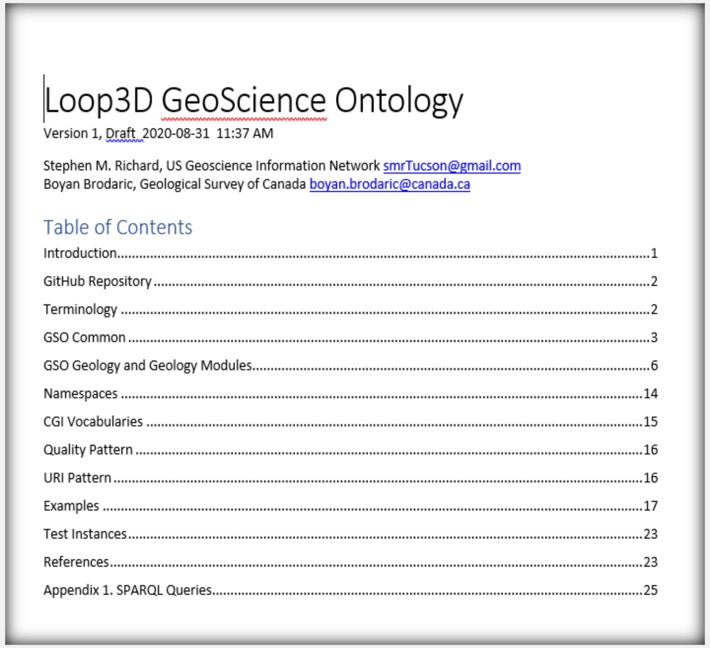
WP #1 – Geoscience Knowledge Manager



GSO top-level


```
bcs:AquaCreekcomplex-dioritic_rock
  gsoc:hasQuality [
      a gsoq:Density ;
      gsoc:determinedBy [
          a gsoc:Mean_Value_Calculation ;
          gsoc:hasConstituent ppbc:weightairoverweightwater ;
          rdfs:comment "average value and standard deviation from 4 observations
          rdfs:comment "dct:source -- British Columbia Geological Survey, 2008, 
        ] ;
      gsoc:hasDataValue 2.88 ;
      gsoc:hasUOM [
          a gsuom:gramspercubiccm ;
        ] ;
      gsoc:hasUncertainty 0.11 ;
      rdfs:label "average  Density for dioritic_rock in the Aqua Creek complex"
    ] ;
```

GSO example petrophysical property encoding



GSO documentation v1

Task 4: progress on GSO development – refinements made post-LOOP workshop Mar 2020; v1 document draft.

Task 5: progress on GSO content – developed petrophysical examples, with more planned.

Task 6: evaluate GKM access and explore *usage scenarios* – petrophysical testing scenario in progress.

WP #2 – Data Pre-Processing & input

Is work on track against plan? update all deliverables
Work completed ◯ On track 🟢 Delayed 🟠 Problem 🔴 Will not happen ⚫ New 🔵

◯ 1. Recruit one post-doctoral fellow for uncertainty: Guillaume Pirot hired, start date 1/9/2019

◯ 2. Recruit one Scientific programmer: Kavitha Madaiah hired, started 17/6/2019

◯ 3. Recruit one post-doctoral fellow geophysics (WP4) : Jeremie Giraud hired, started 1/4/2019

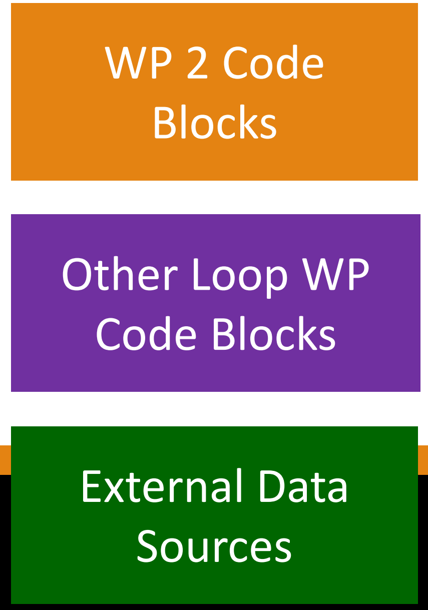
◯ 4. 2 new PhD scholarships candidates found (Babak Ghane (still having visa issues), Nuwan Suriyaachchi)

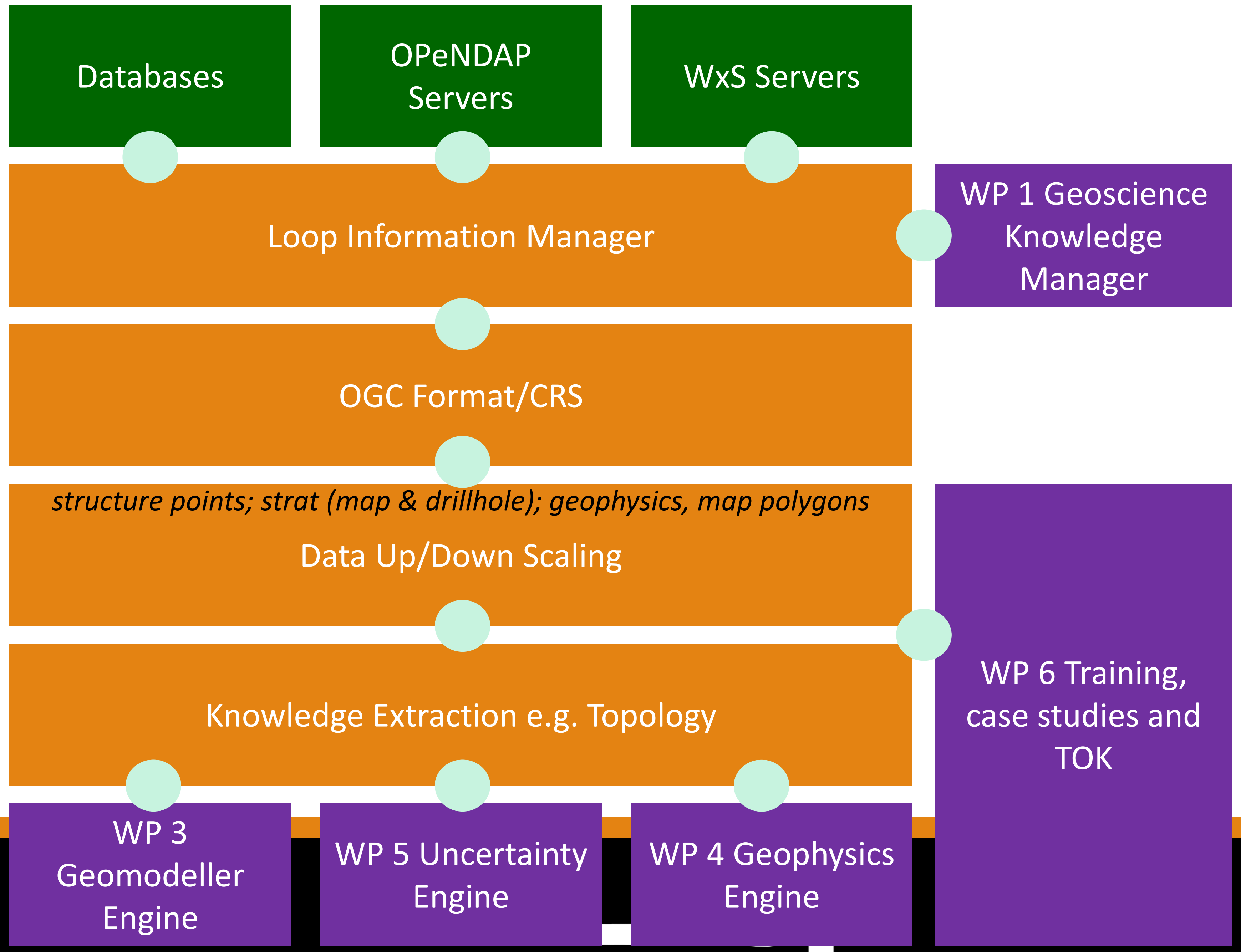
🟢 5. Acquire company data for testing purposes: provisional confirmation from BHP

🟢 6. Define 1-3 year software capabilities

WP #2 – Data Pre-Processing & input

Planned code blocks

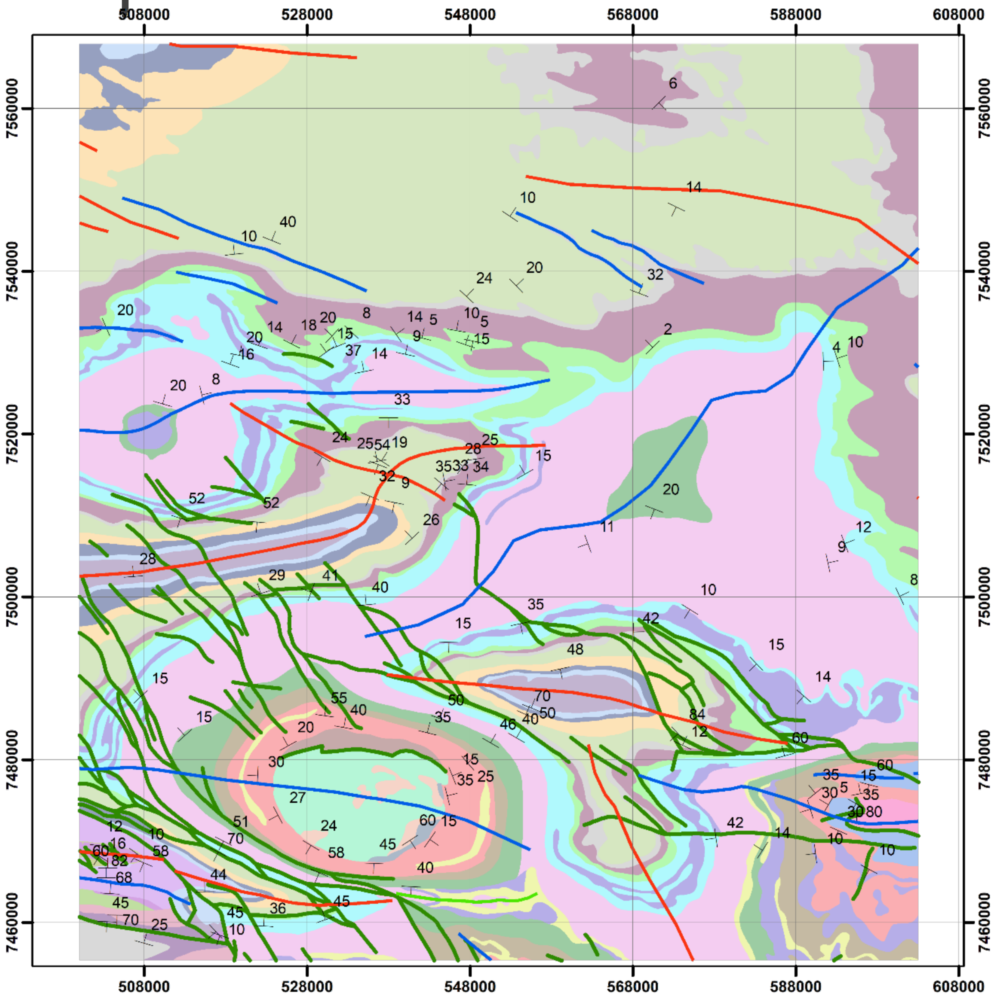




WP #2 – Data Pre-Processing & input

Map2loop proof of concept

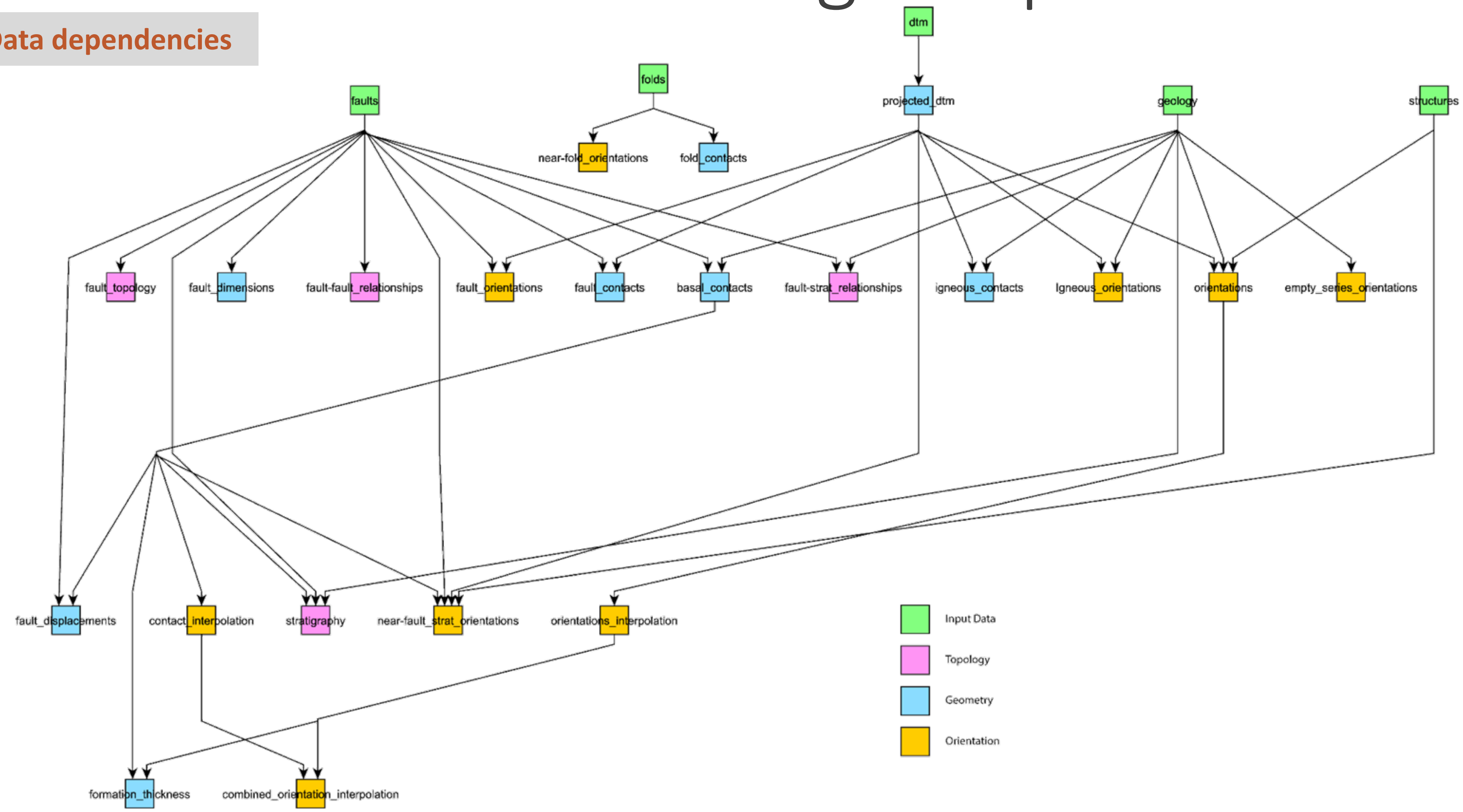
- One of the aims of WP2 is to automate as much as possible the input of data and transformation in appropriate inputs to Loop 3D modelling codes
- In this (first) example we have developed python & C++ codes to automatically derive the input data needed to produce ***gempy, geomodeller and LoopStructural (WP #3)*** models
- Specifically we started from a shapefile of the GSWA 500K geology map of Western Australia; the equivalent fault and fold axial trace layer; the WAROX database of structures and an online Geoscience Australia SRTM topography server
- By performing a topological analysis of the geology map we were able to provide the necessary inputs for a ***gempy, geomodeller and LoopStructural*** models for a 1 degree square of geology
- **No manual intervention was required to build the input layers and models shown in the next slides (apart from lots of coding)**
- Future developments will add sills



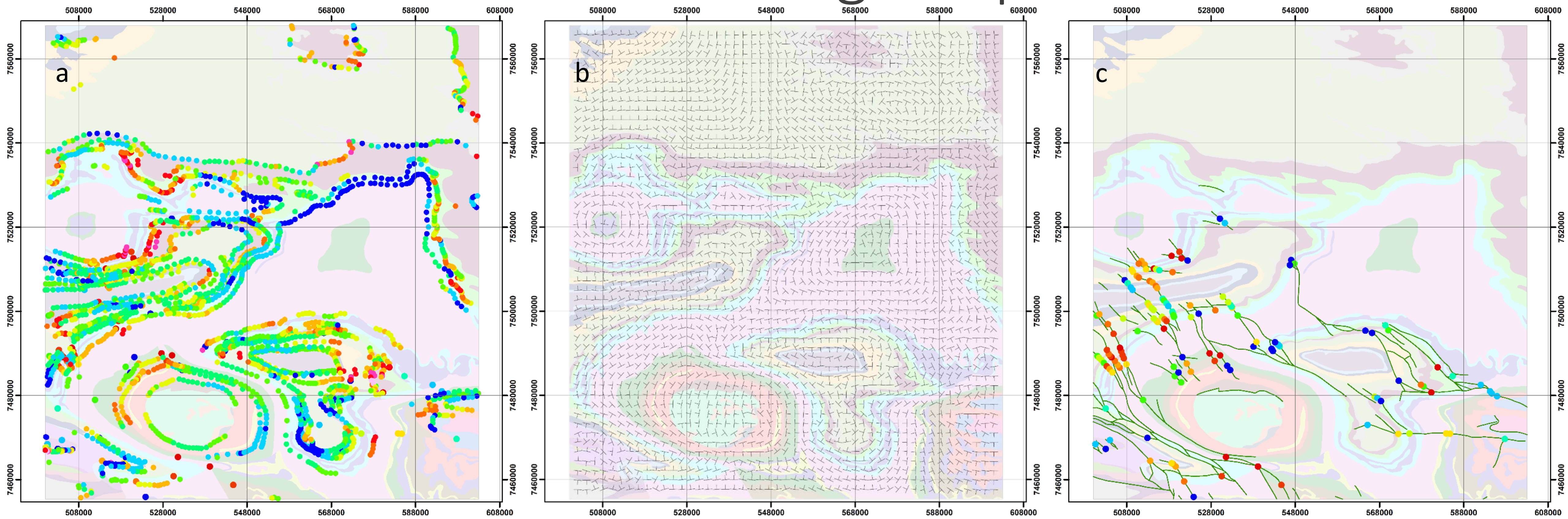
Loop

WP #2 – Data Pre-Processing & input

Map2loop // Data dependencies



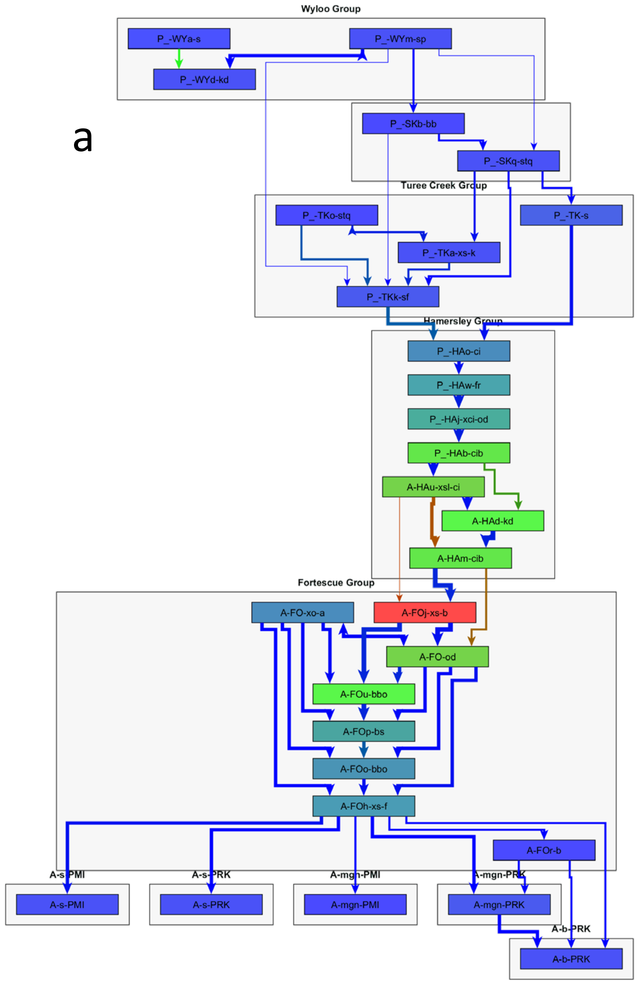
WP #2 – Data Pre-Processing & input



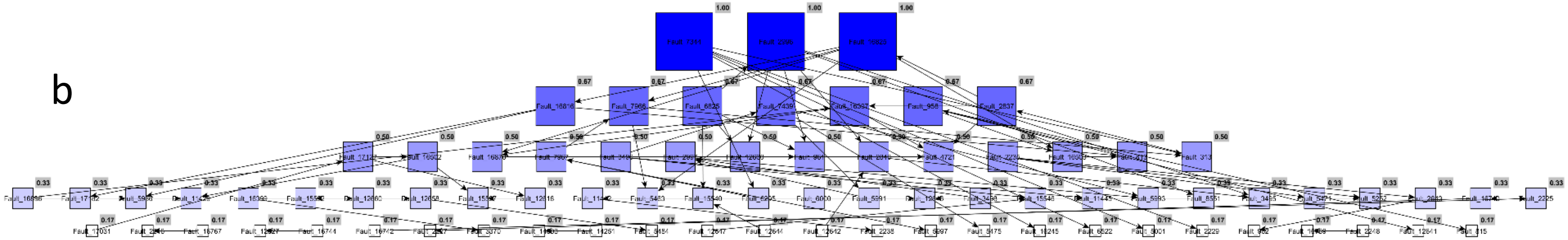
Map2loop // Secondary geological information automatically derived from maps. a) Normalised local formation thickness (hotter colours show thicker formations) b) Interpolated estimated bedding orientations for the Hamersely and Fortescue Groups c) Apparent fault throw (hotter colours show larger throw)

WP #2 – Data Pre-Processing & input

a



b

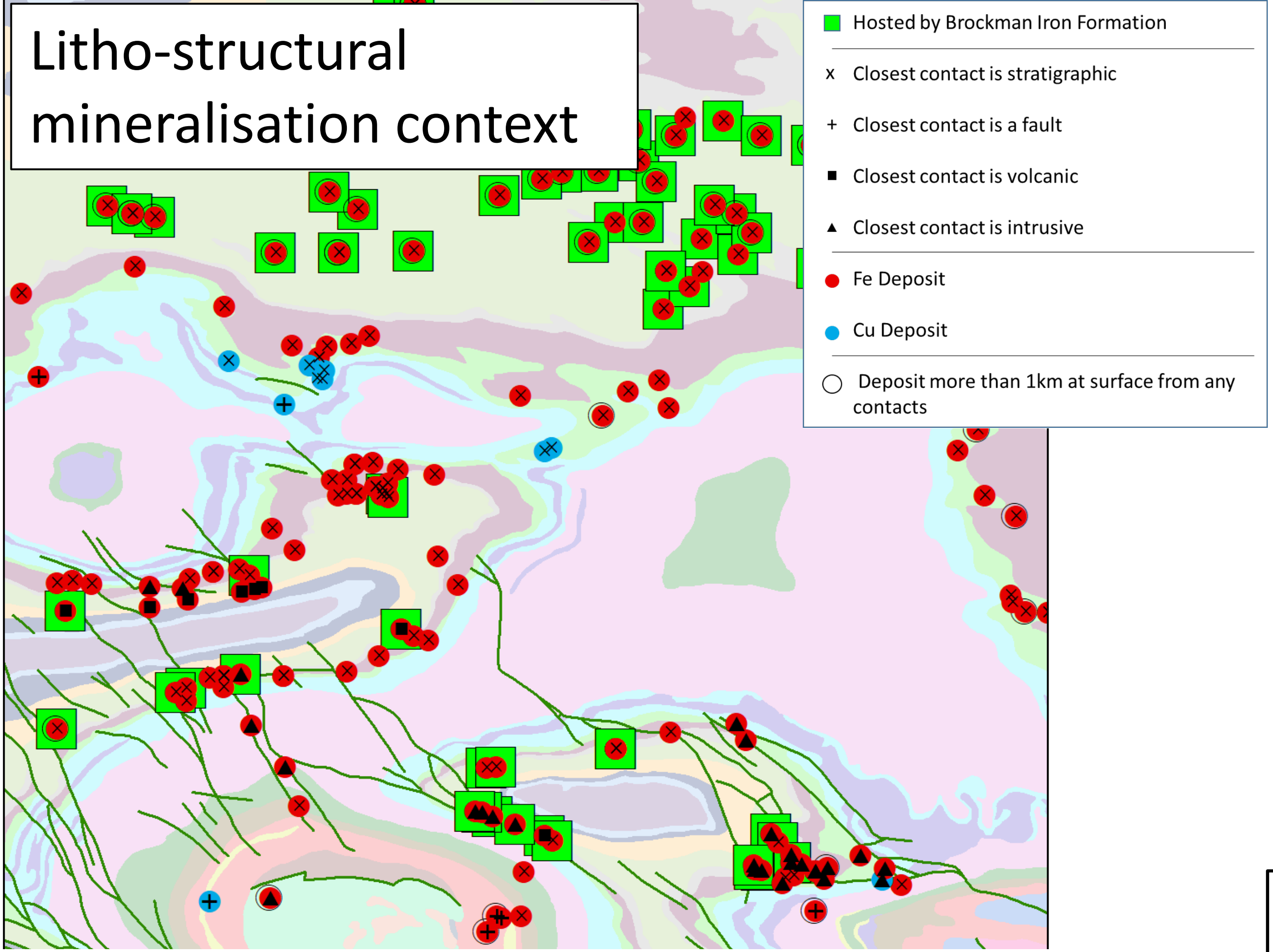


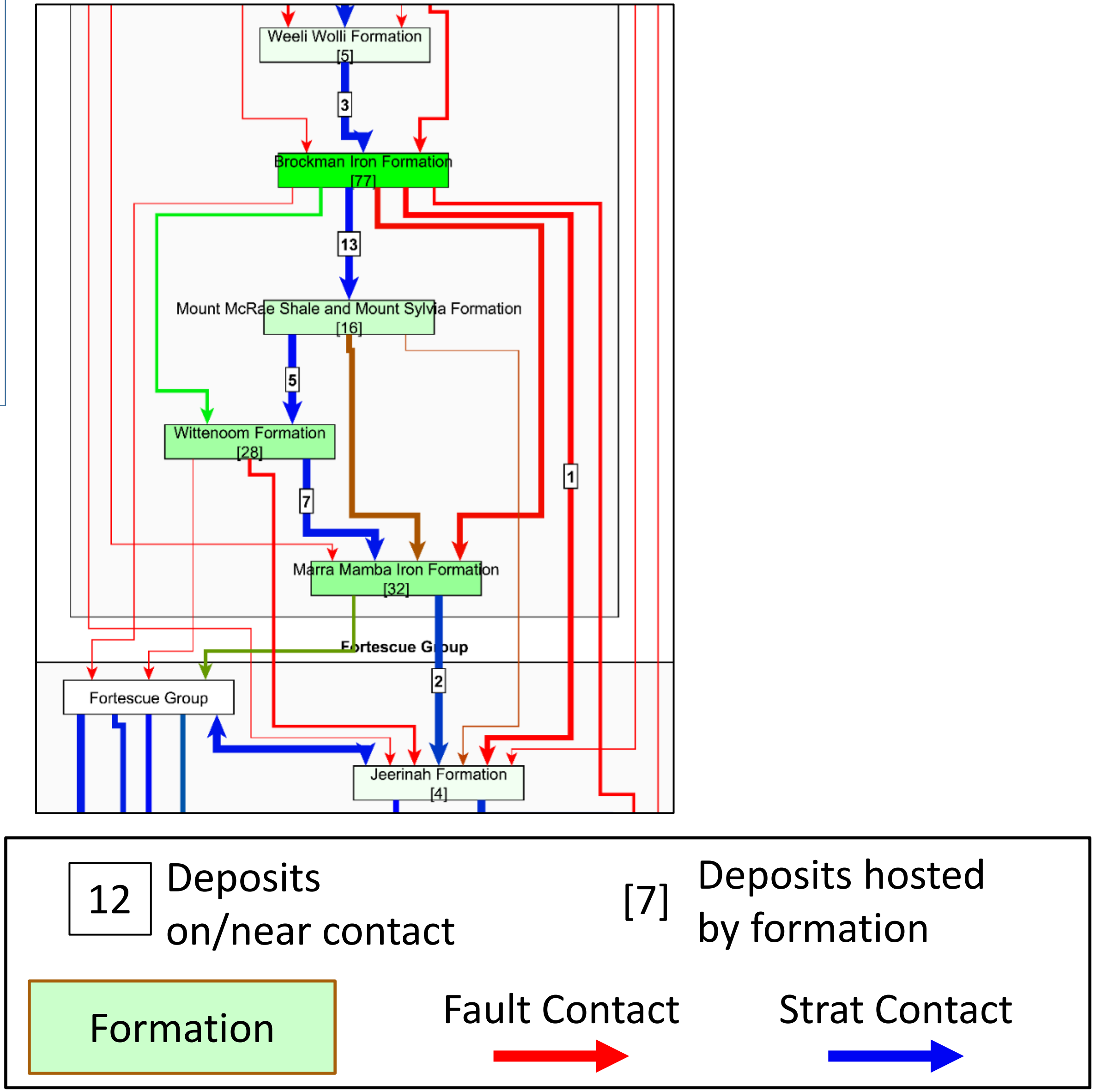
c

code	958	2248	3370	4226	5298	5997	6205	6522	6825	7344	7805	7967	8973	9401	12644	12658	12660	15540	15552	16399	16503	16744	16769	16896	2235	6374	3496	7099	7436	10762	1264
A-FO-od	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
A-FO-xo-a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
A-FOh-xs-f	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1	1
A-FOj-xs-b	1	1	1	0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1
A-FOo-bbo	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	0	1	1
A-FOp-bs	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	0	1	1
A-FOu-bbo	0	1	1	0	1	1	1	1	1	1	0	1	0	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1
A-HAd-kd	1	0	0	0	0	1	1	0	1	1	0	0	1	0	0	1	1	0	1	1	0	1	0	0	1	0	0	0	0	0	1
A-HAm-cib	1	1	0	0	1	1	1	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	1
A-HAu-xsl-ci	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	1
A-mgn-PMI	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	0
A-mgn-PRK	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	1	0	0
A-s-PMI	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
P_-HAb-cib	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	1	1	0	1	1	0	1	0	0	0	1
P_-HAj-xci-od	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0
P_-HAo-ci	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	0
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	0
P_-SKq-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	0
P_-TK-s	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P_-TKa-xs-k	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	0
P_-TKk-sf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
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	0
P_-WYa-s	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	0
P_-WYd-kd	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	0
P_-WYm-sp	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	0

Topological information automatically derived from maps. a) Stratigraphic relationships between the different formations found in the region of interest. Each rectangle represents one formation, and the arrows point to younger formation. b) Fault relationships, each fault is one rectangle, and the larger and darker the rectangle, the more important the fault is based on a centrality index. c) The fault-formation relationship matrix. Green cells indicate that a specific fault (columns) intersects a given formation (rows), otherwise the cell is red.

Litho-structural mineralisation context

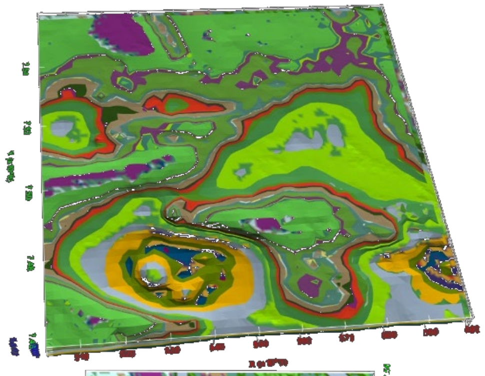


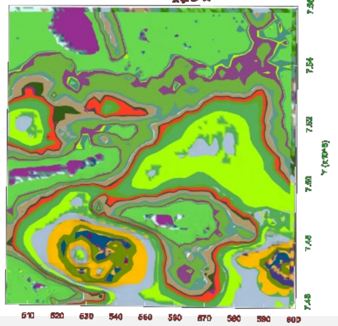


Functionality added to *map2loop* to analyse the litho-structural context of mineral deposits, which will help in defining which elements to retain for modelling

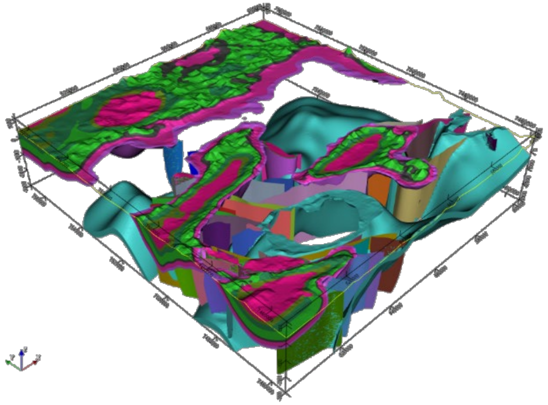
WP #2 – Data Pre-Processing & input

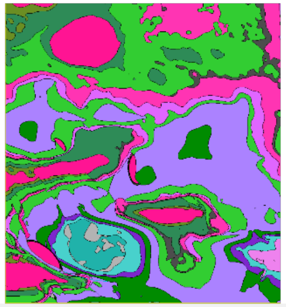
gempy



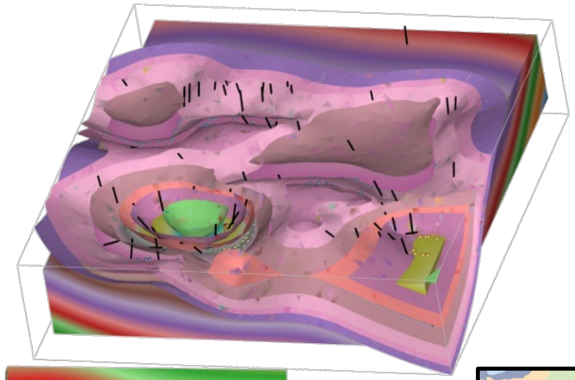


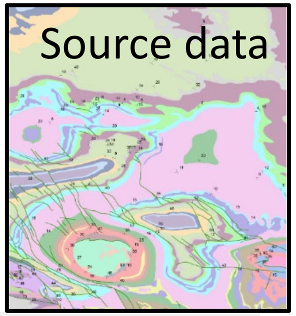
Geomodeller





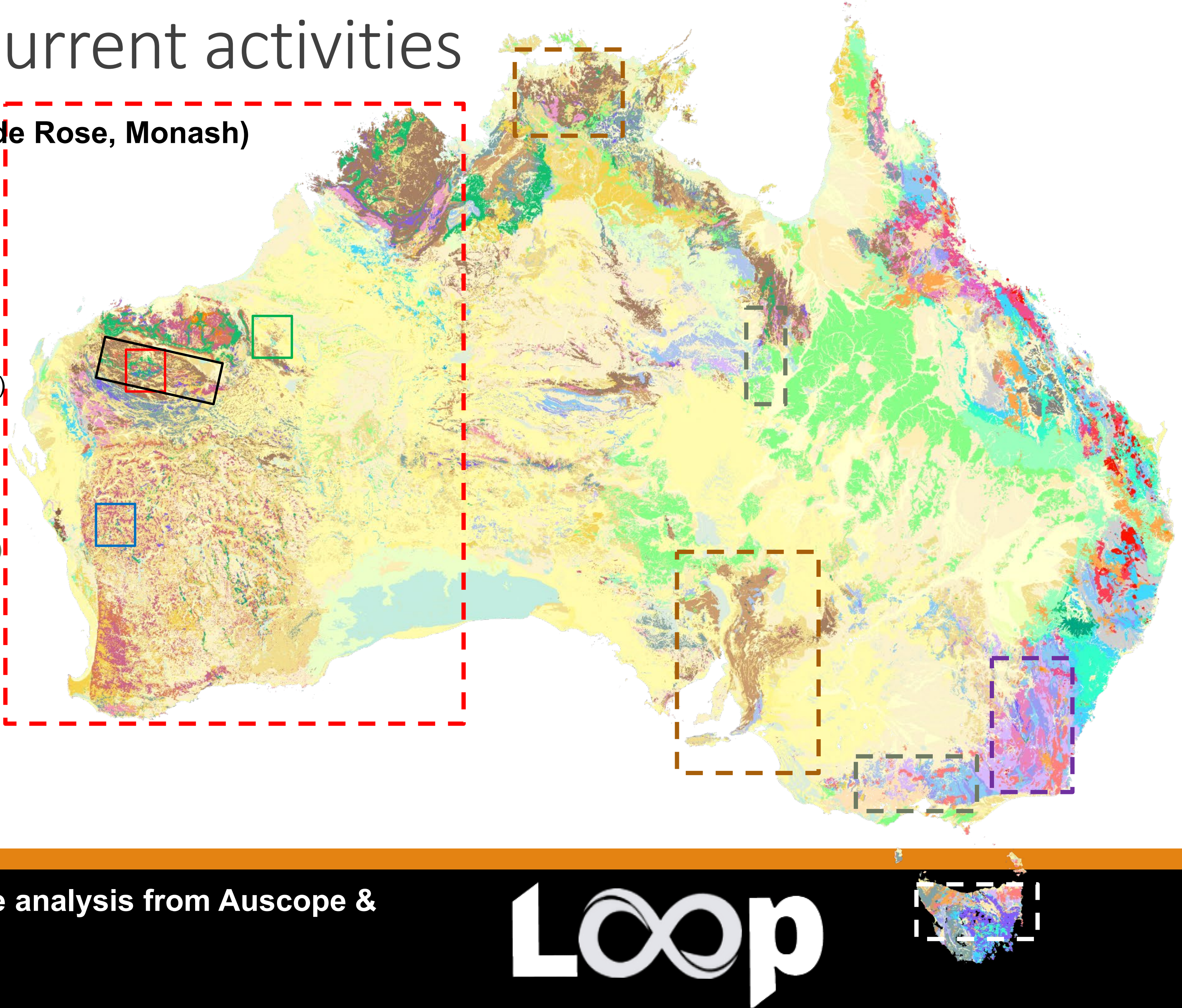
LoopStructural





3D geological model produced using the input data created by map2loop. Top row: 3D model with some layers rendered transparent in the Geomodeller mode to highlight subsurface fault relationships. gempy and LoopStructural have no faults (yet). Lower row: top surface of the geology.

WP #2 – Map2loop-current activities



a) Refactoring of map2loop code: (Yohan de Rose, Monash)

a) Ease of installation

b) Conform code to Loop standards

b) Testing of map2loop code

a) Mark Jessell Proof of concepts

b) Nishka Piechocka (MRIWA 577 Hamersley project)

c) Fabiele Dalmaso Spode

d) (MRIWA 521/554 Paterson/Basins projects)

e) Ranee Joshi Yalgoo Singleton GSB

f) Mt Isa Inlier Rock Valenta/Karen Connors (UQ,AA)

g) NSW Lachlan Orogen examples

h) PCO NTGS

i) Flinders Ranges – GSSA

j) Victoria – GSV

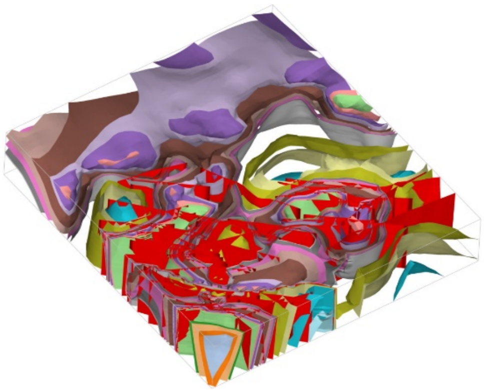
k) Tasmania MRT data

c) Seeking additional funding for drillhole analysis from Auscope & MinEx CRC Opportunity funds

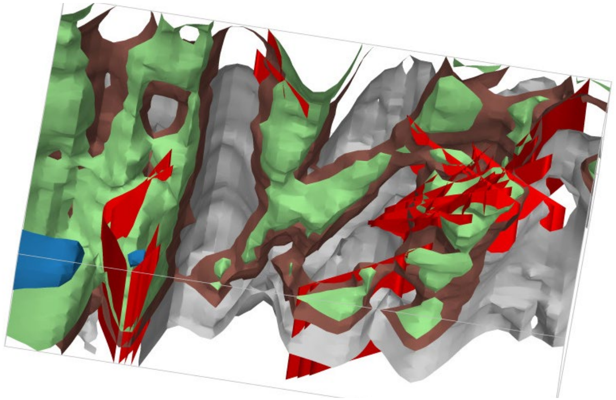
Loop

WP #2 & 3 Proof of concept models
map2loop -> LoopStructural

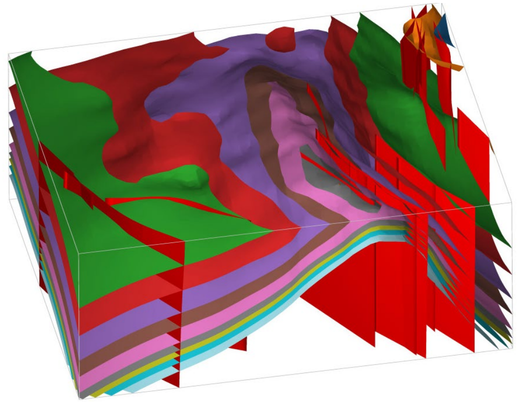
WA



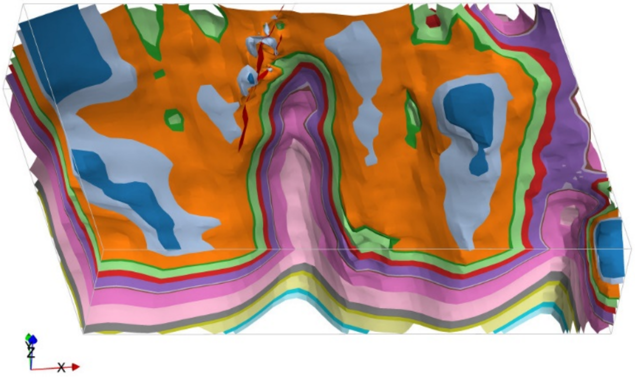
SA



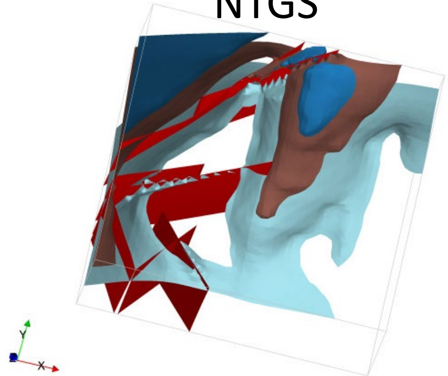
VIC



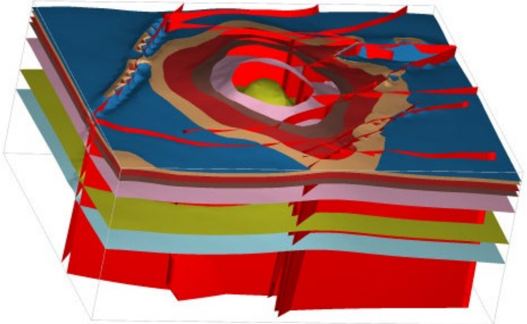
NSW



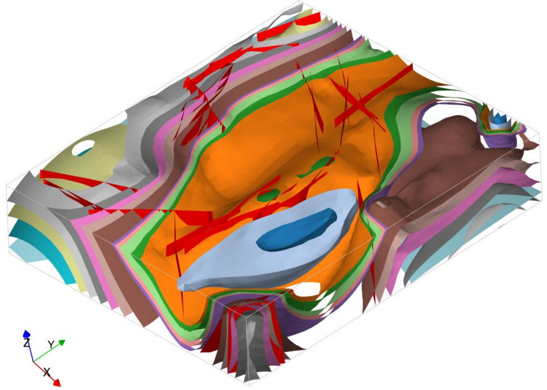
NTGS



QLD



TAS



WP #3 – LoopStructural

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

1. Python library: FME has been renamed to LoopStructural
2. Developing/testing algorithms for representing fault networks (ongoing)
3. Planning a soft release of LoopStructural for beta testers identified at the SGTSG workshop early 2020 (delayed because of licensing issues with TetGen (AGPLV3). Dependency removed & now just testing
4. Planning benchmark paper (GC) – draft for RING meeting
5. Mike Hillier (GSC) working porting tensor interpolation to python
6. Implemented folding code in LoopStructural

WP #3 – LoopStructural

Is work on track against plan? update all deliverables
Work completed ⚪ On track 🟢 Delayed 🟠 Problem 🔴 Will not happen ⚫ New 🔵

7. Loop Structural mailing list created (https://tinyurl.com/w4vp6os)
8. Implemented high level API for LoopStructural – folding, faulting, unconformities, using different interpolation schemes
9. Preparing publication for fault method and another for integration of faults and folds in implicit modeling
10. Conceptual development of intrusion framework
11. Removed reliance on tetgen and implemented structured tetrahedron mesh
12. New API working for polydeformed folds, overprinting faults and unconformities

WP #3 – LoopStructural

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

13. Testing impact of sample location on models produced by LoopStructural by subsampling a dataset on Noddy models for different sampling patterns 1) transect mapping 2) form line mapping.
14. Implementation of the Object-distance Simulation Method (Henrion et al. 2010) for intrusions modelling.
15. Identification of typical shapes for different types of intrusions. This is a work in progress and its outcome will be used to asses the limitations of different scalar fields.
16. Continuously testing link to map2loop and map2loop_v2
17. Link with geophysical codes
18. Implemented probabilistic fold modelling using EMCEE sampler

WP #3 – LoopStructural

Is work on track against plan? update all deliverables
Work completed ⚪ On track 🟢 Delayed 🟠 Problem 🔴 Will not happen ⚫ New 🔵

🟢 19. Implemented probabilistic faults displacement modelling

🟢 20. Discussing link with WP4/5

🟢 21. Ability to create model from parameter dictionary that can be saved as a .yml or .json file

🔵 22. Fault displacement map can be plotted

🔵 23. LoopStructural v1.0.4 released

🔵 24. Testing of Object-distance Simulation Method (ODSIM, Henrion et al. 2010) applied to intrusions modelling.

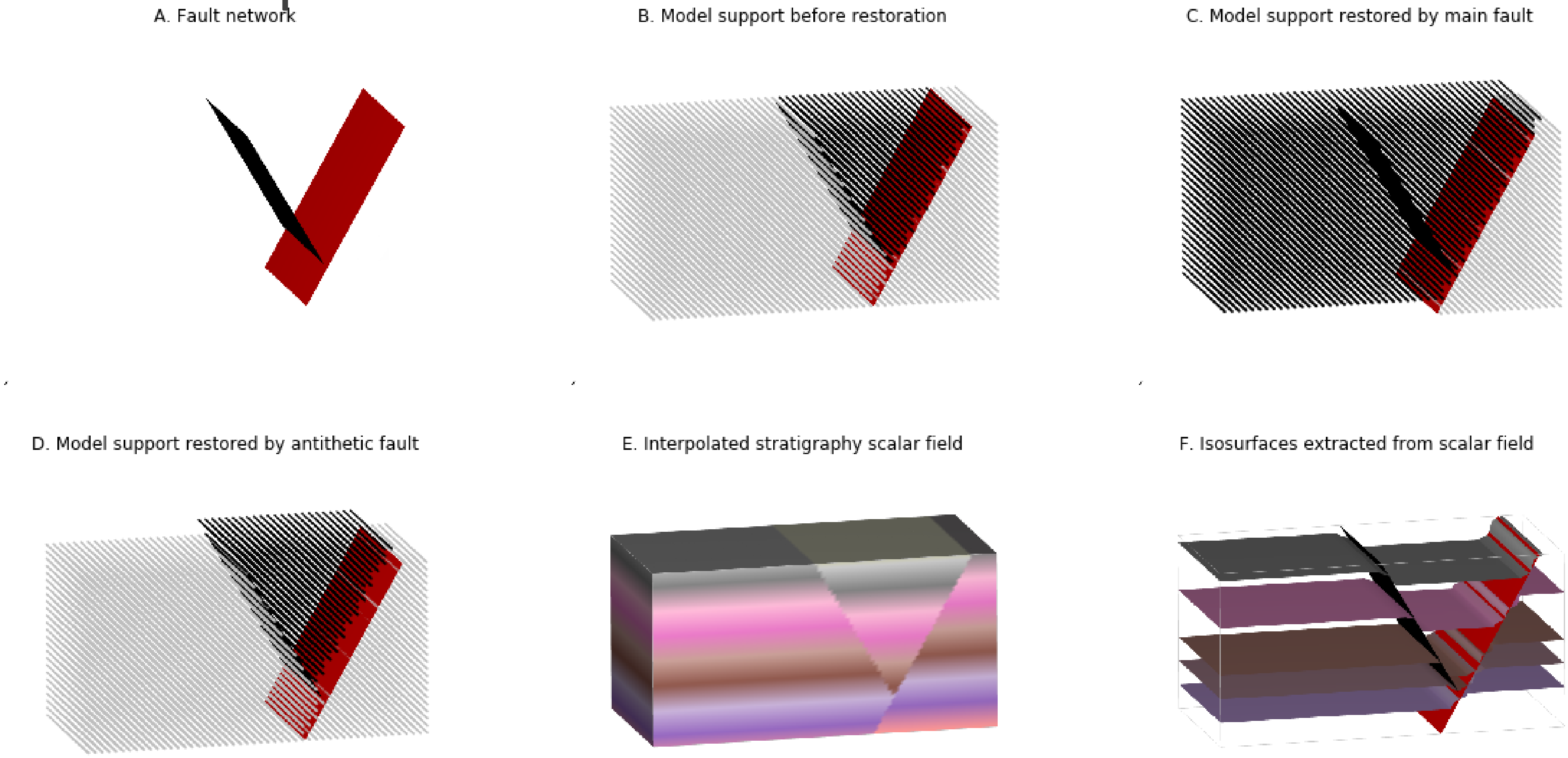
WP #3 – LoopStructural

Is work on track against plan? update all deliverables

Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

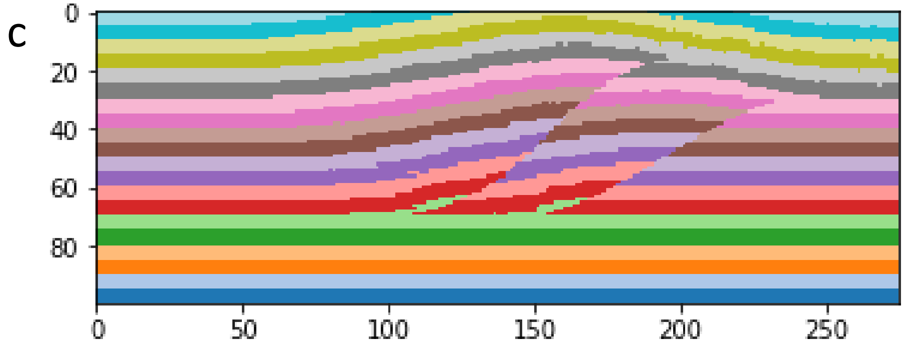
24. Map colours are used for colouring map2loop generated LoopStructural models
25. Draft LoopStructural paper prepared and sent to coauthors
26. Ongoing testing of the value of structural information
27. Direct integration of map2loop with new model creation function

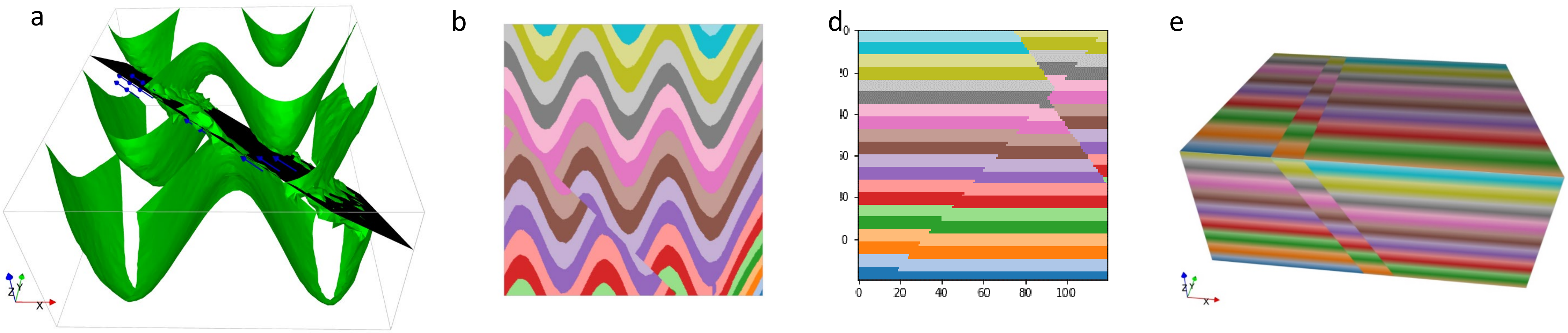
WP #3 – LoopStructural



Implicit fault network for a graben with antithetic faulting.

WP #3 – LoopStructural





LoopStructural – examples: a) faulted folds; b) map view of model a); c) Duplex; d) two antithetic sequential faults; e) two parallel faults with oblique offsets. Faults are modelled as ellipses with an ellipsoidal damage zone with varying offset profiles. Faults as folding events are time aware and are modelled from younger to older faults.

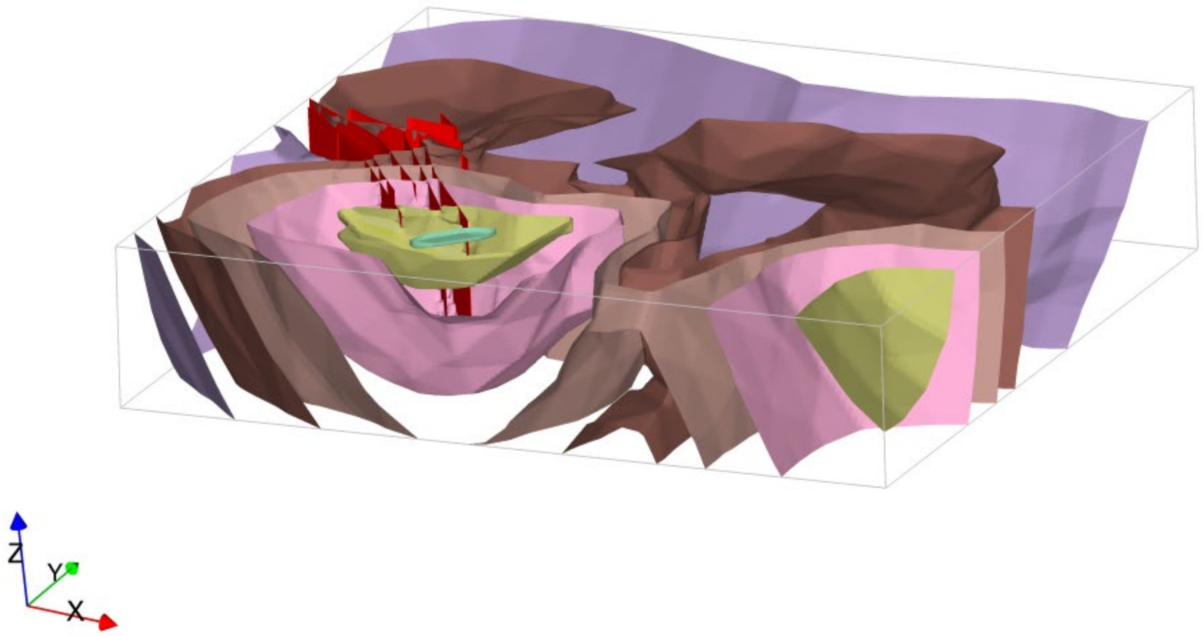
WP #3 – LoopStructural

```
model = GeologicalModel(bb[0,:],bb[1,:])
model.set_model_data(df2)
fold_frame = model.create_and_add_fold_frame('s1',
                                nelements=1e4,
                                            regularisation=[1.,1.,.1],
                                            interpolatortype='PLI',
                                            gxxgy=0.,
                                            solver='lu')
s0 = model.create_and_add_folded_foliation('s0',
                                           fold_frame=fold_frame['feature'],
                                      nelements=1e5,
                                           limb_wl=0.4,
                                     av_fold_axis='True',
                                          solver='lu')
```

executed in 1m 13.3s, finished 13:18:59 2019-12-12

Example of new streamlined api for modelling a folded foliation

WP #3 – LoopStructural

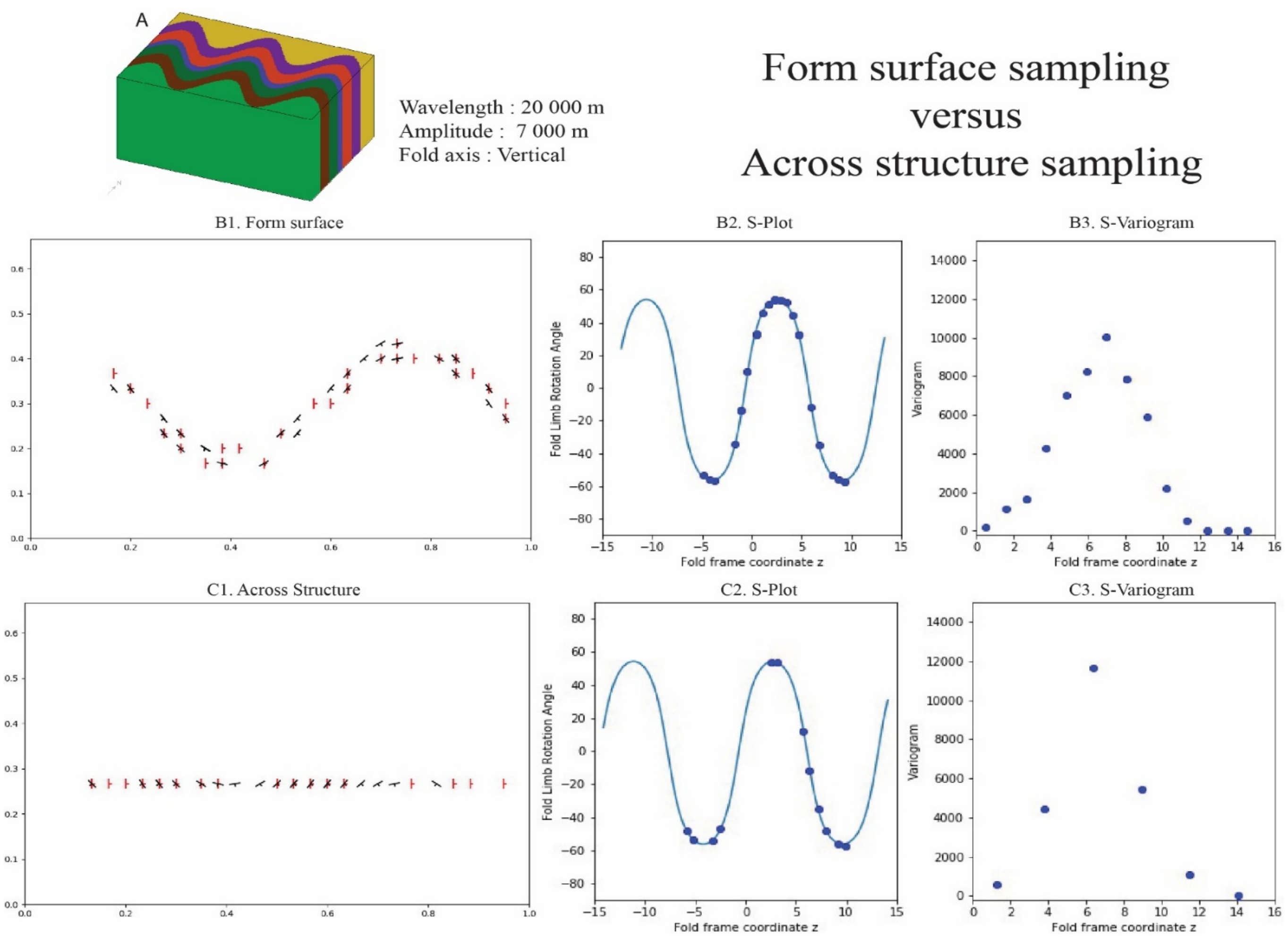


Loop structural modelling using map2loop output and including faults

WP #3 – LoopStructural

Sampling structural data

Form-surface sampling vs Across structure sampling.
The reference model generated using Noddy (A) is an upright cylindrical fold with a fold axis plunging vertically.
B-C1,2,3 are respectively the input dataset, the S-Plot of the resulting model and the S-Variogram.
The models resulting from both samples reproduce a wavelength close to the wavelength of the reference model and the model resulting from the form surface sample is slightly more asymmetrical than the across-structure sample.

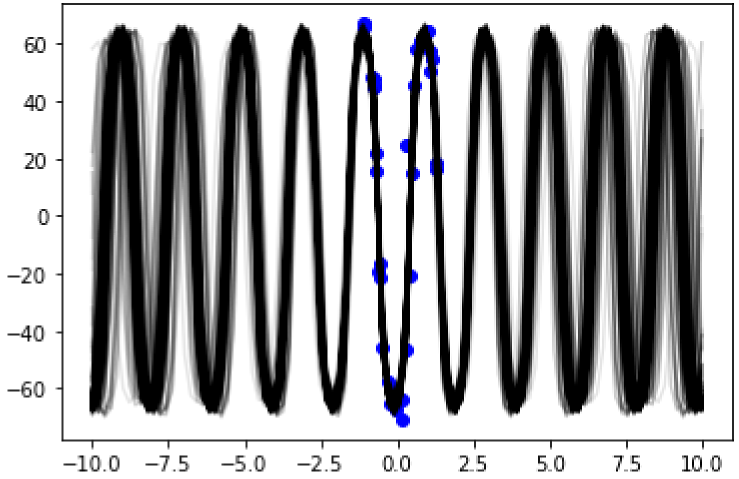


WP #3 – LoopStructural

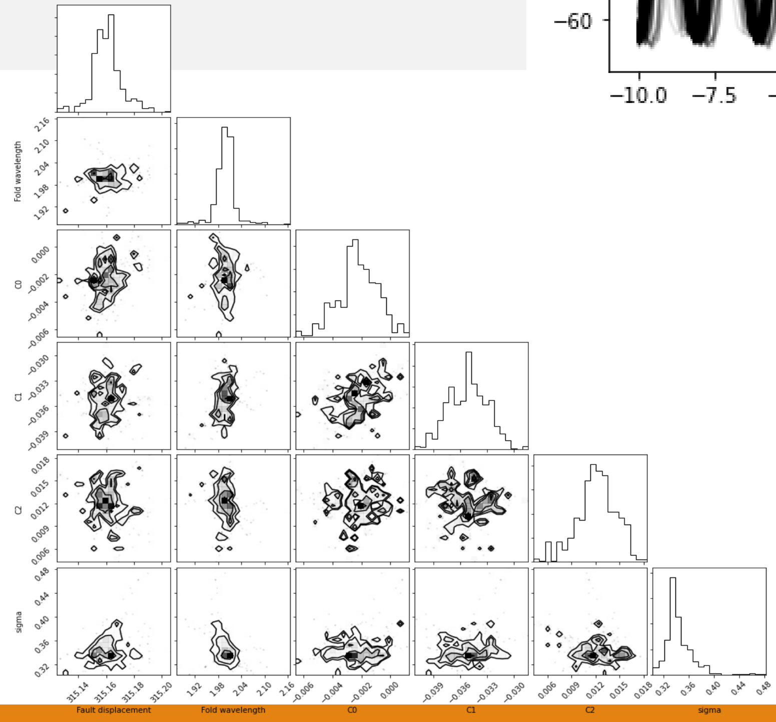
Bayesian modelling – proof of concept

a) Faulted fold series map where probabilistic folding and faulting was used to recover the fault displacement and fold geometry.
b) Posterior probabilities for displacement and fourier series coefficients
c) S-Plot showing 1000 realisations of the fold profile sampled from the posterior distribution.

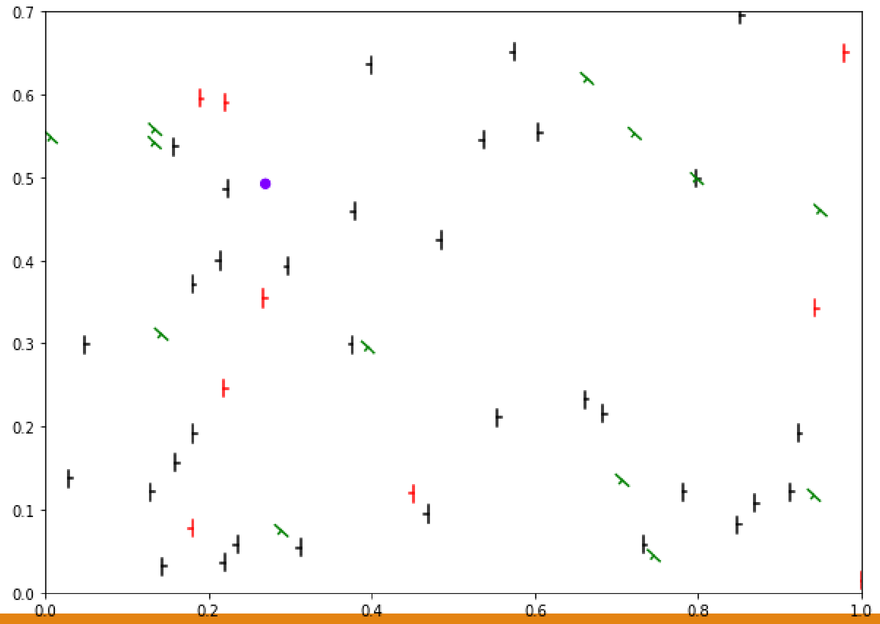
c



b

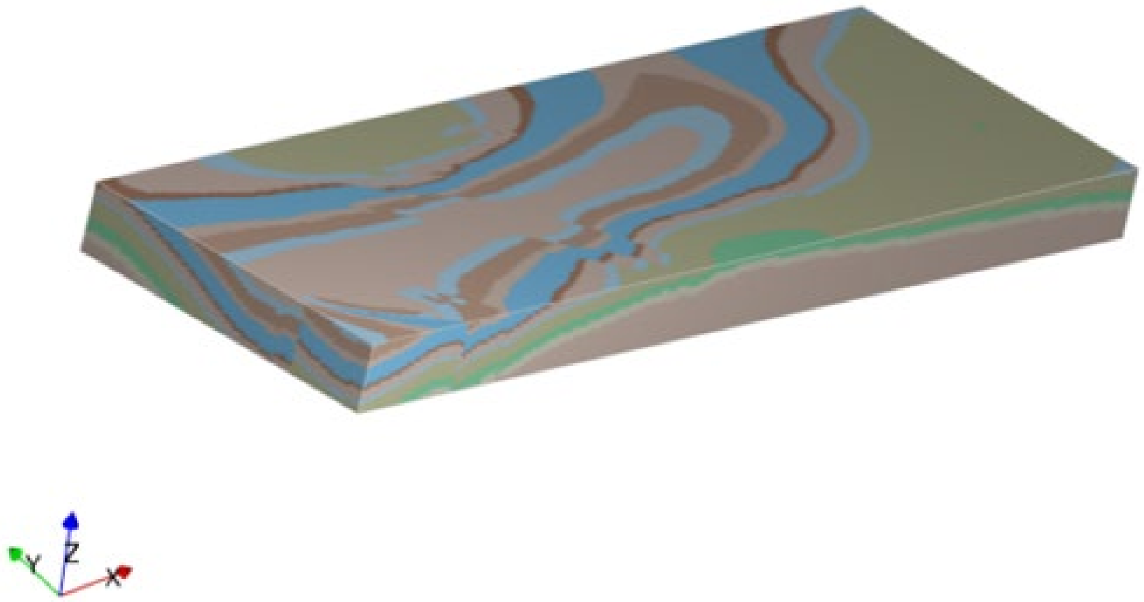


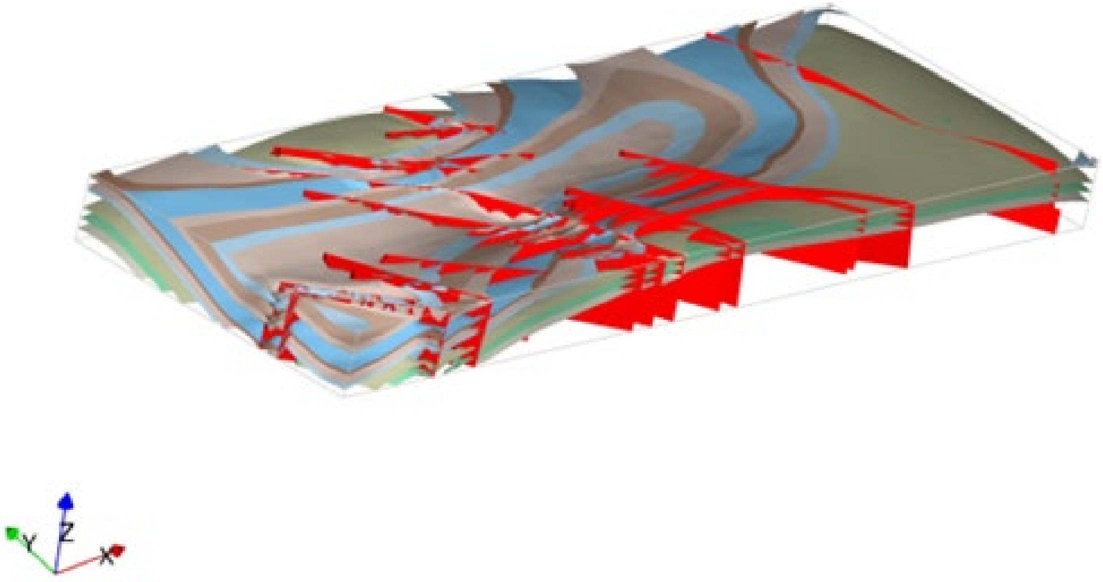
a



WP #3 – LoopStructural

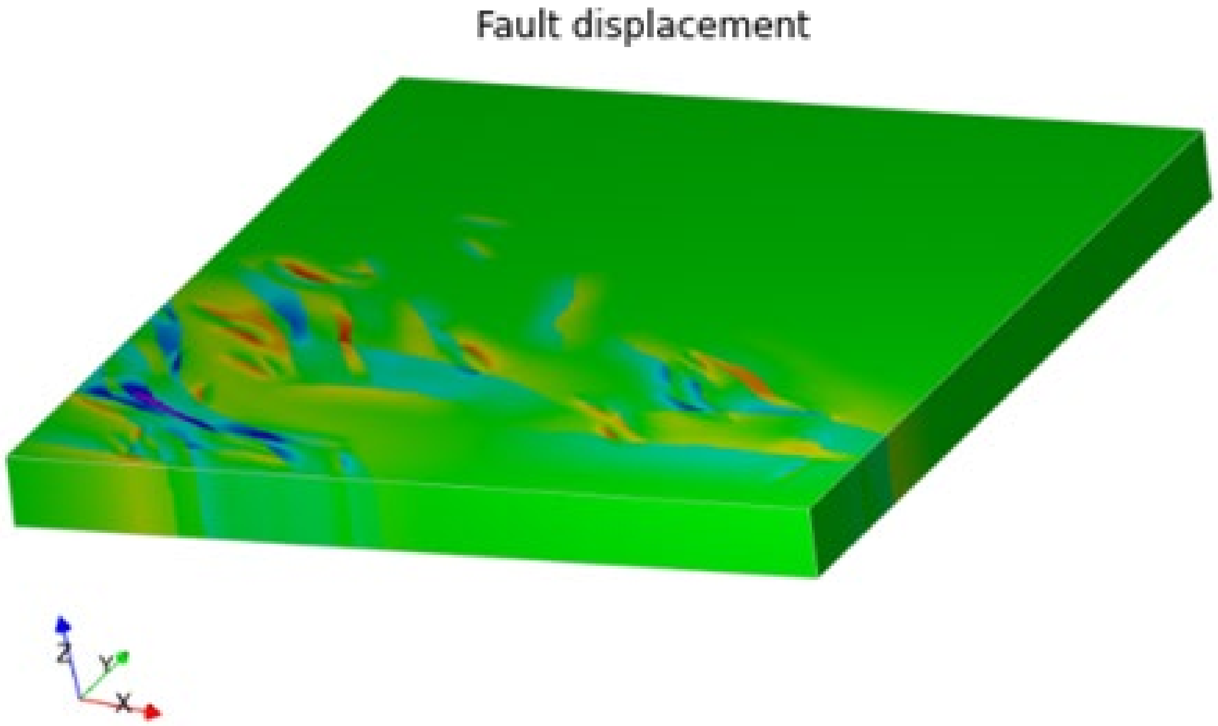
Geological map colours for 3D model
Model for turner syncline using map2loop with surface and geology colours being automatically extracted from 100k mapsheets

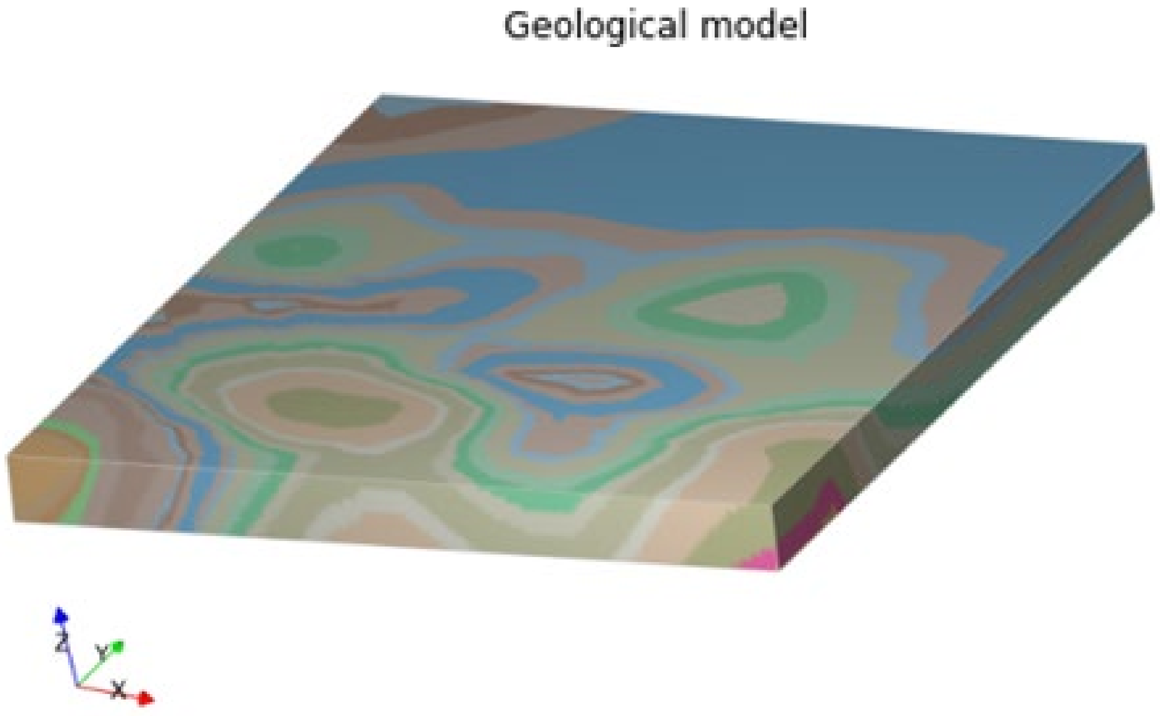




WP #3 – LoopStructural

Fault displacement map
Model for Hamersley area showing fault displacement magnitude. This new visualisation option shows the cumulative fault displacement for the geological model. It can be used in the 3D viewer or in the 2D mapview





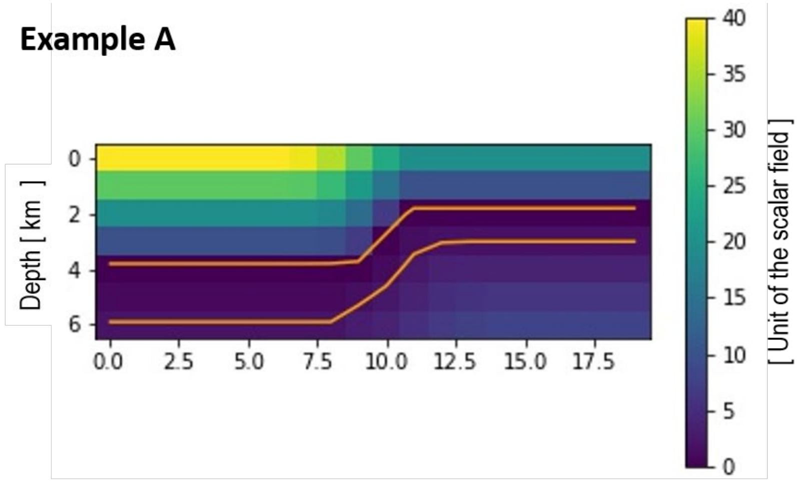
WP #3 – LoopStructural

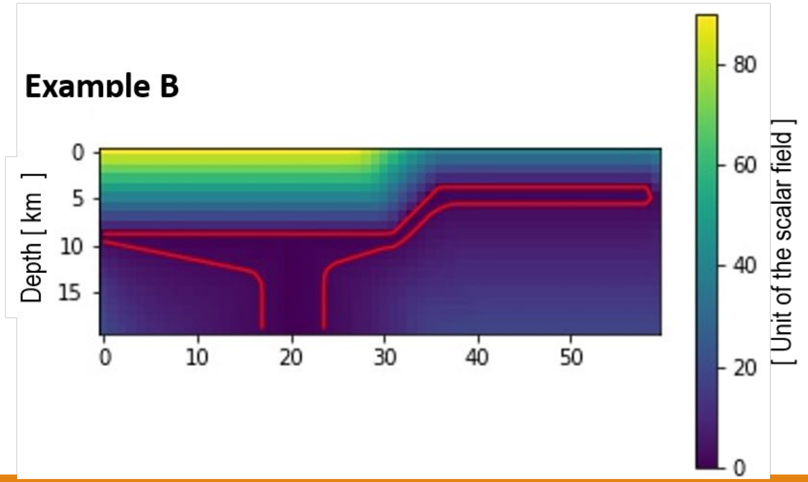
Modelling intrusions

Using the Object-distance Simulation Method (Henrion et al. 2010)

Example A: Sill-dyke-sill transition. Orange contour shows scalar field ϕ(p) = 2.

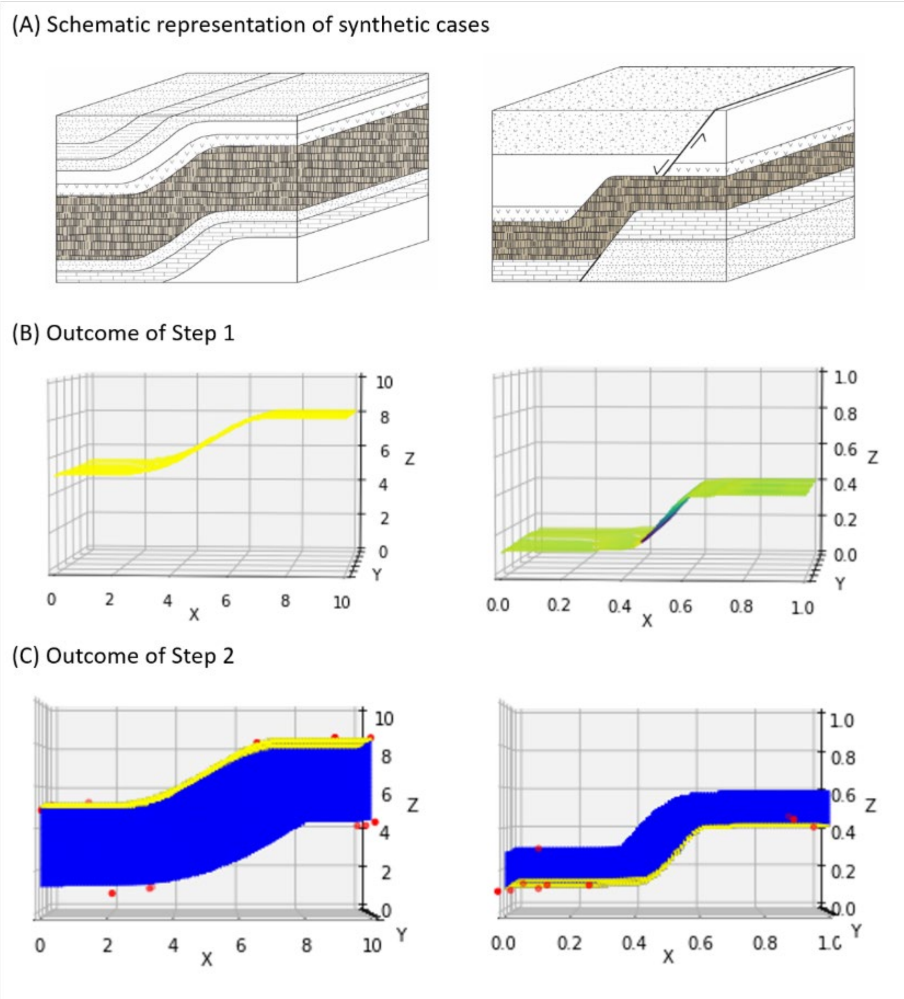
Example B. Feeder-sill-dyke-sill transition. Red contour shows scalar field ϕ(p) = 2





WP #3 – LoopStructural

ODSIM applied to intrusions. (A) Schematic representation of two synthetic cases. To the left, a sheet Intrusion emplaced in a folded and conformable sedimentary sequence. To the right, a sheet Intrusion emplaced in a faulted and conformable sedimentary sequence. (B) Intrusion network. (C) Coarse-scale geometry of the intrusions, showing the intrusion network (yellow surface), the intrusion body (blue volume) and the data points (red dots).



WP #3 – LoopStructural

Figure showing LoopStructural sensitivity to data sampling for folded structures.

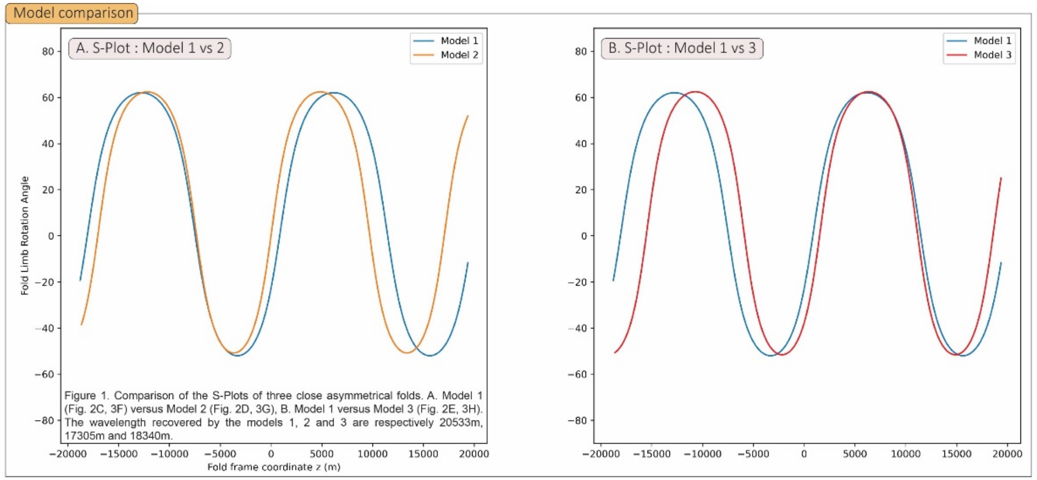


Figure 1. Comparison of the S-Plots of three close asymmetrical folds. A. Model 1 (Fig. 2C, 3F) versus Model 2 (Fig. 2D, 3G), B. Model 1 versus Model 3 (Fig. 2E, 3H). The wavelength recovered by the models 1, 2 and 3 are respectively 20533m, 17305m and 18340m.

Wavelength Recovery : Cylindrical folds

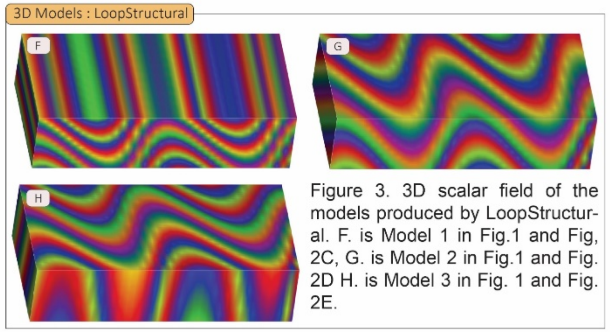


Figure 3. 3D scalar field of the models produced by LoopStructural. F. is Model 1 in Fig.1 and Fig, 2C, G. is Model 2 in Fig.1 and Fig. 2D H. is Model 3 in Fig. 1 and Fig. 2E.

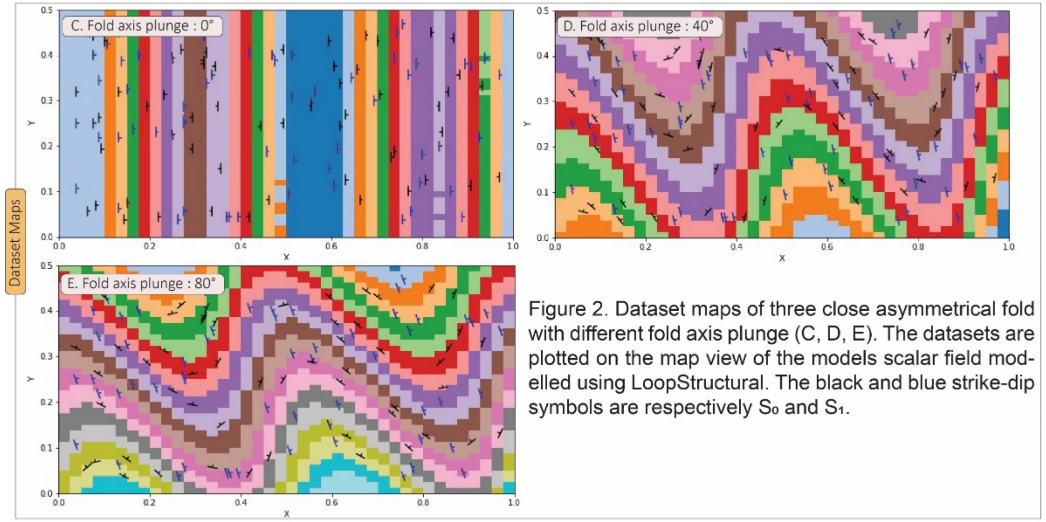


Figure 2. Dataset maps of three close asymmetrical fold with different fold axis plunge (C, D, E). The datasets are plotted on the map view of the models scalar field modelled using LoopStructural. The black and blue strike-dip symbols are respectively S_0 and S_1.

Preliminary conclusions

- The models (e.g. Model 1, Fig. 1, 2C, 3F) that recovered the best the reference wavelength had their inflection points sampled. This, underline the importance of inflection points in sampling folds to constrain any fold wavelength/geometry.
- The asymmetric folds require the sampling of the inflection points that capture the whole wavelength whereas symmetric folds require only inflection points that capture the half wavelength. This difference can be explained by the fact that in asymmetric folds, the fold limb rotation angle at the inflection points in the long limbs will be different of those in short limbs. In symmetric folds, the fold limb rotation angle at the inflection points are equal or very close.
- Sampling at the location of the maximum curvature in the hinges are important to constrain the hinges and hence the fold wavelength. However, not well constrained limbs introduced more variability in the fold geometry than not constrained hinges.
- The comparison between the three models ($M_{1,2,3}$, Fig. 1) showed that the cause behind the difference between the models in terms of wavelength recovery, is matter of the structural location of each measurement than just the distance between measurements.

WP #4 – Integrated Geophysical Inversion

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

1. GLoop/Tomofast-related or potentially related journal papers: accepted in Geophysical Journal International and Geophysics.
2. Redaction of paper towards public release of Tomofast-x inversion platform: delayed but will happen.
3. Redefining file formats for I/O to abide by recognized standards, writing of codes for communication between Tomofast-x and other modules.
4. Documentation of Tomofast and 2D simplified version: Nuwan working on editing it and do website.
5. Model Intercomparison Project – discussed in Busselton; model to be chosen/designed in discussion.

WP #4 – Integrated Geophysical Inversion

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

6. Implicit functions (level-set) to define geometries in geophysical inversion: case study performed, paper came back for revisions; working on revised manuscript.
7. Sub-consortium to support student(s) to extend Tomofast application to IP/Res: suitable student not found.
8. Potential new collaboration(s): discussions with Memorial Uni. of Newfoundland.
9. Damien Ciolczyk 's internship (6 month, double degree ENSG-EOST): delayed beginning but otherwise on track. Working on geology-geophysics integration and probabilistic MT + deterministic gravi cooperative modelling.
10. Joint project with CSIRO on probabilistic MT/potential fields integration/LoopStrucutral interpolation. Progress on synthetic case.

WP #4 – Integrated Geophysical Inversion

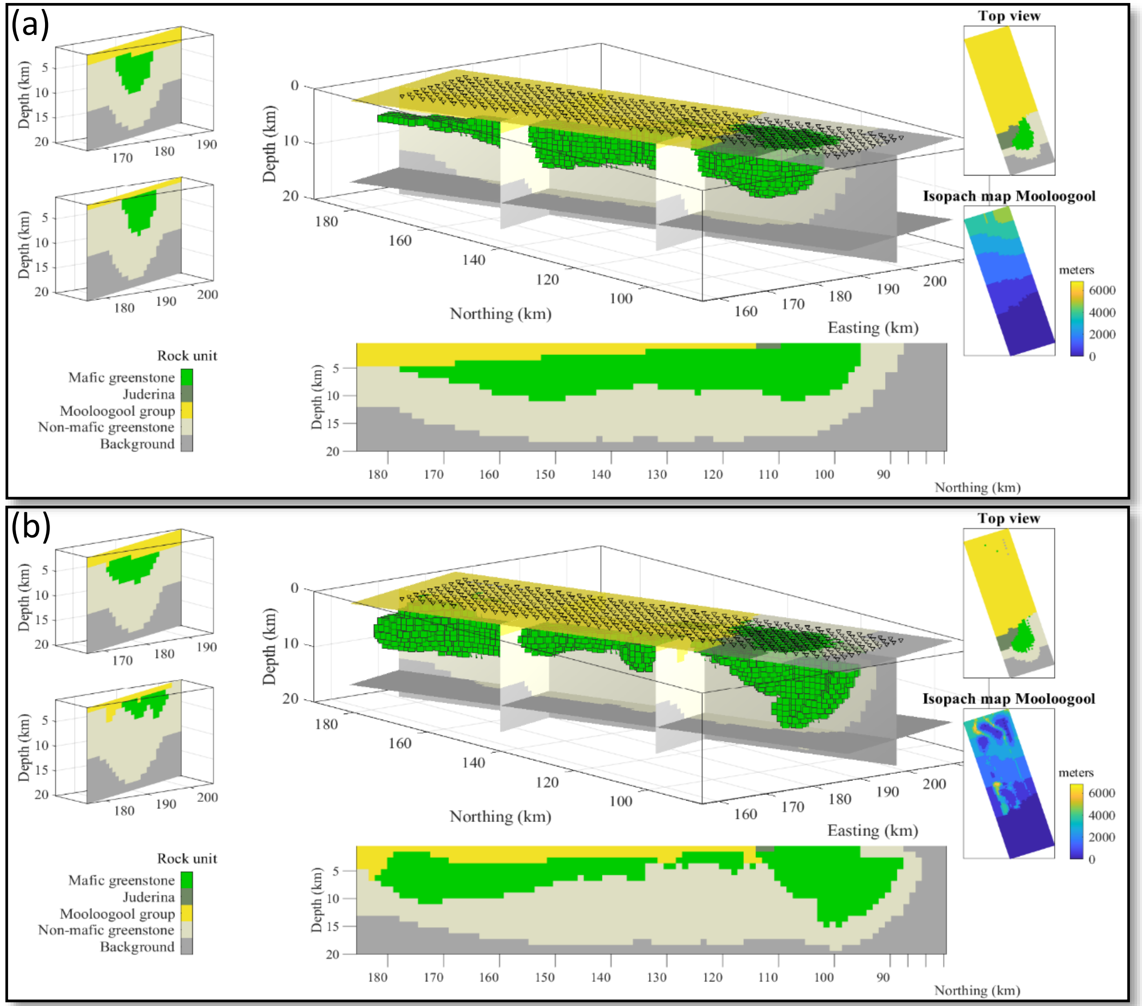
Results of gravity data inversion using level-set formulation of geometries to adjust geological bodies' shapes. Application to greenstone belt from Yerrida basin (WA)

(a) Starting model derived from probabilistic geological modelling alone

(b) Inversion results: geological model deformed and adjusted by level-set inversion of Bouguer anomaly

From Giraud et al. [expected 2020], Generalisation of level-set inversion to an arbitrary number of geological units using a regularized least-squares approach, submitted for publication in Geophysics.

Unpublished material; not for public sharing.

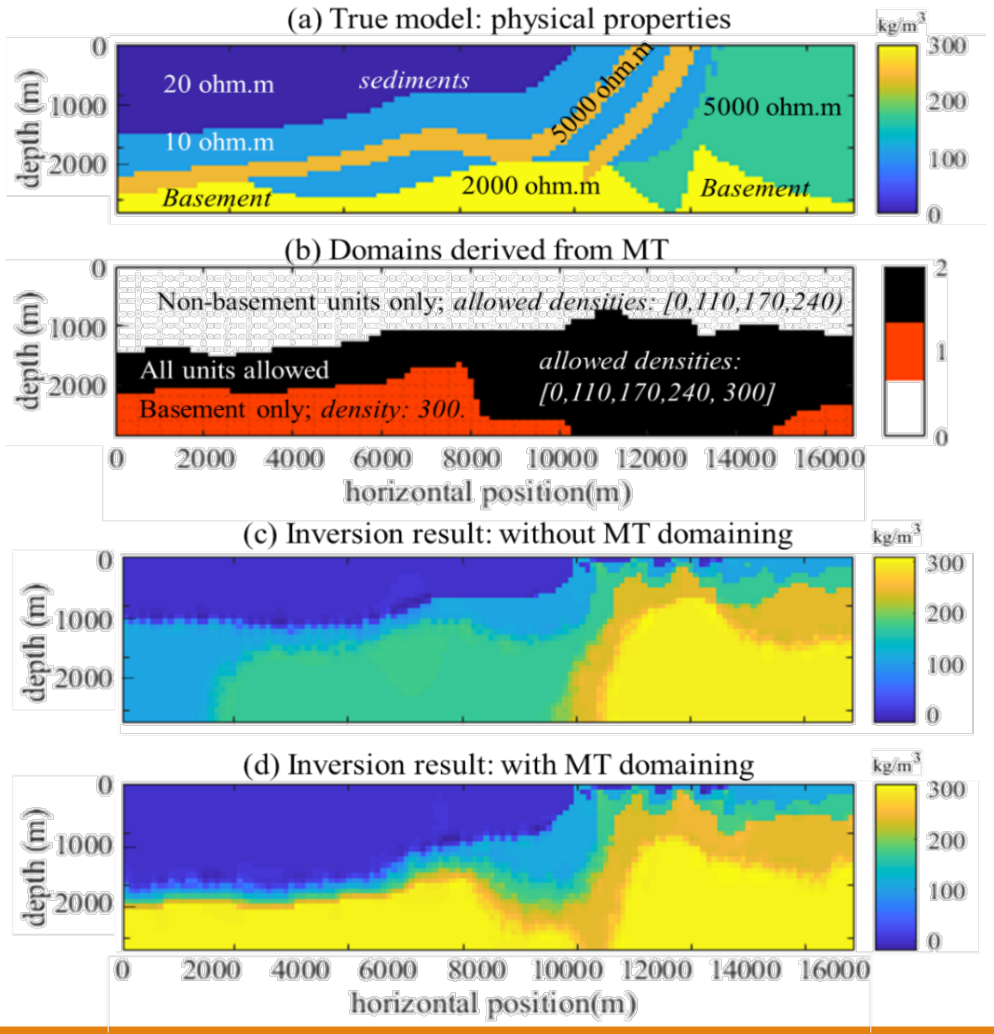


WP #4 – Integrated Geophysical Inversion

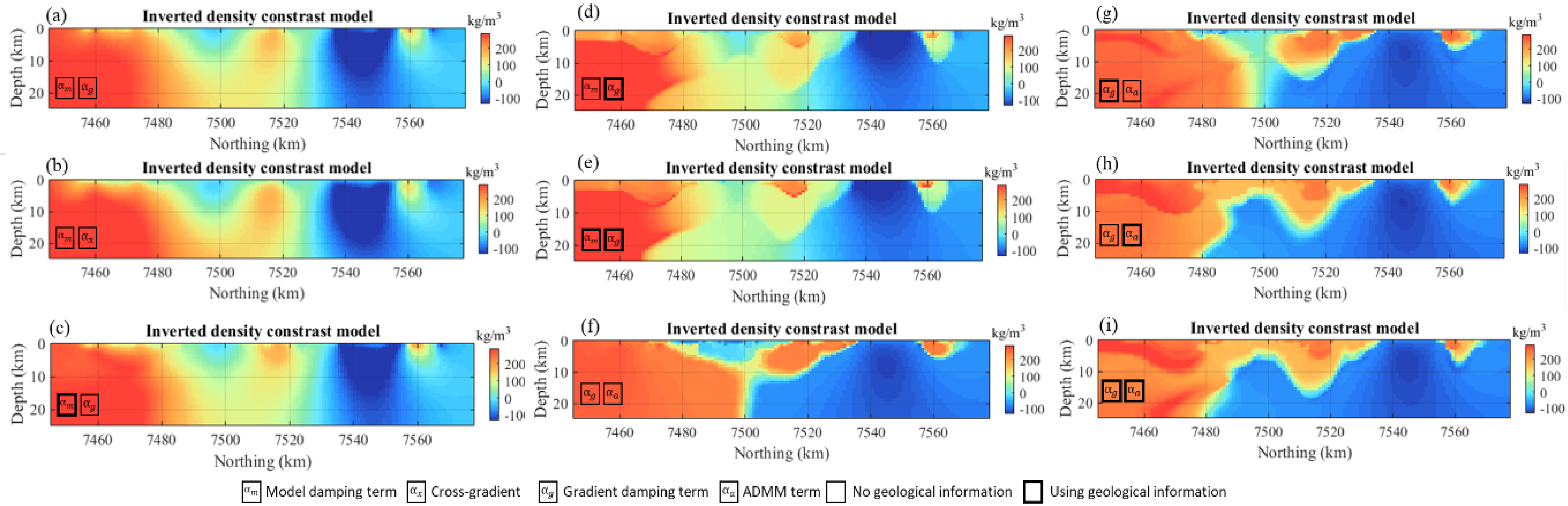
Feasibility study of proposed workflow for the integration of gravity and magnetotellurics data.

Domains are derived from MT probabilities of rock units. Each domain allows a range of densities to be used by gravity inversion accordingly with rock types allowed.

From Giraud et al. 2020 [submitted]. Utilisation of stochastic MT inversion results to constrain gravity inversion, extended abstract submitted to EAGE's
Unpublished material; not for public sharing.



WP #4 – Integrated Geophysical Inversion



Comparison of inversion results for density contrast models recovered using different kinds of constraints from petrophysics and/or geology and/or structural prior information.

From Giraud et al. 2020 [in prep, submission expected in Q4 2020]. Unpublished material; not for public sharing.

WP #5 – Model Analysis & Uncertainty Reduction

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

1. ○ Uncertainty characterization - Guillaume Pirot started September 2nd 2019
2. ● PhD student – Babak Ghane has been offered a place at UWA and has accepted. Awaiting visa approvals
3. ● Ontology development of geophysical methods and mineral systems detection (assoc. with WP1)
4. ● Measuring information loss/change from data upscaling/processing
5. ● Design WP5 analytical framework – aspects related to VoI considered (next slides)
6. ○ Paper preparation: Utility of gravity data with geochemistry to understand basin development
7. ● Paper preparation: Extracting geological knowledge from petrophysics using machine learning on drillcore

Loop

WP #5 – Model Analysis & Uncertainty Reduction

Is work on track against plan? update all deliverables
Work completed ⚪ On track 🟢 Delayed 🟠 Problem 🔴 Will not happen ⚫ New 🔵

8. Paper preparation: Objective assessment of structural geophysical interpretation & impact on 3D uncertainty
9. 3D modelling survey to improve our understanding of modellers needs and uses
10. Letter/paper preparation - 3D modelling and uncertainty quantification: needs and practices in the mining industry
11. Assessing input data quality and uncertainty (from exploratory analysis to data richness, assoc. with WP1 & WP2)
12. Identifying plausible geological scenarios from the Yalgoo-Singleton dataset, based on the probability estimation of spatio-temporal geological events
13. Towards a parametric representation of geological concepts (assoc. with WP2)
14. Reducing prior uncertainty with data integration (additional geological or geophysical data, assoc. with WP1, 2&4)

WP #5 – Model Analysis & Uncertainty Reduction

Is work on track against plan? update all deliverables

Work completed ⚪ On track 🟢 Delayed 🟠 Problem 🔴 Will not happen ⚫ New 🔵

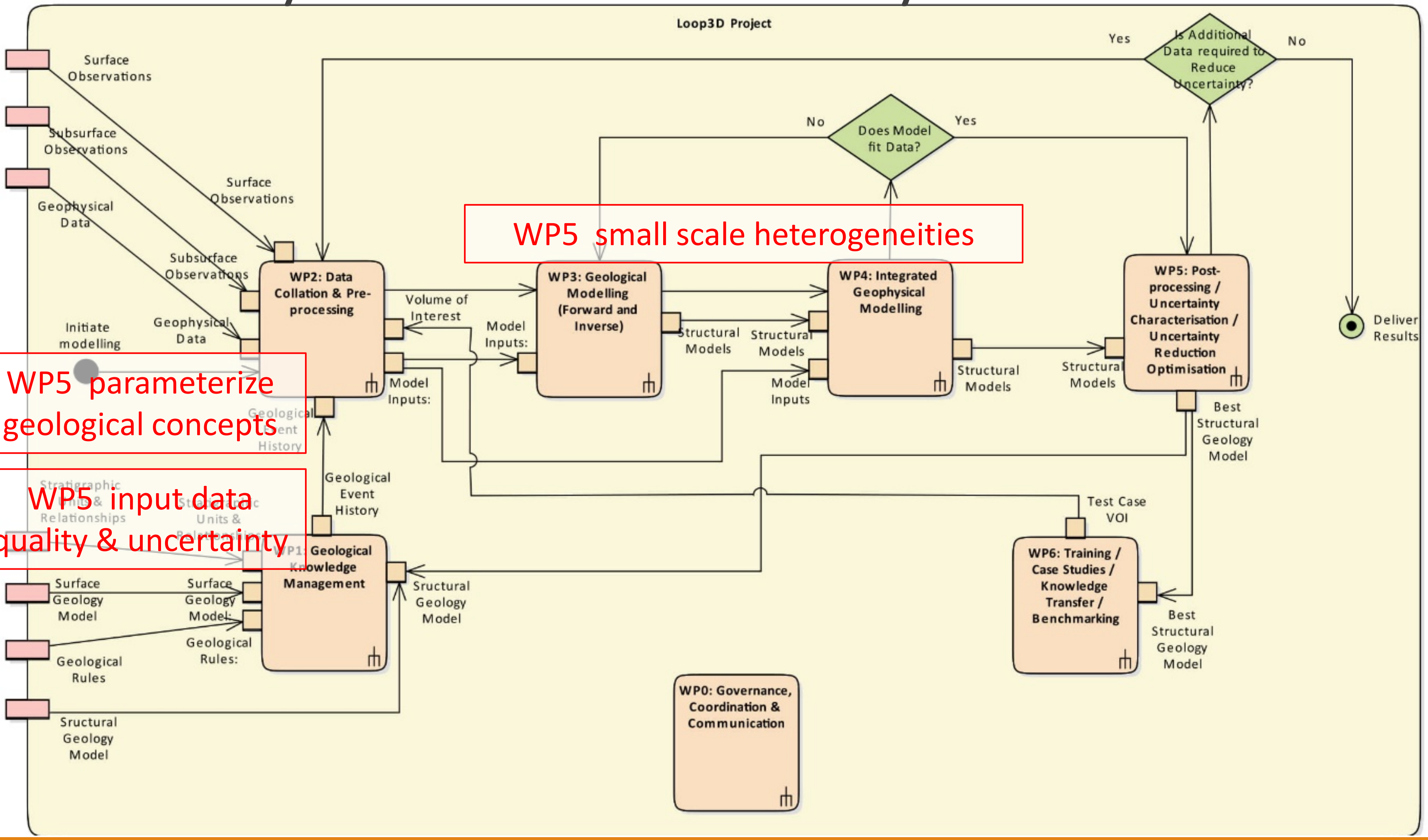
🟠 15. Assessing the effects of hierarchical versus joint inversion on prediction confidence (precision) and bias (accuracy)

🟠 16. Assessing the effects of sampling based versus deterministic driven inversion on prediction confidence (precision) and bias (accuracy)

🟠 17. Importance of small scale heterogeneities: up to what scale does it matters ? (multiple-point statistics, assoc. with WP1, WP2, WP3 & WP4)

WP #5 – Model Analysis & Uncertainty Reduction

WP5 uncertainty reduction with additional gological or geophysical data



WP #5 – Model Analysis & Uncertainty Reduction

Sources of uncertainty
- Errors
- Lack of data
- Unknown

Uncertainty types
- Conceptual (often ignored)
- Parametric and algorithmic (MCMC, CURE-like approaches)
- Stochastic (ensemble modelling)

Objectives
- How does (geological concept) uncertainty affects decision making?
    - Characterize the sensitivity of decision threshold to geological concepts (& other input data, parameters or error)
    - How to define a wide prior of plausible geological scenarios?
    - Improve assessment of input data quality and uncertainty

- Reducing uncertainty (conceptual, parametric and algorithmic prior)
    - Data richness, VoI, where to drill next? what kind of additional geological or geophysical data?
    - Scenario selection via parameter space exploration
    - Bayesian optimization techniques
    - Null-space exploration

- How do methodological choice influence prediction uncertainty?
    - Hierarchical versus joint inversion
    - Deterministic driven versus sampling based approaches
- How and when do small scale heterogeneities matter for mining applications?

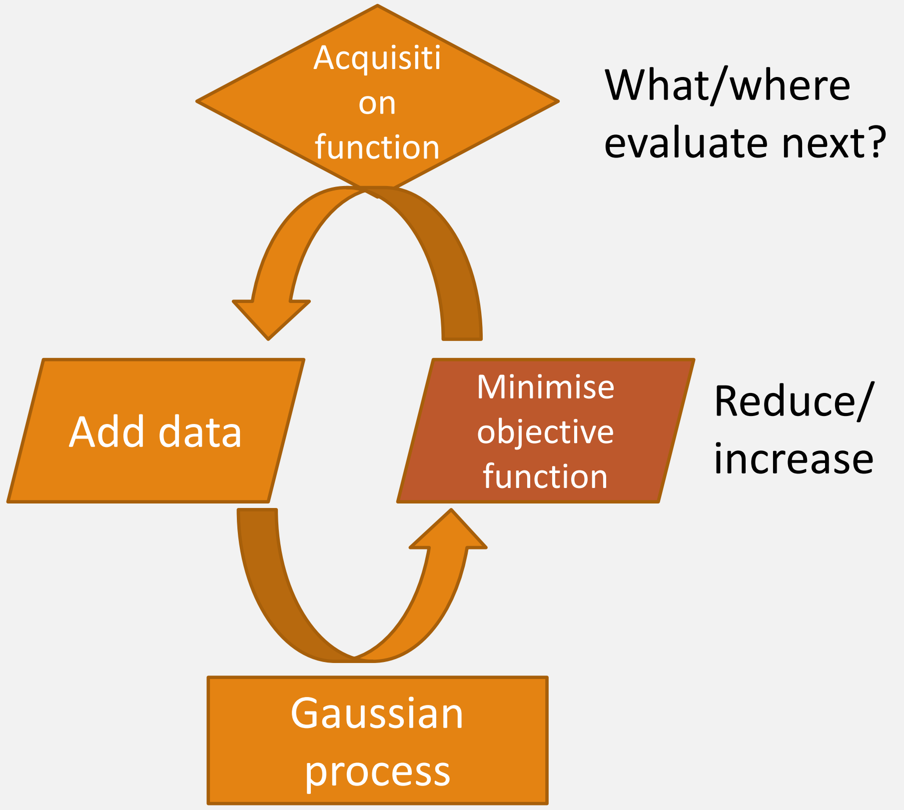
WP #5 – Model Analysis & Uncertainty Reduction

Model engine
Co-kriging (Geomodeller)
Loop Structural
RBF (Leapfrog)

Kriging parameters (global or per formation) Faults not included
Range
Nugget (interfaces, orientations)
Drift degree (0,1,2)
Anisotropy

Bayesian Optimisation

Characterising parametric uncertainty from CURE-like process
Cardinality – Global/Local
Entropy - Global/Local
Spatial entropy - Global/Local
OLS - Global/Local
P1 - Global/Local
Frequency/Probability - Global/Local
Geometric - Geodiversity (Volumes, Surface areas, Depths, neighbourhood relationships) Local
Topology - Multiscale



Ontology (WP1)

? Are we using the right

- Data

for this

- Commodity/ Mineral System

in this

- Region/ Geological domain

Optimising data collection

Remote Sensing
Geophysics
Mapping
Drilling
Geochem

Considering 'Coupling'
e.g. grav and mag
R^2 of the two datasets (simple)

Cost of collection while considering

Logistics <σ
Markets >>σ

OVX – Crude = proxy for logistics
GVZ – Au
VXSLV – Ag
VXGDX – Gold Miners
VXXLE – Energy
Longitudinal Indices
3/6/9/12mth volatility
XGD (ASX allords Au index)

Value of Information

Decision analysis

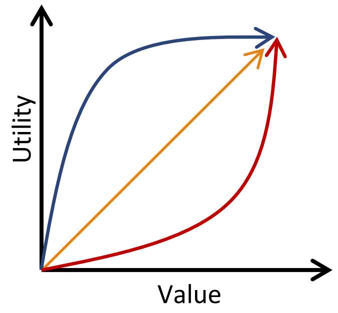
Is the decision process:
Hierarchical?
Flexible?
What sequence is optimal?

Certain Equivalent
(the amount of payoff that an agent would have to receive to be indifferent between that payoff and a given gamble)

This depends on

Risk personalities

- Averse
- Neutral
- Seeking



How do we best communicate this to the decision maker?
There is a tendency for the decision maker to ignore accurate data and information
Can we address this? How to address this?

WP #5 – a Hamersley derived synthetic case

Objective: establish a proof of concept to reduce uncertainty based on the value of information

- Where to drill next? How deep?
- Where to collect more geophysical data
- How fast can geological uncertainty be reduced and stabilized?
- Sensitivity to budget and drilling strategy

Other advantages and challenges of the iterative ensemble modelling approach:

- Mitigate uncertainty underestimation resulting from black-box implicit modelling with fictive pilot drill-holes
- Minimize an iteratively integrated Uncertainty using non-linear multi-objective sampling design
- Ensemble of realizations and reference will be available for further LOOP testing

Agenda

- Define a synthetic reference and prior information (Done)
- Implement pilot drillhole perturbations (Done, improvement in progress)
- Select (Done) and implement the optimization algorithm (Done)

WP #6 – Training, Case Studies & Knowledge Transfer

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

○ 1. Training / Self Tutorial: 'LoopStructural' python library for structural modelling is available to sponsors (email Lachlan Grose to get access to the GitHub – public release mid 2020). This includes Juypter notebooks guiding users through interactive structural modelling workflows. More beta testers required!

○ 2. Loop Workshops:
   - AEGC 2019 conference 2nd-6th September, Perth, WA // Loop/MinexCRC workshop Fri 6th Sep // Workshop on Uncertainty in 3D modelling and Inversion; organised by CET MJ/ML/JG – WP5
   - SGTSG 2019 conference 18th-23th November, Port Lincoln, South Australia // LoopStructural Jupyter notebooks An opt in mailing list was setup at the completion of the workshop with ~30 researchers currently signed up to date // organized by Monash Uni LA/LG/RA // SGTSG LoopStructural workshop successfully completed with 45 participants from academia, geological survey and universities.

○ 3. Visited NTGS to demonstrate LoopStructural and discuss Loop overall including future funding opportunities including in-house case studies and applications.

WP #6 – Training, Case Studies & Knowledge Transfer

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

4. Recruited 3 PhD students to Monash University:
   - Rabii Chaarani to work on the Broken Hill case study looking at the value of structural information in poly-deformed terranes.
   - Fernanda Alvarado: Modelling intrusions: field observations, encoding rules.
   - Marina Jeronimo-Zarate: Integrated geophysical and geological 3D modelling (starting March 2021 – Delayed due to COVID-19).

5. Proposed case study for the Amadeus Basin revised to the Birrindudu Basin in the Northern Territory. NTGS staff member and honours student to be found by early 2021.

6. Proposed visit to the Geological Survey of South Australia in Q2 2019 to discuss SA case study possibilities. Case study proposal - structural mapping (currently underway) in the Tarcoola goldfields. Face to Face meeting not possible due to COVID-19. 2 videomeetings proposed for June 2020.

WP #6 – Training, Case Studies & Knowledge Transfer

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

7. Benchmarking case studies to be developed with ED and established by mid 2019.
8. Plan benchmark paper for comparing existing 3D modelling methods: GC leading this.
9. Develop case study to test fault geometries and apply to geophysical inversion schemes from WP4: Started discussion with JG.
10. Develop a week long course to align with sponsors meeting in mid 2020 for knowledge transfer and feedback to WP1-5.
11. Loop collaboration meeting – UWA/Monash – October 21st to 23rd 2019, Perth. All work programs discussed.
12. Mid Loop progress meeting – 10th to 14th March 2020. In Busselton. Technical sessions, demonstration and hands-on practicals. Map2Loop, LoopStructural, Gloop and uncertainty assessment workflows demonstrated during the meeting.   47 participants

WP #6 – Training, Case Studies & Knowledge Transfer

Is work on track against plan? update all deliverables
Work completed ○ On track ● Delayed ● Problem ● Will not happen ● New ●

13. Develop a program to visit all supporting surveys to develop training and case studies. Ideally a centralized meeting for sponsor surveys proposed but may require one-on-one meetings.

14. A series of video-meetings proposed to sponsors to include: (1) high-level project progress and forward planning including funding; (2) A half day technical workshop (Loopinar) for all interested personnel to outline the software developments to date. Plan to hold these by end of Sep 2020.

15. An advanced video workshop for identified modelling specialists at each survey. This workshop will be hands-on including demonstrations and examples in Jupyter notebook format of the different Loop packages and use of the GUI.

16. Repeat Mid-Loop meeting workshop required for NTGS in mid 2020 due to conference clash in March. 2 videomeetings to be proposed for mid to late 2020.

17. Loop @ GA workshop required mid to late 2020.

WP #6 – Training, Case Studies & Knowledge Transfer

Is work on track against plan? update all deliverables
Work completed On track Delayed Problem Will not happen New

18. Establish a series of training course and source funding opportunities with industry bodies (AusIMM, GSA, ASEG, SEG, IAMG).

19. Development of a 2 day workshop for AESC 8th-12th Feb 2021.

20. Proposed and convene a session on 3D Modelling at AESC Feb 2021

21. Loop focused session for AGU 2020 approved - ‘There’s more than one way to bake a cake; global examples of building interoperable multidimensional geological frameworks’.

22. Proposed videoconference with potential new sponsors (e.g. QLD, TAS, VIC, GNS geological surveys) to outline Loop project progress to date and identify future opportunities.

WP #6 – Training, Case Studies & Knowledge Transfer

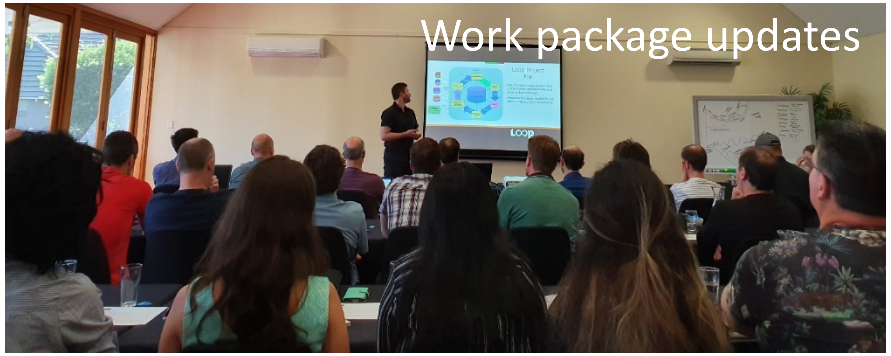
Is work on track against plan? update all deliverables
Work completed ⚪ On track 🟢 Delayed 🟠 Problem 🔴 Will not happen ⚫ New 🔵

- 🟢 23. Website – 2nd version went live 9th April. Update required to fix current format.
- 🟠 24. Establish a calendar of Loop relevant conferences and disseminate to all Loop working groups to increase awareness of the project and outcomes.
- ⚪ 25. Loop generic introduction slides to promote the project. Slide deck to be shared with sponsors to clearly articulate the entire Loop project, leveraging and what sponsors will have access to.
- 🟢 26. Create a Loop related publication folder (dropbox) to share with sponsors.
- 🟢 27. Vision is to have Map2Loop->LoopStructural + potentially uncertainty assessment integrated workflow ready for the AESC 2021
- 🔵 28. Session proposal for SGA 2021 in Rototua, NZ submitted - Automated 3D Geological modelling - new methods and applications from automated data analysis to 3D geological models. Convenors: Robin Armit, Laurent Ailleres & Mark Jessell

Happy memories from the Mid-Loop meeting

The Mid-Loop Meeting was held in early March 2020 in Busselton WA with 50 participants from across the globe. The meeting included 5 days of presentations and hand-ons workshops


Mid-loop participants


Work package updates


Break out sessions

Loop Papers and Conference presentations

- **Papers**
  - de Kemp, E. Submitted. Spatial Agents for Geological Surface Modeling. Mathematical Geosciences.
  - Giraud, J., Lindsay, M., Jessell, M. Submitted. Generalisation of level-set inversion to an arbitrary number of geological units using a regularized least-squares approach. Submitted for publication in Geophysics.
  - Guo, J., Yunqiang Li, Jessell, M., Giraud, J., Li C., Wu, L., Fengdan, L., Shanjun, L, Submitted. 3D Geological Structure Inversion from Noddy-Generated Magnetic Data Using Deep Learning Methods. Awaiting MinEc CRC approval prior to submission to Computers & Geosciences
  - Lindsay, M., Occhipinti, S., Aitken, A., LaFlamme, C., Ramos, L., Submitted. Mapping undercover: integrated interpretation and 3D modelling of a Proterozoic basin. Solid Earth
  - Pirot, G., Joshi, R., Giraud, J., Lindsay, M.D., Jessell, M.W., Ready for Submission. 3D geological modelling in the mining sector: challenges to improve prediction confidence. GMD.
  - Wang, N., Martin, R., Plazolles, B., Chevrot, S., Borisov, D., Ogarko, V., Giraud, J., Monteiller, V., Submitted. On the joint inversion of seismic waveforms and gravimetric anomalies. Geophysical Journal International

Loop Papers and Conference presentations

- **Papers**
  - Martin, R., J. Giraud, V. Ogarko, S. Chevrot, S. Beller, Jessell, M., In Press. Three-dimensional gravity anomaly inversion in the Pyrenees using compressional seismic velocity model as structural similarity constraints. Geophysical Journal International.
  - Ogarko, V., J. Giraud, R. Martin, Jessell, M., In Press. Disjoint intervals bound constraints using the alternating direction method of multipliers (ADMM) for geologically constrained inversions: application to gravity data. Geophysics.
  - Giraud, J., Lindsay, M., Jessell,M., Ogarko, V., 2020. Towards plausible lithological classification from geophysical inversion: honouring geological principles in subsurface imaging, Solid Earth, 11, 419-436.
- **AESC 2021 – Hobart Online**
  - Moro, P., Giraud, J., Ogarko, V., Jessell, M. Lithospheric structure of the Kidson reflection seismic line 18GA-KB1 (Western Australia) from 2D multi-constrained gravity inversion
  - More to come – Deadline Sep 28.

Loop Papers and Conference presentations

- **AGU Fall Meeting 2020 – Online**
  - Ailleres, L., Jessell, M., deKemp, E., Caumon, G., Grose, L., Welmann, F., Armit, R., Brodaric, B., Loop: an Integrated and Interoperable Platform Enabling 3D Stochastic Geological and Geophysical 3D Modelling
  - Alvarado, F., et. al., Modelling of Igneous Intrusions Based on Emplacement Mechanisms
  - Brodaric, B. and Richard, S.M. The GeoScience Ontology.
  - Chaarani, R., et al., The effect of structural data distributions on 3D fold geometries
  - Giraud, J., Pirot, G., Jessell, M., Lindsay, M. Recovering lithology geometries via geophysical data inversion based on a generalized level set approach.
  - Grose, L., et al., LoopStructural 1.0: Time aware geological modelling
  - Parquer, M., de Kemp, E., Brodaric, B., Hillier, M. Automated 3D geological consistency checking: a geomodelling tool.
  - Rashidifard, M. Giraud, J. Lindsay, M., Jessell, M., Ogarko., V. Constrained Gravity Geometry Inversion with Sparse Low-Uncertainty Data.

Loop Papers and Conference presentations

- **Conference Extended papers 2019-2020**
  - Jessell, Mark Lindsay & Vitaliy Ogarko. 2020. Loop 3D geological modelling: speeding up the workflow. GSWA Open Day extended Abstract, Feb 2020.
  - Giraud, J., Lindsay, M., Ogarko, V., and Jessell, M., Sensitivity of constrained geophysical inversion to geological input measurement uncertainty. Extended Abstract, EAGE Annual Meeting London 2019.
- **EAGE "3rd Conference on Geophysics for Mineral Exploration and Mining" 2020 – Submitted**
  - Giraud, J., Seille, H., Visser, G., Ogarko, V., Lindsay, M., Jessell, M. Utilisation of stochastic MT inversion results to constrain gravity inversion, extended abstract.
  - Rashidifard, M., Giraud, J., Ogarko, V., Jessell, M., Lindsay, M. Cooperative inversion of seismic and gravity using a weighted structure-based constraint, extended abstract

Loop Papers and Conference presentations

- **EGU General Assembly 2020**
  - Caumon, G., Godefroy, G., Marchal, P., 2020. Fault network uncertainty assessment with a generative graph-based algorithm – Current status and perspectives.
  - Collon, P., Rongier, G., Parquer, M., Clausolles, N., Caumon, G., 2020. Uncertainty assessment in subsurface modeling: considering geobody shape and connectivity in complex systems
  - de la Varga, M., Wellmann, F., 2020. Probabilistic Machine Learning in Structural Geology
  - Giraud, J., Seillé, H., Visser, G., Lindsay, M., Jessell, M., 2020, Utilisation of stochastic MT inversion results to constrain potential field inversion, https://doi.org/10.5194/egusphere-egu2020-15067
  - Grose, L., Laurent, G., Ailleres, L., 2020. Using structural frames to integrate structural geology into implicit 3D modelling
  - Rashidifard, M., Giraud, J., Ogarko, V., Lindsay, M., Jessell, M., 2020, Cooperative inversion of gravity and seismic data with different spatial coverage

Loop Papers and Conference presentations

- **RING 2019**
  - Grose et al., Fault modeling kinematics
- **AEGC 2019**
  - Grose et al., Integrating fault kinematics into implicit 3D modeling of fault networks
- **SGTSG, 2019**
  - Ailleres et al., overview of the Loop project
  - Lindsay, M., Spratt, J., Aitken, A.R.A., Occhipinti, S., Dentith, M. (2019) A multiscale investigation of a gold mineral system in the eastern Yilgarn SGTSG2019
  - Giraud, J., M. Lindsay, V. Ogarko, M. Jessell, Geology and geophysics-based lithological classification for structural interpretation in the Yerrida basin (Western Australia), SGTSG
  - Giraud et al., Integration of geology and geophysical inversions
  - Grose et al., Fault modelling using kinematics
  - Joshi et al., Multiscale 3D geological modelling

Loop Papers and Conference presentations

- **Other - Submitted**
  - Lindsay, M.D., Jessell, M.W., Pirot, G., Giraud, J. 2020 Optimising the Collection of Geoscientific Data with Uncertainty Analysis, AOGS, Hongcheon, S. Korea
  - Lindsay, M., Occhipinti, S., Aitken, A., LaFlamme, C., Ramos, L., 2020, Mapping Undercover: Using Integrated Potential Field Interpretation, Inversion and 3D Modelling to Assess Basin Prospectivity, 2020, AOGS, Hongcheon, S. Korea
  - Lindsay, M.D., Jessell, M.W., Pirot, G., Giraud, J., 2020, Just add data: if only it were that simple Target2020, Perth, Western Australia
  - Lindsay, M.D., Spratt, J., Aitken, A.R.A., Occhipinti S.A., Dentith, M., Shragge, J. 2020 An Integrated Multi-Scale Study of Crustal Structure and Prospectivity of the Eastern Yilgarn Craton and Adjacent Albany-Fraser Orogen, MRIWA Report 476, p.180
  - Pirot, G., Joshi, R., Jessell, M., Lindsay, M., 2020. From geological data and historical scenarios to conceptual models, Subsurface 2020 conference

Loop Visitors

Visitors to CET

- Damien Ciolczyk, MSc Eng. Student doing internship remotely School and Observatory of Earth Sciences (Strasbourg, France), to perform joint geologically constraints geophysical modelling using Loop tools.
- Roland Martin (CNRS/Université Paul Sabatier, Toulouse, France) visited from 16 to 27th March. Focus on applying techniques developed in inversion platform Tomofast-x.
- Ashwani Prabhakar: 3 month internship to work on testing TOMOFASTx inversion codes (WP5) Complete, draft manual available.
- Clement Barriere: 2 month internship to work on TOMFASTx code. Jupyter notebook version of 2D tomofast near completion.
- Li Zhen Cheng: 6 month visiting scholar to work on integrated geology/geophysics inversion (WP5)
- Jiateng Guo: 12 month visiting scholar to work on building massive 3D database for 3D models and their geophysical response for Machine Learning
- Prototype map2model code allows fully automatic 3D model construction from geological maps (Mark Jessell & Vitaliy Ogarko), with internal UWA workshop held in Feb 2020 as preparation for Busselton workshop
- The UWA Loop group was part of a research collaboration that has been awarded a $10M grant to build a graduate school in Data Analytics for Resources and Environments (DARE), the project will be led by Prof Sally Cripps and will have multiple hubs with the lead at Sydney University.
- Nishka Piechocka to work part-time at UWA in 2020 on building a 3D model of the Hamersley Basin using Loop technologies thanks to new MRIWA funding for a CSIRO-led project.

Loop Github content

Repository

- Richard, S.M. (2020) Loop3D GeoScience Ontology, Loop3D Technical Report. https://github.com/Loop3D/GKM/blob/master/Draft1.1Report.docx.
- LoopStructural
- map2loop
- Dh2loop

- Details and more to come in the next quarterly report.