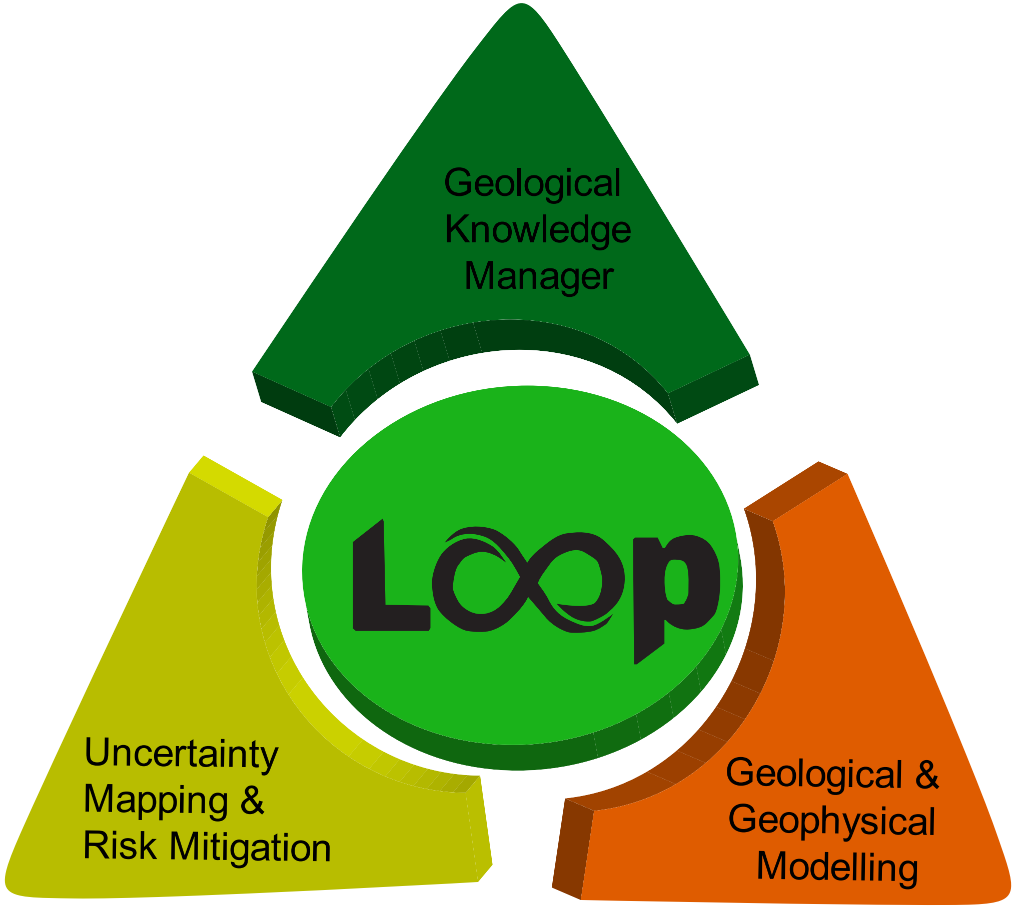
An integrated and interoperable platform enabling 3D stochastic geological modelling

Quarterly Report #10
May 2021

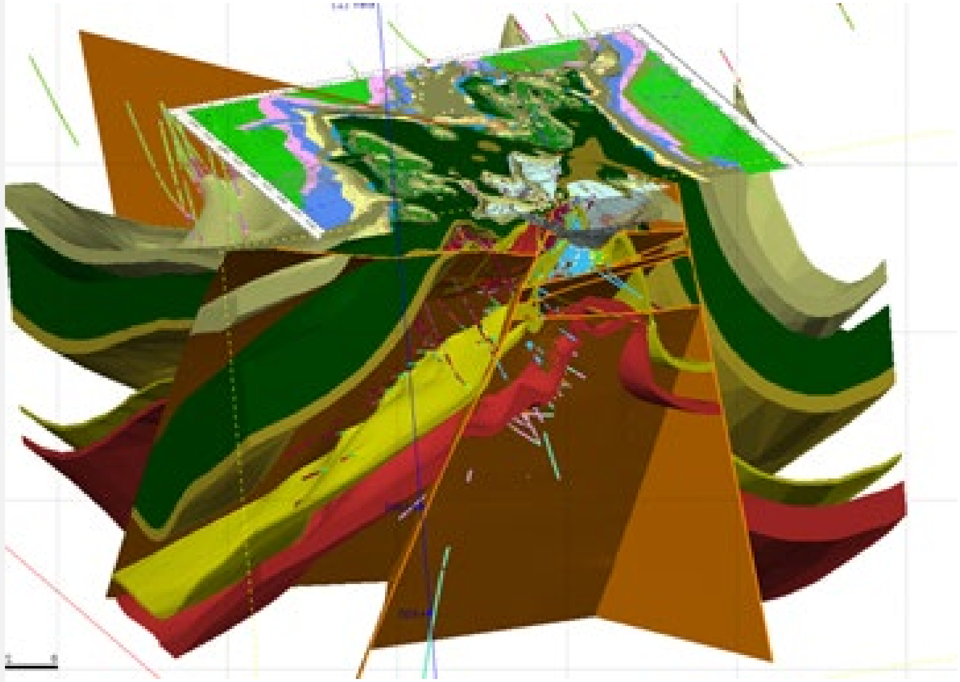


Loop – Why a new platform?

- 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

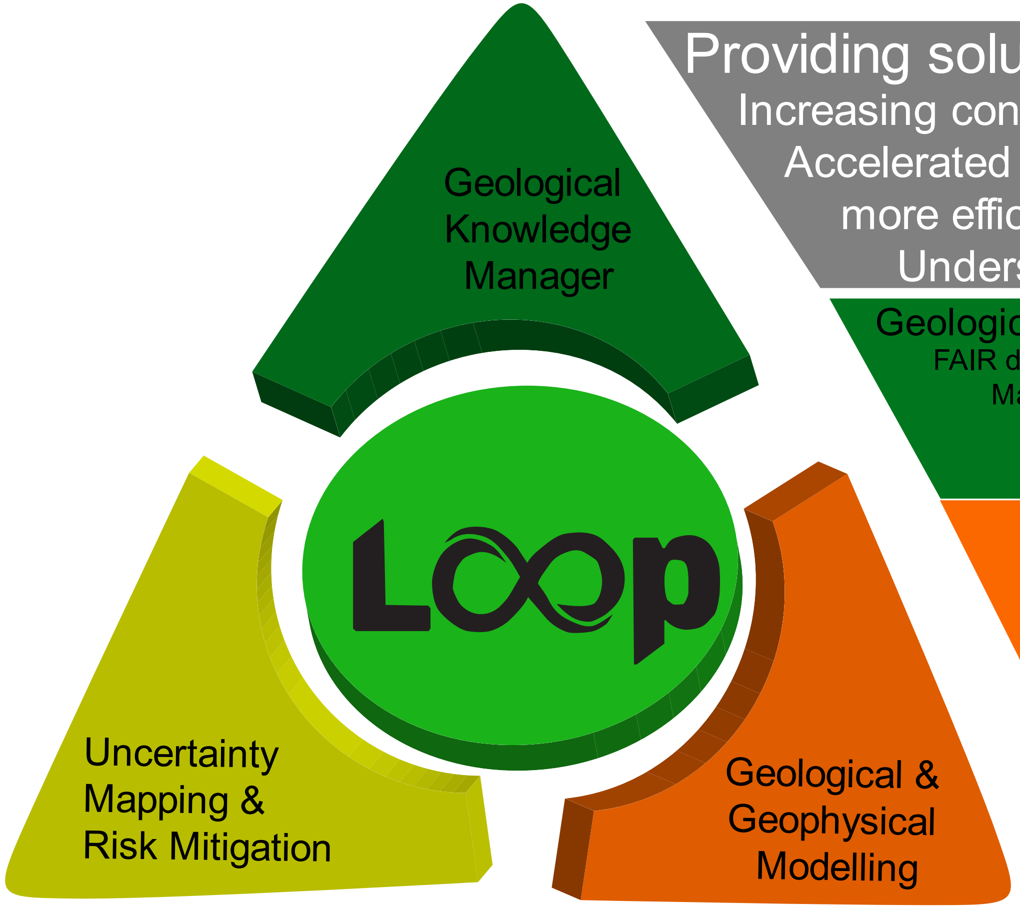
- **Open-source is the future**
  https://github.com/Loop3D/LoopStructural



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

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

* 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

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 / Commission géologique du Canada · MICROMINE · BHP

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 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

Welcome to New Partners in the ARC LP200301341 – "Loop - Enabling Interoperable, Integrated & Probabilistic 3D Geological Modelling" *application*.
Let's hope we get funded!!

New Partners

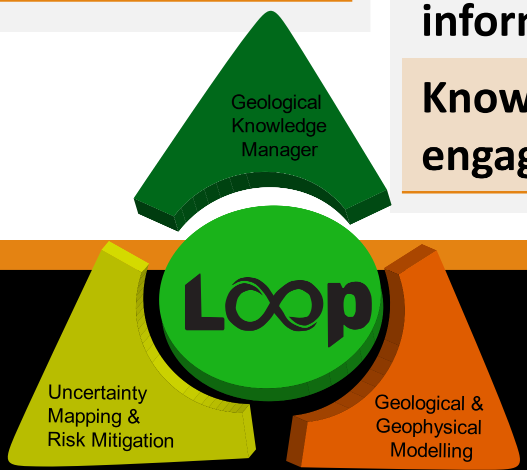
Governance

One Steering Committee:

Chair	Carina Kemp (Aarnet)
Monash – Lead CI	Laurent Ailleres
UWA / MinEx CRC	Mark Jessell
AuScope	Tim Rawling
Geoscience Australia	Steve Hill
GSWA / State and Territory Surveys of Australia	Klaus Gessner
BRGM / OneGeology	Matthew Harrison

Research and Development team:

Lead Chief Investigator	Laurent Ailleres (Monash)
Senior Software Architect	Roy Thomson (Monash)
Geological Knowledge Manager	Boyan Brodaric (Geol. Survey Canada)
map2lopp (pre-processing)	Mark Jessell (UWA)
LoopStructural	Lachlan Grose (Monash)
Geophysical integration and modelling	Jeremie Giraud (UWA)
Uncertainty & value of information	Guillaume Pirot & Mark Lindsay (UWA)
Knowledge transfer & community engagement	Robin Armit (Monash)



Highlights THIS Quarter

Staff movement:

- We are sad to see Jeremie Giraud and Mark Lindsay leave from UWA to fortunately go to more stable position. I, on behalf of the entire research and sponsors team, would like to thank them both for their work in Loop, their contribution to scientific discussions, the development of innovative methods for geophysical modelling and uncertainty characterisation and their invaluable contribution to students's supervision.
  - Mark is gone to CSIRO where he is the “Science Leader – Minerals 4D” bridging the gap between geology / exploration and data analytics. Mark remains on an adjunct position at UWA as well and promises to remain involved as much as he can.
  - Jeremie is joining the Universite of Lorraine, in the RING group, where he has taken up a prestigious “EU Marie Curie” post-doctoral fellowship. Jeremie will remain involved as well in Loop

Highlights THIS Quarter

Staff movement:

- We are also sad to see Marion Parquer finish her post-doctoral work at the Geological Survey of Canada. Similarly, I, on behalf of the entire team, would like to thank her for her innovative development of the 3D geological consistency checker and her scientific contribution in general.
- Marion has taken up a position at Universite de Lorraine as well and promises to remain involved as much as she can. We look forward to further collaboration with her!!

- In better news, Vitaliy Ogarko will join UWA to work on the MinEx opportunity funding OP6. Vitaliy Ogarko, one of the original authors of TOMOFAST and of map2model (the topology engine in map2loop) will commence at UWA 1st July 2021. Please join me in welcoming (back) Vitaliy to the team.

Highlights THIS Quarter

- The Geoscience Ontology has been released (B. Brodaric and S. Richard)! Have a look on the Loop3d.org website under publications / data are also available under “downloads”
- The GeoSwarm has been released (E. de Kemp) – loop3D.org under downloads. Eric has a paper in discussion in GMD also available form loop3.org under publications.
- Two Auscope Opportunity funding grants were submitted in June
- A surge in papers in discussion or now published in the Special Issue of Geosci. Model Dev.
- PhD candidate Fernanda Alvarado models the Voisey’s Bay intrusion!! See p.70 of this report
- The Loop application is making awesome progress – see p.29 and the download section of Loop3d.org
- Guillaume Pirot generalises the concept of ensemble generation to Loop and proposes a mitigation method for the underestimation of uncertainty using pilot-sticks (see the next slide)

Funding and Resources

Funding and Resources – Current Applications

ARC LP200301341 Enabling Interoperable, Integrated & Probabilistic 3D Geological Modelling – imminent announcement

Auscope Opportunity Funding: 2 x applications – outcome known in Jul-Aug 2021

- *3D uncertainty quantification cloud compute facility* – to support cloud computing of Loop stochastic uncertainty quantification.

- *A Bayesian approach to building a continental-scale fault network of Australia* – to develop a Bayesian framework for the analysis of faults geometry, offset and kinematics from maps.

Current Funding

Project 6- Automated 3D geological modelling

$1.2M Project 6 – CRC + $540K awarded March 2021
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*

Loop

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

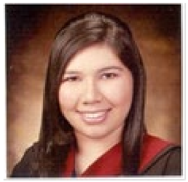
- Monash Uni: Laurent Ailleres, Robin Armit, Peter Betts, Sandy Cruden, Tiangang Cui, Jerome Droniou
- UWA: Mark Jessell, Mark Lindsay (now a DECRA Fellow)
- RING – Nancy, FRA: Guillaume Caumon
- RWTH Aachen, GER: Florian Wellmann
- GS of Canada: Eric de Kemp
- BGS - UK: Matthew Harrison (now with BRGM)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

Loop

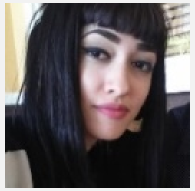
People – leverage of collaborative research in open source

- 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: Rachel Heaven, Edd Lewis, Russell Lawley, Katherine Royse (CDO BGS)

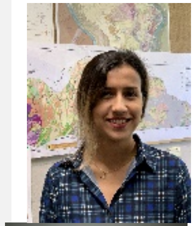
The most important resource: People! (PhD)



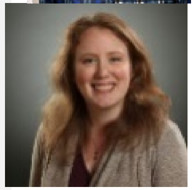
- Multi-scale 3D modelling Yalgoo–Singleton greenstone belt (Ranee Joshi, 21/1/2019) (MinEx CRC scholarship)



- 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)

The most important resource: People! (PhD)

- 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)

Loop

WP #0 – Infrastructure // Software Development

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

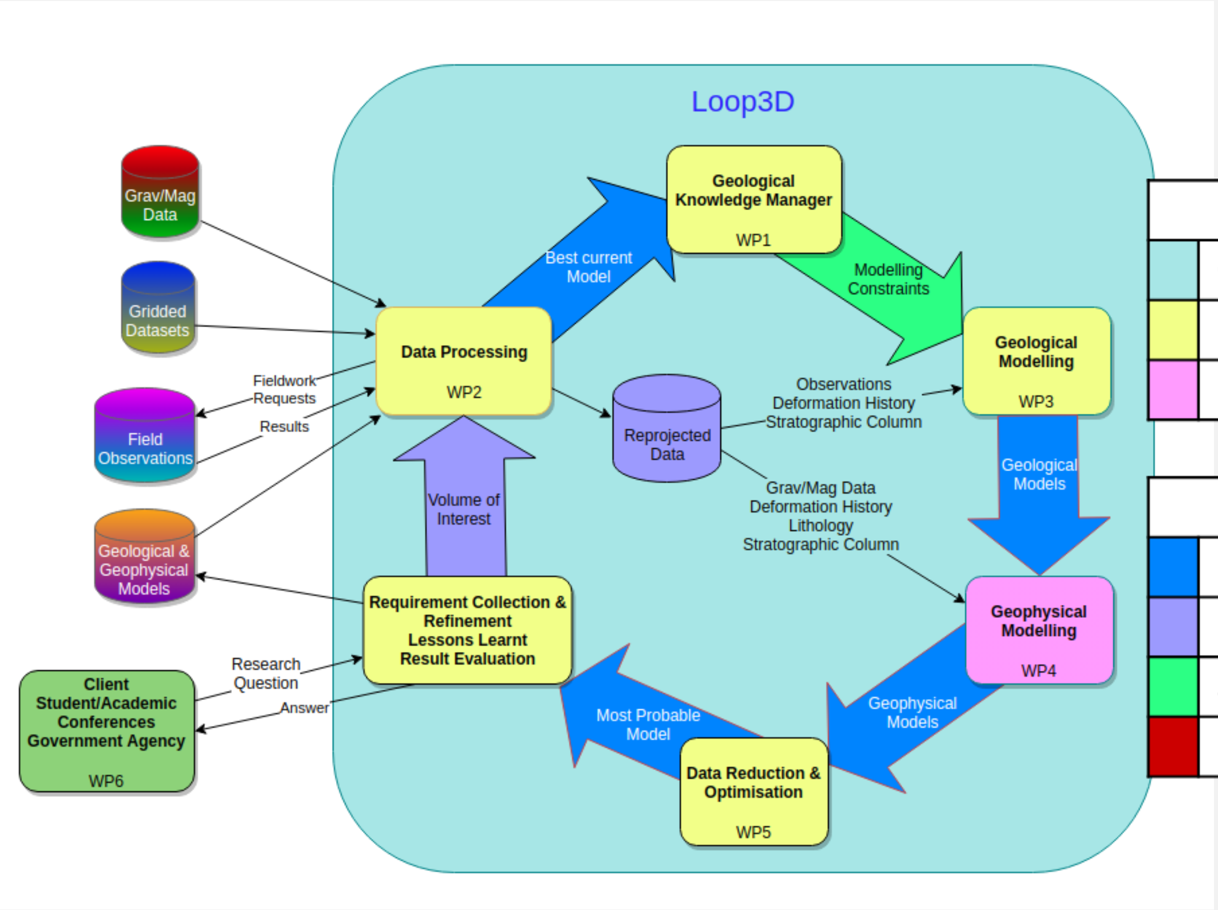
7. Report on redefinition of the work packages / report of meeting / Distributed via email, google drive and slack
8. Software architecture: First-pass UI design complete and data passing from online sources, re-projected, sampled, used in forward inverse structural modelling and displayed, incorporating new version of map2loop
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.
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. Software architecture: (ongoing) Incorporation of additional WP software modules and also online data sources (GADDS2, OneGeology)
15. Implementation of parallel processing of python modules within GUI including optimisation
16. Full access to configuration options of Data Collection and Geological Modelling steps within GUI
17. Demonstration and first release of GUI software in mid March 2021
18. Rework graph of stratigraphic column ordering and permutations, adding extracted event relationships
19. Addition of custom data import/export functionality

WP #0 – Infrastructure // Software Development



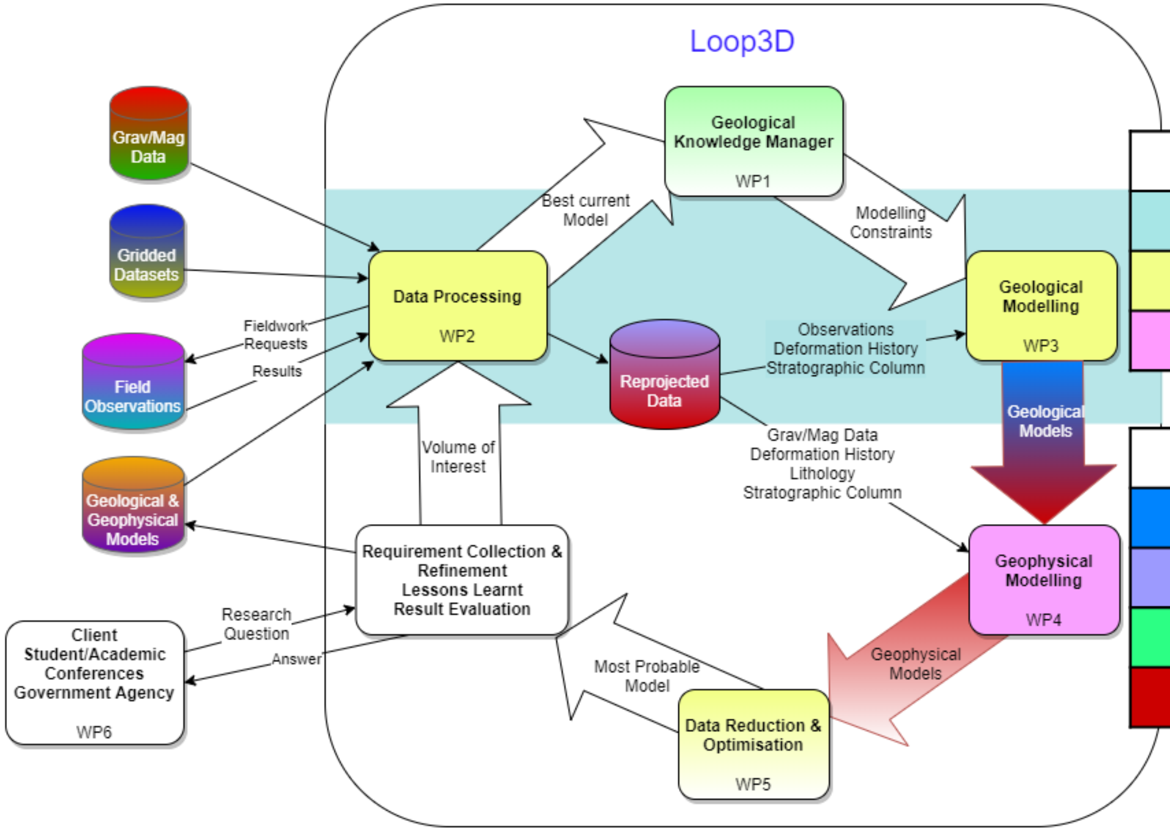
Language
C/C++
Python
Fortran

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

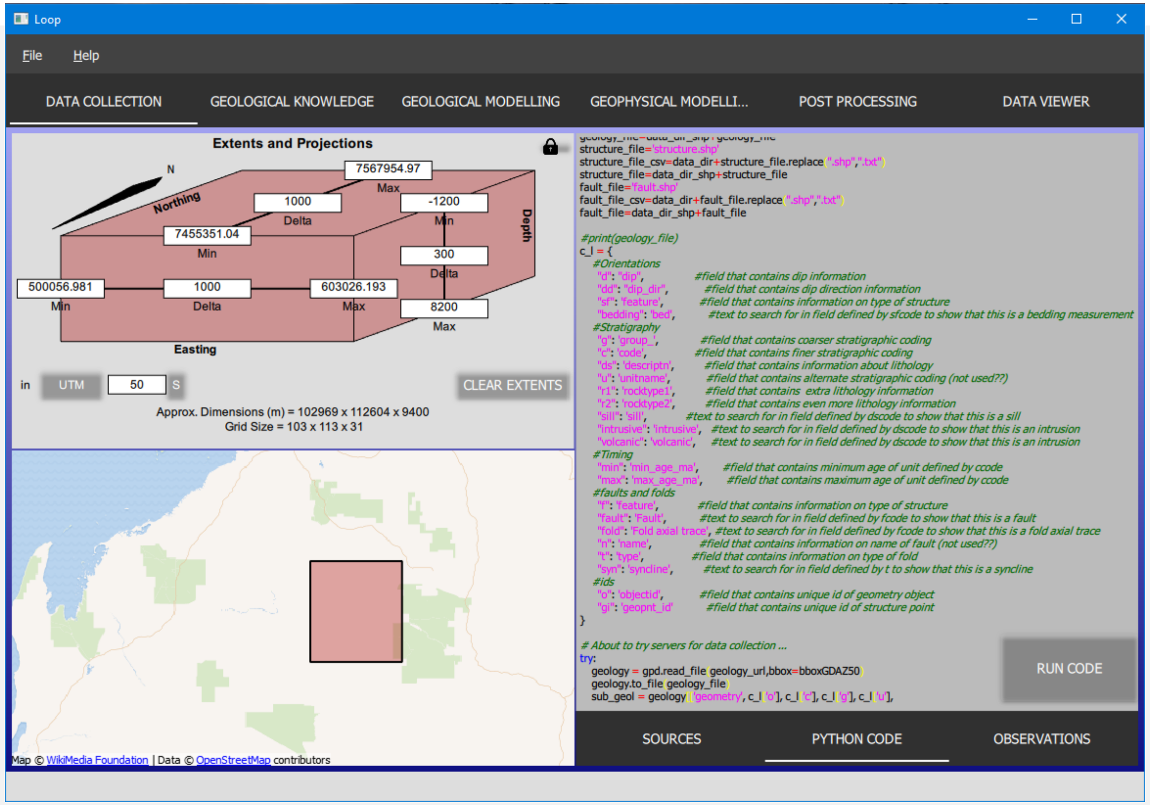


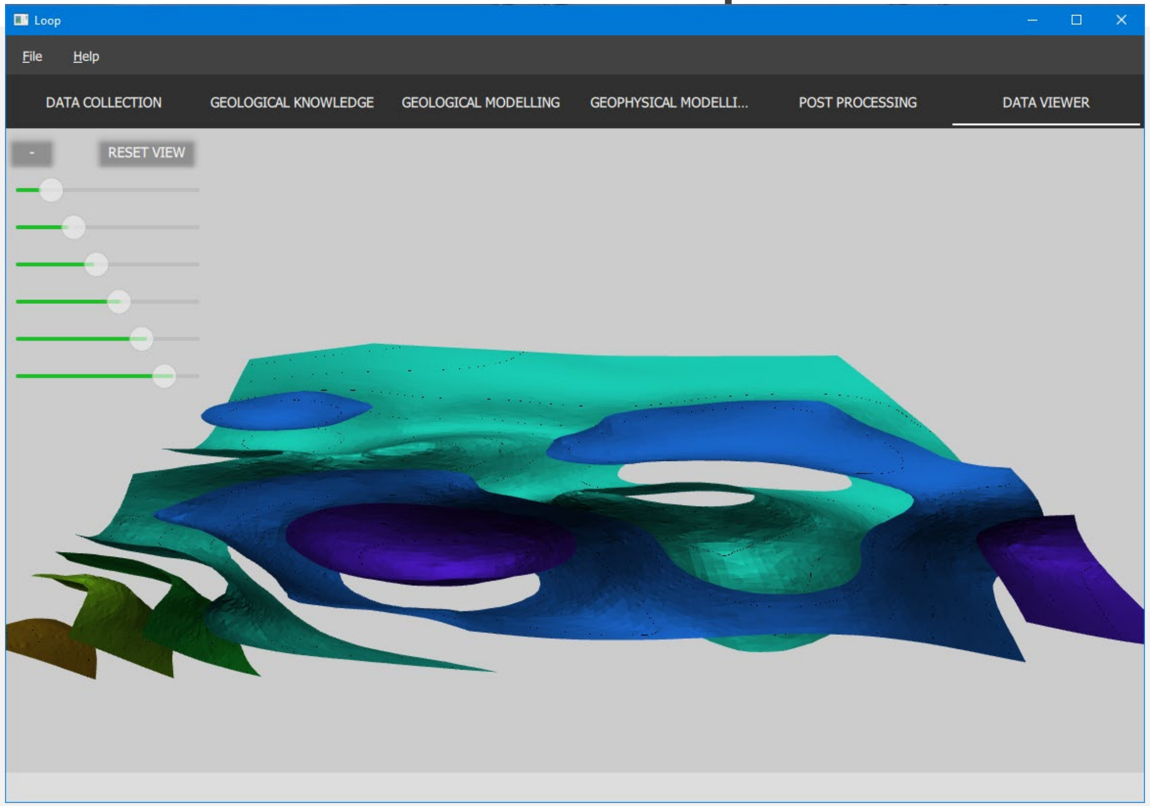
Language	
	C/C++
	Python
	Fortran

Data Type	
	3D
	1D Pointcloud
	SparQL
	Plain Text

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

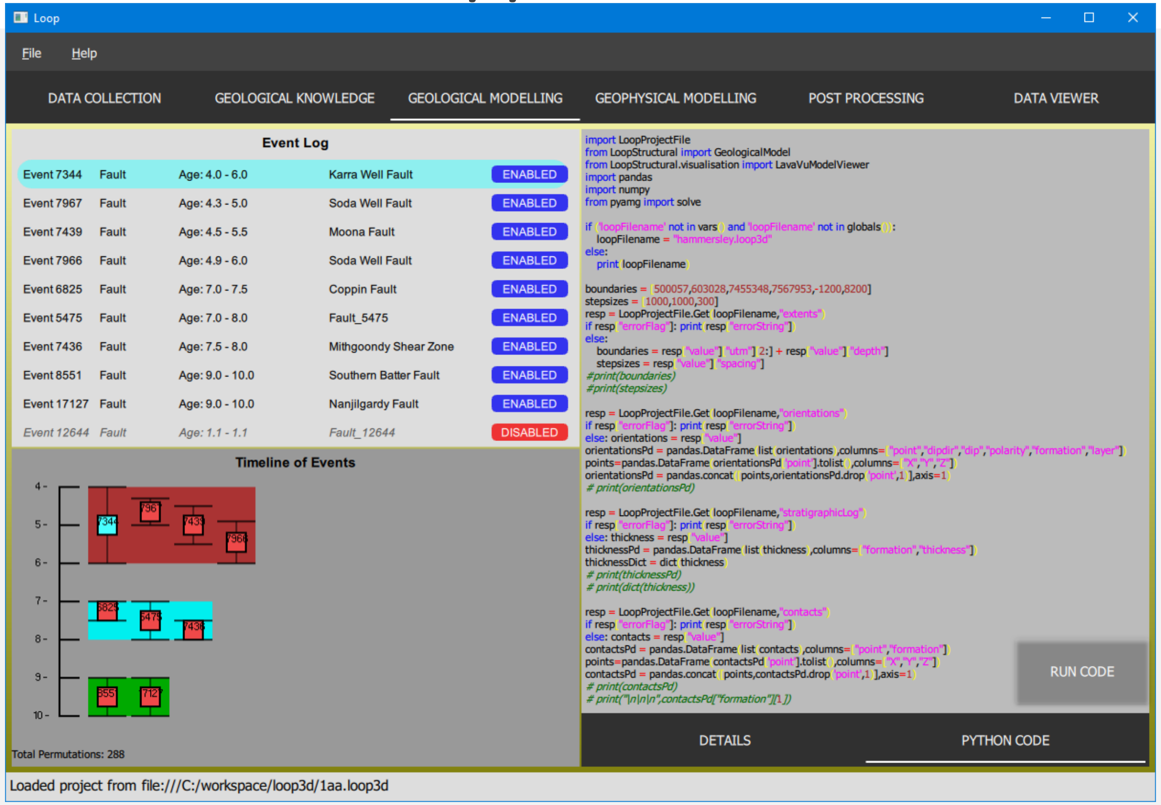
WP #0 – Infrastructure // Software Development





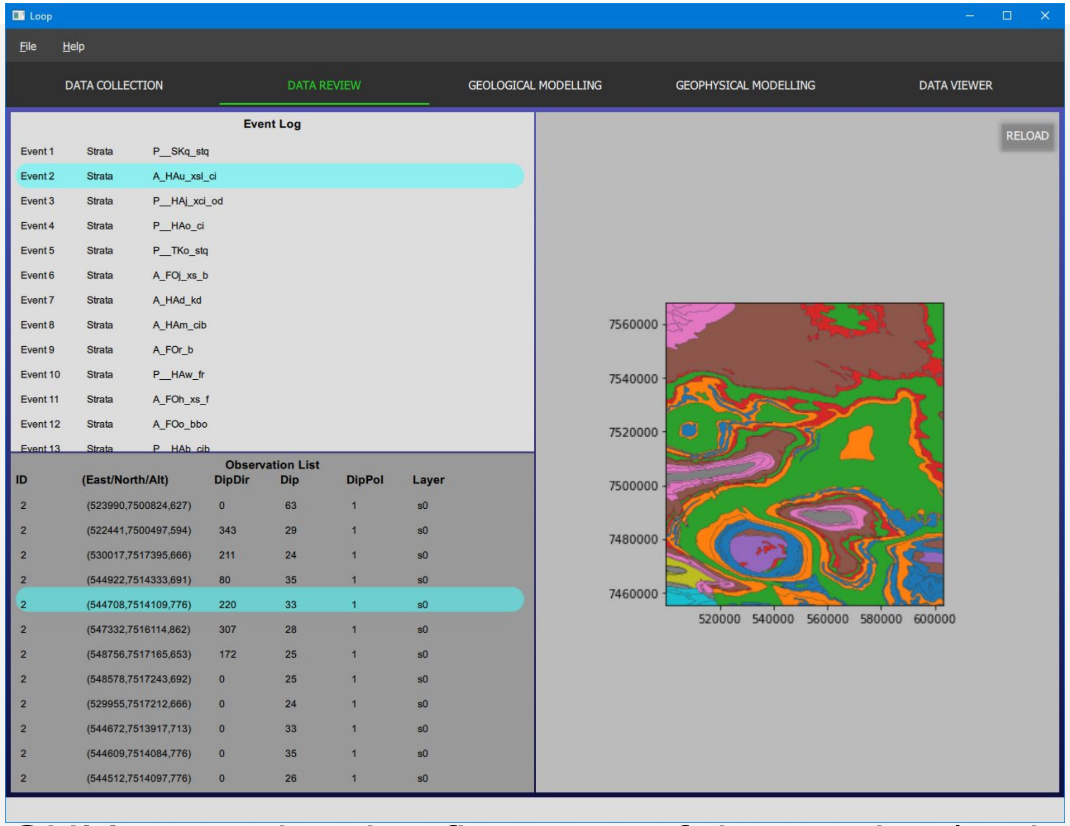
Left – GUI in construction showing the workflow to modelling. First step: setting the model volume of interest and running WP2 map2loop to extract data for modelling (WP #1 & 2).
Right: iso-slices through a first pass LoopStructural model of the Hammersley Group.

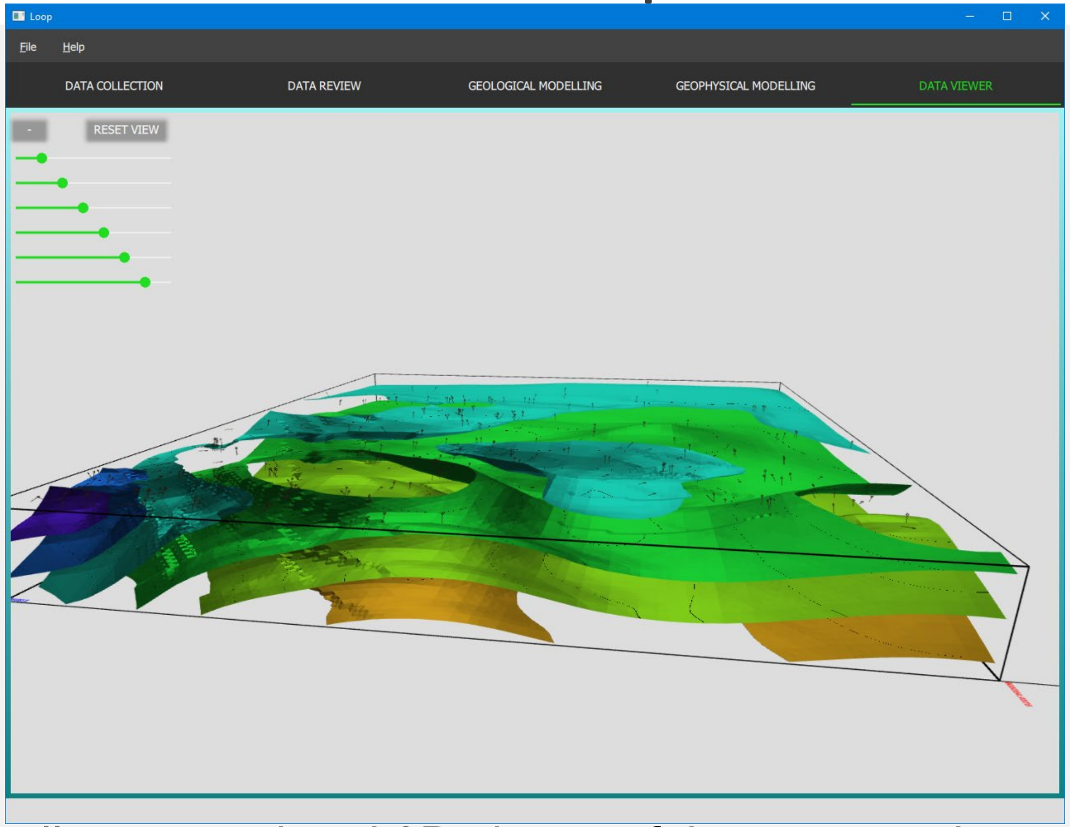
WP #0 – Infrastructure // Software Development



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

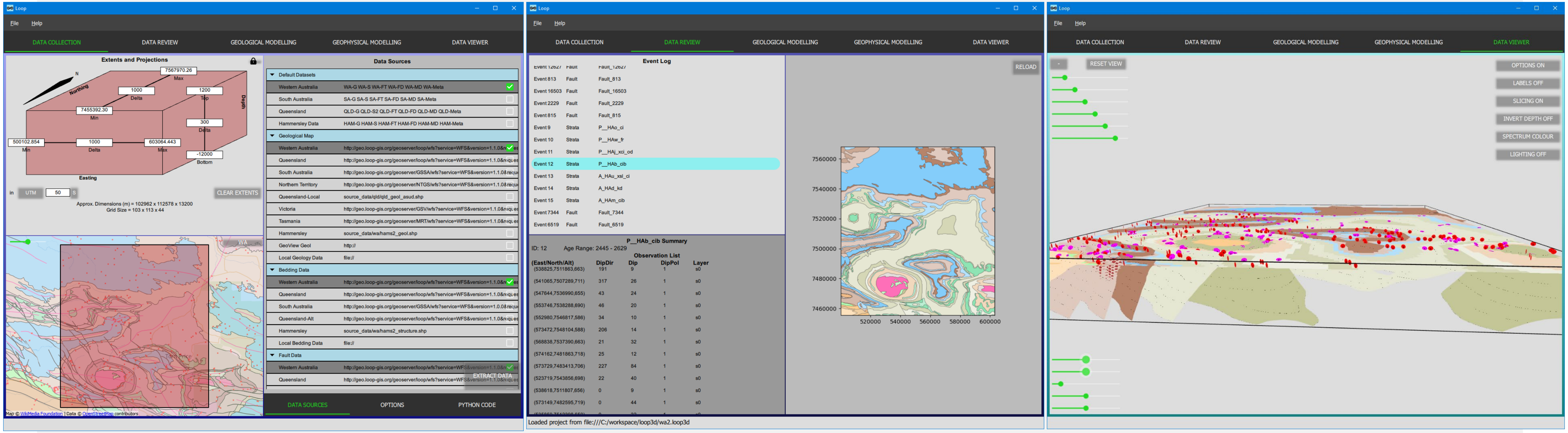
WP #0 – Infrastructure // Software Development





GUI Image showing first pass of data review/update UI as well as an updated 3D viewer of the same region with observation arrows

WP #0 – Infrastructure // Software Development



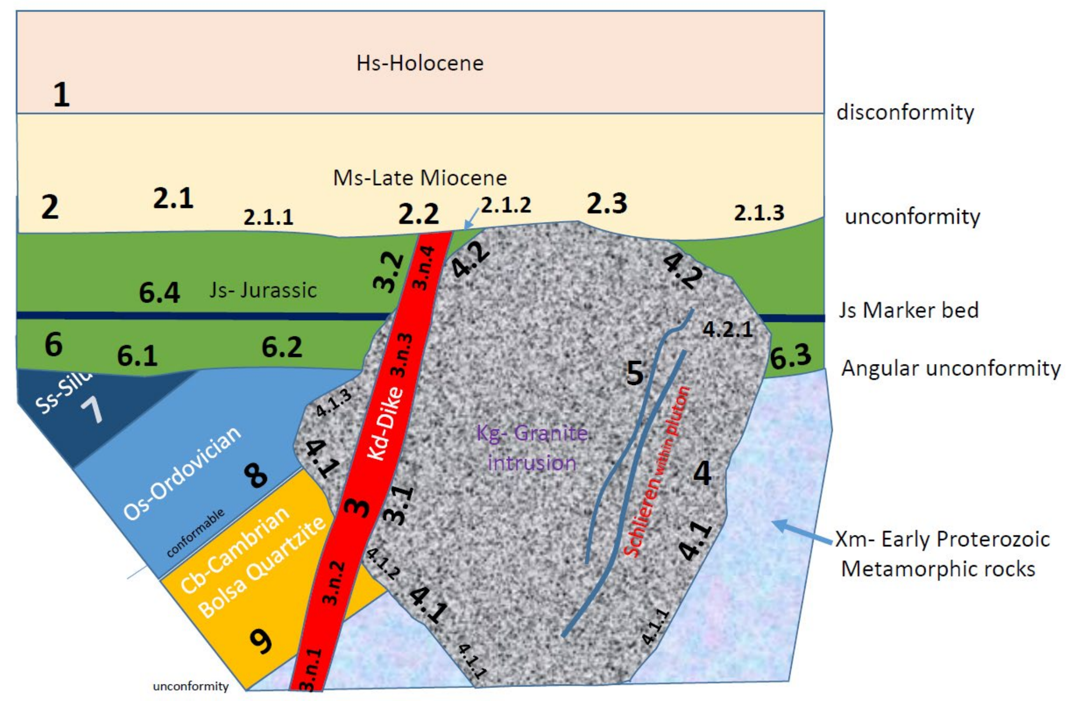
GUI Image showing sequence of data from collection -> review -> 3D model with slicing volumetric data

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

- Particular
  - Endurant
    - Feature
      - Dynamic_Feature
      - Inherent_Feature
      - Integral_Feature
      - Part_Feature
      - Spatial_Feature
    - Inherant
      - Quality
      - Role
    - Physical_Endurant
      - Amount_Of_Matter
      - Physical_Object
    - Situation
      - Geologic_Setting
    - Spatial_Region
  - Perdurant
    - Event
    - Process
    - Time_Region
      - Time_Instant
      - Time_Interval

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, F
        ] ;
      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

Loop3D GeoScience Ontology

Version 1, Draft 2020-08-31 11:37 AM

Stephen M. Richard, US Geoscience Information Network smrTucson@gmail.com
Boyan Brodaric, Geological Survey of Canada boyan.brodaric@canada.ca

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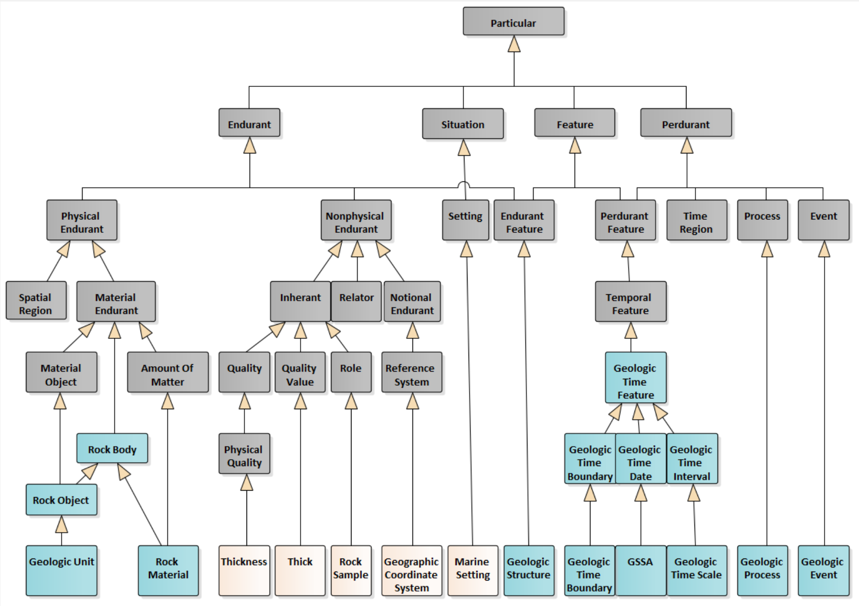
GSO documentation v1

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

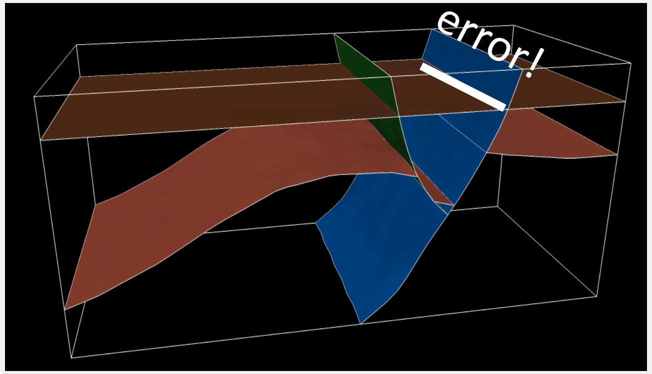
Task 5: progress on GSO content – developed petrophysical examples, with more planned.

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

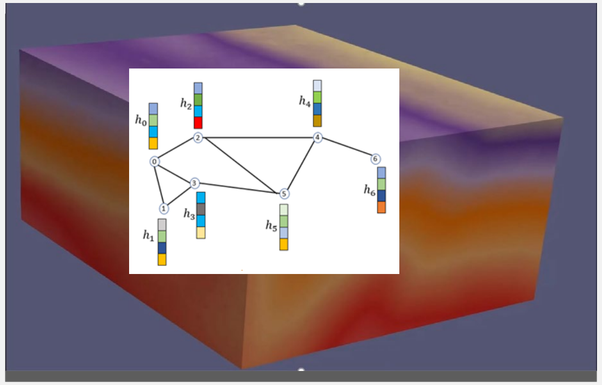
WP #1 – Geoscience Knowledge Manager



GSO top-level



3D Model Consistency Checker



3D GNN Modeller

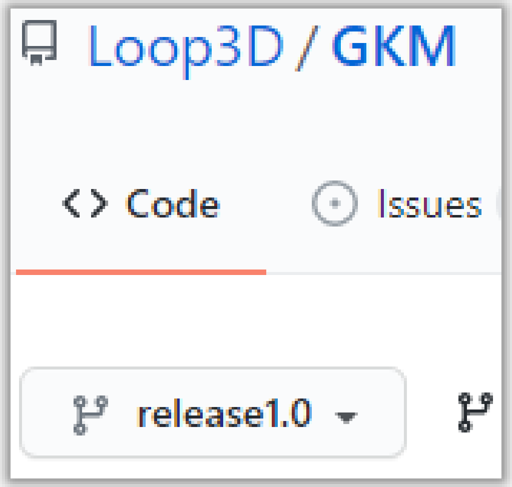
Task 4: progress on GSO development – major refinements completed; reference document completed.

Task 5: progress on GSO content – refined test examples.

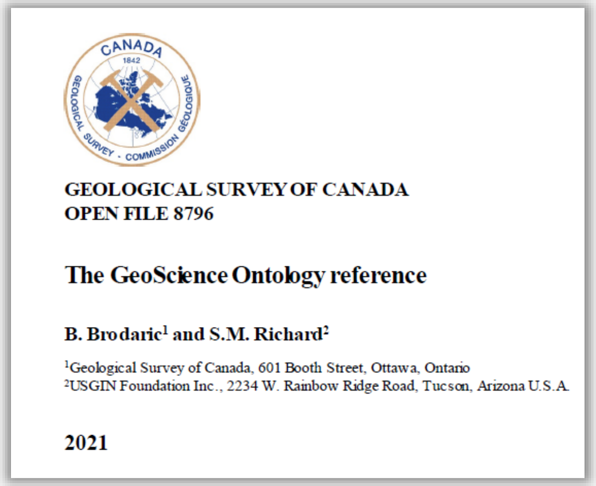
Task 6: evaluate GKM access and explore *usage scenarios* – consistency checker and GNN modeller prototyped.

WP #1 – Geoscience Knowledge Manager

Public release of the GeoScience Ontology (GSO)



public GitHub


CANADA
1842
GEOLOGICAL SURVEY · COMMISSION GÉOLOGIQUE

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8796

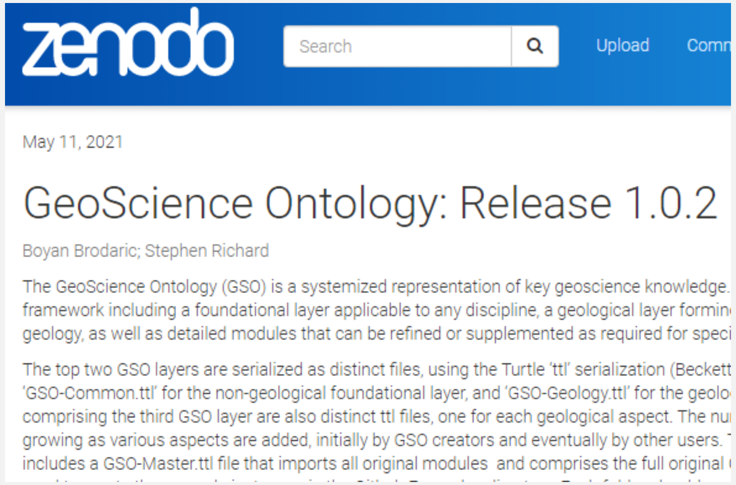
The GeoScience Ontology reference

B. Brodaric[1] and S.M. Richard[2]

[1]Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario
[2]USGIN Foundation Inc., 2234 W. Rainbow Ridge Road, Tucson, Arizona U.S.A.

2021

published reference



published ontology files

Task 4: progress on GSO development – public release of GSO: (1) Github, (2) reference doc, (3) ontology files.

Task 5: progress on GSO content – further refined test examples.

Task 6: evaluate GKM access and explore *usage scenarios* – published GNN modeler paper, refined algorithm.

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 – HR News and new project

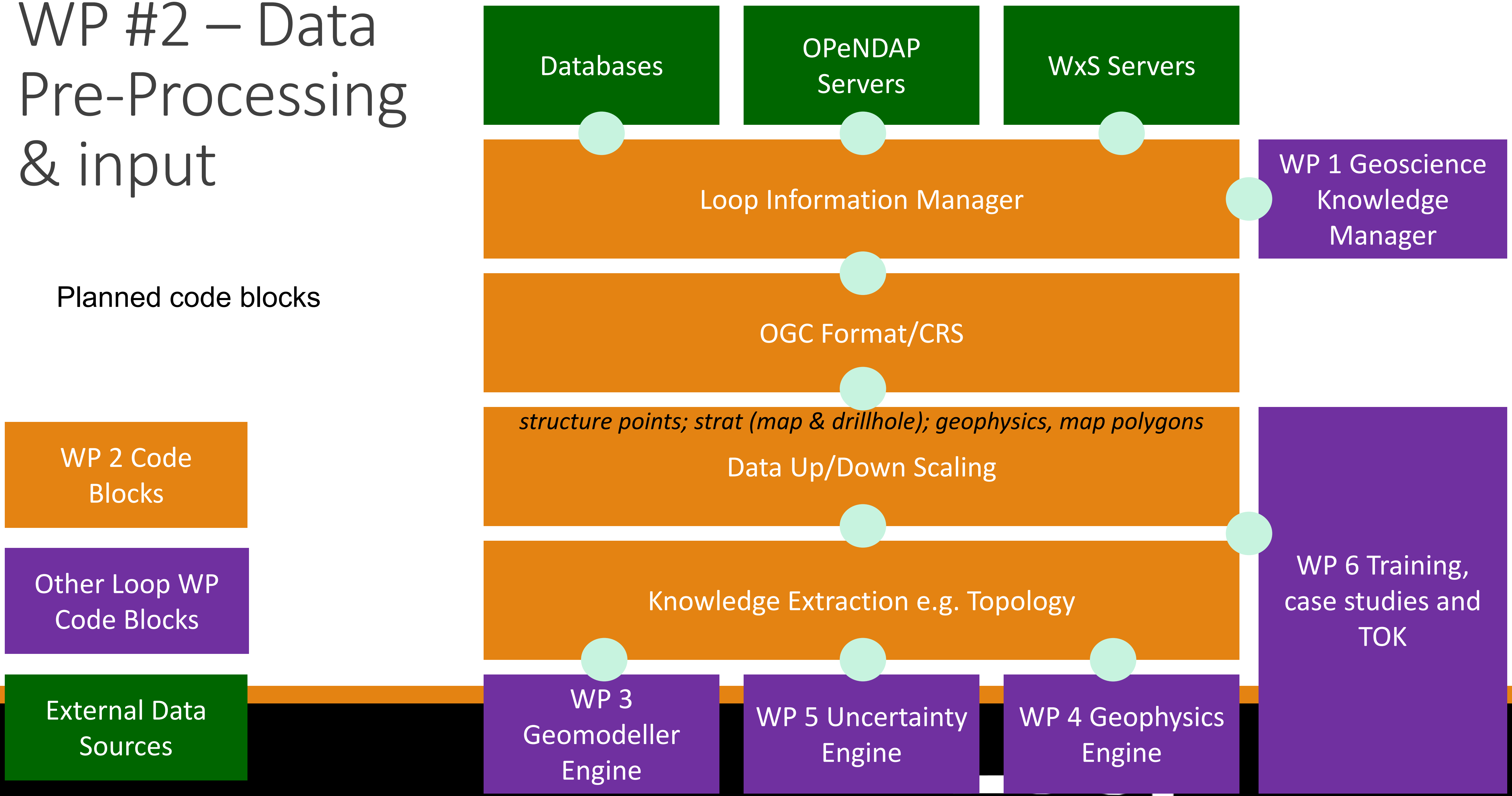
HR News from WP2: MinEx Opportunity Fund OP6 hires **Vitaliy Ogarko**

The project *RECOVERY OF LITHOLOGICAL AND STRATIGRAPHIC DATA FROM DRILLHOLE DATABASES* has been funded to support a programmer at DataCode in India and a 3-year postdoc at UWA. Legacy and new drillhole data are a key constraints for geological understanding and subsequent 3D prediction. Company databases held by Australian Geological Survey Organisations (GSOs) contain complexly coded lithological information, but limited stratigraphic data. This project will develop Open Source algorithms automating the extraction of lithological and stratigraphic data.

Vitaliy Ogarko, one of the original authors of TOMOFAST and of map2model (the topology engine in map2loop) has been hired and will commence at UWA 1st July 2021.

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

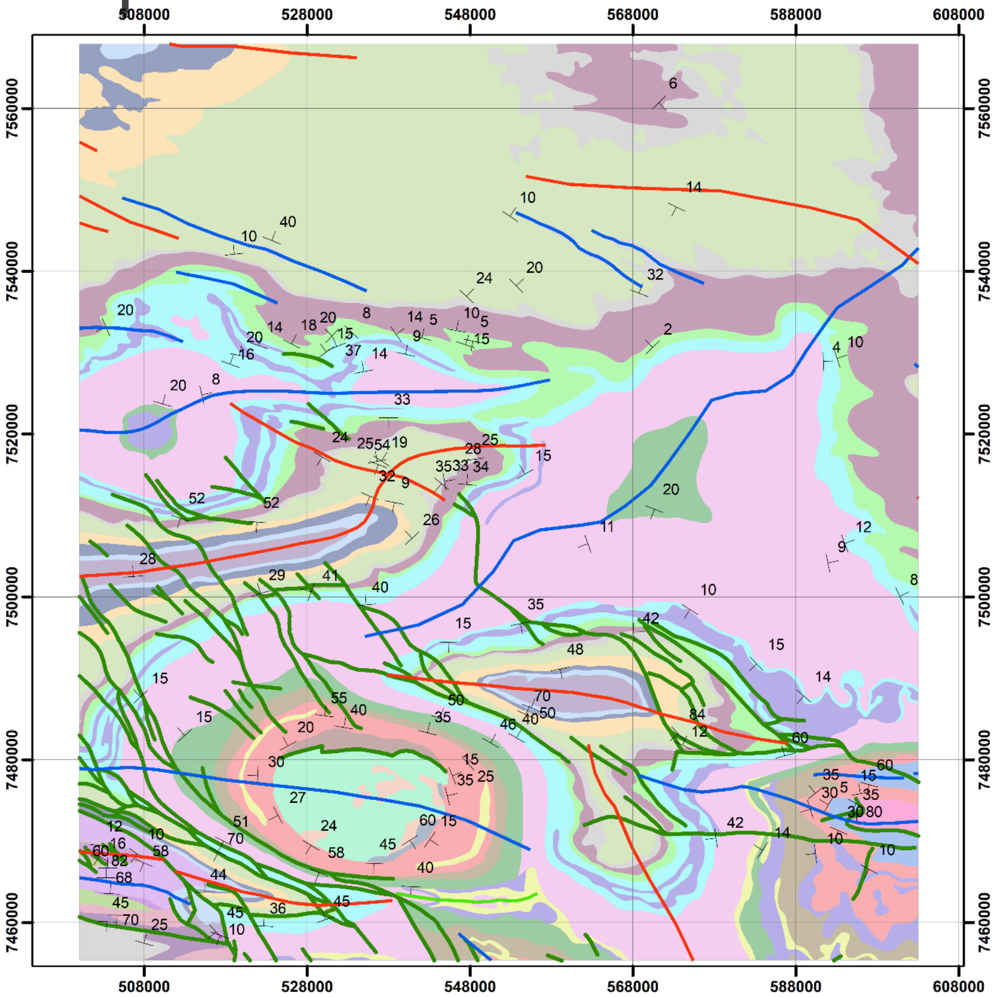
- In this (first) example we have developed python & C++ codes to automatically derive the input data needed to produce ***gempy, geomodeller and LoopStructural (WP #3)*** models

- 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

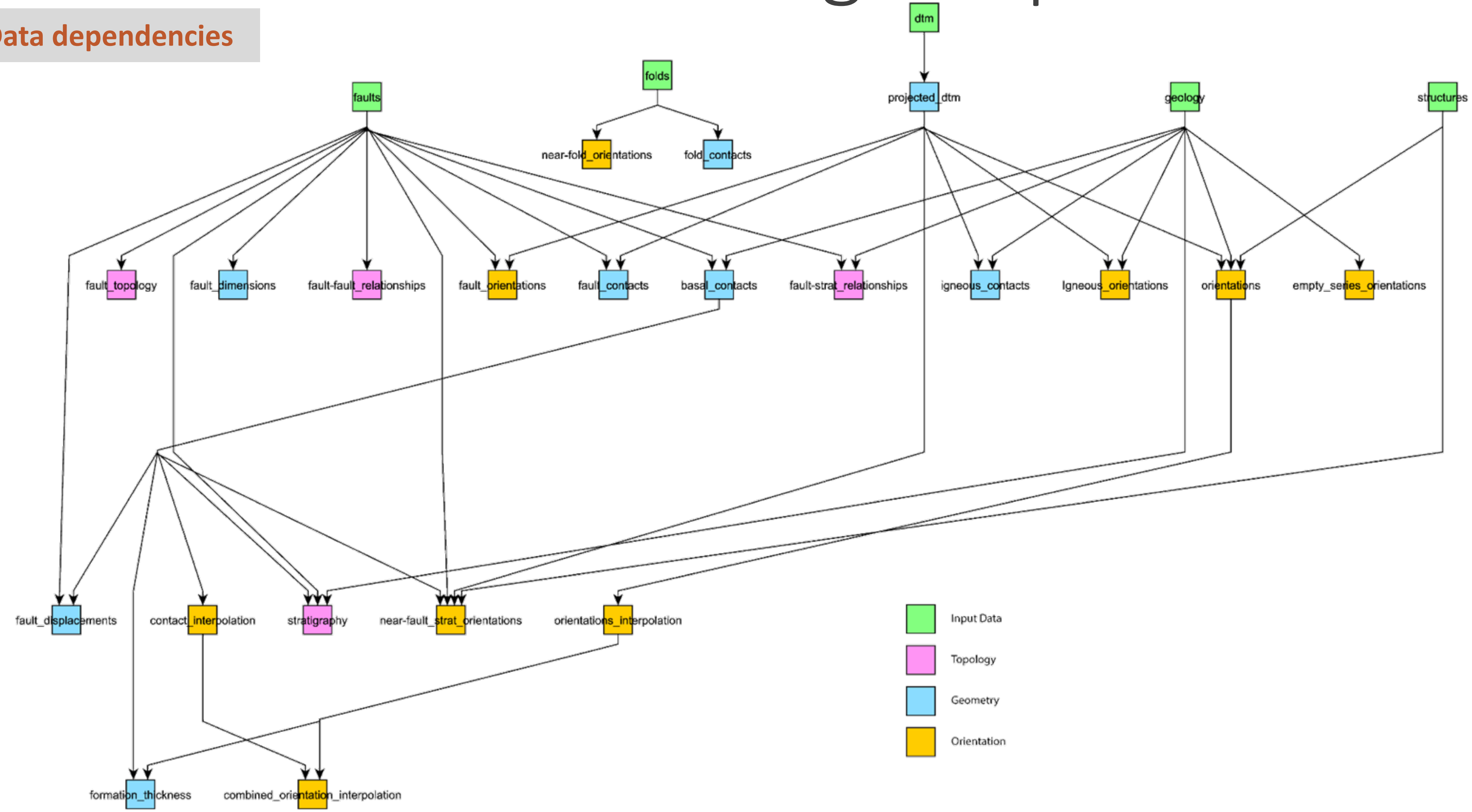
- **No manual intervention was required to build the input layers and models shown in the next slides (apart from lots of coding)**

- Future developments will add sills

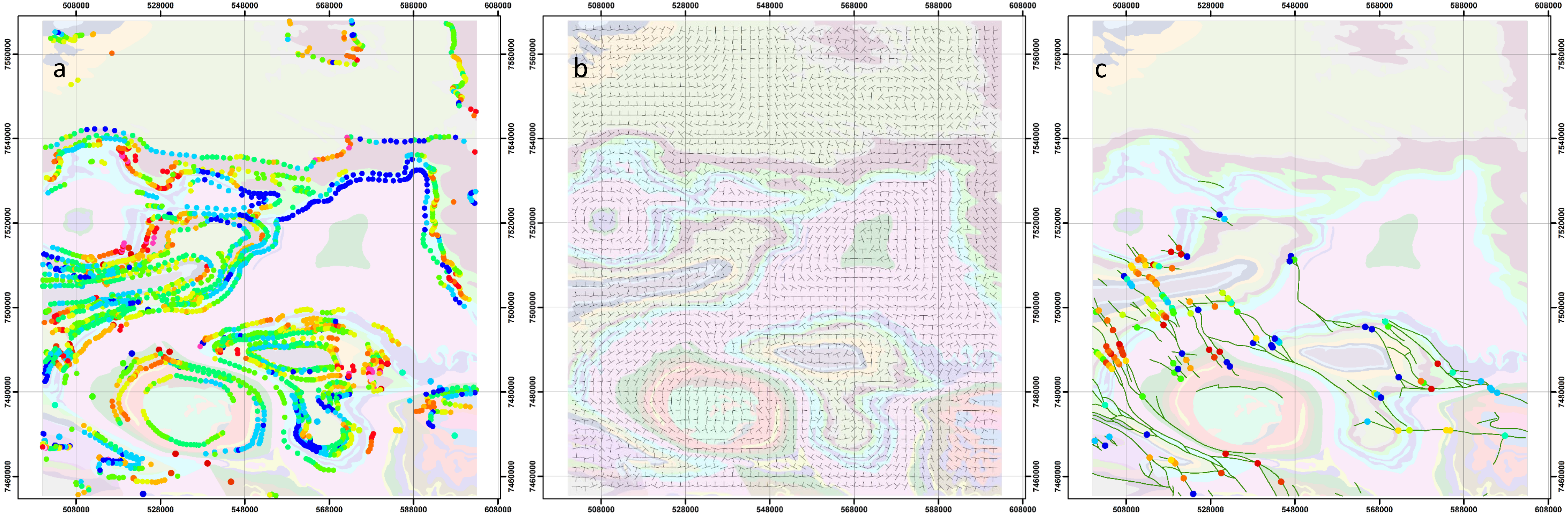


WP #2 – Data Pre-Processing & input

Map2loop // Data dependencies



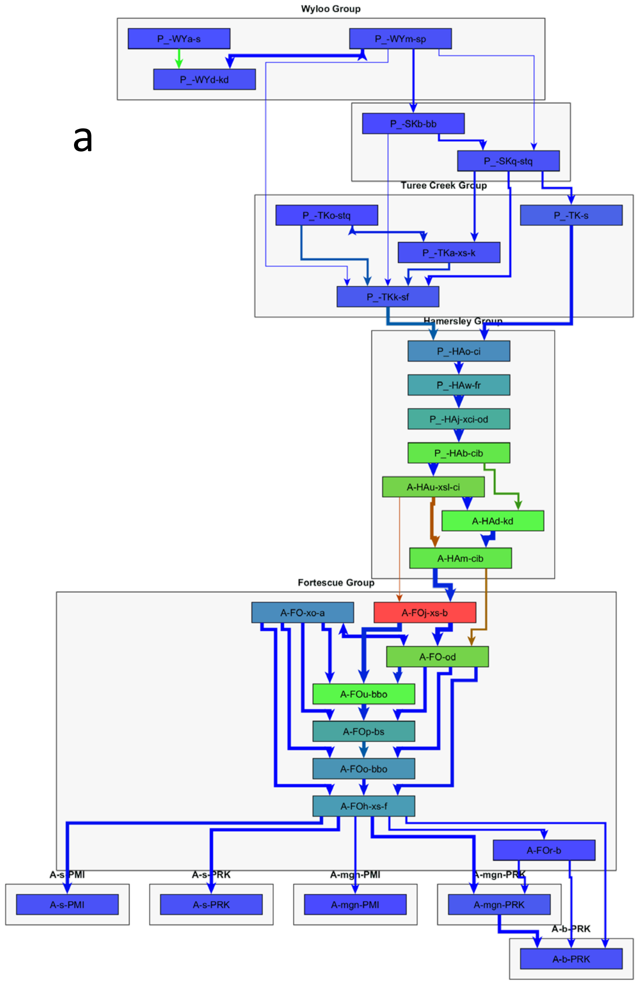
WP #2 – Data Pre-Processing & input



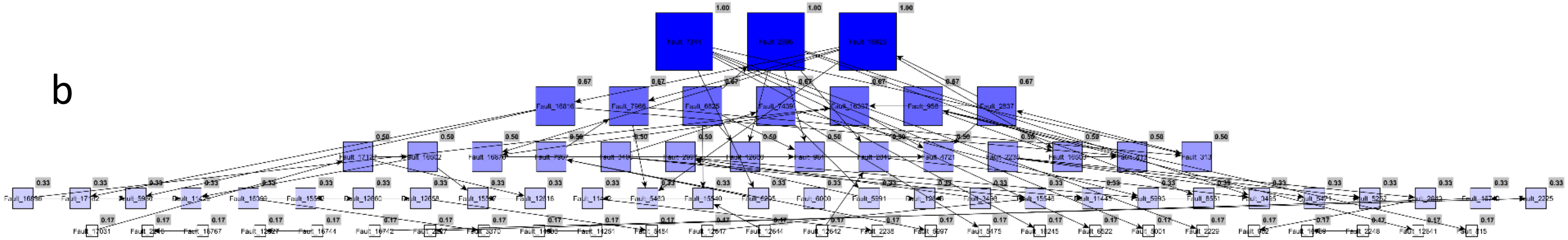
Map2loop // Secondary geological information automatically derived from maps. a) Normalised local formation thickness (hotter colours show thicker formations) b) Interpolated estimated bedding orientations for the Hamersely and Fortescue Groups c) Apparent fault throw (hotter colours show larger throw)

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	
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	
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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	
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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	
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	
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	
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	
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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	
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	
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	
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	
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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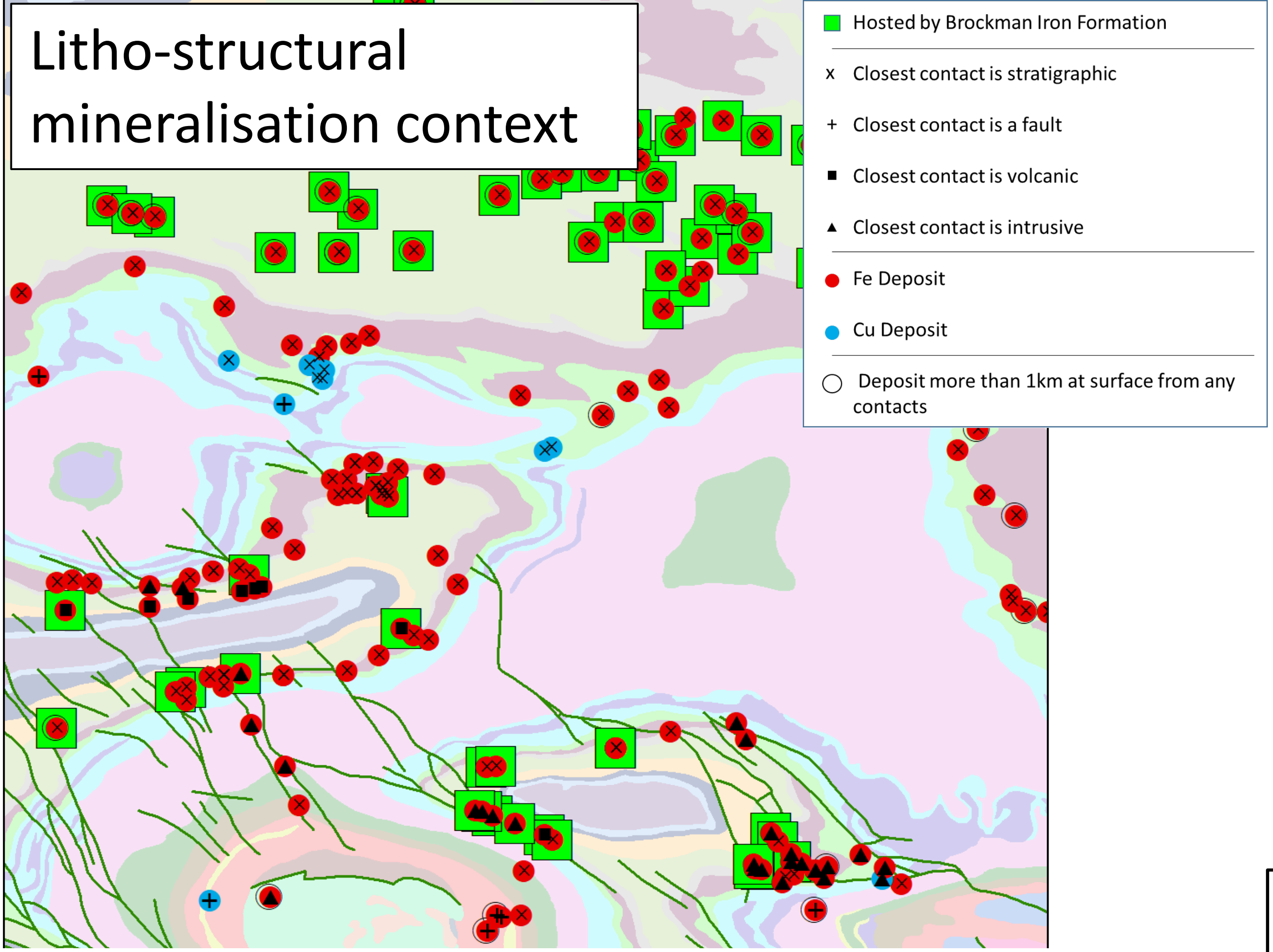
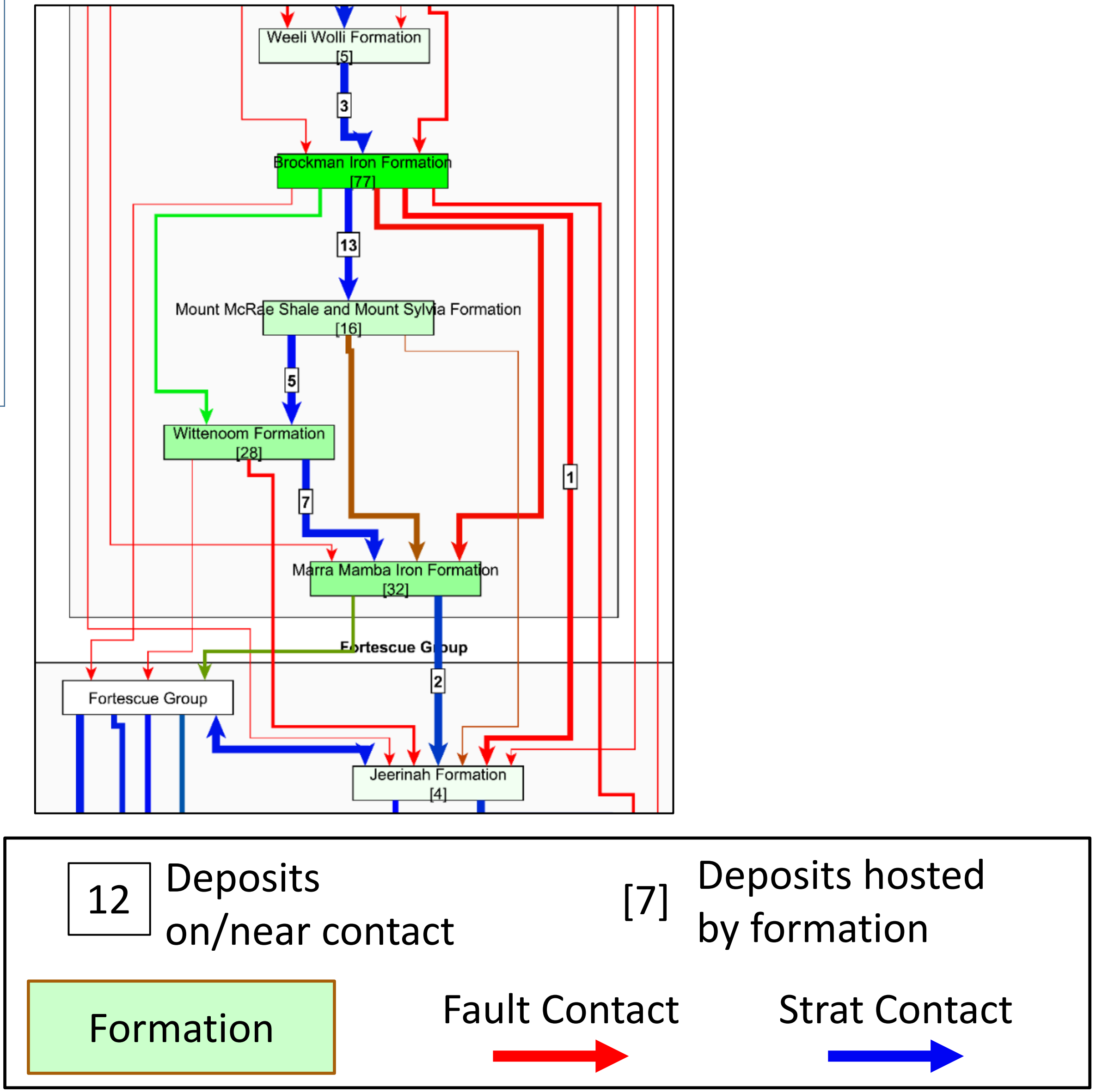
P_-WYd-kd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
P_-WYm-sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

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.

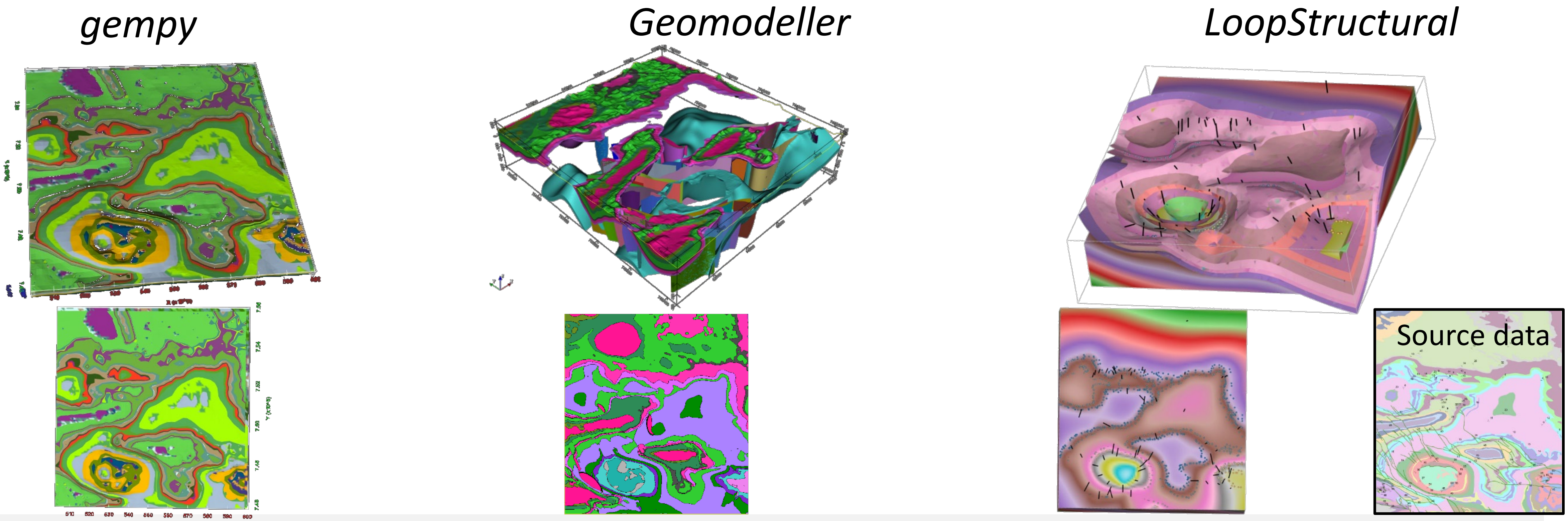
Litho-structural mineralisation context





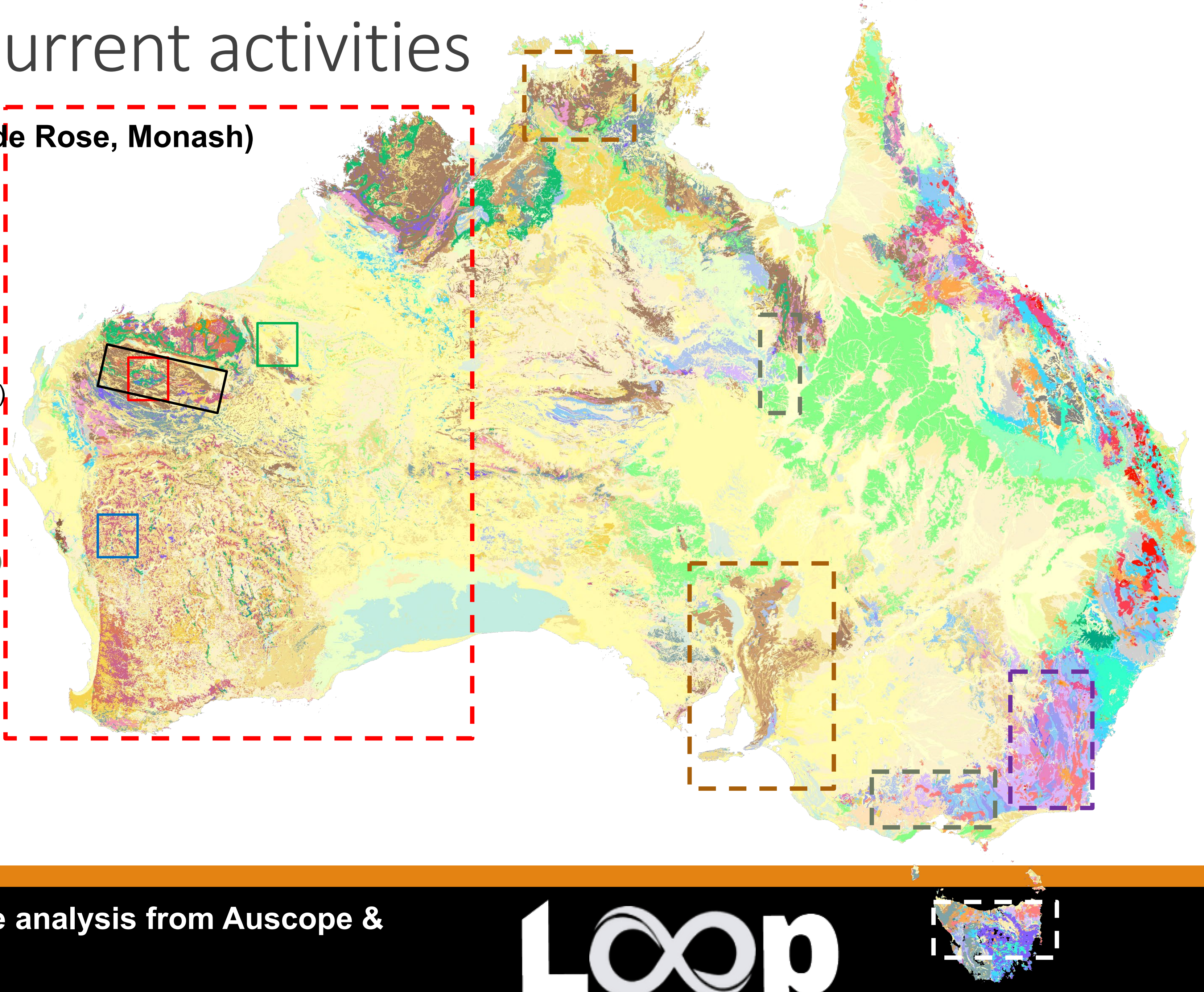
Functionality added to *map2loop* to analyse the litho-structural context of mineral deposits, which will help in defining which elements to retain for modelling

WP #2 – Data Pre-Processing & input



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

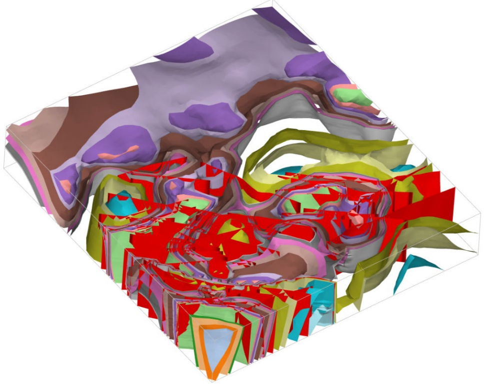
k) Tasmania MRT data

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

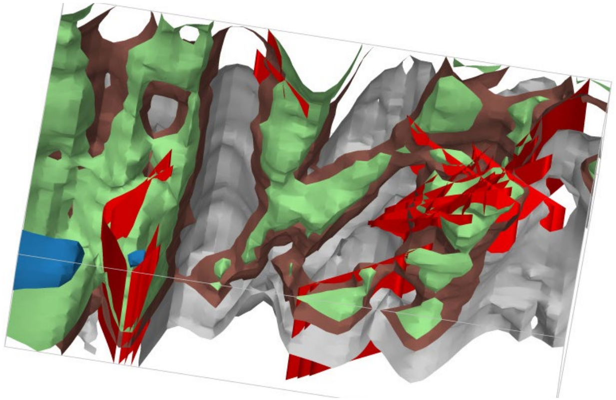
Loop

WP #2 – Proof of concept models

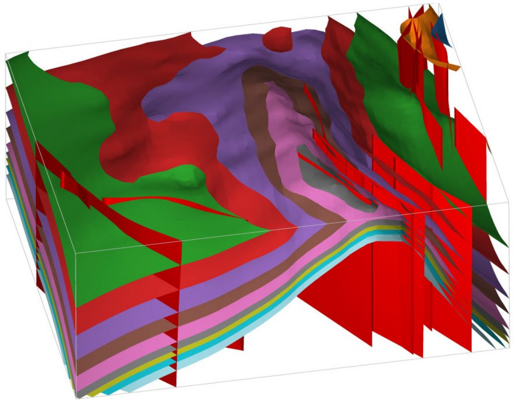
WA



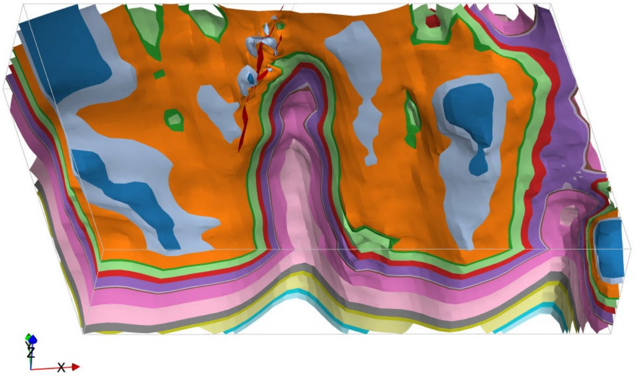
SA



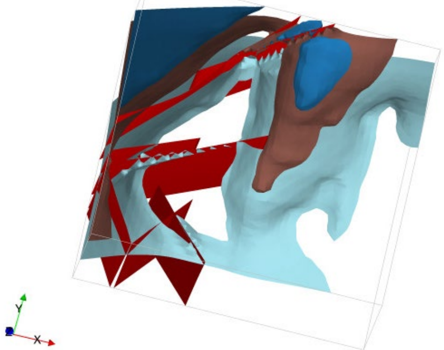
VIC



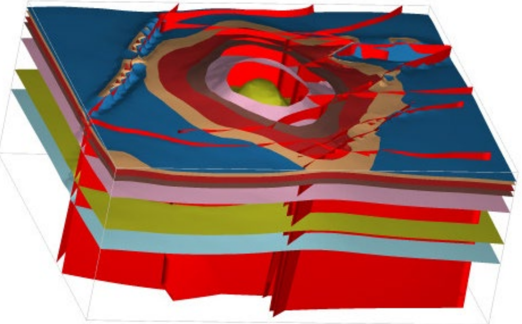
NSW



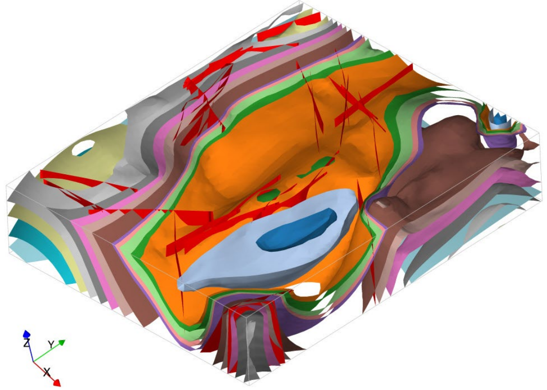
NTGS

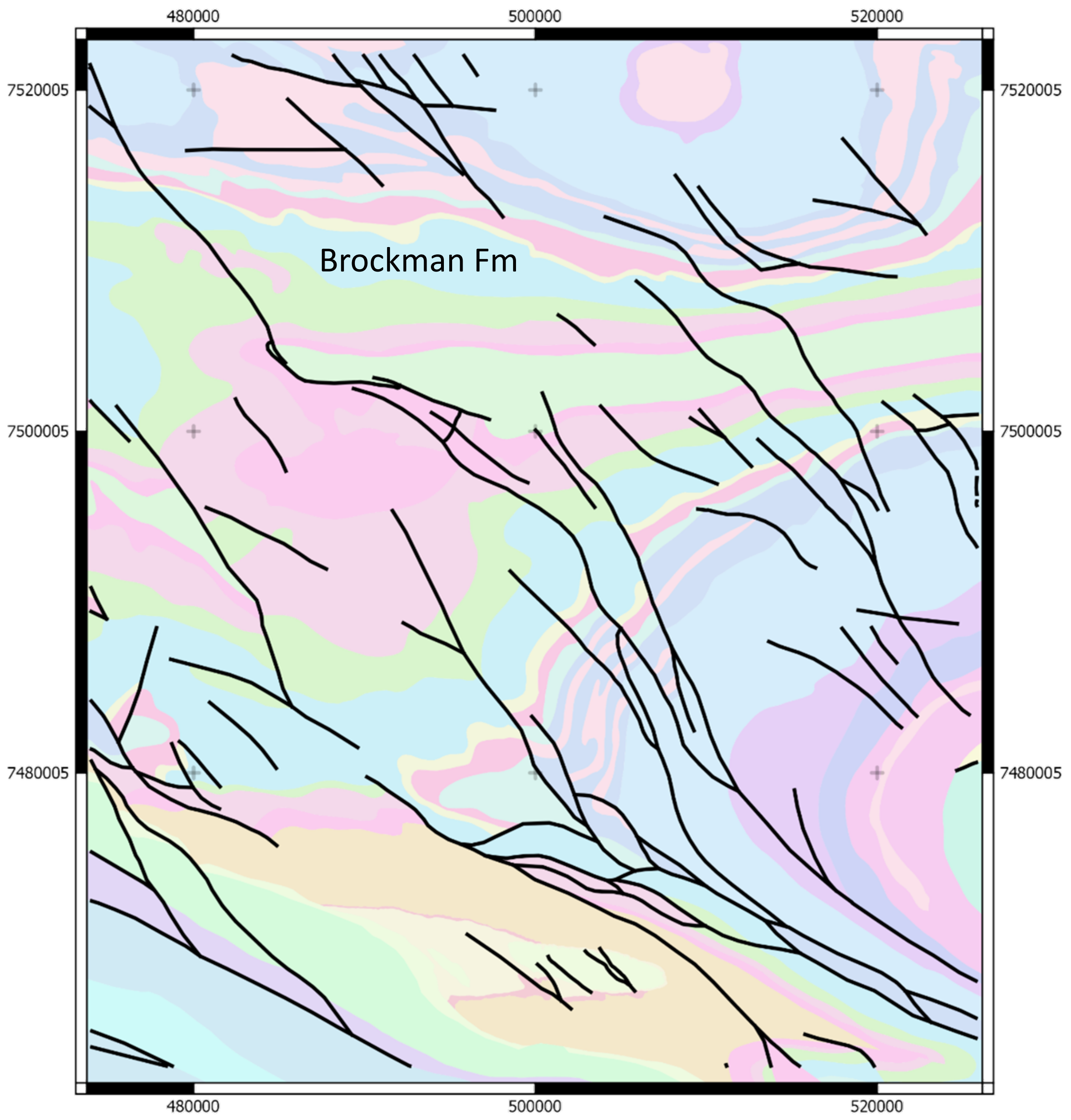


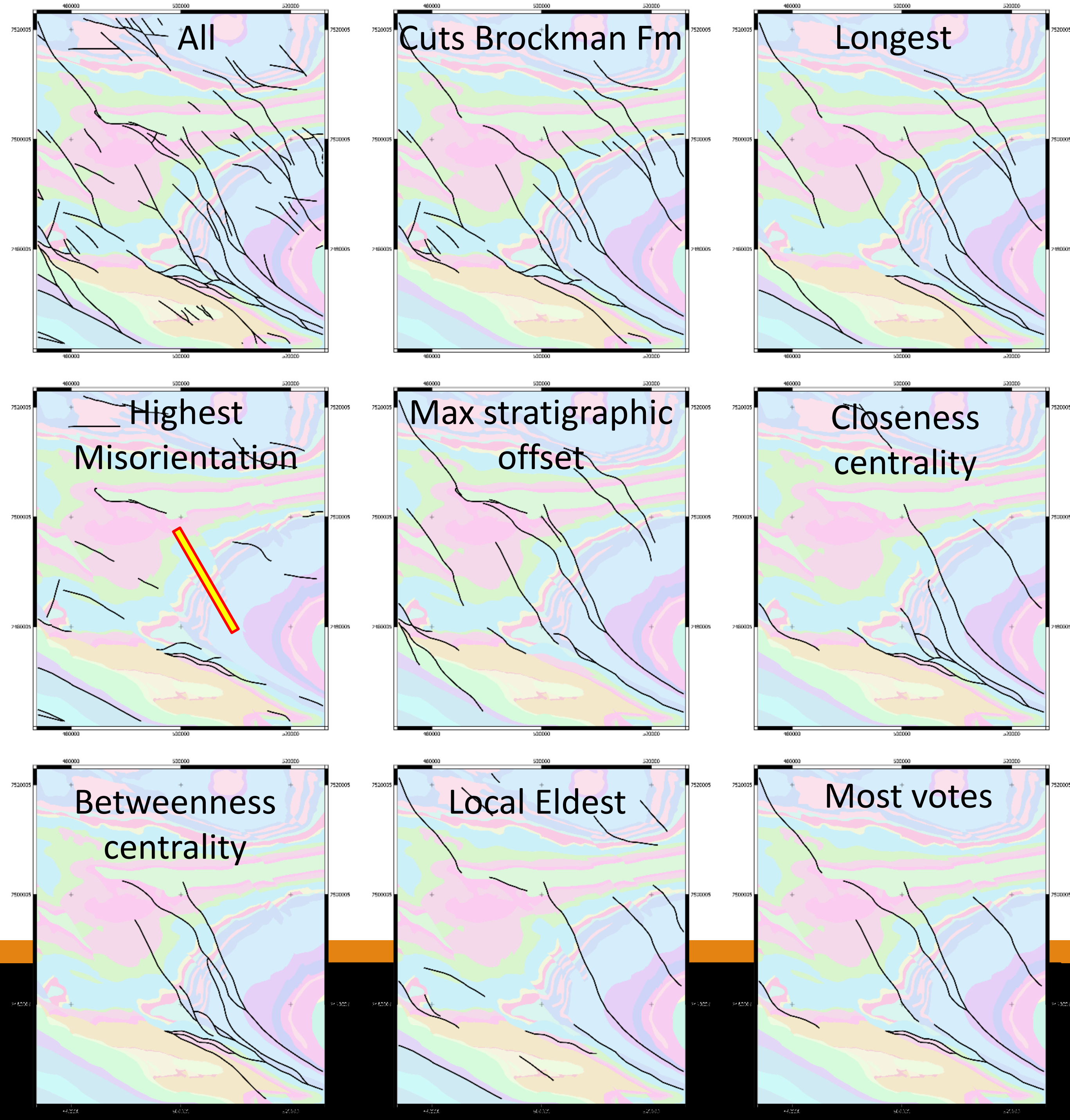
QLD



TAS







Which Faults to Model?

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 FME

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 with 25 people currently (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
17. Started to discuss 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 ●

25. Map colours are used for colouring map2loop generated LoopStructural models
26. Draft LoopStructural paper prepared and sent to coauthors
27. Ongoing testing of the value of structural information
28. Direct integration of map2loop with new model creation function
29. LoopStructural paper reviews received corrections due march 2021
30. LoopSturctural 1.0.8 released
31. LoopStructural refactored so model elements are only evaluated when required

WP #3 – LoopStructural

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

32. Quadratic interpolation using triangular mesh – paper in prep, figure showing comparison to linear
33. Probability branch of LoopStructural created including Theano wrapper for gradient evaluation
34. Testing inversion of fault geometry
35. Conda, pip and docker builds + loopstructural works on google colab
36. Intrusion frame testing ongoing
37. Value of structural information using probabilistic definition of folds
38. Loopstructual documentation updated

WP #3 – LoopStructural

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

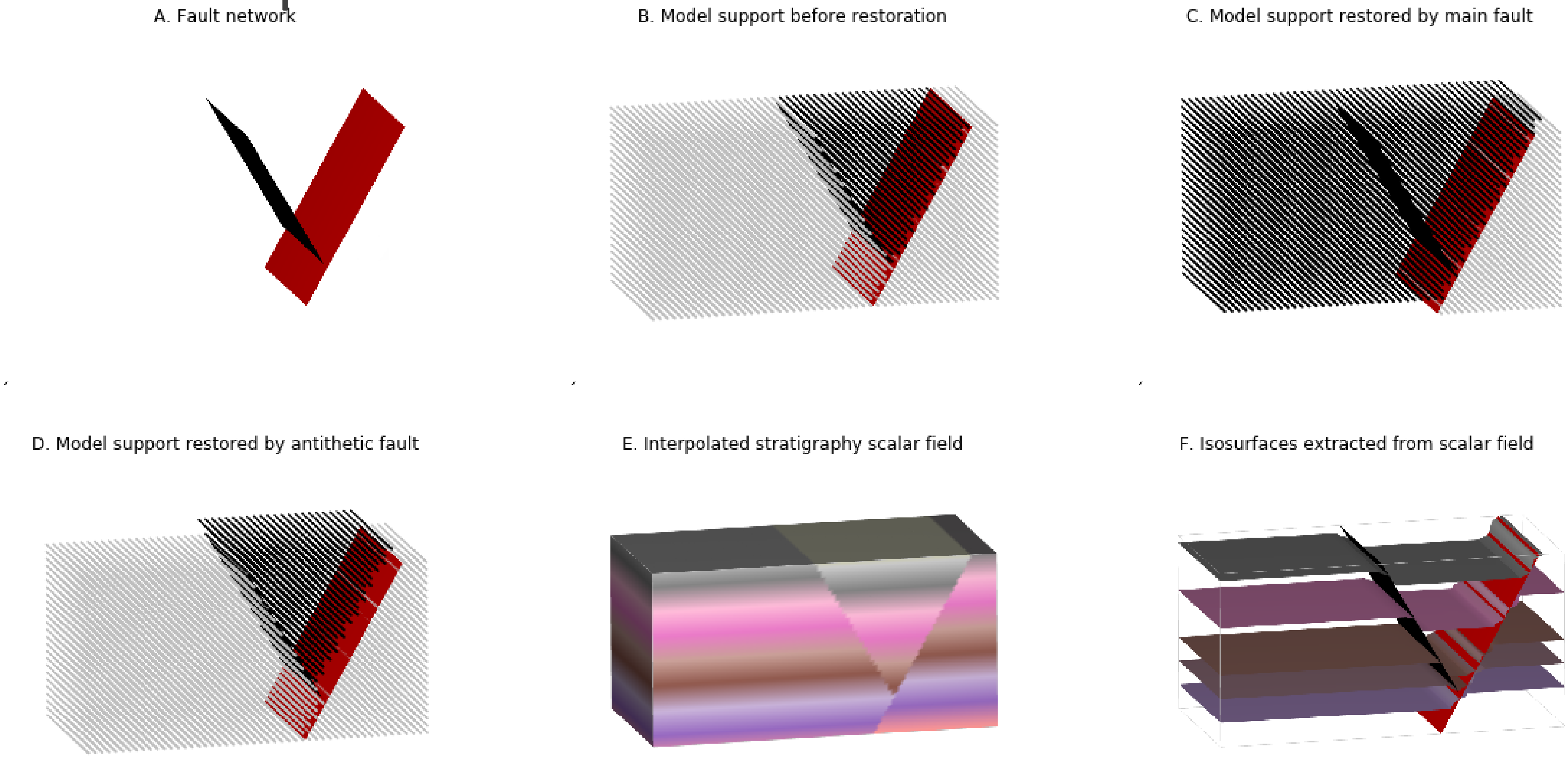
39. Automated documentation building and deployment for LoopStructural
40. Released version 1.1 of LoopStructural (changes here)Quadratic interpolation using triangular mesh – paper in prep, figure showing comparison to linear
41. LoopStructural paper accepted and will be published in GMD special issue soon
42. Fault paper submitted to GMD in discussion currently
43. Inversion of fault geometry using pymc3 showing promising results (attached figure) and will be presented at RING meeting
44. Tested uncertainty of models due to thickness variations

WP #3 – LoopStructural

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

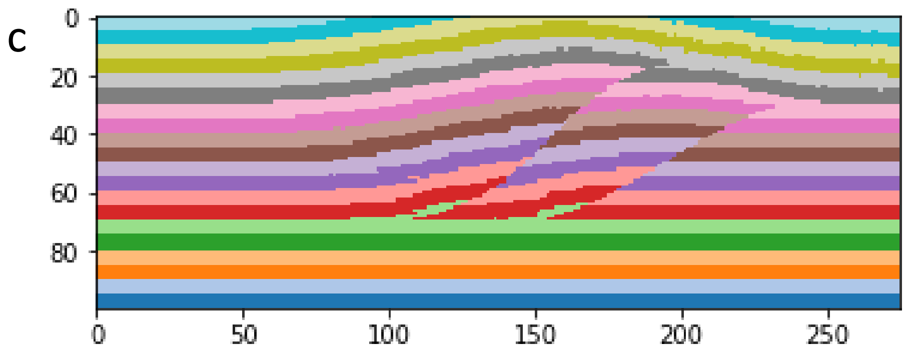
45. Intrusion modelling uses sequential gaussian simulation to build body of intrusion
46. Testing intrusion model on Voiseys bay case study
47. LoopStructural paper accepted and will be published in GMD special issue soon
48. Fault paper submitted to GMD in discussion currently
49. Inversion of fault geometry using pymc3 showing promising results (attached figure) and will be presented at RING meeting
50. Tested uncertainty of models due to thickness variations

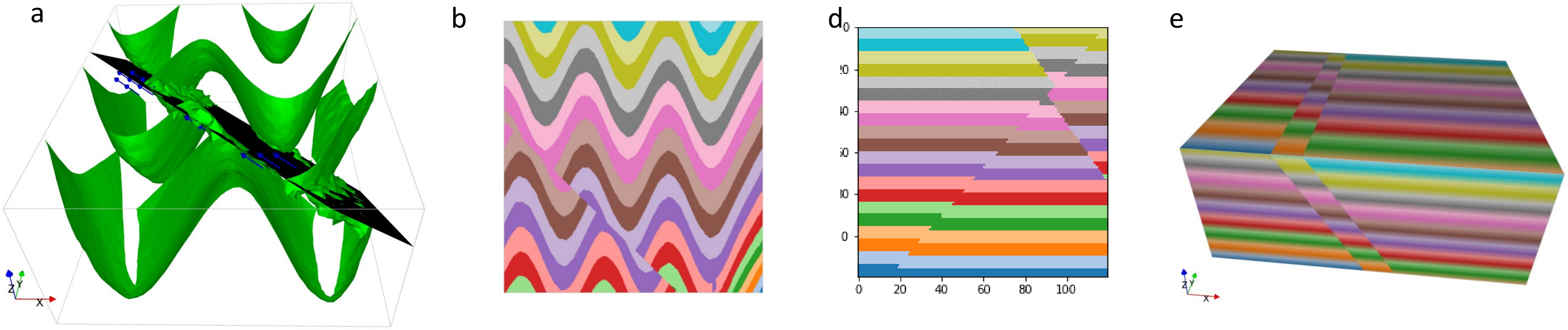
WP #3 – LoopStructural



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.

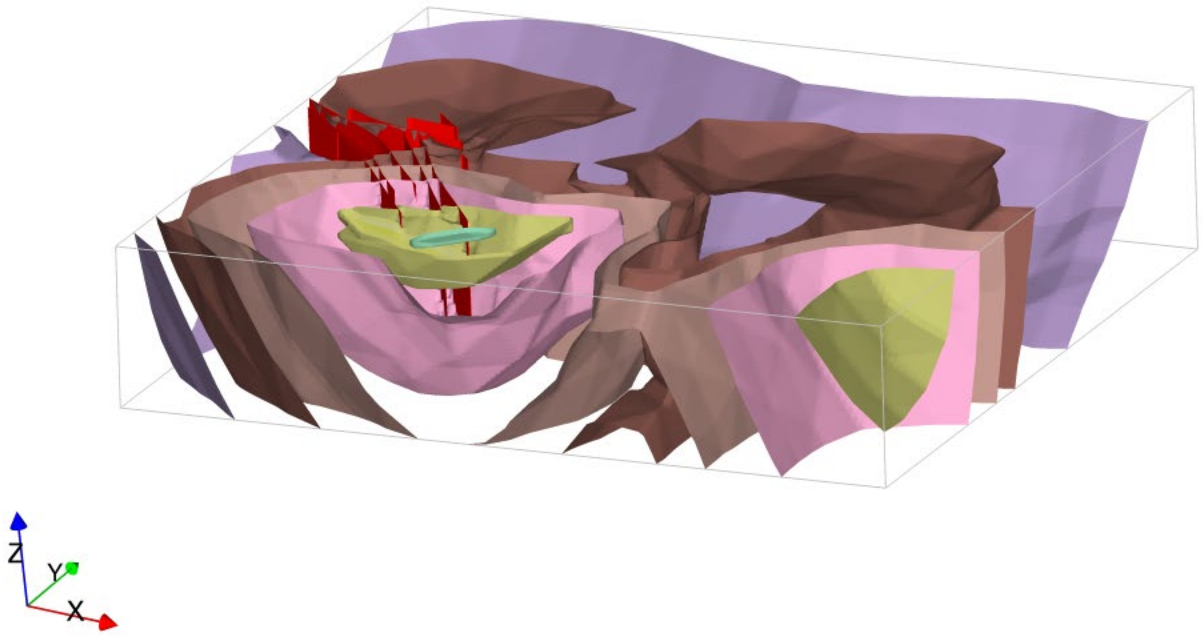
WP #3 – LoopStructural

```
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

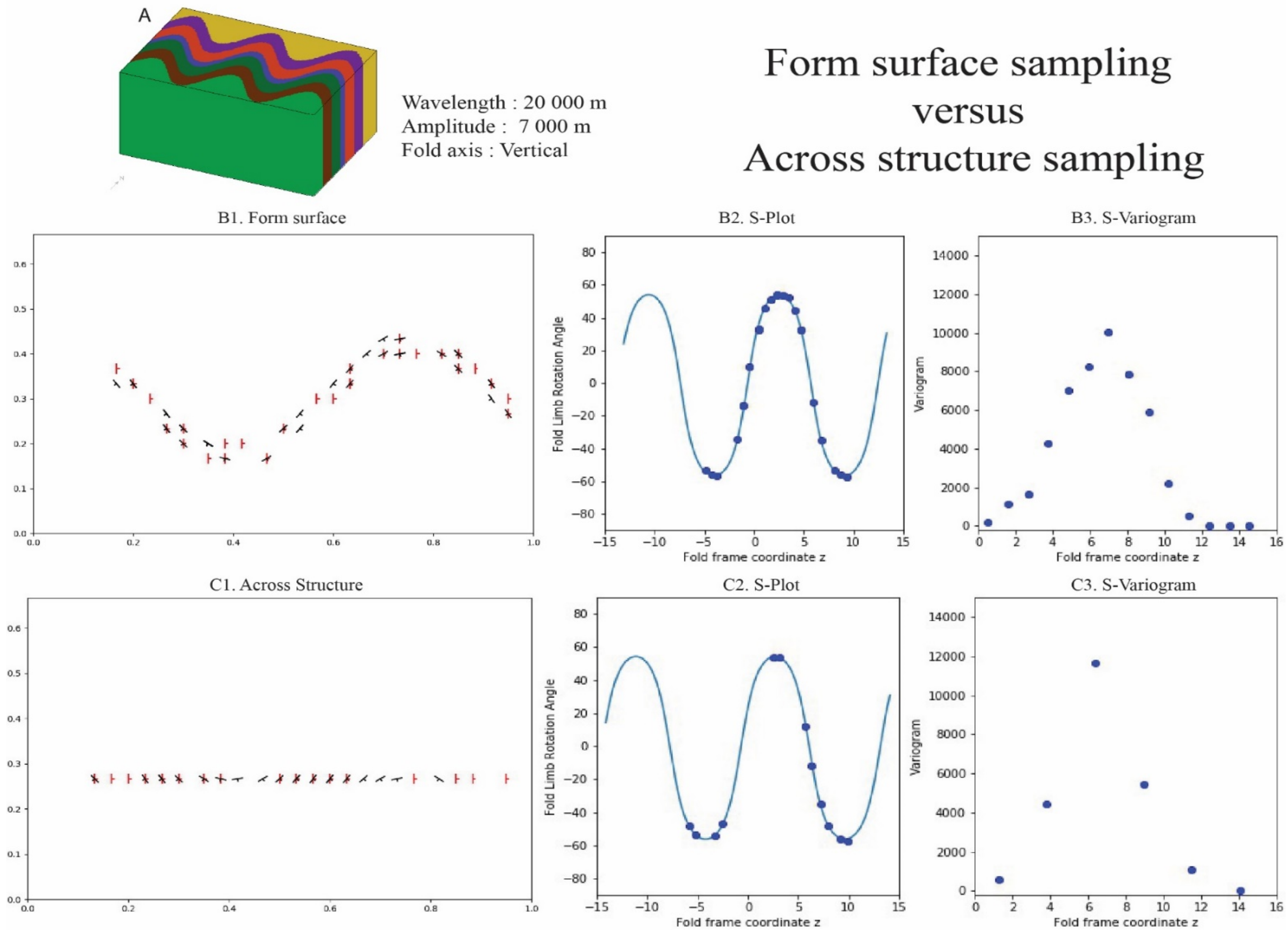


Loop structural modelling using map2loop output and including faults

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.



Loop

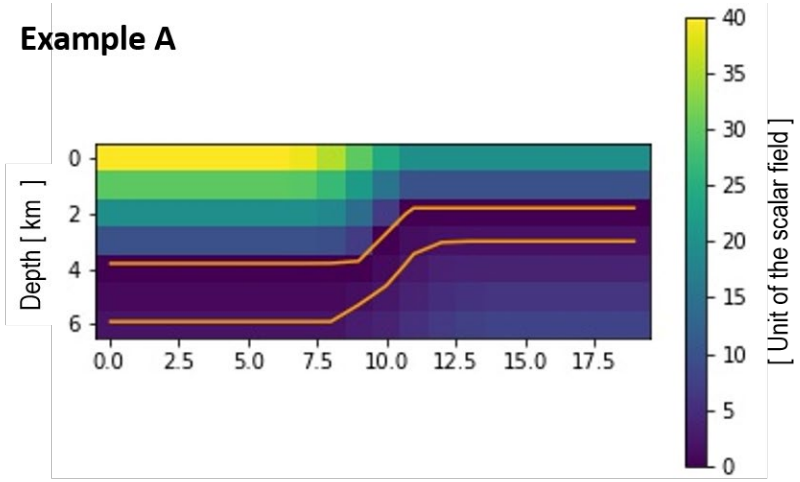
WP #3 – LoopStructural

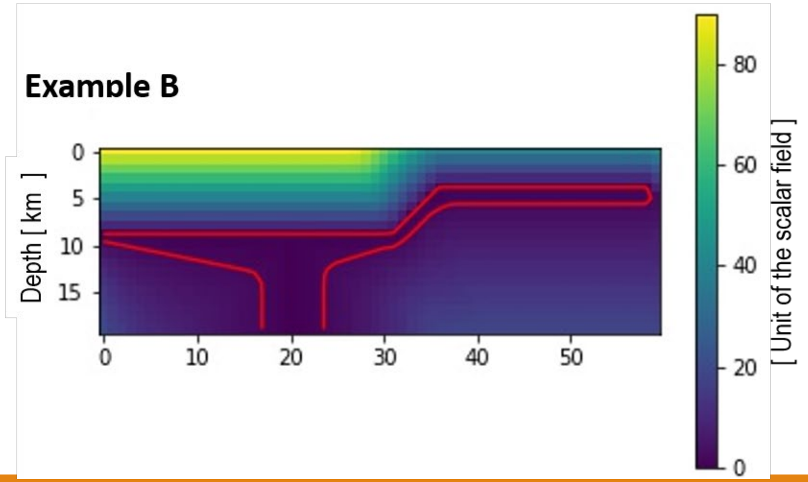
Modelling intrusions

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



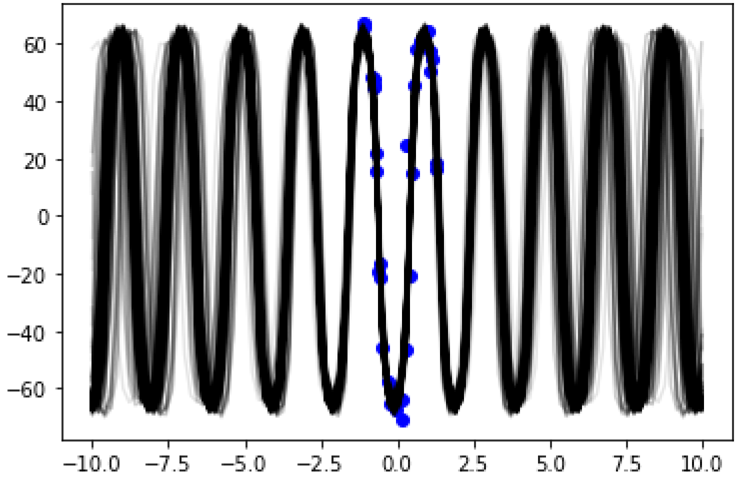


WP #3 – LoopStructural

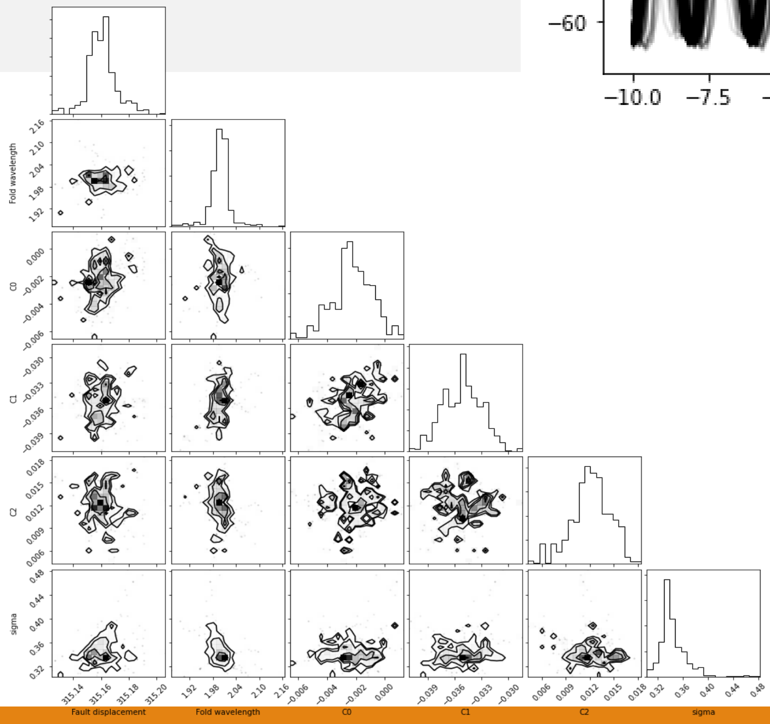
Bayesian modelling – proof of concept

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.

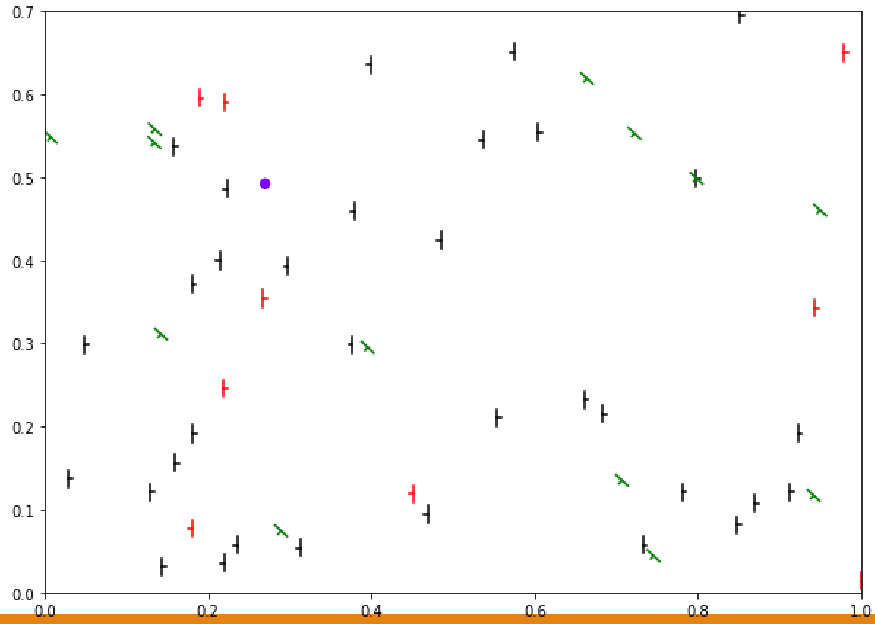
c



b

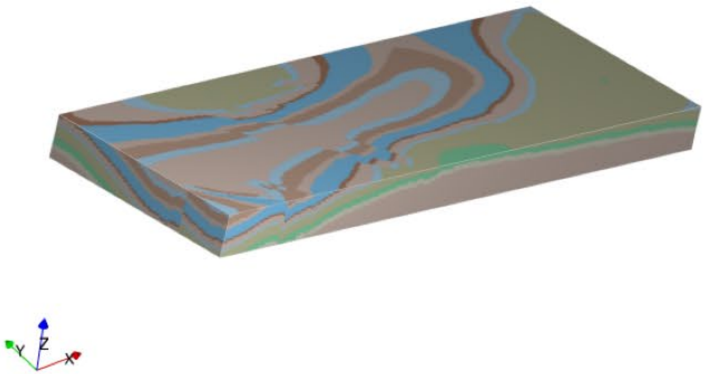


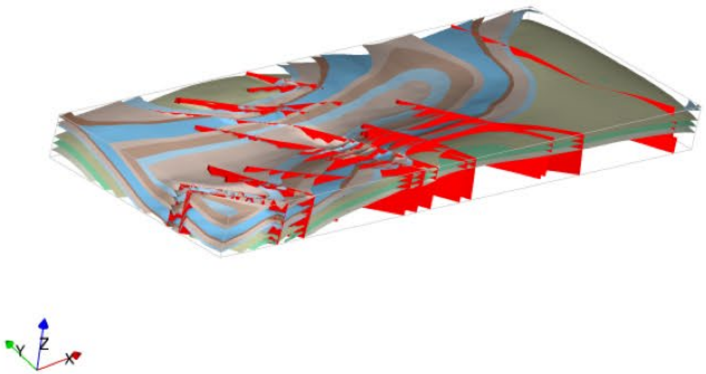
a



WP #3 – LoopStructural

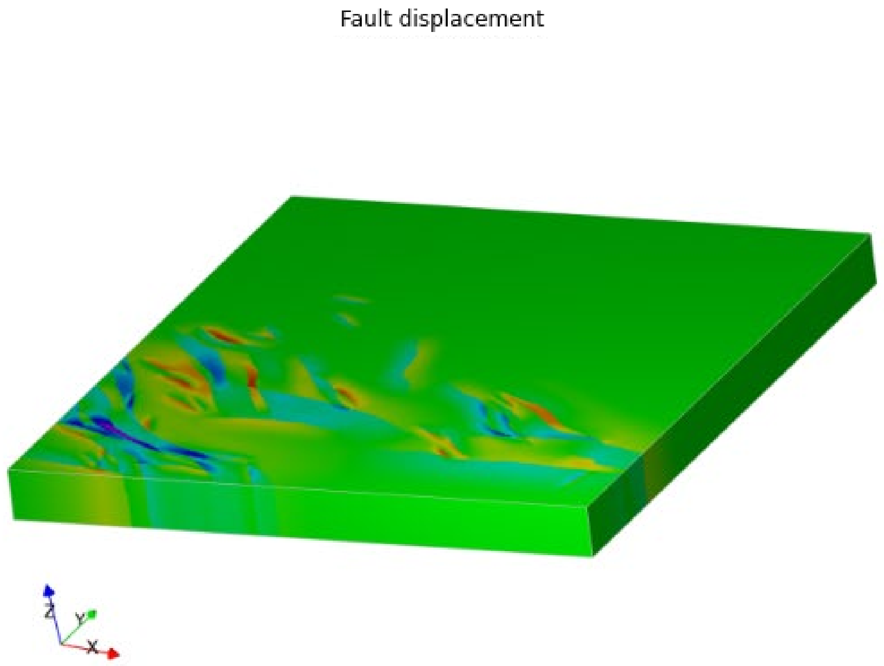
Geological map colours for 3D model
Model for turner syncline using map2loop with surface and geology colours being automatically extracted from 100k mapsheets

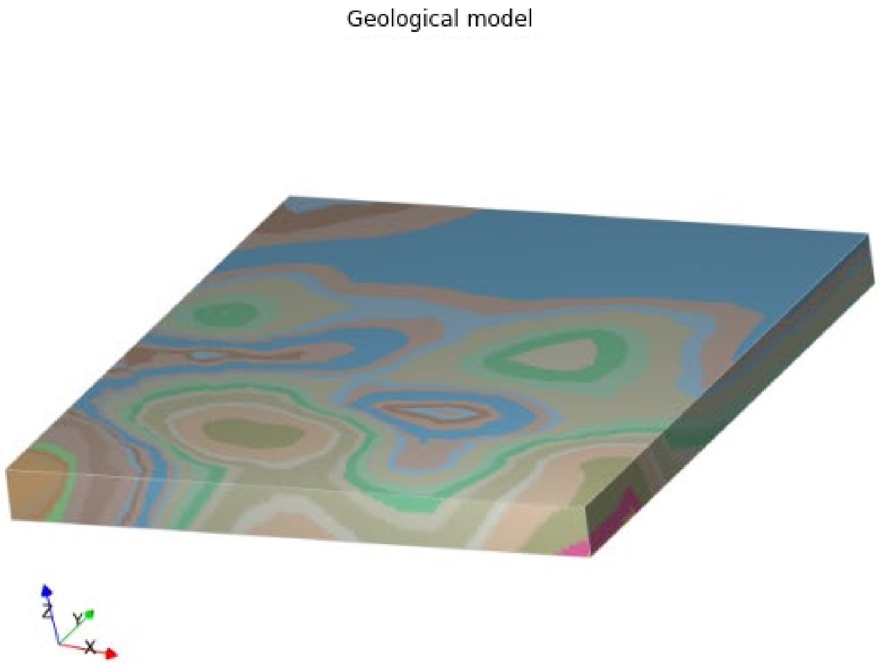




WP #3 – LoopStructural

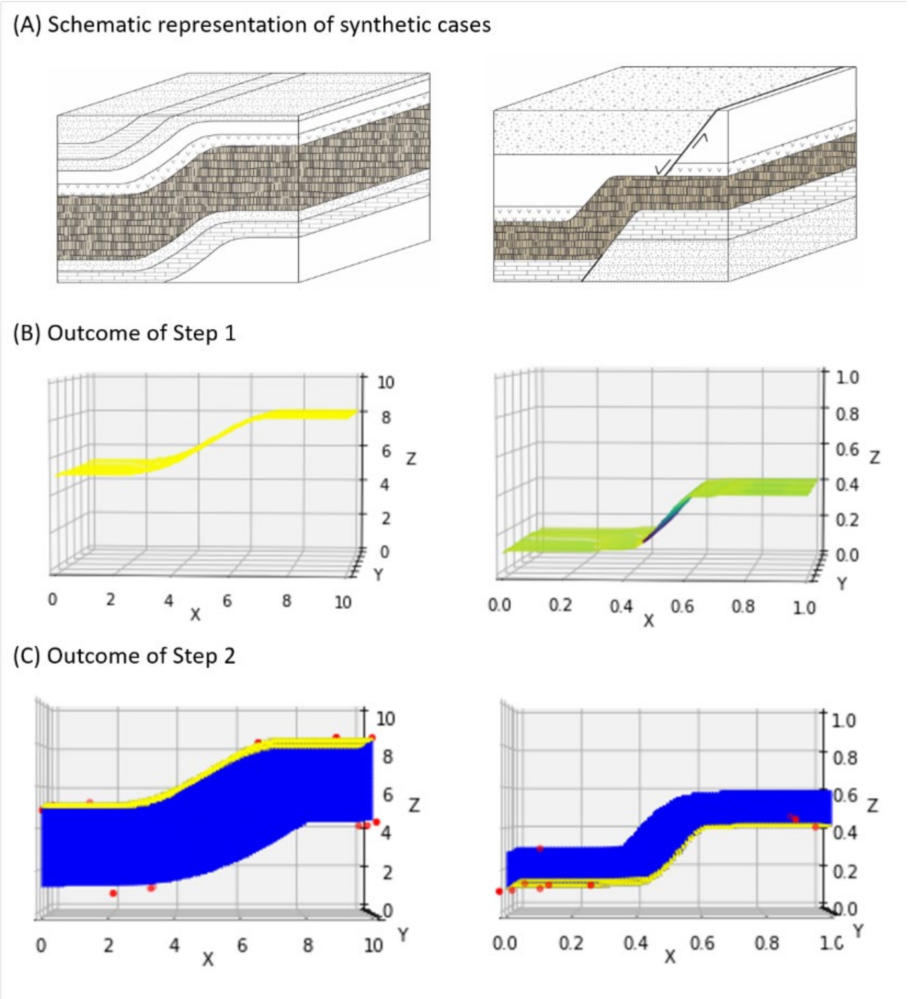
Fault displacement map
Model for Hamersley area showing fault displacement magnitude. This new visualisation option shows the cumulative fault displacement for the geological model. It can be used in the 3D viewer or in the 2D mapview





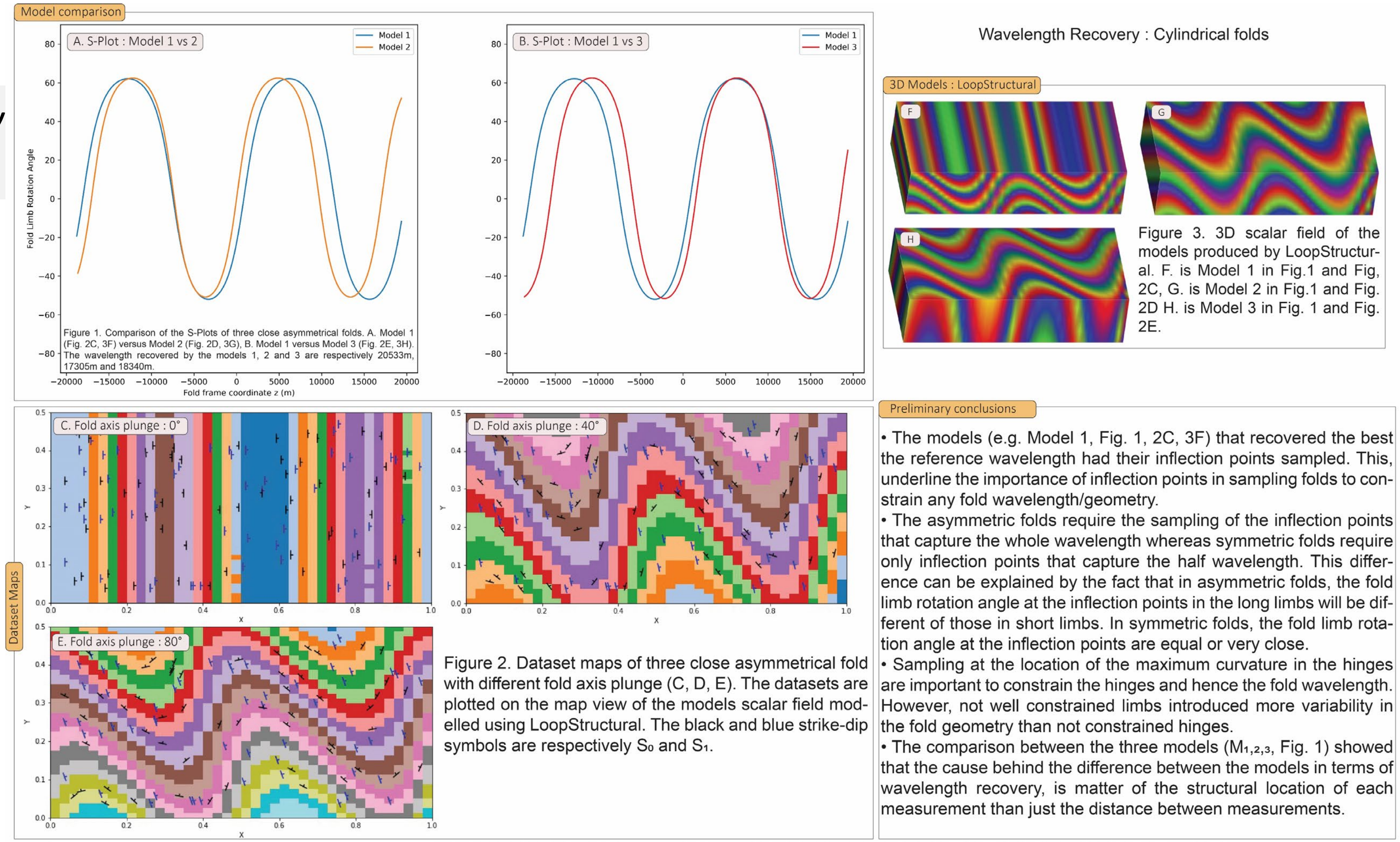
WP #3 – LoopStructural

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).



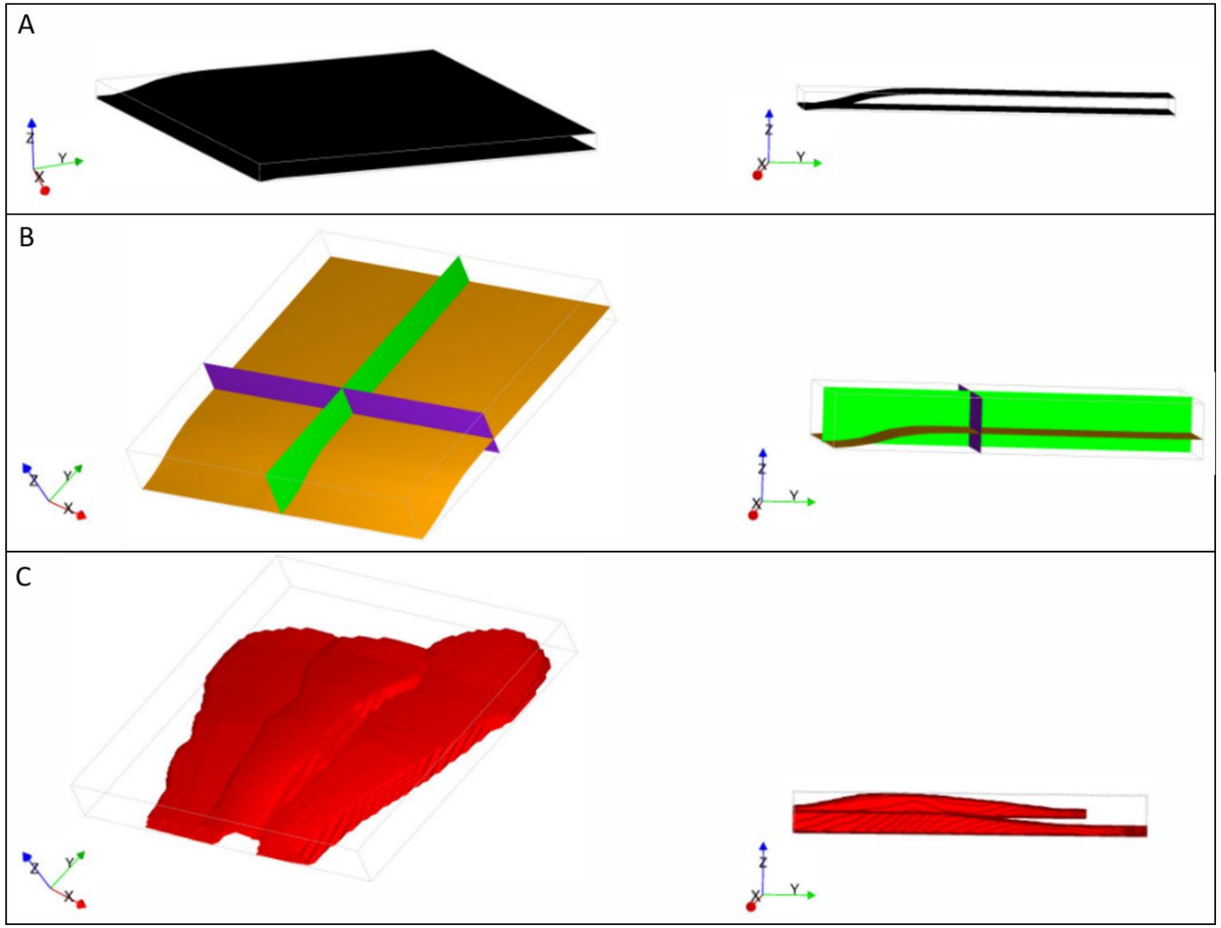
WP #3 – LoopStructural

Figure showing LoopStructural sensitivity to data sampling for folded structures.



WP #3 – LoopStructural

Synthetic example representing the main features of a sill complex and sill segmentation. The middle intrusion exploits a pre-existing structure and propagates through a higher stratigraphic level. Closer to the source, the intrusions coalesce and develop broken bridges structures. At distal locations, the intrusions remain unconnected, developing bridges between them. (A) Intrusion network surface; (B) Structural frame of middle intrusion; (C) Isosurface 0 representing the outer surface of the intrusion.

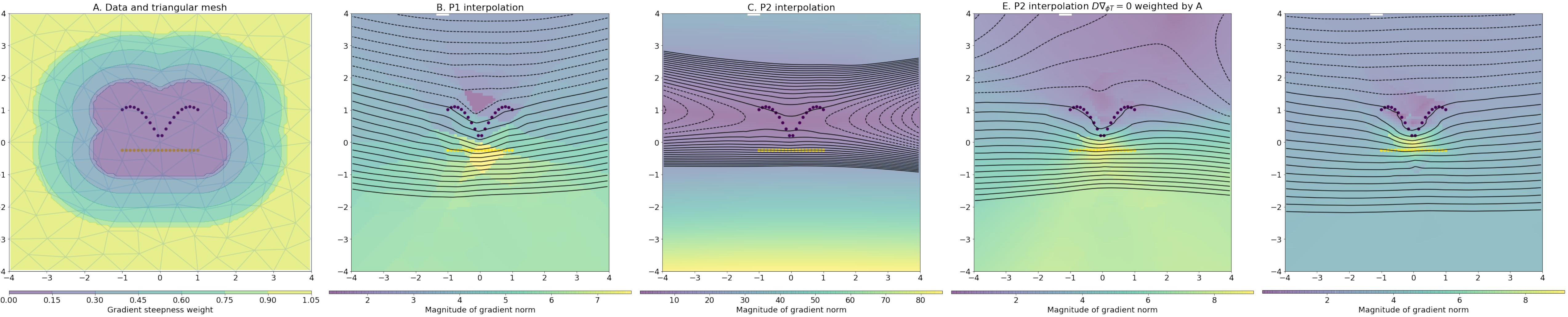


WP #3 – LoopStructural

Fault intersection matrix calculated from 3D fault surfaces. This can be compared with the map pattern to identify intersections below the map

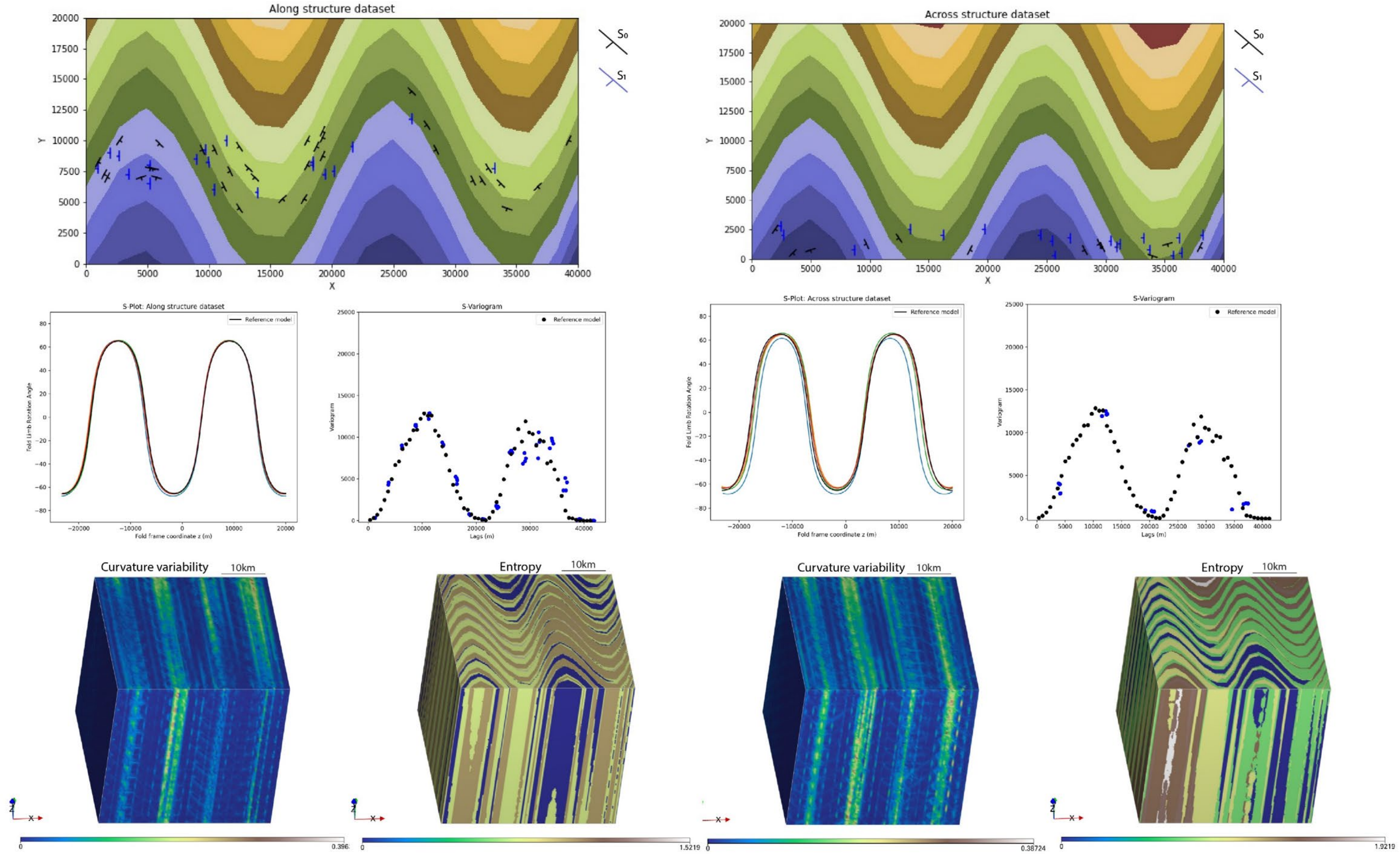
	Fault_2248	Fault_2843	Fault_3496	Fault_3498	Fault_12647	Fault_12658	Fault_12660	Fault_14378	Fault_15552	Fault_16769	Fault_2997
Fault_2248	0	0	0	0	0	0	0	0	0	1	0
Fault_2843	0	1	0	0	0	0	0	0	0	0	0
Fault_3496	0	0	1	0	0	0	0	0	0	0	0
Fault_3498	0	0	0	0	0	0	1	0	0	0	1
Fault_12647	0	0	0	0	1	0	0	0	0	0	0
Fault_12658	0	0	0	0	0	1	0	0	0	0	0
Fault_12660	0	0	0	0	0	0	1	0	1	0	0
Fault_14378	0	0	0	0	0	0	0	1	0	0	0
Fault_15552	0	0	0	0	0	0	1	0	1	0	0
Fault_16769	1	0	0	0	0	0	0	0	0	1	0
Fault_2997	0	0	0	1	0	0	0	0	0	0	1

WP #3 – LoopStructural



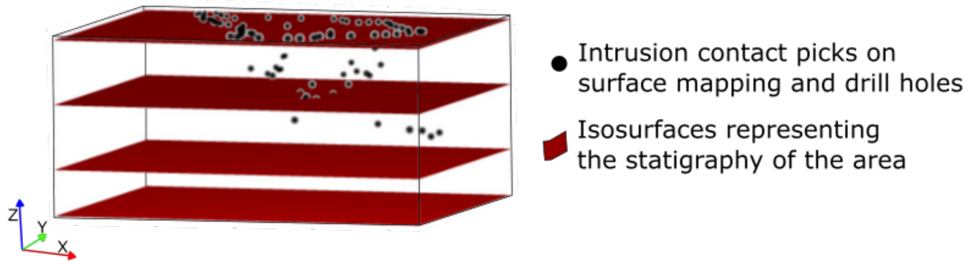
2D interpolation comparison: A) reference data and spatial weighting function B) Linear interpolation. C) quadratic interpolation *D)* quadratic interpolation using gradient steepness weight and E) quadratic interpolation using weight function from A) for gradient steepness.

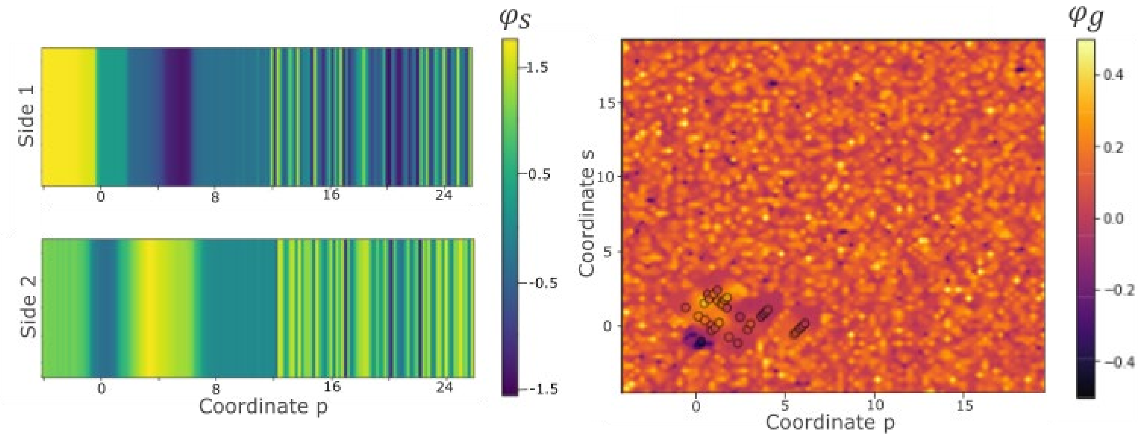
WP #3 – LoopStructural

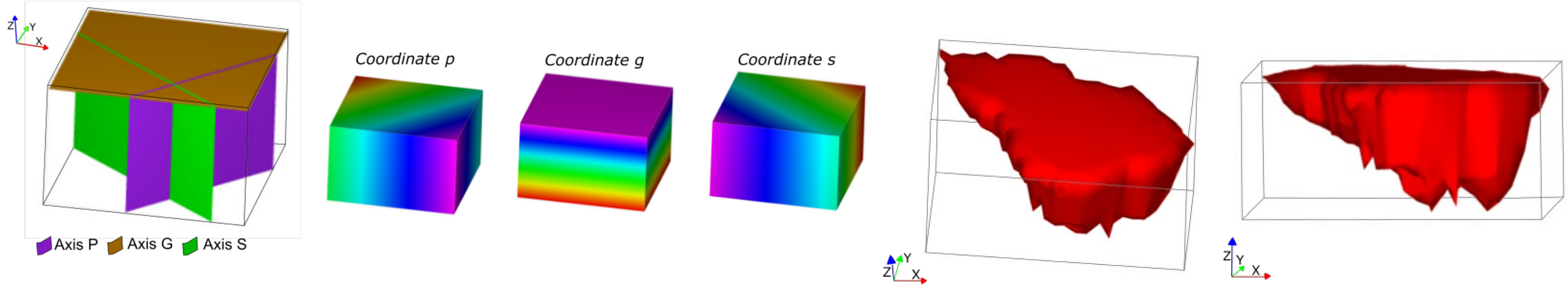


3D Comparison between form surface and across structure sampling using a cylindrical upright fold example (three perturbed datasets are used for each example). The fold curvature variability shows that the hinges display high variability between the models. These results show that the way of mapping and sampling structural data produce datasets that lead to different model geometries. When modelling complex fold geometries the variability is expected to be very high.

WP #3 – LoopStructural



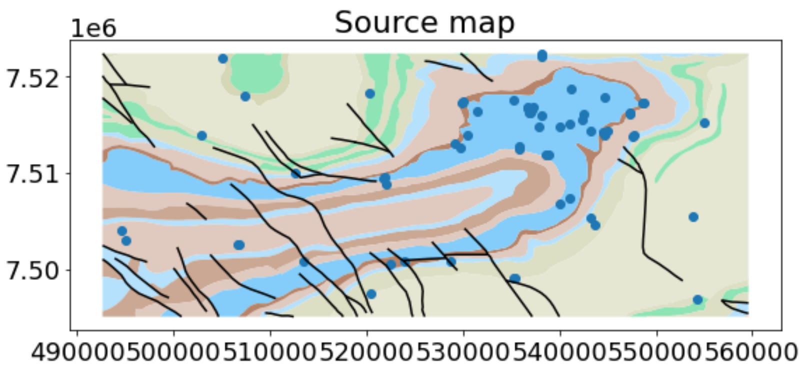




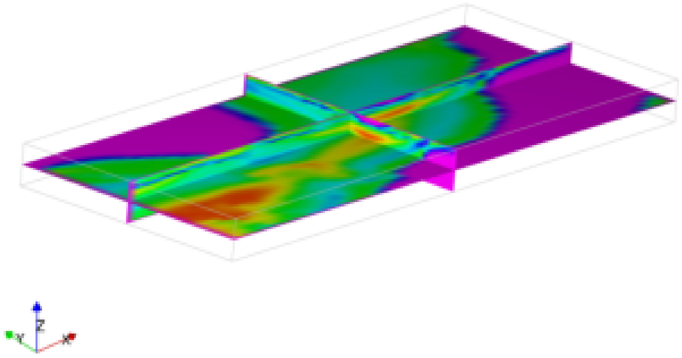
Structural frame of Voisey's Bay intrusion. Top left: intrusion contact points and horizontal stratigraphy. Bottom left: Structural frame axes and coordinates. Top right Realization of residual values φ_s (left) and φ_g (right). Bottom: resulting intrusion body

WP #3 – LoopStructural

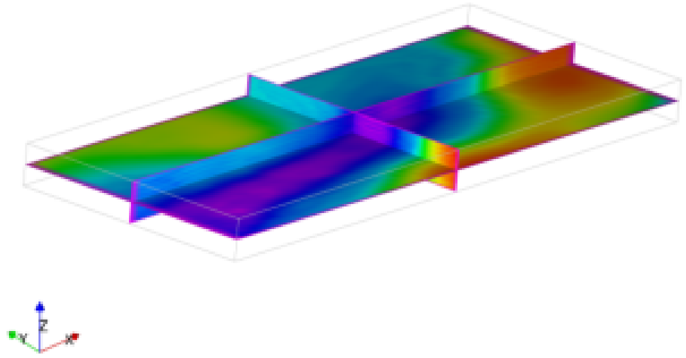
Source map processed by map2loop for LoopStructural. The thickness of each stratigraphic unit is estimated locally by map2loop and a global value (median) is usually used as input into the 3D model. Here we sample the thickness values from a probability density function where the mean and standard deviation are defined by the map2loop calculated values.

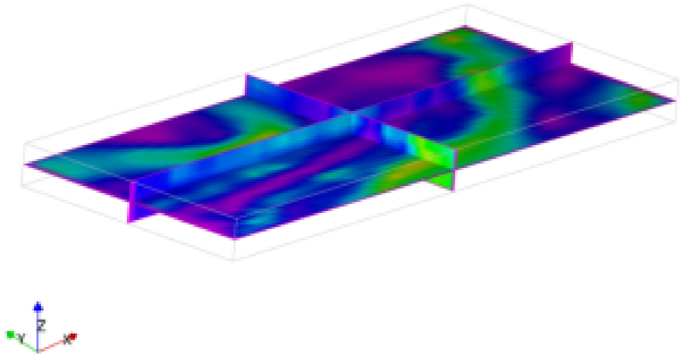


A. Stratigraphic Entropy



B. Continuous Entropy





The result show that thickness estimates can contribute to the resulting model geometries. Stratigraphic entropy is concentrated near the faults and continuous entropy (the variability in the scalar field is concentrated in the cream unit which has the highest apparent thickness variability in the map. Angle variability highlights the variation in the geometry resulting from the thickness estimates.

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. Phase 1: Progress on synthetic case and starting field application. Use of LoopStructural planned in phase 2.

🔵 11. Marie Curie Fellowship awarded to Jeremie Giraud to develop Geology-Geophysics joint modelling in/with Loop.

WP #4 – Integrated Geophysical Inversion

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

○ 12. Case study using data from Yamarna region using 3D geometrical inversion of gravity data constrained by sparse 2D seismic modelling.

○ 13. Developed methodology for integration of 1D MT + passive seismic for depth to basement modelling.

○ 14. Started case study in collaboration with GTK (Finnish geological survey) for shallow seismically-constrained geometrical gravity inversion in vicinity of ore body.

● 15. Preprint of GMD discussion paper showcasing Tomofast-x: publicly available.

● 16. Preprint of level-set (geometrical inversion) paper: accepted paper publicly available.

● 17. Preprint of Solid Earth discussion paper for item 12: publicly available.

WP #4 – Integrated Geophysical Inversion

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

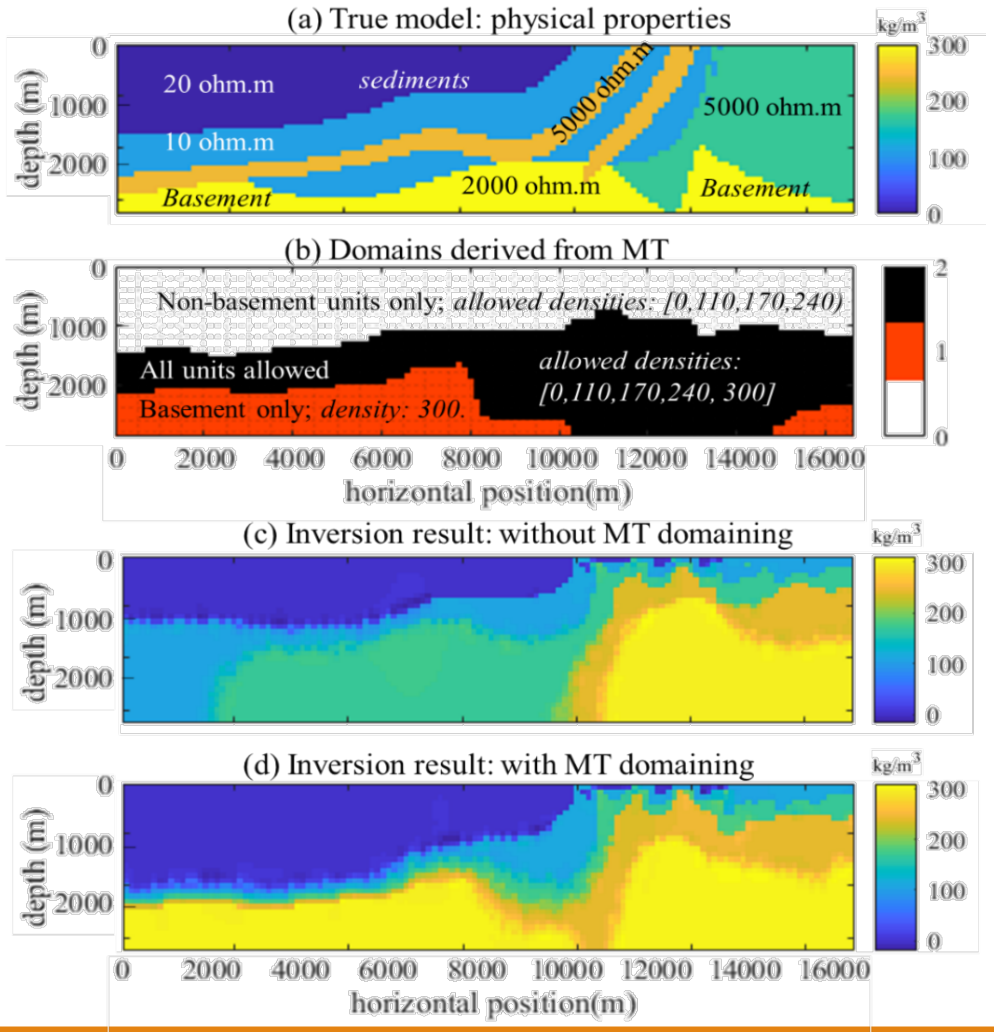
● 18. Paper for item 13, proof-of-concept and case study of 1D MT + mag. data: nearly ready for submission.

WP #4 – Integrated Geophysical Inversion

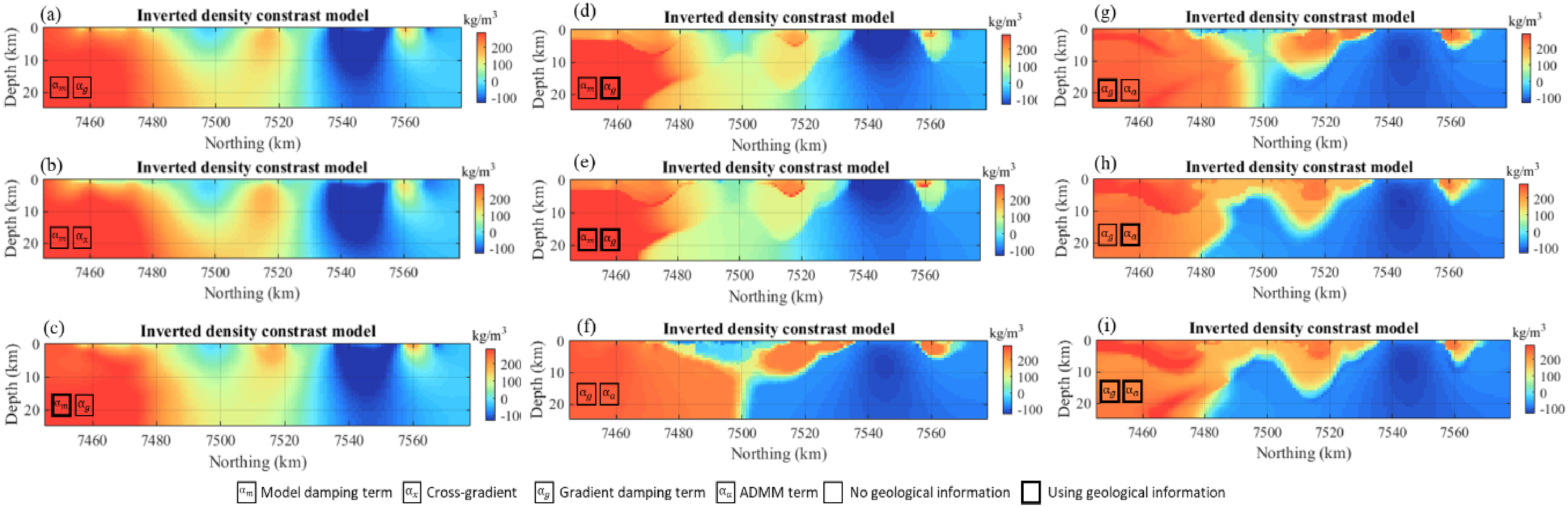
Feasibility study of proposed workflow for the integration of gravity and magnetotellurics data.

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

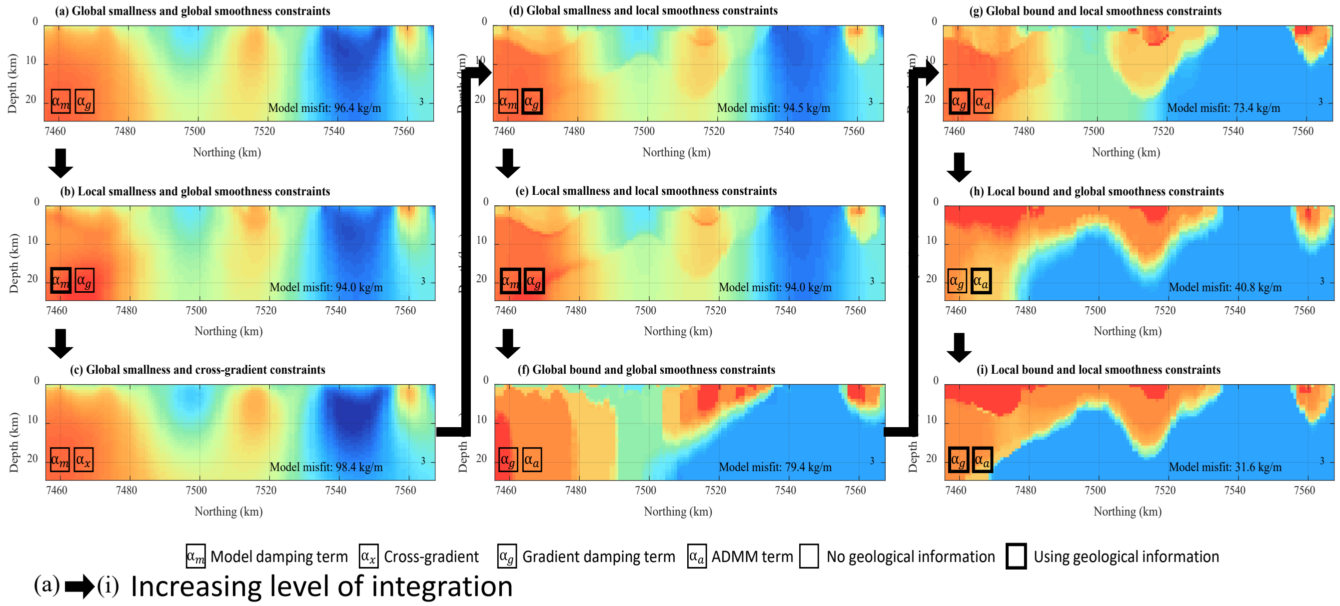


Comparison of inversion results for density contrast models recovered using different kinds of constraints from petrophysics and/or geology and/or structural prior information.

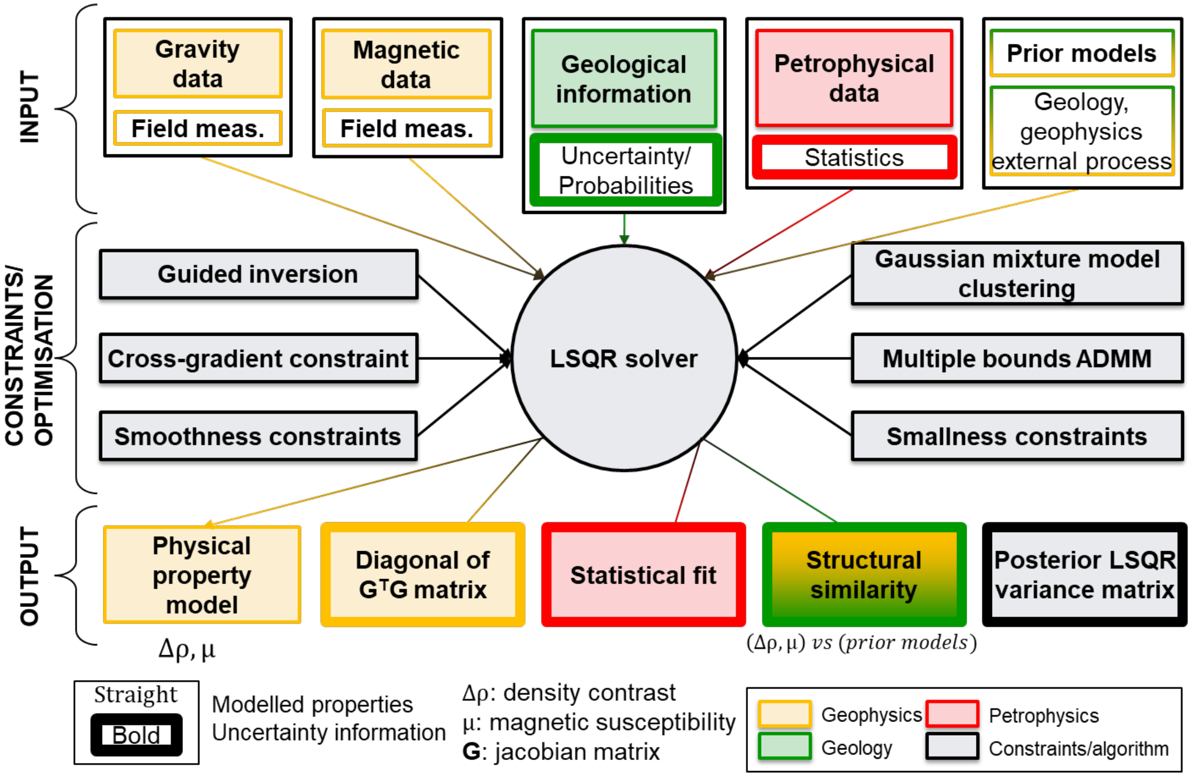
From Giraud et al. 2020 [in prep, submission expected in Q4 2020]. Unpublished material; not for public sharing.

WP #4 – Integrated Geophysical Inversion

Finalisation of Tomofast-x inversion platform and preparation of released complete. Code and examples online in referenced repository; paper submitted.



Sensitivity study to data integration in inversion



Tomofast-x functionalities summary

From Giraud et al. 2021 [submitted in Q1 2021].

WP #4 – Integrated Geophysical Inversion

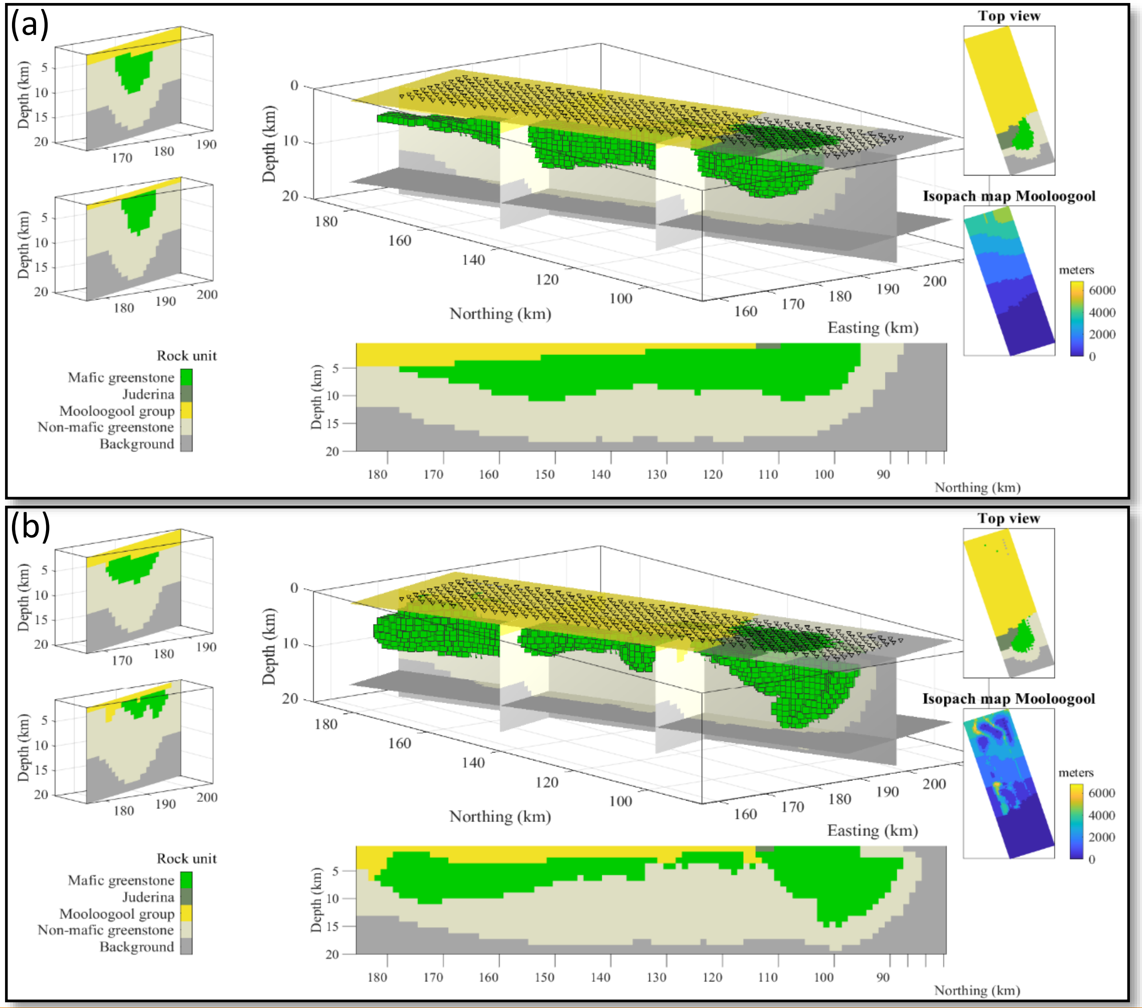
Results of gravity data inversion using level-set formulation of geometries to adjust geological bodies' shapes. Application to greenstone belt from Yerrida basin (WA)

(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., 2021 [pending], 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.

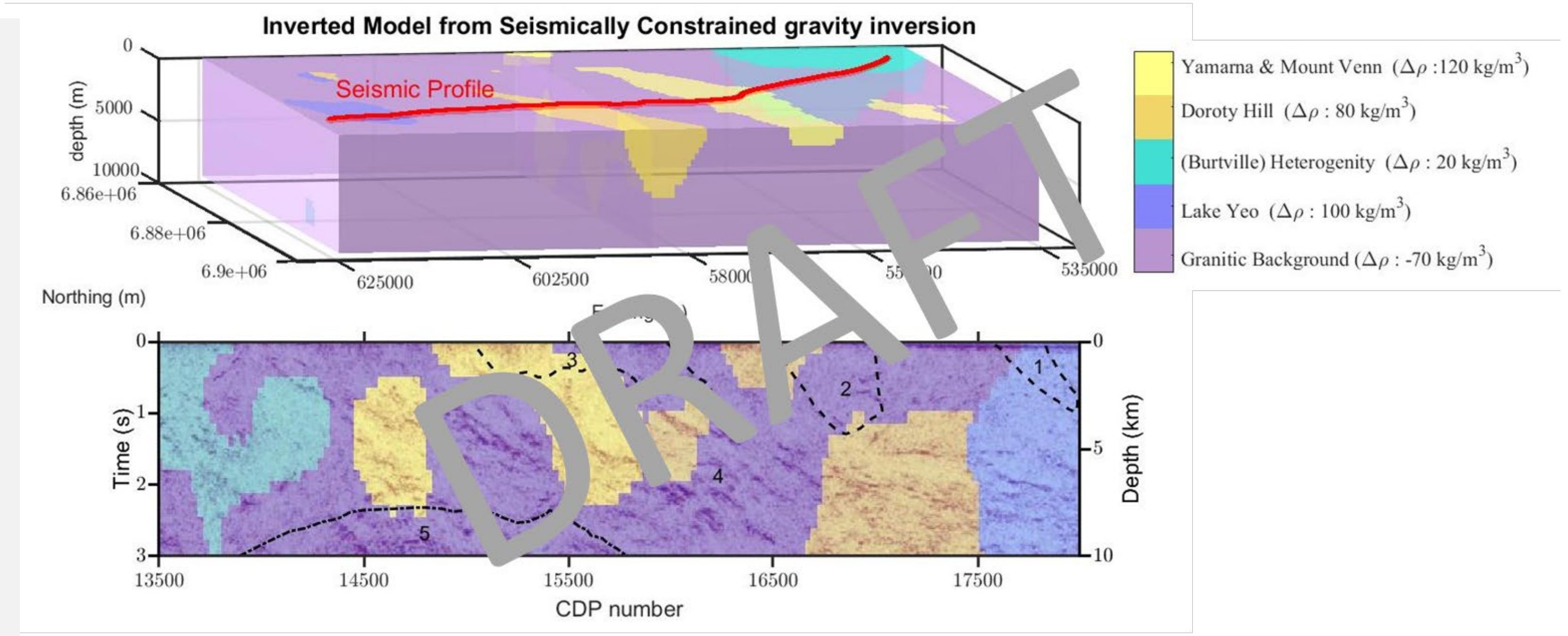


WP #4 – Integrated Geophysical Inversion

Field application example of 3D geometrical gravity inversion using a generalized level-set formulation constrained by sparse 2D seismic modelling in the Yamarna area.
From Rashidifard et al. 2021 [in prep].

A 2D crooked seismic line is used to constrain 3D level-set gravity inversion to adjust the geometry of geological units. Topological rules are applied during inversion.

Unpublished material: for internal use only.

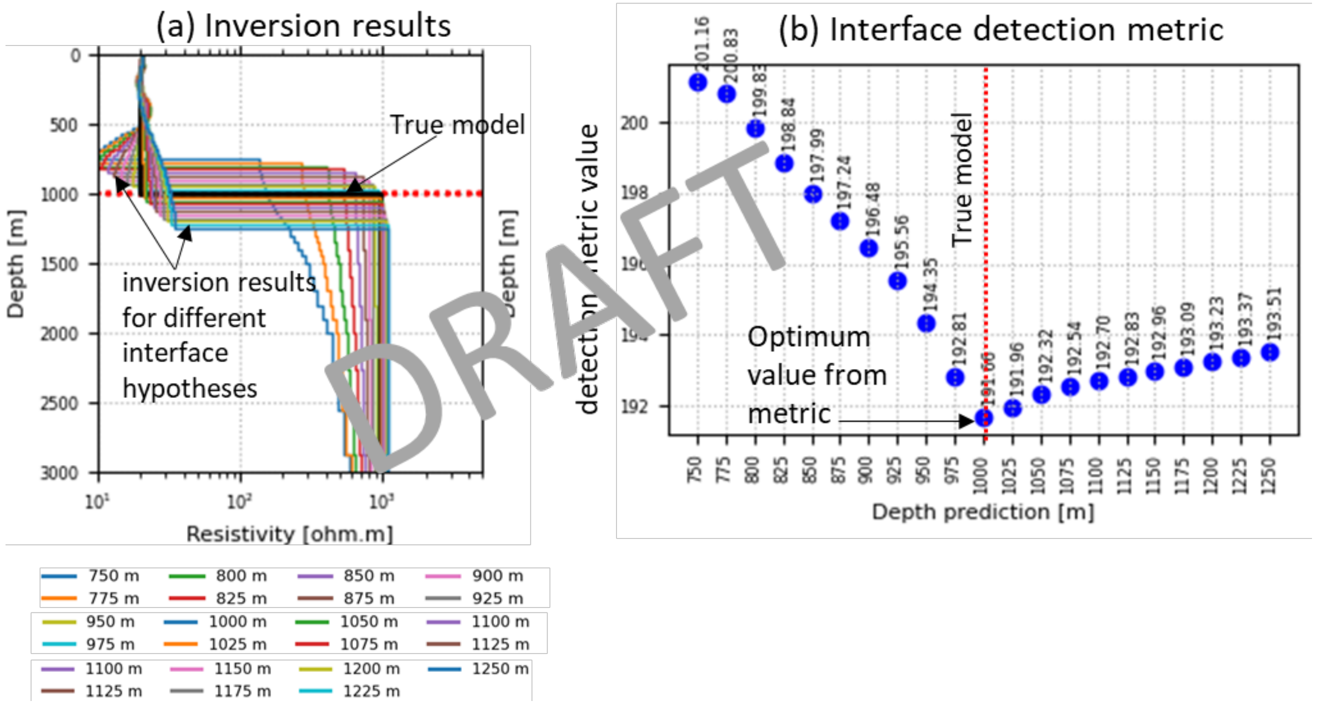


WP #4 – Integrated Geophysical Inversion

Numerical investigation for constraining MT inversion using passive seismic to reduce the depth-to-basement uncertainty.
From Suriyaarachchi et al. [in prep].

Depths for the basement interfaces are sampled from the range compatible with passive seismic modelling and tested against MT data inversion. The metric introduced here is calculated from MT inversion results. Tests reveal that it is minimum at the true interface depth and is suitable for depth-to-basement modelling and uncertainty reduction.

Unpublished material: for internal use only.

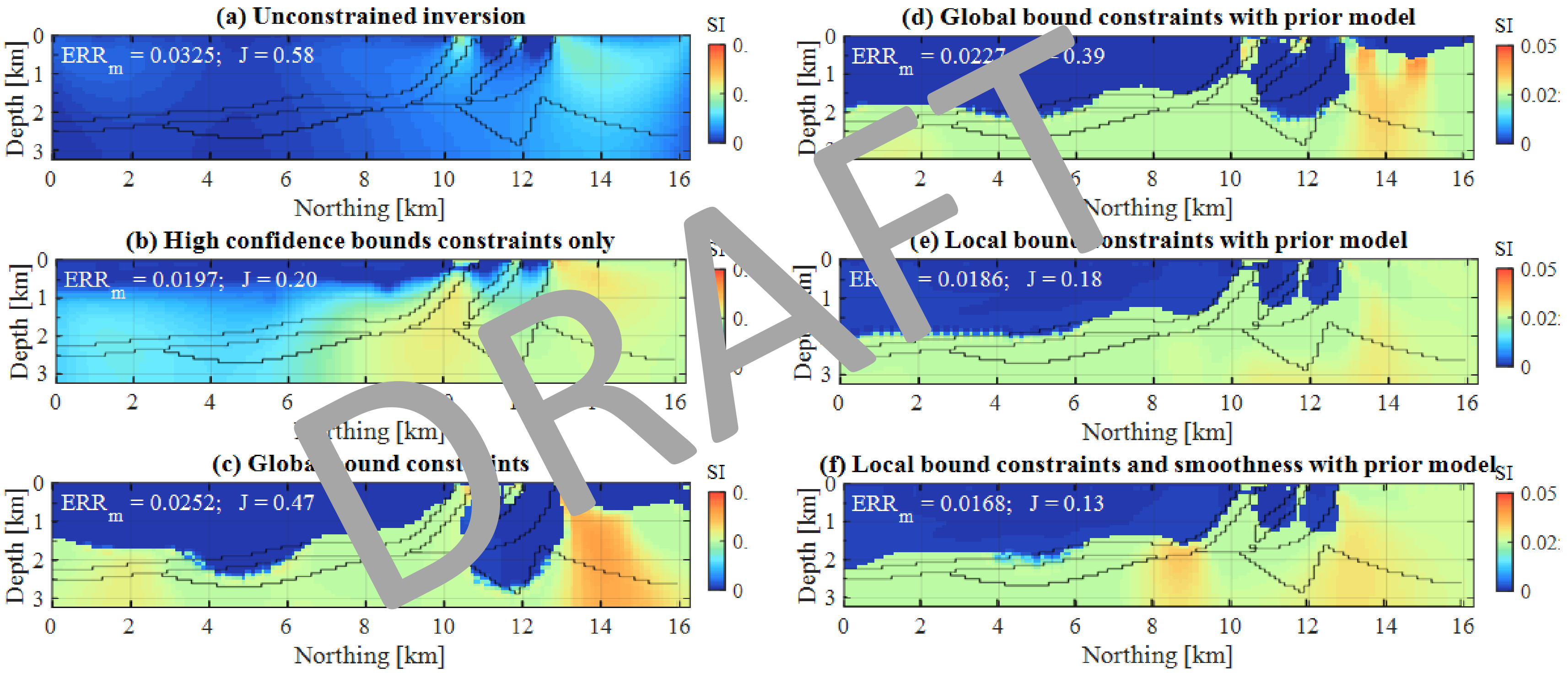


WP #4 – Integrated Geophysical Inversion

Utilisation of probabilistic MT to constrain magnetic inversion.

The grey lines materialise the interfaces between geological units in the true model. ERRm refers to the RMS model misfit between inverted and true model. The progression from (a) through (e) increasingly uses MT information to categorize basement vs non-basement units. From Giraud et al. 2021 [in prep].

Unpublished material: for internal use only.



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 (Paper published – Solid Earth)

● 7. Paper preparation: Extracting geological knowledge from petrophysics using machine learning on drillcore

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 ●

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

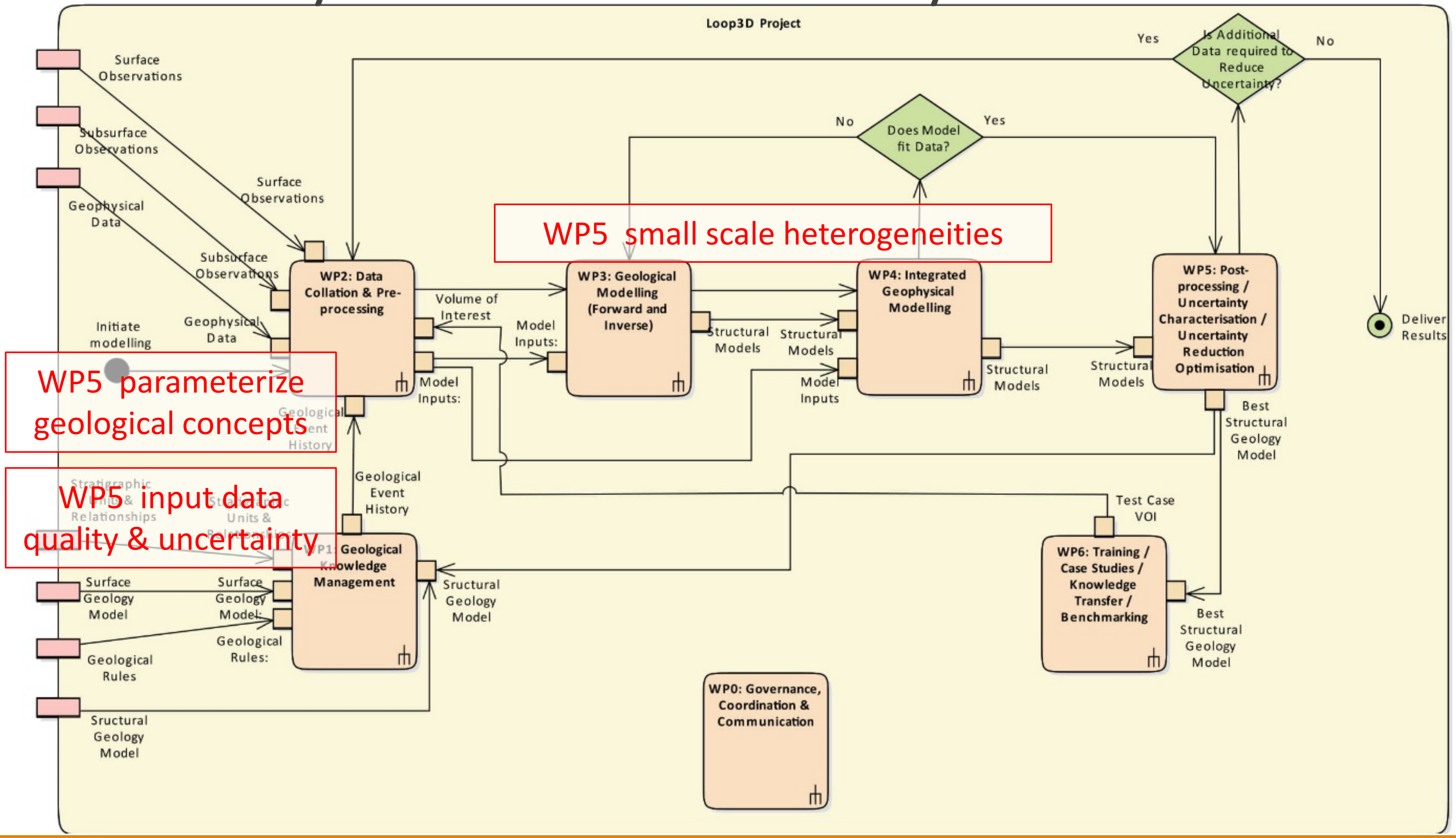
15. Assessing the effects of hierarchical versus joint inversion on prediction confidence (precision) and bias (accuracy)

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



Loop

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?

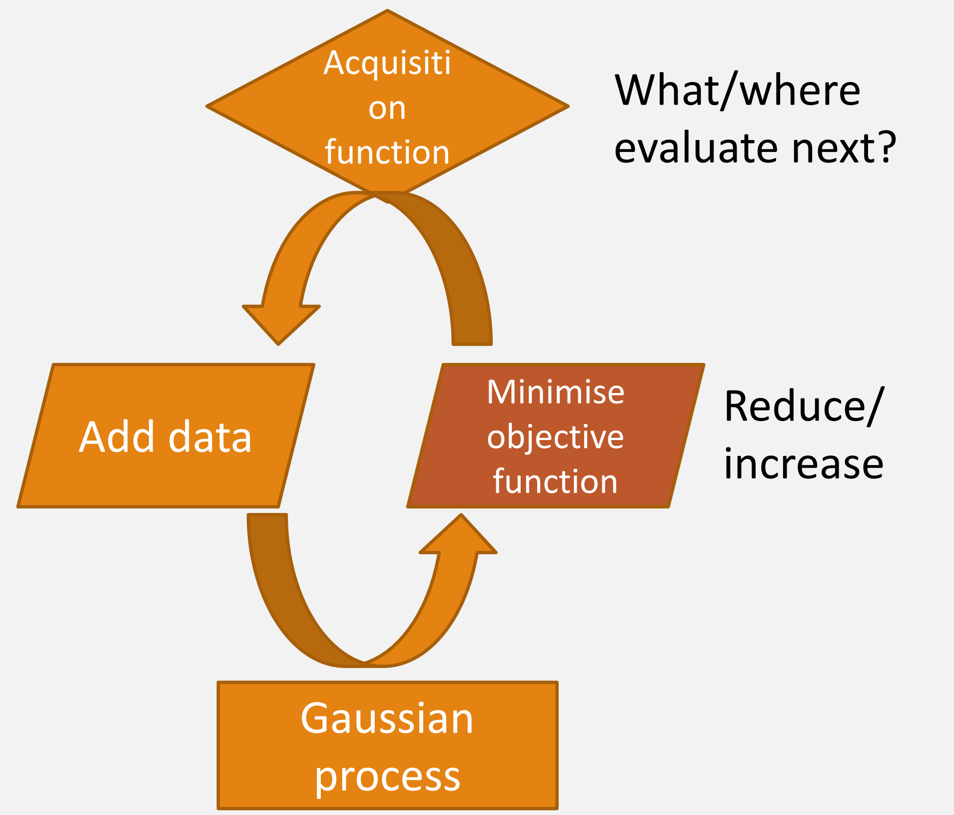
WP #5 – Model Analysis & Uncertainty Reduction

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

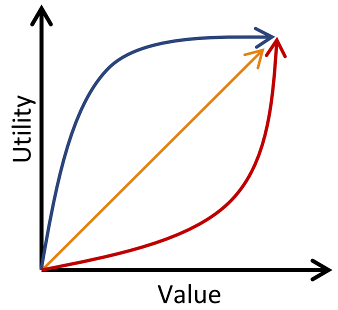
Decision analysis

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

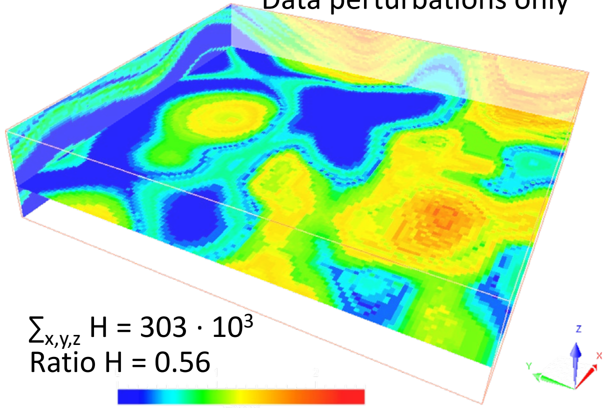
- Define a synthetic reference and prior information (Done)
- Implement pilot drillhole perturbations (Done, improvement in progress)
- Select (Done) and implement the optimization algorithm (Done)

WP #5

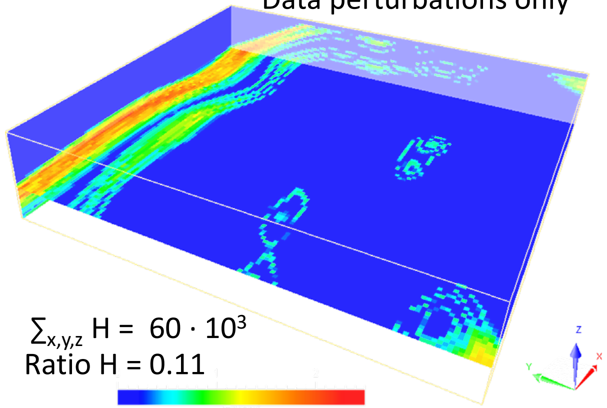
1. ensemble generator integrated in the workflow
2. mitigating uncertainty underestimation with Pilot-Stick Perturbations (illustration below)

Entropy H as uncertainty indicator

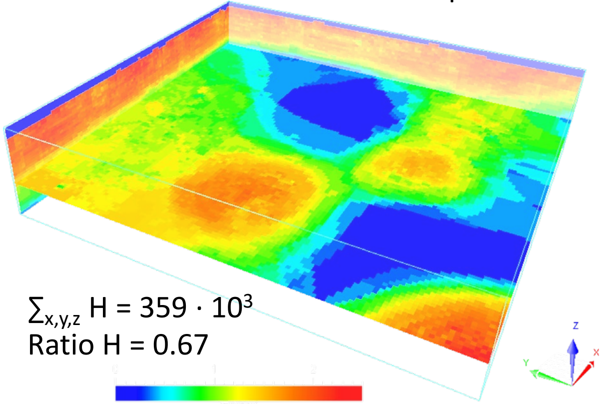
Data perturbations only



Data perturbations only

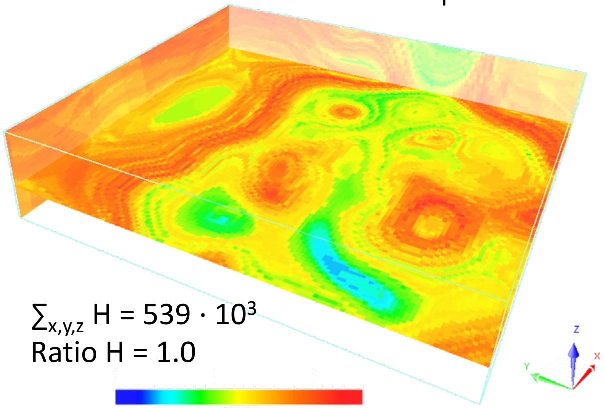


Pilot-stick and data perturbations



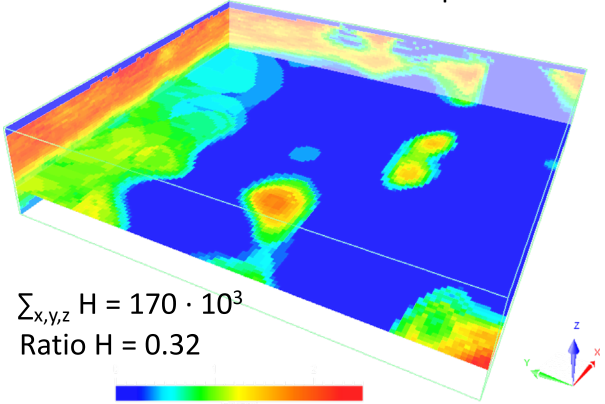
from 20 Full Pilot-Stick models

Pilot-stick and data perturbations



from 20 LoopStructural realizations

Pilot-stick and data perturbations



from 20 3D GeoModeller realizations

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

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 🔵

◯ 29. Map2loop and LoopResources presentation at Global ROAR 1010 session, November 2020

◯ 30. Loop European Workshop held in March 2021

◯ 31. Loop/MinEx CRC workshop held in March 2021

◯ 32. Tutorial on 3D modelling with Loop provided at Transform 2021, April 2021

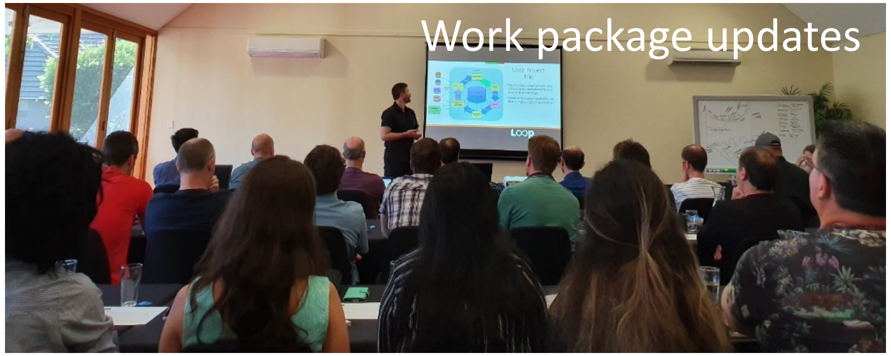
◯ 33. EGU presentation ‘Current and future limits to automated 3D geological model construction’ April 2021

🔵 34. Loop presentation at GeoHug scheduled for September 2021

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

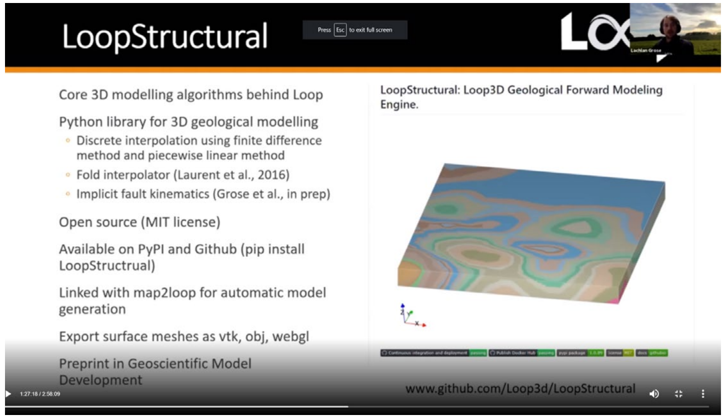


Work package updates

Break out sessions

Happy memories from the virtual 2020/21 Loop sessions

The Loop team has presented at EGU, Roar, GA and provided a very well attended European Worskhop in 2020/21. These are available on the Loop website – loop3d.org



Loop Papers and Conference presentations

- **Papers (new / paper status changed)**
  - Geoscientific Model Development – Special Issue: The Loop 3D stochastic geological modelling platform – development and applications (Laurent Ailleres coordinator)
    - de Kemp, E., 2021. Spatial Agents for Geological Surface Modelling. Geosci. Model Dev. Discuss. https://doi.org/10.5194/gmd-2021-66
    - Giraud, J., Ogarko, V., Martin, R., Jessell,M., Lindsay, M., 2021. Structural, petrophysical and geological constraints in potential field inversion using the Tomofast-x v1.0 open-source code. Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-14
    - Grose, L., Ailleres, L., Laurent, G., Jessell, M., 2021. LoopStructural 1.0 time aware geological modelling. Geosci. Model Dev., 14, 3915-3937. DOI: https://doi.org/10.5194/gmd-14-3915-2021
    - Grose, L., Ailleres, L., Laurent, G., Caumon, G., Jessell, M., Armit, R. 2021. Realistic modelling of faults in LoopStructural 1.0. Geosci. Model Dev. Discuss, https://doi.org/10.5194/gmd-2021-112

Loop Papers and Conference presentations

- **Papers (new / paper status changed)**
  - Geoscientific Model Development – Special Issue: The Loop 3D stochastic geological modelling platform – development and applications (Laurent Ailleres coordinator)
    - Jessell, M., Ogarko, V., Lindsay, M., Joshi, R., Piechocka, A., Grose, L., de la Varga, M., Ailleres, L., Pirot, G., 2021. Automated geological map deconstruction for 3D model construction. Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-400
    - Joshi, R., Madaiah, K., Jessell, M., Lindsay, M., Pirot, G., 2021. dh2loop 1.0: an open-source python library for automated processing and classification of geological logs. Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-391

Loop Papers and Conference presentations

- **Papers (new this quarter)**
  - Guo, J., Li, Y., Jessell, M., Giraud, J., Li, C., Wu, L., Li, F., Liu, S., 2021. 3D Geological Structure Inversion from Noddy-Generated Magnetic Data Using Deep Learning Methods. Computers & Geosciences (149), 2021, 10.1016/j.cageo.2021.104701.
  - Hillier, M. et al., Three Dimensional Structural Geological Modelling using Graph Neural Networks. Submitted – Math. Geosciences
  - Ogarko, V., Giraud, J., Martin, R., Jessell, M., 2021. Disjoint intervals bound constraints using the alternating direction method of multipliers (ADMM) for geologically constrained inversions: application to gravity data. Geophysics, 86: G1-G11
  - 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.
  - Martin, R., Giraud, J., Ogarko, V., Beller, S., Gegout, P., Jessell, M., 2020. Three-dimensional gravity anomaly inversion in the Pyrenees using compressional seismic velocity model as structural similarity constraints. Geophysical Journal International, ggaa414

Loop Papers and Conference presentations

- **Papers (new this quarter)**
  - Rashidifard, M., Giraud, J., Lindsay, M., Jessell, M., Ogarko, V. Constraining 3D geometric gravity inversion with 2D reflection seismic profile using a generalized level-set approach: application to Eastern Yilgarn craton. Solid Earth. 10.5194/se-2021-65
- **Submitted Papers**
  - 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.
  - 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., Jessell, M. 3D geological modelling in the mining sector: challenges to improve prediction confidence. Geoscientific Model Development - Special Issue: The Loop 3D stochastic geological modelling platform – development and applications.
  - 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

Loop Papers and Conference presentations

- **EGU 2021 – Abstracts submission**
  - Hillier, M., Wellman, F., Brodaric, B., de Kemp, E., Schetselaar, E. Using Graph Neural Networks for 3-D Structural Geological Modelling. Proceedings: European Geophysical Union Annual Meeting 2021.
- **2021 Presentations**
  - Brodaric, B. and Richard, S. (2021) Stratigraphic Knowledge and the GeoScience Ontology. MinEx Opportunity Fund Project 6 Workshop, 30 March 2021.
  - Schetselaar, E. (2021) Lithostratigraphic encoding of drillhole data: a basic requirement for building 3D geological models. MinEx Opportunity Fund Project 6 Workshop, 30 March 2021.
  - Brodaric, B. and Richard, S. (2021) The GeoScience Ontology. CGI-IUGS webinar, 23 June 2021.
  - Brodaric, B., de Kemp, E., Hillier, M., Parquer, M., Russell, H. Enhanced Methods for National 3D Geological Modelling in Canada. US National Geological Mapping Forum, 28 Jan 2021.

Loop Papers and Conference presentations

- **Loopinars – Loop European Workshops March 2021** (presenter listed only)
  - Ailleres, L. Loop – overall vision and progress
  - Alvarado, F. Structural frames for modelling intrusions
  - Brodaric, B. and Richard, S. The GeoScience Ontology.
  - Chaarani, R. The value of structural data in folded domains
  - Giraud, J. Level-set inversions method and application to the Yerrida greenstone beltGrose, L. LoopStructural – Structural frame for the geometrical modelling of polydeformed terranes
  - Giraud, J. Use of prior information to constrain geophysical inversions in Tomofast
  - Giraud, J. The future of inversions – Guided inversions and geology/geophysics inversions
  - Heaven, R.E. Extracting Stratigraphic Knowledge from Text and Visualising in an Interactive Network Graph.
  - Hillier, M. Using Graph Neural Networks for 3D Structural Geologic Modelling.
  - Jessell, M. Map2loop – generating an augmented dataset from maps analysis for 3D structural modelling
  - Joshi, R. dh2loop 1.0: an open-source python library for automated processing and classification of geological logs
  - Lindsay, M. Reducing uncertainties: data quantity versus data precision
  - Lindsay, M. Regional mineral exploration and calculation of the value-of-Information
  - Montsion, R. Structural complexity from the interpretation of geophysical data

Loop Papers and Conference presentations

- **Loopinars – Loop European Workshops March 2021** (presenter listed only)
  - Parquer, M. Automated 3D Geological Consistency Checking.
  - Pirot, G. Propagation of Pilot-Stick Perturbations through different geological modelling engines – how does it influence uncertainty assessment?
  - Pirot, G. Reducing epistemic uncertainty related to sparse spatial data with Pilot-Stick Perturbations
  - Rashidifard, M. Using sparse seismic and small-scale morphological constraints in level-set inversions
  - Suriyaarachchi, N. Passive seismic derived geological constraints for MT inversions
  - Thomson, R. The Loop GUI

Loop Papers and Conference presentations

- **AESC 2021 – Hobart Online**

  - Ailleres, L., Grose, L., Caumon, G., Jessell, M. LoopResources – Reducing the Mining Footprint
  - Grose, L., Ailleres, L., Laurent, G., Jessel, M. LoopStructural 1.0 time aware geological modelling (Keynote)
  - Jessell, M., Ogarko, V., Lindsay, M., Joshi, R., Piechocka, A., Grose, L., de la Varga, M., Fitzgerald, D., Aillères, L., Pirot, G. Reproducible 3D model construction using map2loop
  - Lindsay, M., Pirot, G., Jessell, M., Giraud, J., Scalzo, R., Cripps, E., Aitken, A. Geophysical Data Optimisation for Modelling: Data collection in a value-of-information framework
  - Lindsay, M., Richard, S., Brodaric, B., Giraud, J., de Kemp, E., Jessell, M. The "Loop" knowledge manager: property retrieval and geophysical modelling
  - 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
  - Pirot, G., Lindsay, M., Grose, L., de La Varga, M., Jessell, M. Propagation of data and algorithmic uncertainty based on borehole calibration and perturbation – a sensitivity analysis

Loop Papers and Conference presentations

- **AESC 2021 – continued**
  - Pirot, G., Lindsay, M., Jessell, M. Optimization of sequential drilling locations to reduce geological uncertainty
  - Rashidifard, M., Giraud, J., Lindsay, M., Jessell, M., Ogarko, V. Constrained Gravity Geometry Inversion with Reflection Seismic Section (Keynote)
  - Rashidifard, M., Giraud, J., Ogarko, V., Lindsay, M., Jessell, M. How to computationally include regional interpretations into the seismic imaging process.
  - Suriyaarachchi, N., Giraud, J., Seille, H., Jessell, M., Lindsay, M., Hennessy, L., Ogarko, V. A new approach to integrate passive seismic HVSR depth models in magnetotelluric (MT) 1D inversion to characterize the cover-basement interface
  - Giraud, J. Lindsay, M., Jessell, M. Morphological gravity inversion to refine geological models

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
  - Lindsay, M., Occhipinti, S., LaFlamme, C., Aitken, A., Ramos, L.N.R.A. Mapping Undercover: Using Integrated Potential Field Interpretation, Inversion and 3D Modelling to Assess Basin Prospectivity
  - Parquer, M., de Kemp, E., Brodaric, B., Hillier, M. Automated 3D geological consistency checking: a geomodelling tool.

Loop Papers and Conference presentations

- **AGU Fall Meeting 2020 – continued**
  - Pirot, G., Lindsay, M., Grose, L., Jessell, M. A sensitivity analysis of geological uncertainty to data and algorithmic uncertainty
  - Rashidifard, M. Giraud, J. Lindsay, M., Jessell, M., Ogarko., V. Constrained Gravity Geometry Inversion with Sparse Low-Uncertainty Data.
- **Other presentations**
  - Suriyaarachchi, N., Giraud, J., Seille, H., Jessell, M., Lindsay, M., Hennessy, L., Ogarko, V., 2020. Integration of Magnetotellurics (MT) and Passive seismic data to characterize cover depth, MinEx CRC annual conference 2020.
  - Rashidifard, M., Giraud, J., Ogarko, V., Jessell, M., Lindsay, M., 2020. Integrated Inversion/Modelling of Gravity Data and Reflection Seismic Data with Different Spatial Coverage, Invited speaker at ASEG Tech Night.
  - Ailleres, L., Nov 2020 - Amira Global ROAR 1010 2020 - LoopResources - Reducing the Mining Footprint
  - Jessell, M., Nov 2020 - Amira Global ROAR 1010 2020 - map2loop - Automated map deconstruction for 3D models
  - Ailleres, L., Aug 2020. Loop – an integrated, interoperable platform enabling 3D stochastic geological modelling, Geoscience Australia Public Talk.

Loop Papers and Conference presentations

- **Other presentations ct'd**
  - Giraud, J., Lindsay, M., Jessell, M., Ogarko, V., 2020. Towards plausible lithological classification from geophysical inversion: honouring geological principles in subsurface imaging, SEG 2020 Annual meeting (workshop 10: Machine Learning/Artificial Intelligence in Mineral Exploration)
- **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 & Reports (new)**

  - Brodaric, B. and Richard, S.M. (2021) The GeoScience Ontology Reference; Geological Survey of Canada, Open File 8796, 34 p. https://doi.org/10.4095/328296
  - Brodaric, B., Richard, S., 2021. The GeoScience Knowledge Manager Release 1.0. https://github.com/Loop3D/GKM
  - Brodaric, B. and Richard, S.M. (2021) The GeoScience Ontology Release 1.0.2; Zenodo, 11 May 2021. https://doi.org/10.5281/zenodo.4750707
  - 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

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. Project Completed.
- 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

- Richard, S.M. (2020) Loop3D GeoScience Ontology, Loop3D Technical Report. https://github.com/Loop3D/GKM/blob/master/Draft1.1Report.docx.
- LoopStructural: The geometric and structural geology ruled modelling engine of Loop https://github.com/Loop3D/LoopStructural
- map2loop: Automated analysis of geological maps and data augmentation for input into LoopStructural https://github.com/Loop3D/map2loop-2
- dh2loop: Automated extraction of consistent lithologies code/names along drill holes https://github.com/Loop3D/dh2loop
- GeoSwarm: Spatial agents scalar and vector fields interpolator https://github.com/Loop3D/GeoSwarm
- Uncertainty indicator draft package (a collection of notebooks to illustrate the various indicators) https://github.com/Loop3D/uncertaintyIndicators