Loop 3D geological modelling: speeding up the workflow

by

M Jessell[1], M Lindsay[1] and V Ogarko[2]

Introduction

The Loop 3D consortium aims to improve all aspects of the geological modelling workflow to reduce the construction speed and cost, and improve the quality and value of 3D geological models. In this study, we present the first attempts at improving that part of the workflow related to the transformation from raw data to first model, which is one of the most time-consuming parts (hours to days) of the model-building process. Starting from standard Geological Survey of Western Australia (GSWA) map products, and by extracting primary and secondary geometric information as well as fault and stratigraphic topological relationships, we are able to export a complete input file for three geomodelling packages (gempy, LoopStructural and GeoModeller) in under five minutes.

Prototype Loop Information Manager

The goal of the Loop Information Manager is to take digital geological data, either from files or online data servers, and extract the maximum geological information available for use as constraints on the 3D modelling process, as well as other geological studies.

Input data

In this proof of concept, we use the 2016 1:500 000 State interpreted bedrock geology map of Western Australia (GSWA, 2016) and the Western Australian Field Observation database (WAROX) as sources of the data needed to build
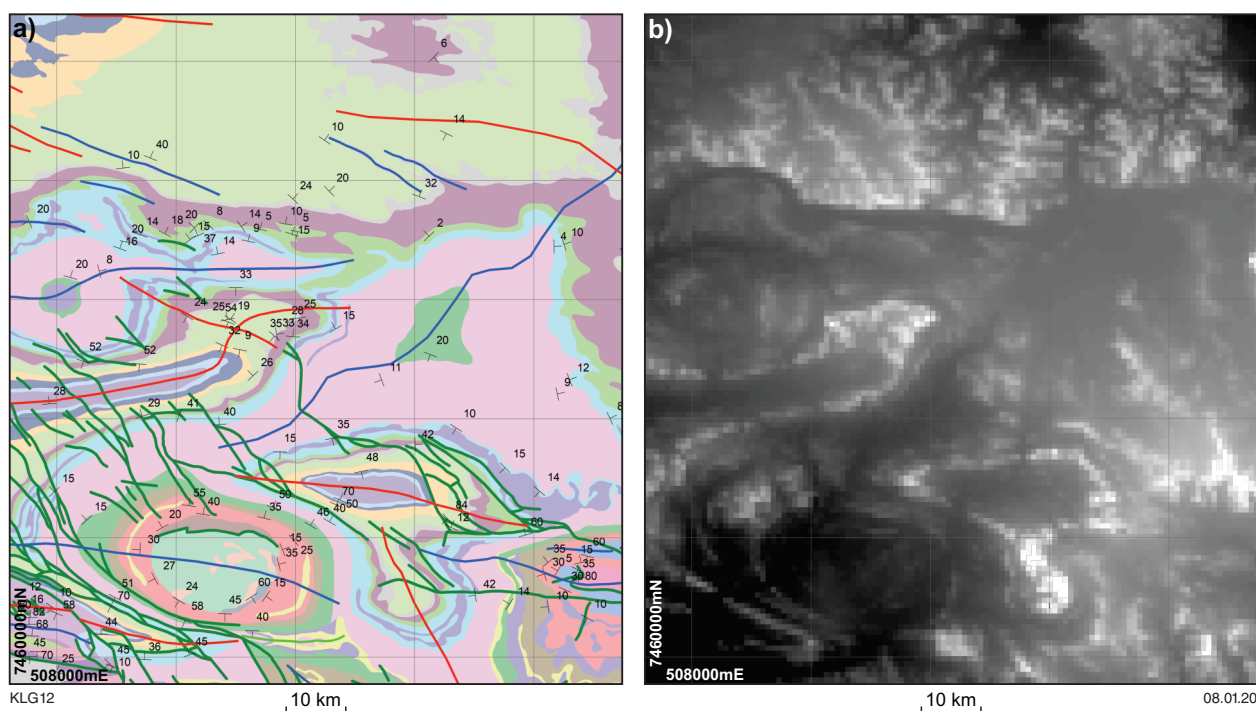

Figure 1. Input data for model: a) 1:500 000 interpreted bedrock geology of the Rocklea Dome/Turner Syncline region of Western Australia, showing the different datasets used to create the 3D model. Red lines are synclines, blue lines are anticlines, green lines are faults and structural symbols show bedding orientations. The region shown is approximately defined by latitudes -22°S and 23°S, and longitudes 117°E and 118°E. Grid references are MGA coordinates, Zone 50; b) SRTM digital terrain model sourced directly from Geoscience Australia (2016) at <http://gaservices.ga.gov.au>

1   Centre for Exploration Targeting, School of Earth Sciences, The University of Western Australia, Stirling Highway, Crawley WA 6009

2   Faculty of Engineering and Mathematical Sciences, International Centre for Radio Astronomy Research, The University of Western Australia, Stirling Highway, Crawley WA 6009

a first-pass model of the region around the Rocklea Dome and Turner Syncline in the Hamersley region of Western Australia (Fig. 1). The area consists of upright refolded folds of Archean and Proterozoic stratigraphy overlying an Archean basement cut by over 50 northwest–southeast trending faults that form a part of the Nanjilgardy Fault System.

Derived modelling inputs

Using a series of scripts contained with the C++/python *map2loop* package (https://github.com/Loop3D/map2loop) we are able to convert the input layers into primary data: structural dips of beds; fault and fold traces; and the stratigraphic base of each unit, which represent decimated equivalents of the source data. In addition, we can derive secondary information: apparent fault throw, interpolated bedding orientations and local formation thickness that are needed by some modelling systems (Fig. 2).

The third class of modelling constraints derived by the *map2loop* algorithms extract spatial and temporal topology from the map layers. Specifically, it creates network diagrams showing the stratigraphic relationships between units in the region of interest (c.f. Thiele et al., 2016), network diagrams of the relationships between faults, and relationship tables showing whether a particular fault cuts a formation or group (Fig. 3).

Resulting 3D model

The outputs of *map2loop* described above provide all of the information required to build a 3D geological model in GemPy (de la Varga et al, 2019), LoopStructural (https://github.com/Loop3D/LoopStructural) and GeoModeller (www.intrepid-geophysics.com). In Figure 4, we show the 3D model and top surface of the volume as calculated using GeoModeller, together with an uncertainty voxel based on the variation in lithology at the voxel model for a randomly generated suite of models based on the input data (Pakyuz-Charrier et al., 2018).

While this is very much a work in progress, the ability to generate all necessary input data for a geological model from a set of geological layers in a matter of minutes demonstrates the potential for this approach to reduce the entry barrier for geologists who wish to make 3D models as part of their exploration or research programs. The whole system relies on the quality of the input data, and when under cover, different and more geophysics-centric approaches need to be taken. A description of the integration of geophysics into the workflow is being developed by the Loop consortium, but is beyond the scope of this abstract.

Acknowledgements

References

de la Varga, M, Schaaf, A and Wellmann, F 2019, GemPy 1.0: open-source stochastic geological modeling and inversion, Geoscientific Model Development, v. 12, p. 1–32, doi:10.5194/gmd-12-1-2019.

Geological Survey of Western Australia 2016, 1:500 000 State interpreted bedrock geology of Western Australia, 2016: Geological Survey of Western Australia, digital data layer, <www.dmp.wa.gov.au/geoview>.

Geoscience Australia 2016, Digital Elevation Model (DEM) Shuttle Radar Topography Mission (SRTM) 1 Second over Australian Bathymetry Topography: Geoscience Australia, digital dataset, <http://gaservices.ga.gov.au>.

Pakyuz-Charrier, E, Lindsay, M, Ogarko, V, Giraud, J, and Jessell, M 2018, Monte Carlo simulation for uncertainty estimation on structural data in implicit 3-D geological modeling, a guide for disturbance distribution selection and parameterization, Solid Earth, v. 9, p. 385–402, doi:10.5194/se-9-385-2018.

Thiele, ST, Jessell, MW, Lindsay, M, Ogarko, V, Wellmann, JF and Pakyuz-Charrier, E 2016, The topology of geology 1: topological analysis: Journal of Structural Geology, v. 91, p. 74–87.
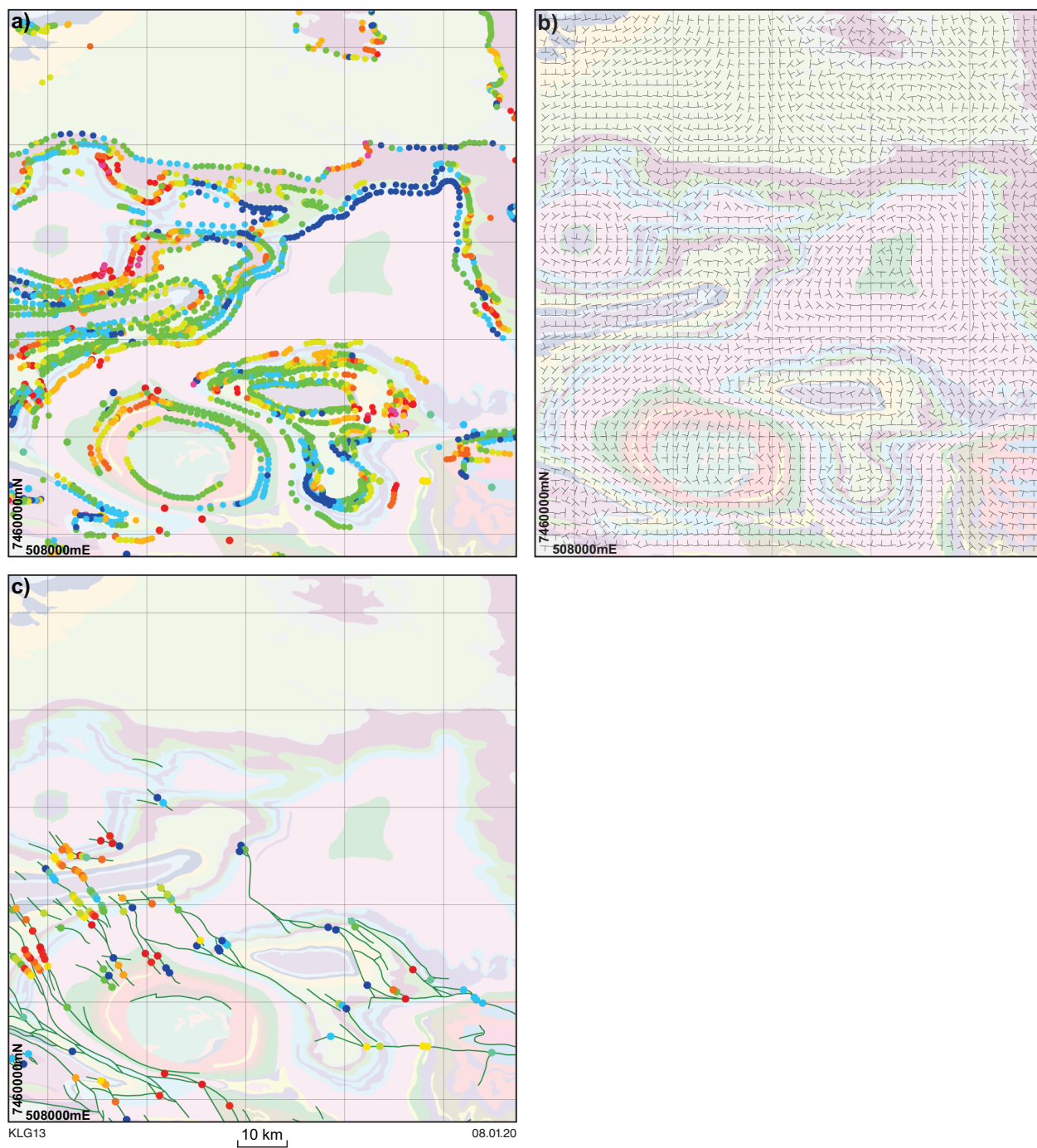
Figure 2. Secondary geological information automatically derived from maps: a) normalized local formation thickness (hotter colours show thicker formations); b) interpolated estimated bedding orientations for the Hamersley and Fortescue Groups; c) apparent fault throw (hotter colours show larger throw)
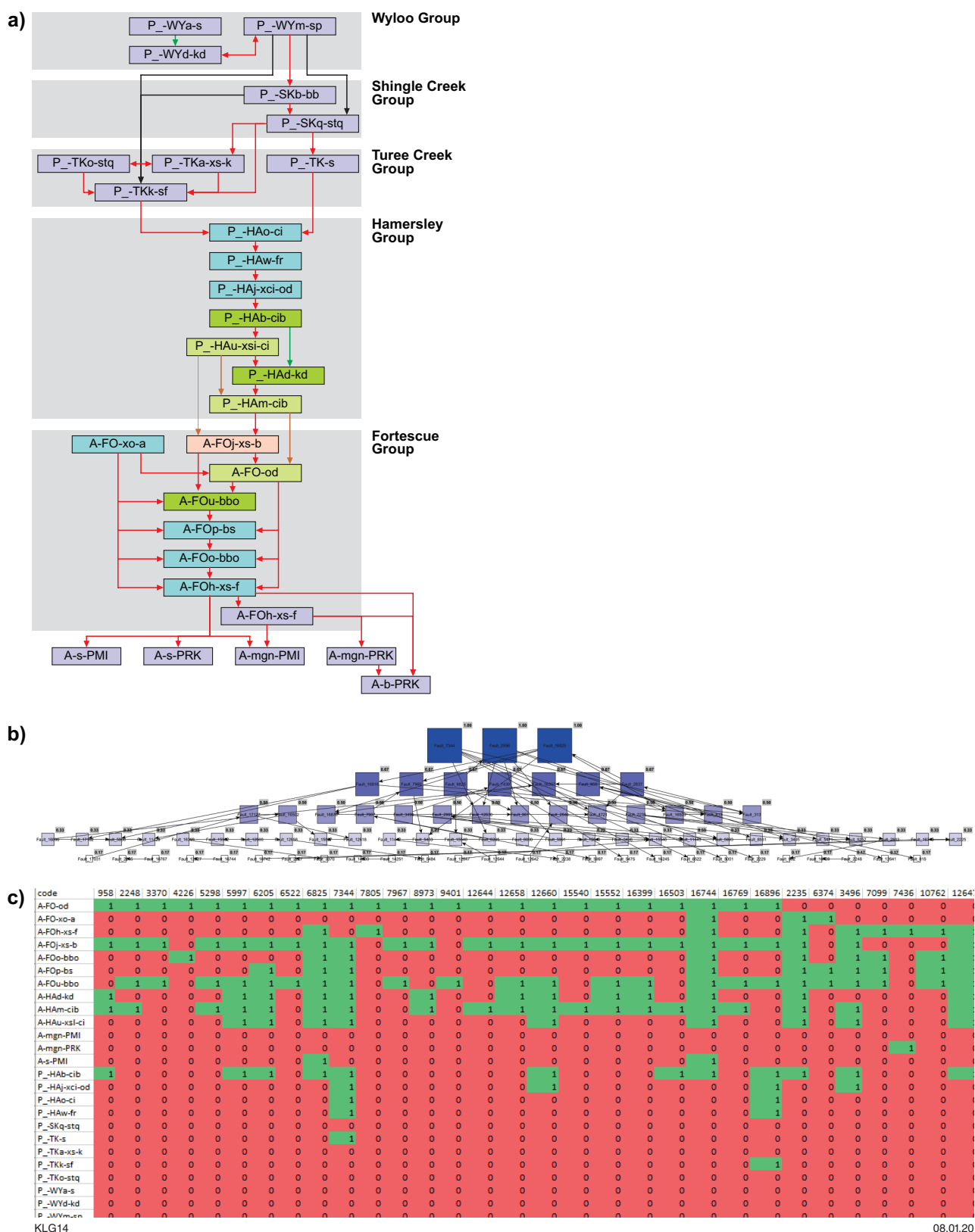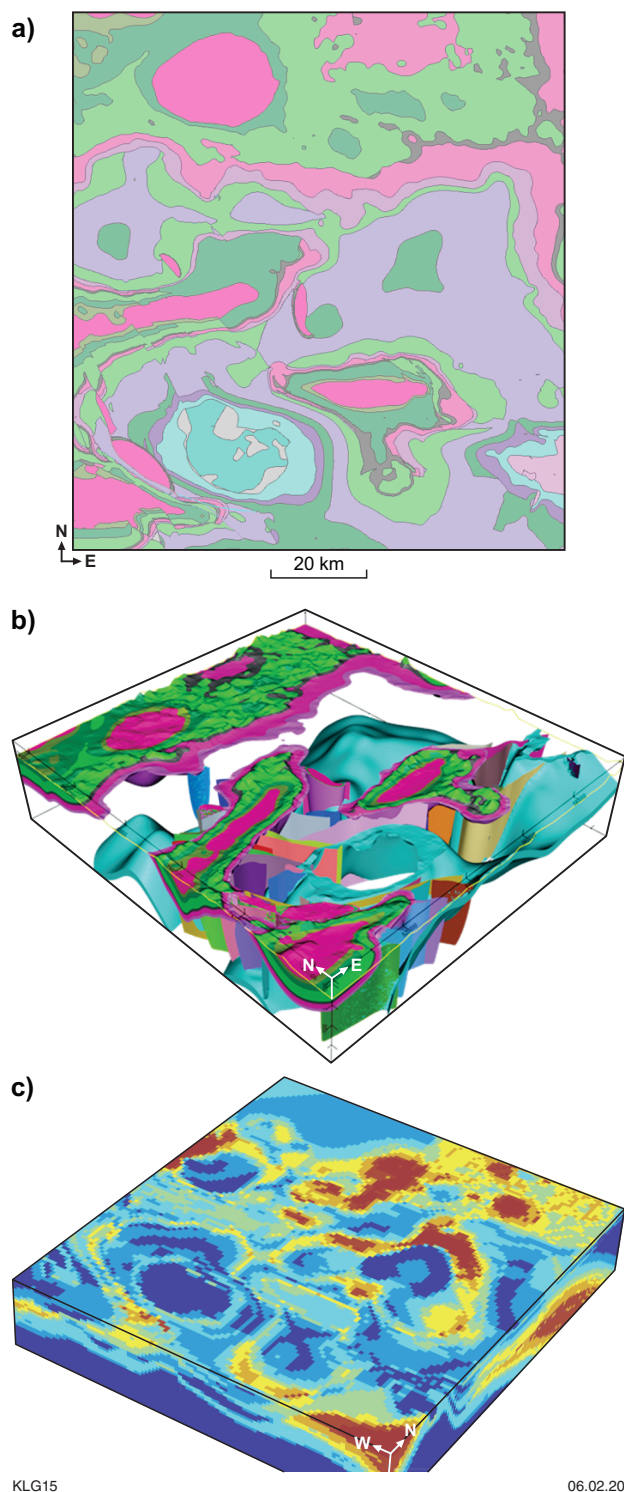
Figure 3. **Topological information automatically derived from maps: a) stratigraphic relationships between the different formations found in the region of interest. Each rectangle represents one formation, and the arrows point to younger formations; b) fault relationships, each fault is one rectangle, and the larger and darker the rectangle, the more important the fault is based on the number of faults that connect to it; c) the fault-formation relationship matrix. Green cells indicate that a specific fault (columns) intersects a given formation (rows), otherwise the cell is red**

Figure 4. 3D geological model produced using the input data created by *map2loop* by creating an intermediate 'taskfile' that can be converted by the GeoModeller system into the full model: a) top surface of the geology; b) 3D model with some layers rendered transparent to highlight subsurface fault relationships; c) uncertainty voxet produced by building a suite of 300 models and comparing them on a voxel by voxel basis (hotter colours represent parts of the model that are less well constrained by the data)