Using LOOP 3D modelling to unlock the knowledge held in BGS maps

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Abstract

Geological 2D bedrock maps are ideally supposed to be the intersection of a 3D geological conceptual model with topography. However, often when you try to build 3D models from geological maps you find that this is not always the case. Sometimes geometries that might seemingly work on a 2D map face, do not actually project into 3D in the way the geologist imagined. This is especially true for older maps which may have been constructed before modern geological understandings like plate tectonics or sequence stratigraphy. Most geological maps are reviewed by other geologists who may have their own differing backgrounds and biases and therefore is no automatic way of assessing the geometrical accuracy of a map.

The British Geological Survey (BGS) produces geological mapping at a range of scales. Our highest resolution national mapping is our 1:50,000 digital map dataset. This was compiled from BGS's New Series 1:50 000 and 1:63 360-scale (one-inch to one-mile) paper maps with updated nomenclature, including a few 1:100 000-scale maps of Orkney and the Hebrides. As such it still uses a few maps that were surveyed before 1918 (Figure 1). Up until recently we did not have a way of assessing the geometrical accuracy of a map and determining if they need resurveying. The development of open-source implicit modelling platforms, specifically designed to work with geological map data by the LOOP project, means there is now a tool that we can use to understand the 3D geometrical accuracy of the geological map. Here in we discuss the results of the trials where we have used Map2Loop and Loop Structural to help us understand and improve our geological mapping.

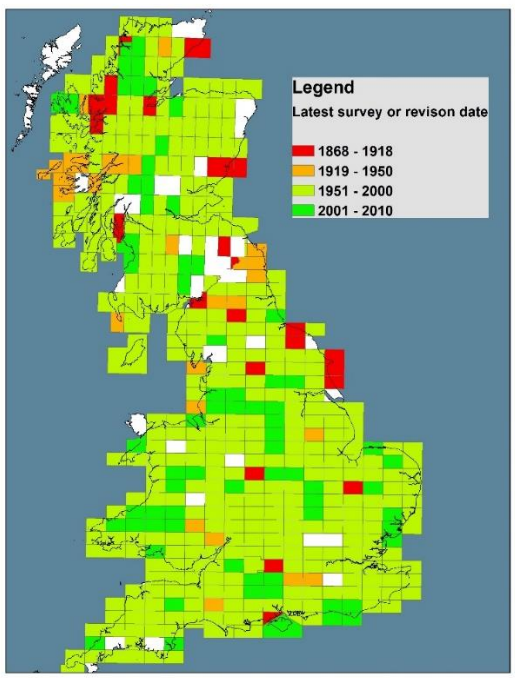

Figure 1. The latest survey or revision date of 1:50 000 bedrock mapping in Great Britain.

The LOOP project, is an open-source 3D geological modelling platform being developed by a research consortium supported by Geoscience Australia and One Geology. A component of the LOOP development programme is Map2Loop and Loop Structural –tools that can be used for the semi-automated construction of 3D geological models directly from bedrock geological maps (Jessell et al 2021, Grose et al 2021a, b). LOOP Structural used implicit geological modelling to create 3D models (Grose et al 2021a, b). Implicit modelling is different to the explicit methods. In implicit modelling surfaces are not constructed on an individual horizon-by-horizon basis. Instead, implicit modelling uses all the data simultaneously to interpolate a continuous 3D scalar field that is a representation of the total stratigraphy and structure of a defined volume. Surfaces are then extracted from this implicit field in a subsequent step. Implicit modelling thus counters many of the difficulties created by sparse and irregularly distributed input data, that really requires pooling to understand the 3D relationships of a set of surfaces (Newell, 2018).

Since the release of Map2Loop and Loop Structural in 2021 BGS has been running trials to see if these programs can help us improve our geological mapping and our ability to understand what is happening below the surface. There have been two key applications that we have trialled thus far: Improving map fault networks and understanding the variation of thickness of stratigraphic units.

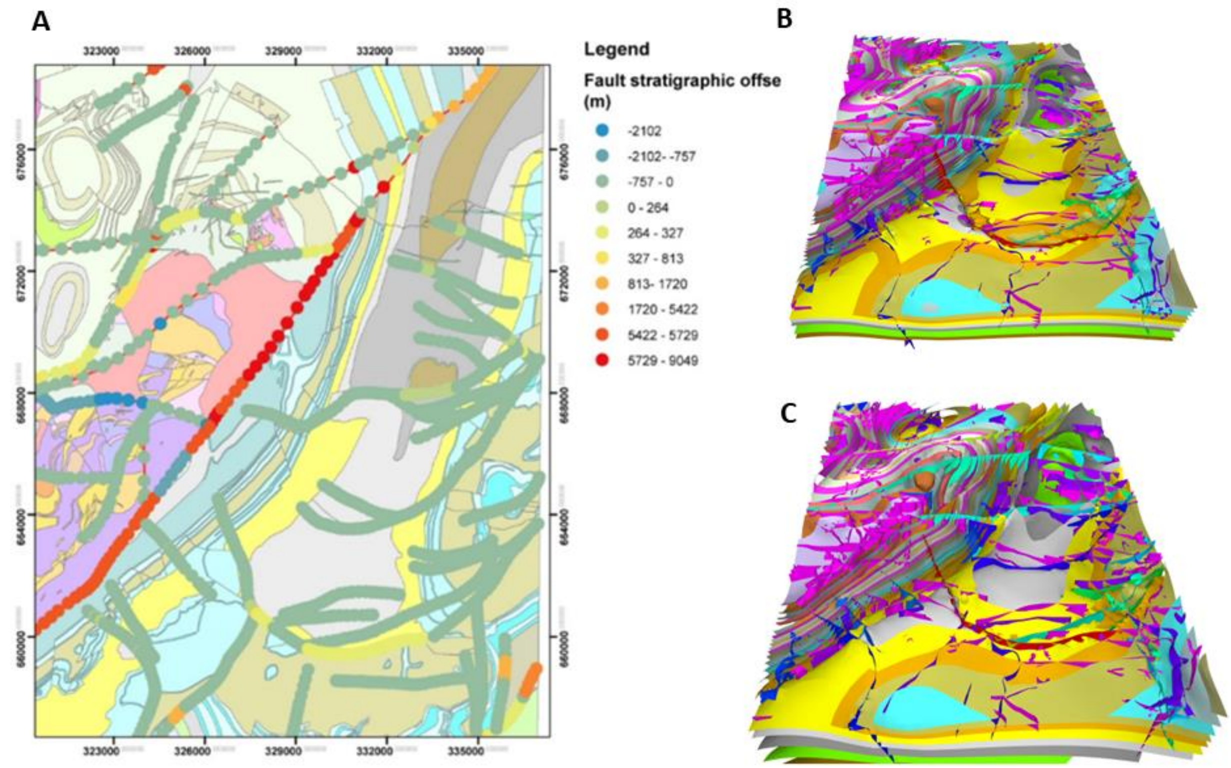

Figure 2 A) The calculated stratigraphic offset for faults on the existing Edinburgh bedrock sheet. Note the varying offset on the same fault. B) Shows at LOOP Structural model created using the current map linework. C) Shows how the model changes once the fault network is 'healed'.

When BGS transformed their paper maps to a digital dataset the capture of the linework was often not digitised by geologists. As a result, faults can be made up of many separate fragments which means they do not always reflect consistent topological representation of geological structures. Map2Loop expects that all parts of a fault with the same stratigraphic displacement are part of the same line. If the fault has been digitised in fragments (Figure 2A) the code will treat each fragment as separate faults. This means that when run through Map2Loop the calculated stratigraphic displacement will apparently change along the same fault. However, this can be used by a geologist to very quickly identify faults that need to be 'healed' for the model to calculate properly. This also often highlights areas where the kinematics of the fault network needs further consideration (Figure 2B and C). Furthermore, the relatively short time it takes for Map2Loop and Loop Structural to go from map to 3D model (the model shown in Figure 2 containing 261 faults and 16 horizons, took 30 minutes to run) means the model can be iterated easily and different topologies can be tested.

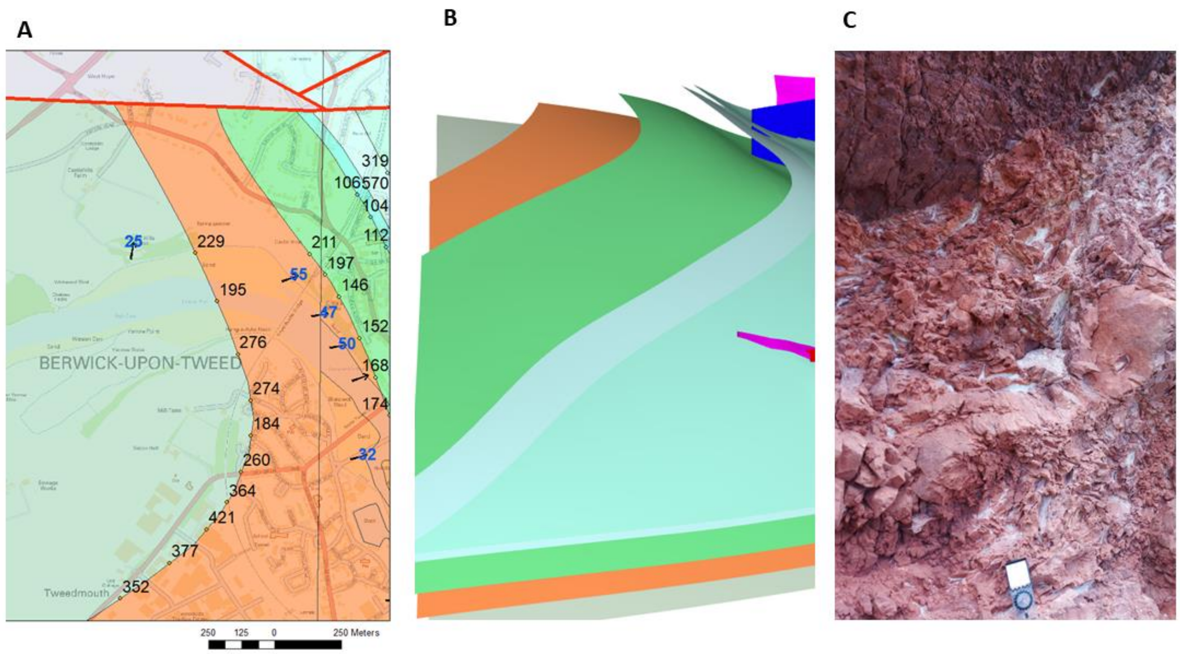

Figure 3 Using LOOP to understand stratigraphic thinning of units. A) showing the calculated thickness of units at the base of beds (in black, dips in blue) showing thinning of the unit into a fault. B) the 3D model of the units. C) Field evidence of deformed mudstone clast in thinned unit.

The other main application has been to look at understanding of variations in thickness of stratigraphic units from map data. In areas of the country where there is only mapping it can often be hard to understand variations in thickness of units. Stratigraphic columns on the sides of maps often give an over generalized view of the thickness. However, if there is good geomorphological control on the geological boundaries Map2Loop allows you to calculate the thickness of a unit at hundreds of locations on the map (Figure 3A). This means that things like thinning of units cause by major faults and folding can be clearly identified (Figure 3A) and this can then be used to identify field targets (Figure 3C) to test the map. This leads to a fuller understanding of the variation of thickness across a geological map and improves the ability to give estimates of how a unit may vary in 3D space.

One of the biggest challenges facing the geological surveys who are transitioning from 2D to 3D is understanding the knowledge held in their 2D maps and highlighting those areas that need to be resurveyed. The tools being developed by the LOOP project are allowing us to understand the projected geometries shown on our maps and project it in to the subsurface where it can be compared with subsurface data such as boreholes. As such it is one of the most exciting developments in Geological Survey 3D mapping in the last 5 years.

References

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