Introduction to Deforming Networks

Authors: Samantha Ross[1], Mike Gurnis[2], Ting Yang[2], S Liu[2],
[1]EarthByte Research Group, School of Geosciences, The University of Sydney, Australia
[2]Division of Geological and Planetary Sciences, California Institute of Technology

It has been updated by Behnam Sadeghi, using the latest Muller et al. (2019) plate reconstructions and GPlates 2.2 interface!

EarthByte Research Group, School of Geosciences, The University of Sydney, Australia

Aim

This tutorial is designed to introduce the user to how to interact with Deforming Topological Networks in GPlates to visualise intraplate deformation.

Included files

Click here to download the data bundle for this tutorial.

The tutorial dataset (8.1-Deforming_Introduction.zip) includes the following files:

Global Rotation File: Muller_etal_2019_CombinedRotations.rot

Coastline File: Muller_etal_2019_Global_Coastlines.gpmlz

Plate Polygons:
Muller_etal_2019_PlateBoundaries_DeformingNetworks.gpml

Deforming Network Files:

Boundary Exterior.gpml (exterior of deforming network)

Deform_Network.gpml (actual deforming network)

Deform_Points_Andes.gpml (points that define deformation)

AndesDeformationDemo2.rot (rotation file for deforming network)

See https://www.earthbyte.org/category/resources/ for additional EarthByte data sets.

This tutorial dataset is compatible with GPlates 2.2.

Background

Representing deformation with topologies

Not all regions of Earth's surface are governed by the rules of rigid plate motions. Some regions undergo small reversible, elastic deformation over short time scales, such as those associated with great earthquakes, while others undergo permanent deformation, usually slowly over long time scales. Some otherwise rigid plates are composed of regions that are deforming. In this section, we will show how to build a reconstruction of a deforming region with GPlates.

One of the first steps when building a tectonic model is to identify all the important elements of the study region, at all the various levels of the crustal hierarchy. The largest geographical scale of the crust is modeled with the main, long lived, tectonic plates. The plates are defined by the system of well known tectonic elements (subduction zones, mid-ocean ridges, and transform faults). Often, a published global plate model will be your starting point for developing regional detailed models.

The deforming zones are smaller in size, shorter in life time and often occur between major plates and during plate development cycles. Further refinements in space and time may be modeled with fine scale features such as faults, blocks, sutures, fold belts, individual units of rock, and/or fossil collections.

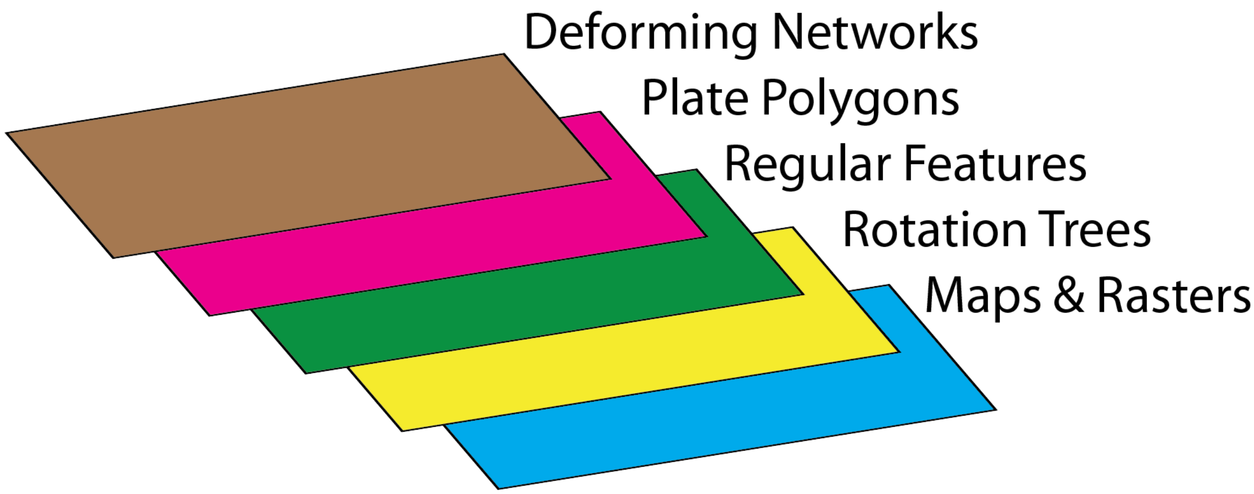


Figure 1: Hierarchy of layers in plate models.

We model a TopologyNetwork's deforming zone with three levels of Delaunay Triangulations. The basic level is shown in black triangles, the Constrained Triangulation in grey and the Mesh Triangulation is shown in colour from the Plate ID of the Topology Network Feature.

The geometry type of each source feature will set constraints on how the feature contributes to the TopologyNetwork's triangulations. A single point feature will contribute as a single vertex in the triangulation. A line feature will contribute as a set of constraints, so that individual interior segments of a line (vertex to vertex) will be constrained edges in the triangulations. A polygon feature will contribute like a line feature, with the additional constraint that the first and last vertices also form a constraining edge.

These constraints ensure that the TopologyNetwork's triangulations obey the shapes of their underlying source features. During the constraining and meshing processing, additional vertices will be added to the triangulations based upon the Delaunay algorithms. Linear interpolation is used to find the velocity and displacements for features found within the mesh, and reconstruct them in the deforming area.

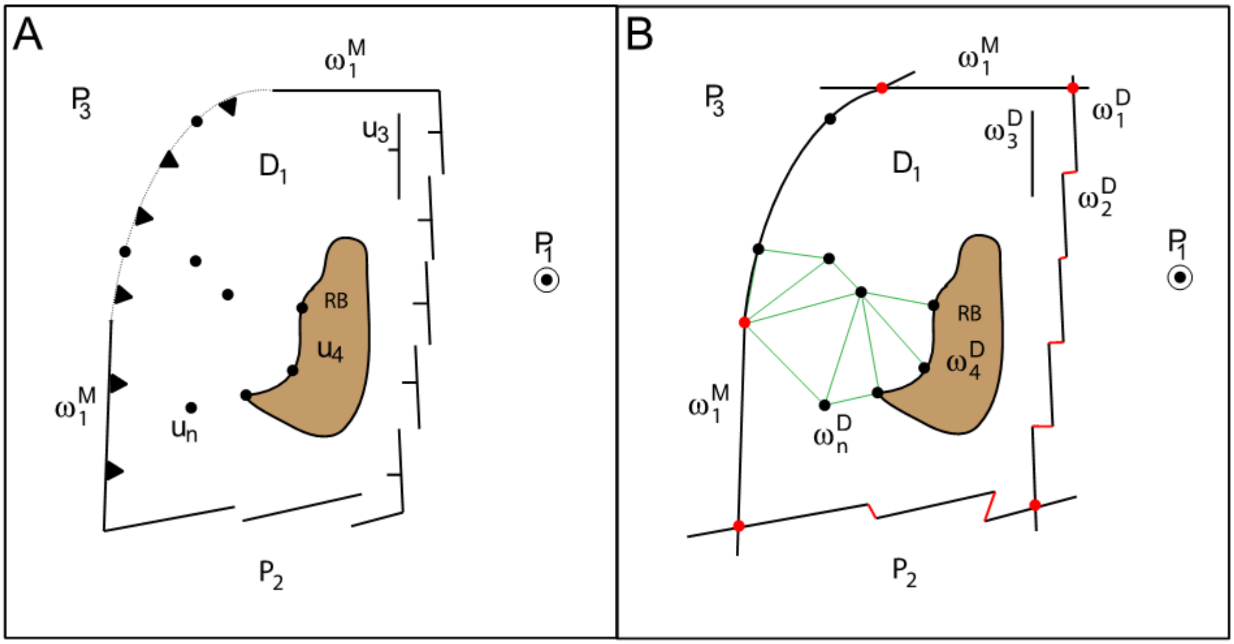


Figure 2: Schematic of the generic features that are incorporated into the topological network algorithm. Red dots represent dynamically computed intersections between plate boundaries. Black dots are deformation points, RB=rigid block, D1=deforming region 1, P1=plate 1. **A)** Geological data and concepts used in the reconstruction **B)** Computer representation of this information. Implementation of the deforming region that is consistent with the concepts of a continuously closed plate (CCP). The continuous deformation is represented by a triangular mesh, formed by Delaunay triangulation algorithms.

Exercise 1 – Working with Deforming Networks

We will visualise a deforming network for the Andes region based on reconstructions by Arriagada et al. (2008). You can learn how to build a deforming network from these reconstruction rasters in Tutorial 8.2 and from other data in Tutorial 8.3.

1. Open GPlates and load in all the files in the tutorial bundle using File > Open Feature Collection *or* by dragging and dropping all the files onto the globe.

2. Rotate the globe so that South America is in view (Figure 3)

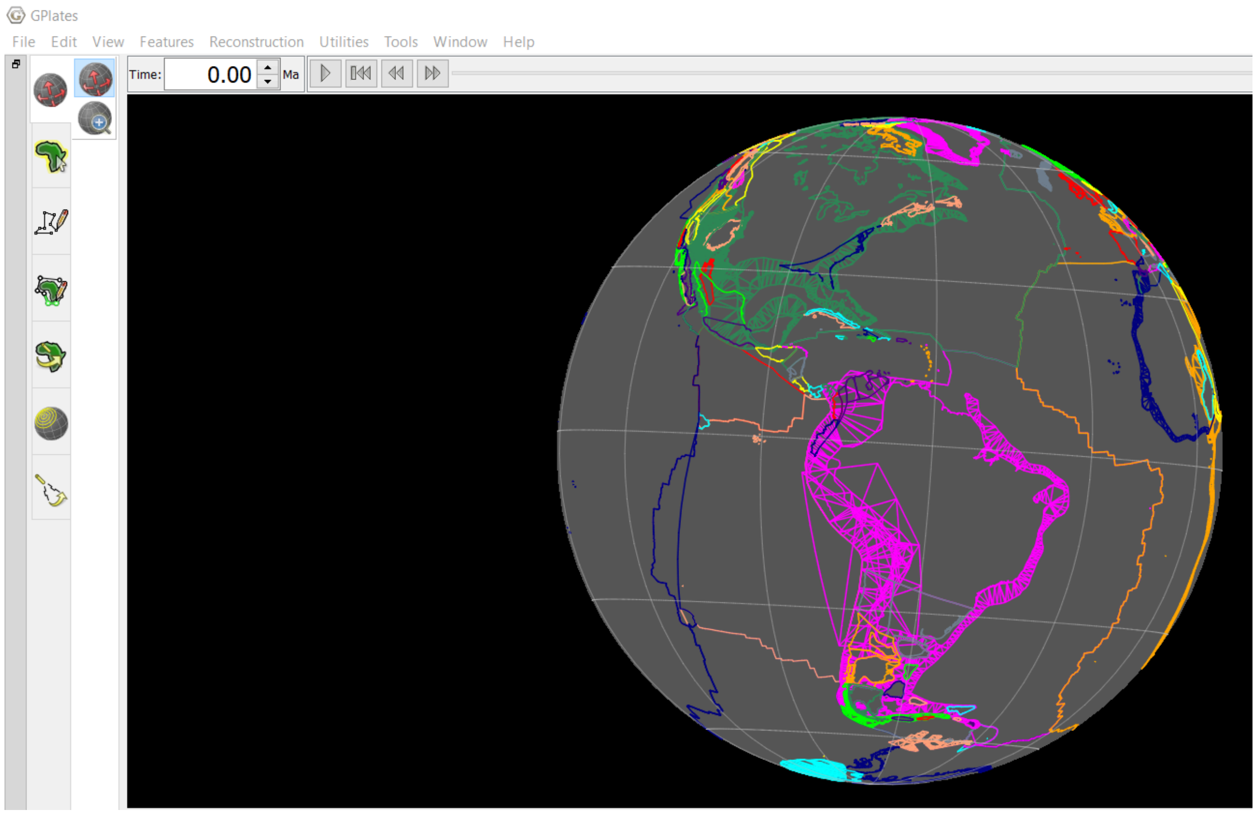


Figure 3: Orientation of the globe with South America in view.

You will notice that where the Andes are, there are a number of points and a box around these points. The box will define our deforming network.

3. Set the anchored plate to 201 (Reconstruction > Specify Anchored Plate ID...)

4. Go to Window > Show Layers

Notice that there is a new gold/brown layer which we have not seen before (Figure 4). This is a Resolved Topological Networks Layer.

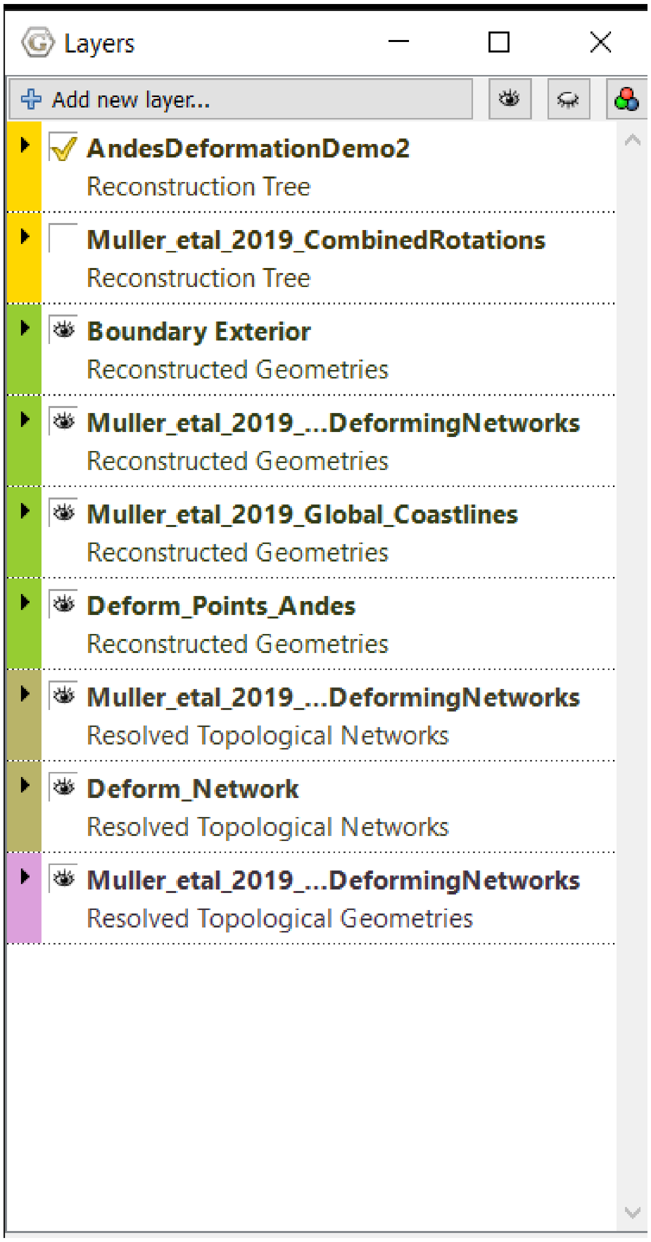


Figure 4: Layer Window showing new Resolved Topological Networks Layer

Also notice that the rotation file selected is the 'AndesDeformationDemo2'.

5. Change the checked rotation file to 'Muller_etal_2019_CombinedRotations' and then expand the layer and add a connection to the AndesDeformationDemo2 (Figure 5).

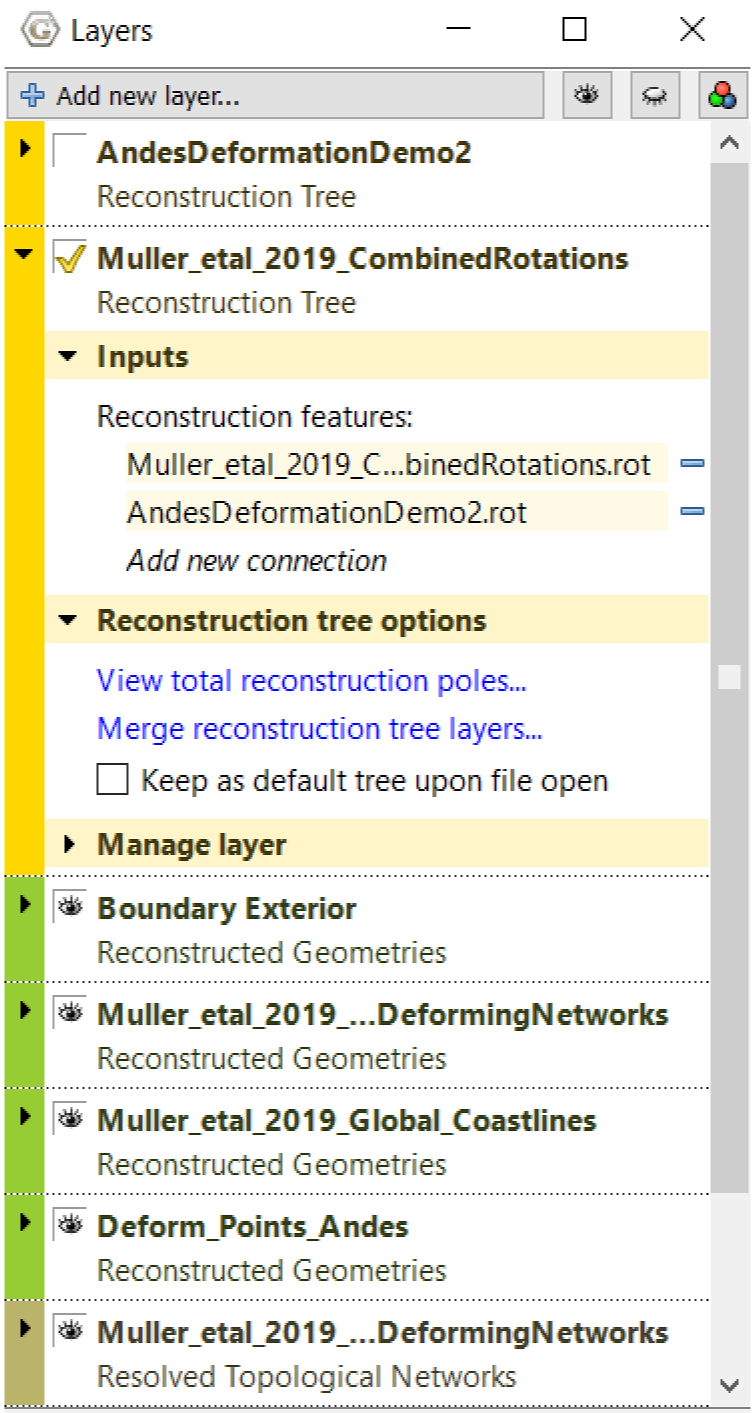


Figure 5: Layer Window showing correctly selected rotation file and a connection to the AndesDeformationDemo2 rotation file.

6. Expand the gold Topological Network Layer to view all of the different options available (Figure 6).

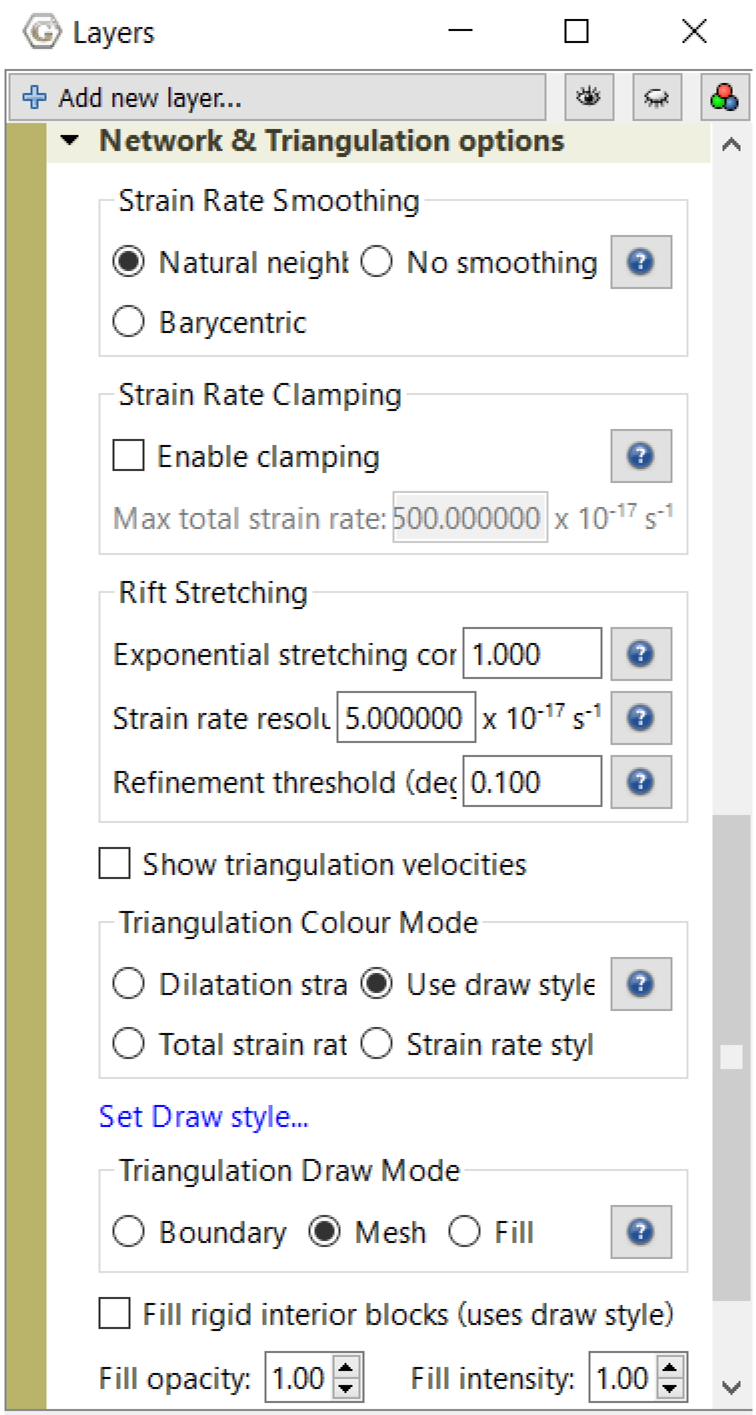
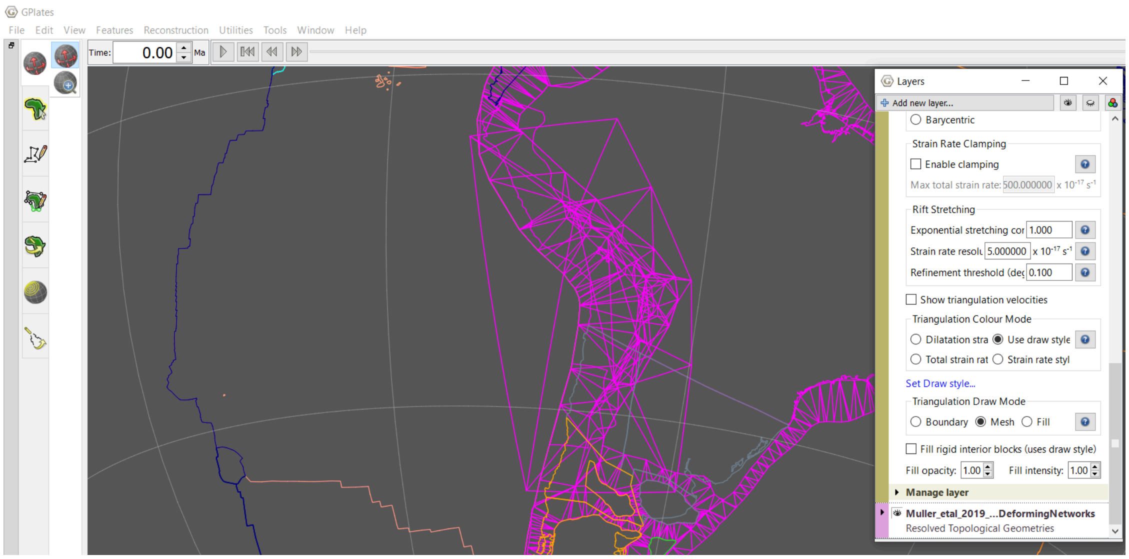


Figure 6: Layer Window showing options for Resolved Topological Networks Layer.

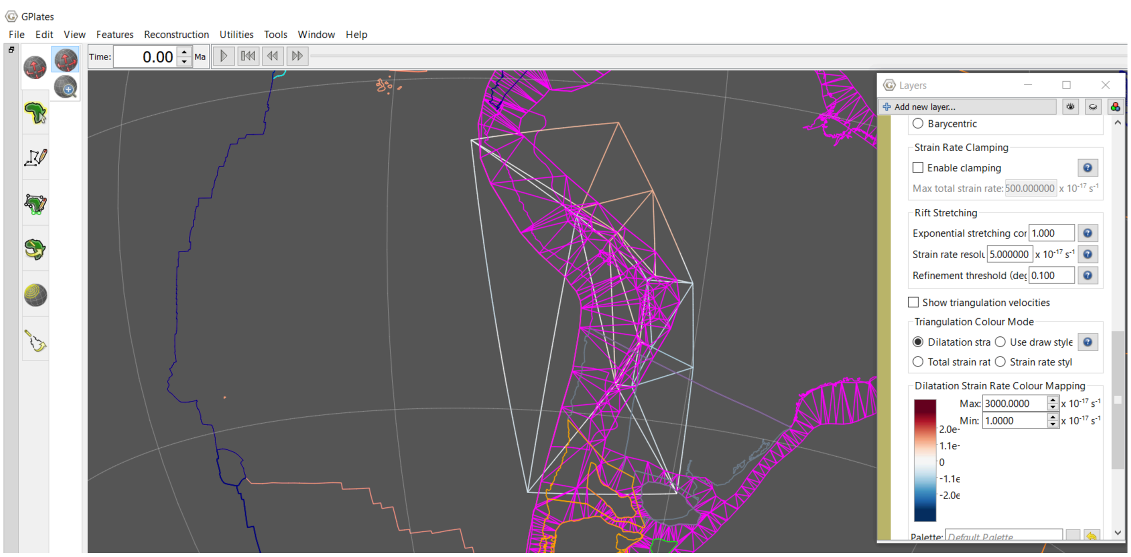
7. To make the Topological Network visible, under Triangulation Colour Mode, select ‘Dilatation Strain Rate’.

Notice that we now have a triangulated network where the Andes are (Figure

7). The points within the network allow deformation to be defined, as each point has a different motion path depending on its location. The more points within the network, the more detailed the deformation that can be modelled.



Before



After

Figure 7: Deforming network for Andes region before amd after selecting 'Dilatation Strain Rate'.

8. We can also visualise this deforming network in a different way by ticking the checkbox 'Fill' in the 'Triangulation Draw Mode' on the Layers window (Figures 8 & 9).

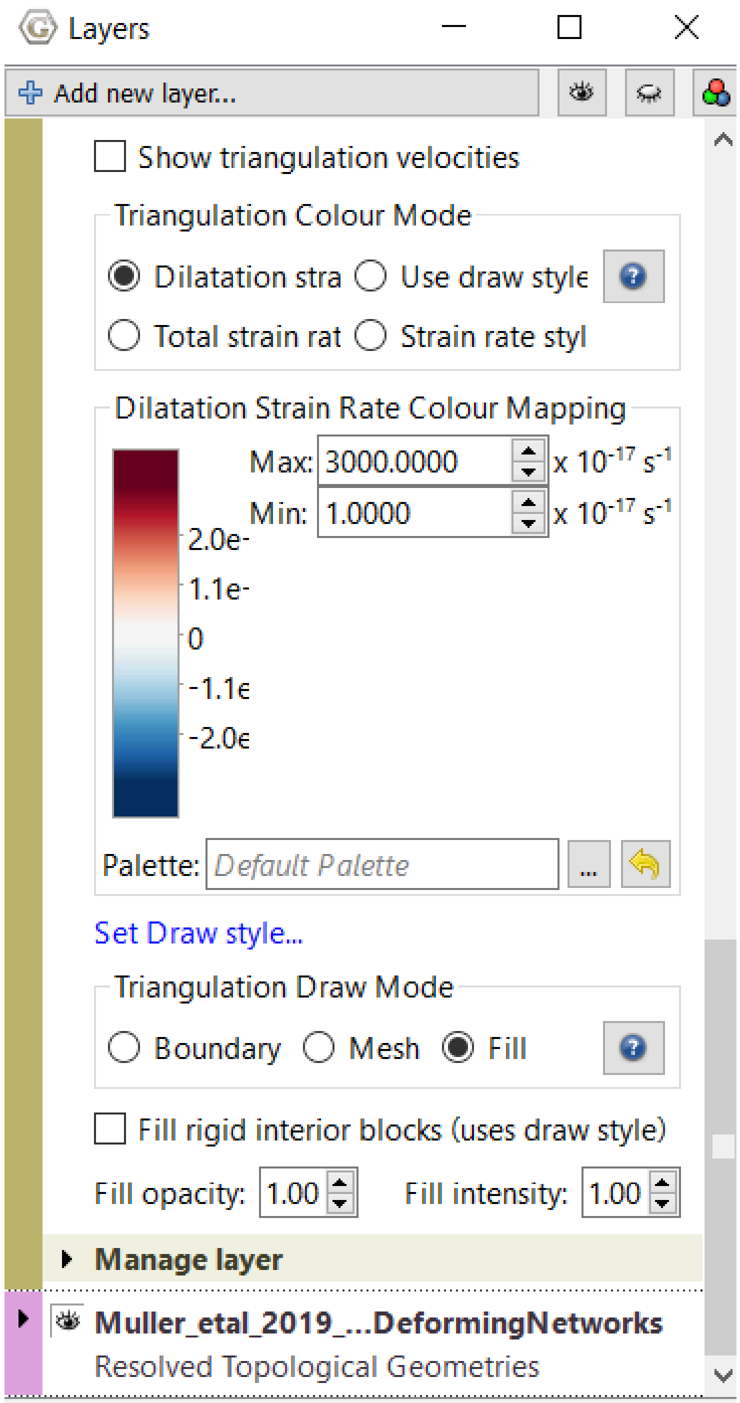


Figure 8: Layer window showing ticked 'Fill' triangulation to visualise the deforming network in a different way.

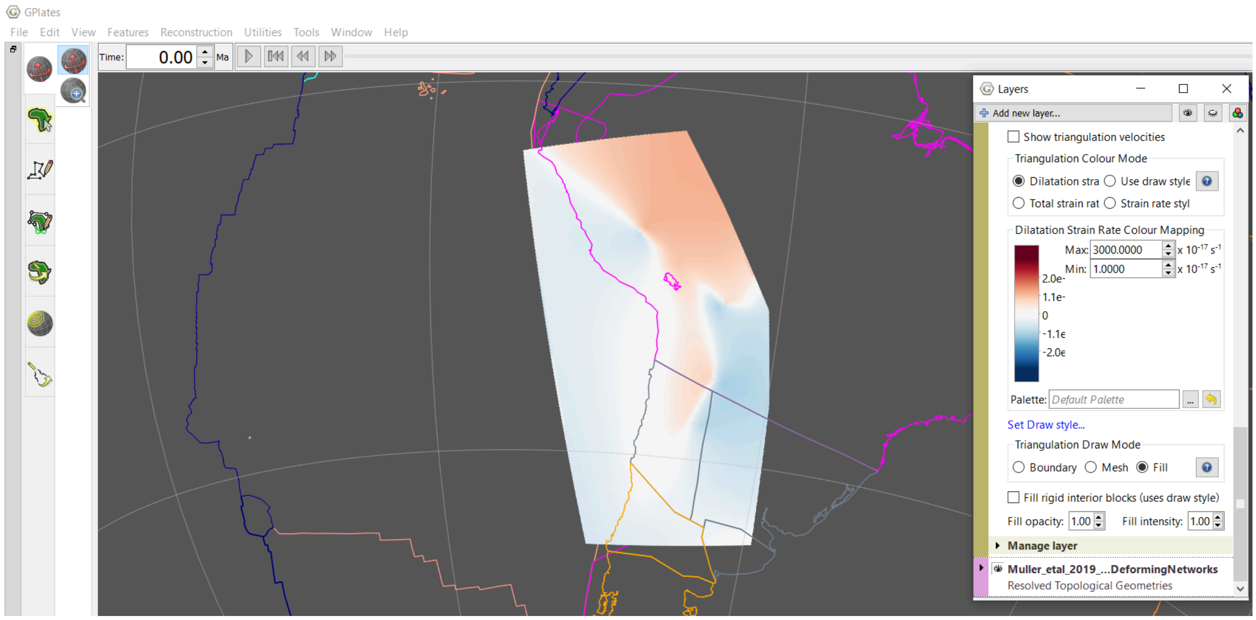


Figure 9: Deforming network with a filled triangulation.

This allows us to visualise the strain over a region.

8. Change the time to 15 Ma and see how the Topological Network has deformed relative to present, and how the strain rate is different (Figure 10).

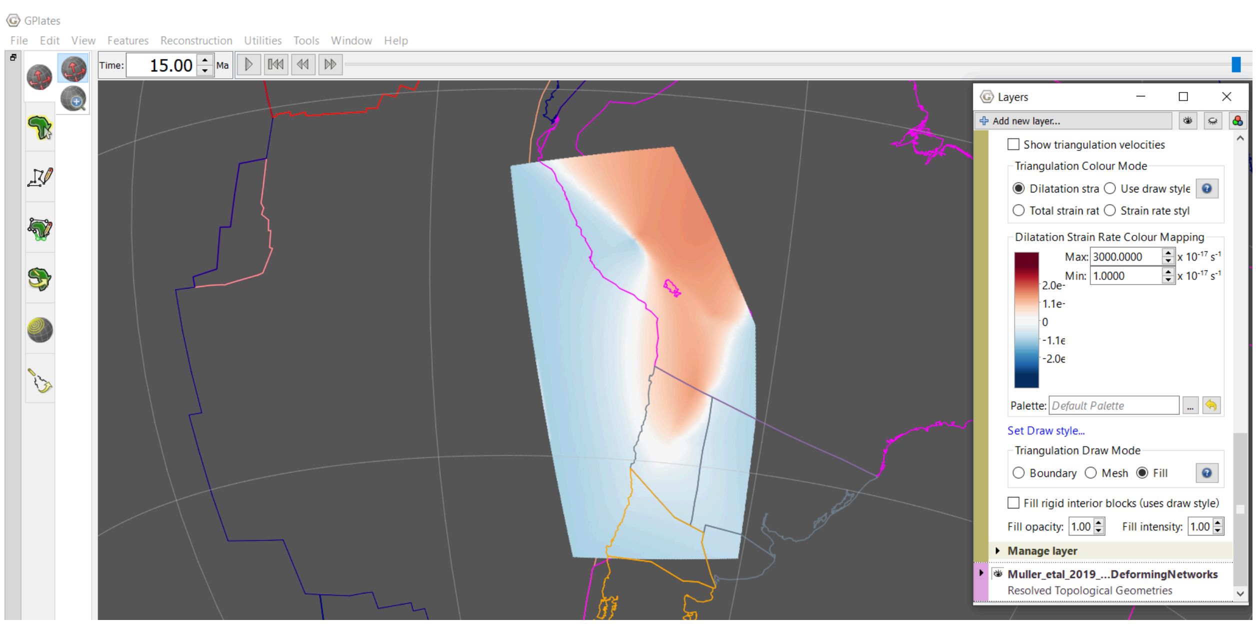


Figure 10: Deforming network with a filled triangulation at 15 Ma.

9. Play around with other ways of visualising the network in the Layers window, and also look at how the network changes through time (back to 45 Ma).

References

Arriagada, C., Roperch, P., Mpodozis, C., & Cobbold, P. R. (2008). Paleogene building of the Bolivian Orocline: Tectonic restoration of the central Andes in 2-D map view. *Tectonics*, *27*(6), doi:10.1029/2008TC002269

Müller, R. D., Zahirovic, S., Williams, S. E., Cannon, J., Seton, M., Bower, D. J., Tetley, M. G., Heine, C., Le Breton, E., Liu, S., Russell, S. H. J., Yang, T., Leonard, J., and Gurnis, M., 2019, A Global Plate Model Including Lithospheric Deformation Along Major Rifts and Orogens Since the Triassic: Tectonics, v. 38, no. 6, p. 1884-1907. doi: 10.1029/2018tc005462.