

Tracking Crustal Thickness Changes

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Aim

This tutorial is designed to introduce the user to the functionalities that allow changes in crustal thickness to be visualised in deforming areas.

Included files

[Click here](#) to download the data bundle for this tutorial.

The tutorial dataset (8.4-Crustal_Thickness.zip) includes the following files:

Ex1-3 Project file: Crustal_Thickness1-3.gproj - includes the following:

Rotation file: Global_EarthByte+230-0Ma_GK07_AREPS.rot

Coastline file: Matthews_etal_GPC_inrev_Coastlines_Polyline.gpmlz

North Atlantic Deforming Network files:

Deforming Network Features: NATL_Deforming_EarthByte.gpml

Continent Ocean Boundaries:

NATL_BreakUP-COBs_Deforming_EarthByte.gpml

Age Segments:

NATL_Age_Segments_extinctDef_EarthByte.gpml

Deforming Mesh:

NATL_PhaseI_DeformationMesh_EarthByte.gpml

Background

Deforming networks are useful for modelling plates that do not remain rigid. Crustal thickness does not remain constant during this deformation, and it can be useful to track and visualise in different ways how the crust changes thickness through time.

There are two different ways to visualise crustal thickness in GPlates 2.0. The first is relative change, where we select the Scalar Type as 'gpml:CrustalThinningFactor'. The crust at this time is given a value of 1 and the crust at subsequent times is given a value that represents the proportion of change with respect to this time (eg set 120 Ma) i.e. crust with a value of 1.5 has thickened in comparison to the initial thickness while crust with a value of 0.5 is thinner than the original crust. Hence the time that you originally reconstruct to in order to generate the points is very important for the relative crustal thickness calculations. It doesn't matter where you reconstruct to, as long as you know what time you are reconstructing to and keep this in mind.

The second way to visualise crustal thickness is by selecting Scalar Type 'gpml:CrustalThickness'. This allows you to specify the actual thickness of the crust when you generate the points. The default is 40 km however you can set it to whatever is most accurate for your region. As you visualise crustal thickness through time, rather than seeing the relative changes in thickness, you will be able to see the absolute changes to crustal thickness. It is also important to remember at what time you generate the points, as this will be the time that the crust is assigned a thickness of 40km.

Exercise 1 – Visualising crustal thickness changes in the North Atlantic

This exercise is designed to introduce you to how GPlates represents and tracks changes to crustal thickness in a forward modelling sense, whereby relative changes to crustal thickness are calculated with respect to a time in the past.

1. Open GPlates and load in the project file 'Crustal_Thickness.gproj' by either dragging and dropping it onto the globe, or File > Open Project...
2. Rotate the globe such that the North Atlantic is in view at 120 Ma (Figure 1).

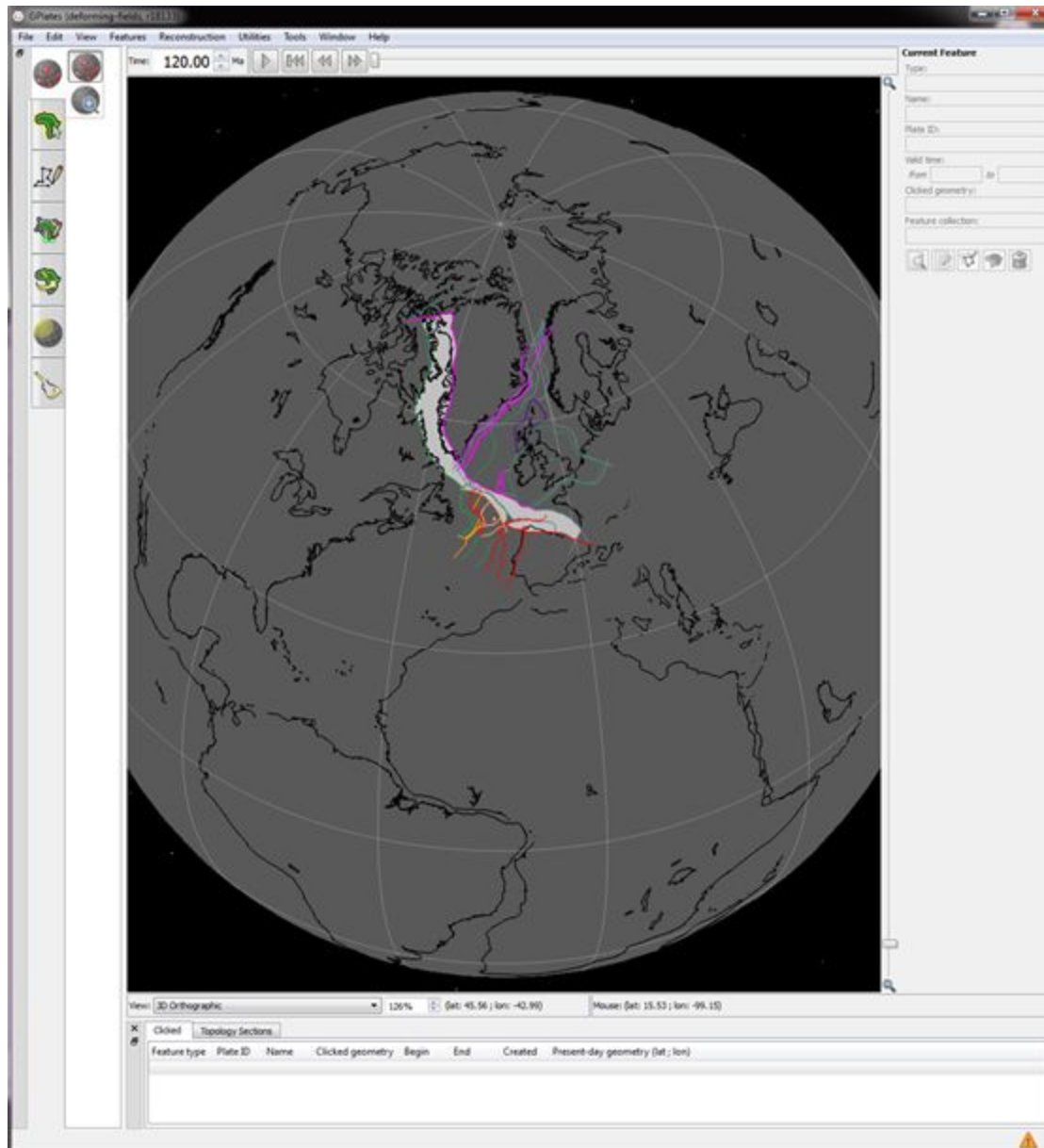


Figure 1: Screenshot of globe focused on North Atlantic at 120 Ma

Notice that there is a polygon that is shaded silver. This is a deforming network of the North Atlantic and we will use it to visualise changes to crustal thickness through time.

2. **Ensure that the reconstruction time is set to 120 Ma.** This is the time we want to calculate relative changes in crustal thickness with respect to and your results will look different if you don't begin at 120 Ma.

3. Using the select feature tool, select the deforming network region by clicking anywhere in the silver shaded area (the boundary of the region

should turn white once selected).

4. Go to Features > Generate Crustal Thickness Points

A new dialog should open where we will specify the parameters for calculating crustal thickness (Figure 2). The parameters are specific to each deforming region.

The dialog box is titled "Generate Crustal Thickness Points". It contains the following fields and controls:

- Initial Crustal Thickness:**
 - Scalar Type: `gpml:CrustalThinningFactor` (dropdown menu)
 - Thinning factor: 1.000 (spin box)
- Uniform Point Distribution:**
 - Density level: 6 (spin box)
 - Spacing: 0.625 (spin box) degrees
 - Random offset: 0.00 (spin box) %
- Common Feature Properties:**
 - Plate ID: 0 (spin box)
 - Begin (time of appearance): 0.00 (spin box) Ma ☒ Distant Past
 - End (time of disappearance): 0.00 (spin box) Ma ☐ Distant Future
 - Name: Rockall_DFM (text field)

Buttons at the bottom: Previous, Next, Create, Cancel.

Figure 2: Generate Crustal Thickness Points Dialog (Step 5)

Now we will generate the points inside the deforming region that will be used to represent relative changes in crustal thickness (select scalar type `'gpml:CrustalThinningFactor'`).

5. Specify the following parameters (Figure 3):

- Density level = 6 (default - specifies point density in the deforming

- region. See note at end of this exercise for more information)
- Random offset = 0 % (default)
- Plate ID = 0 (default)
- Begin time = 120 Ma (this is the time we have reconstructed back to, to generate the points)
- End time = 62 Ma (default)
- Name = North_Atlantic_Crustal_Thickness (or whatever you'd like to call it)

Figure 3: Generate Crustal Thickness Points window with specified parameters for North Atlantic

6. Go Next > Create a new feature collection > Create

You should now notice that there are green points within our deforming network region (Figure 4). These are the points that will represent crustal thickness and are confined to within the deforming region.

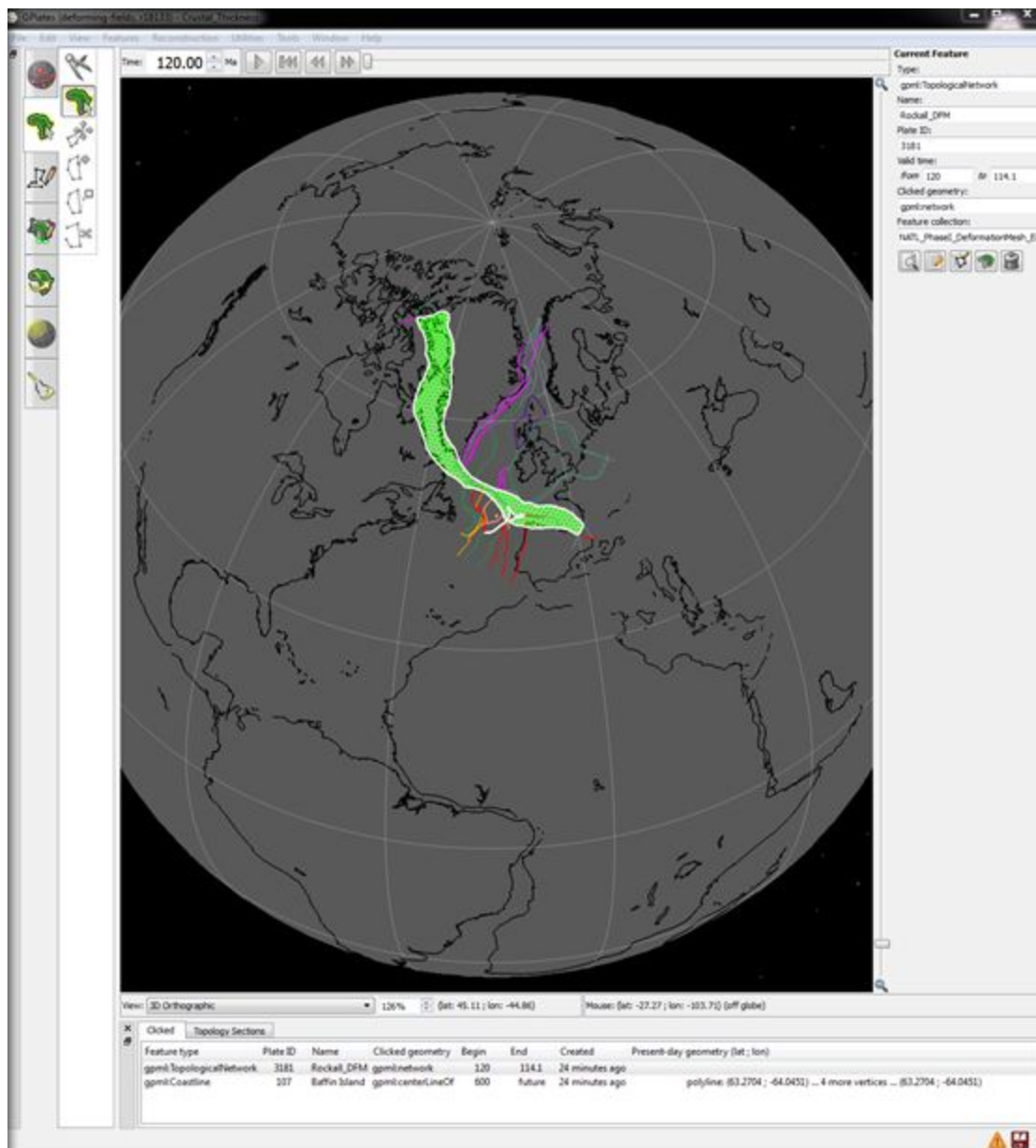


Figure 4: Newly generated crustal thickness points within the deforming region

7. Open the Layer Window (Window > Show Layers...)

You should notice that two new layers have been produced - a green one (reconstructed geometries) and a dark grey one (reconstructed scalar coverages).

8. Expand the options for the green reconstructed geometries layer (Figure 5).

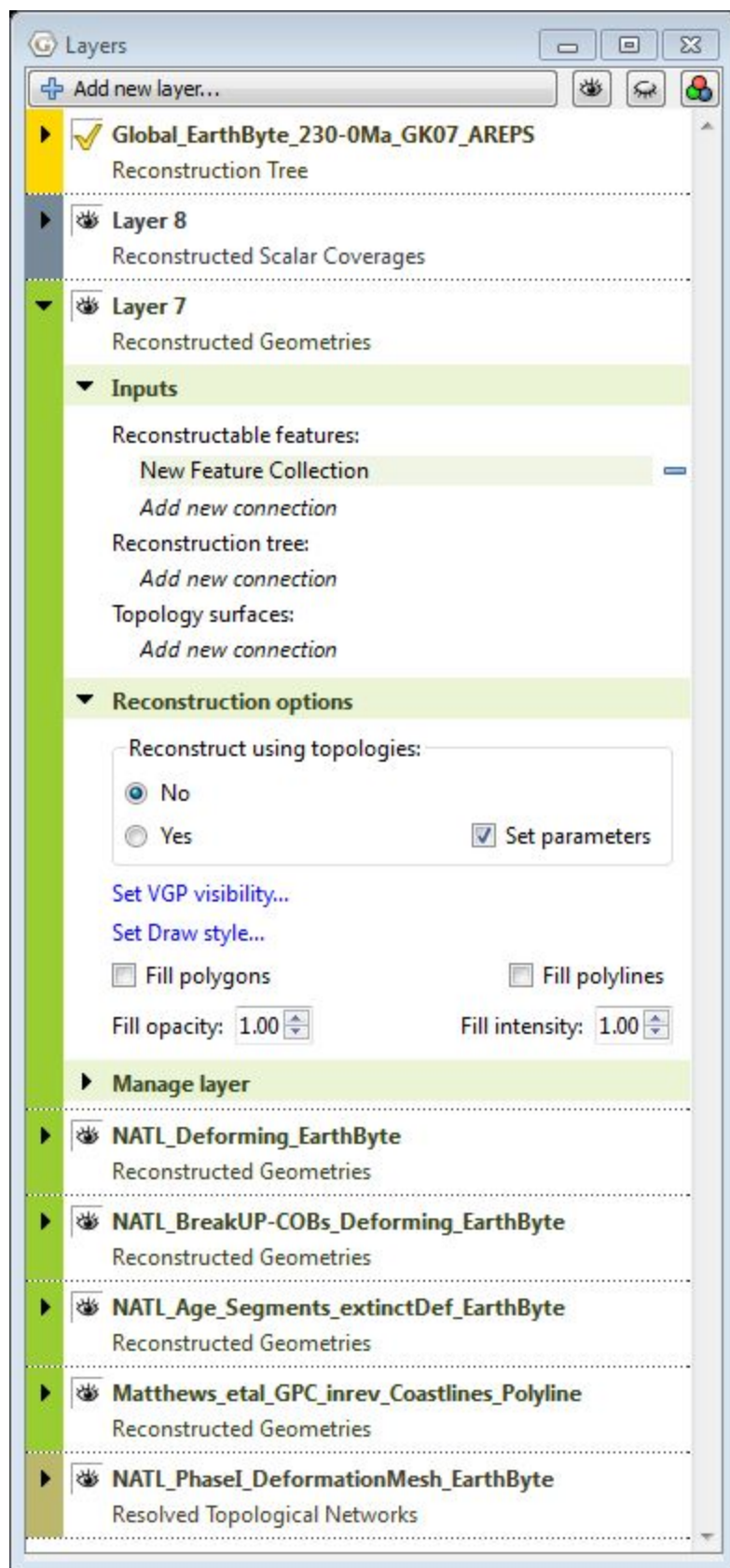


Figure 5: Layer options for our crustal thickness points

9. Under Inputs > Topology Surfaces, add a new connection to the North Atlantic deforming network (Figure 6).

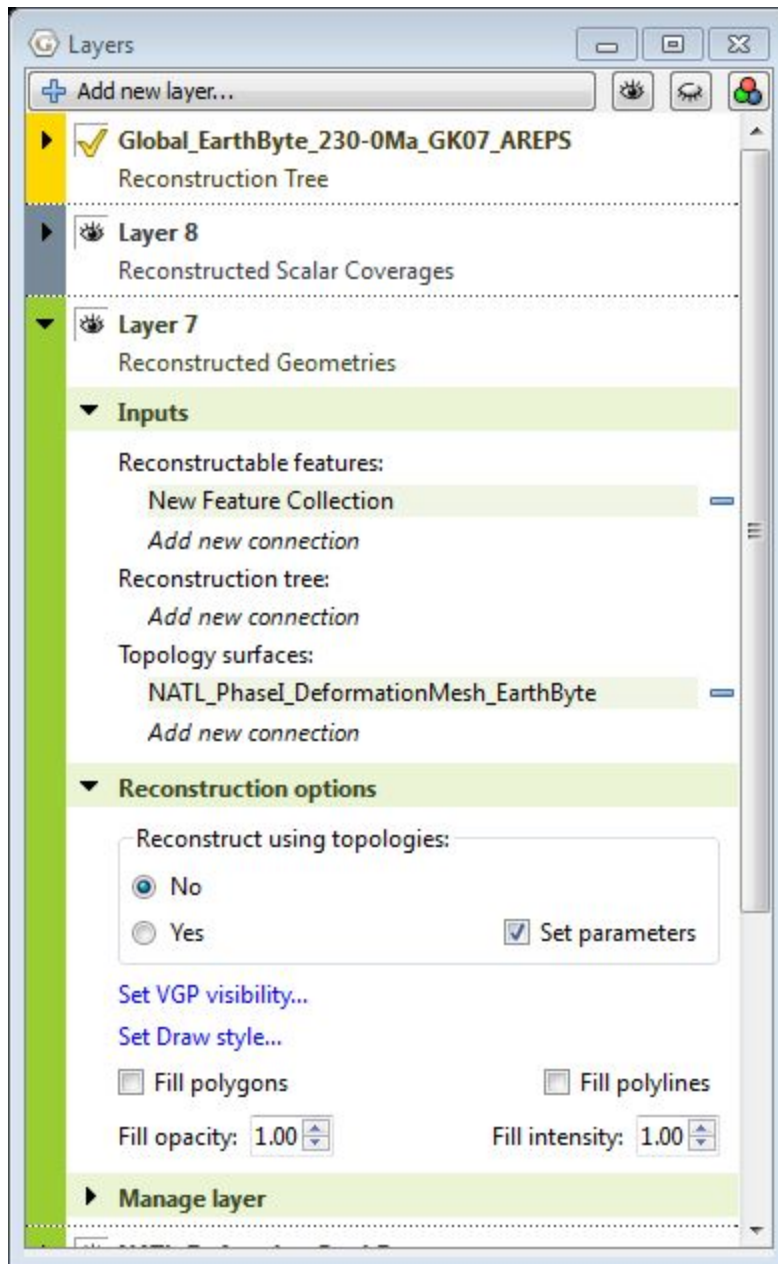


Figure 6: Layer options for our crustal thickness points showing the connection to the topology surface

Note: Although we connect a deforming network in this tutorial, rigid topologies (pink layers) can also be used.

10. Under Reconstruction Options, select 'Yes' for Reconstruct using topologies. This will bring up a new window where we set Topology Reconstruction Parameters as follows:

- Youngest Age = 62 Ma (default)
- Oldest Age = 120 Ma
- Time Increment = 1 Ma (default)

Leave all other options as default (Figure 7) then click OK.

Note: If you do not select 'Yes', the crustal thickness will be calculated in relation to whatever topologies are loaded in GPlates. In this tutorial, there is only one layer of topologies loaded in, so it will reconstruct based on this by default. If, in other models, there are multiple topology layers loaded, this step becomes very important.

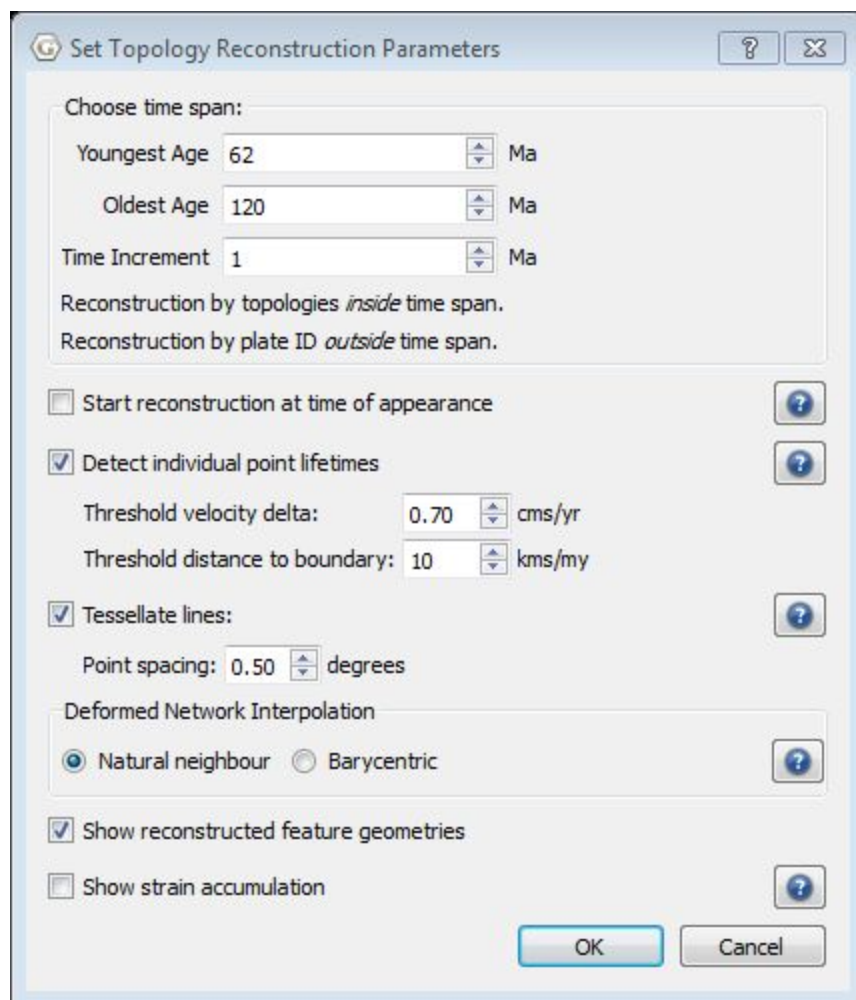


Figure 7: Set Topology Reconstruction Parameters

11. Expand the options under the dark grey layer and change the Palette Range to between 1.5 and 0.5, since we are looking at relative changes in crustal thickness and the original value is set as 1 (Figure 8).

Note: the palette range can be changed to any range you'd like however it is recommended that 1 is in the middle since it represents the original crustal thickness at 120 Ma and the colours diverge appropriately.

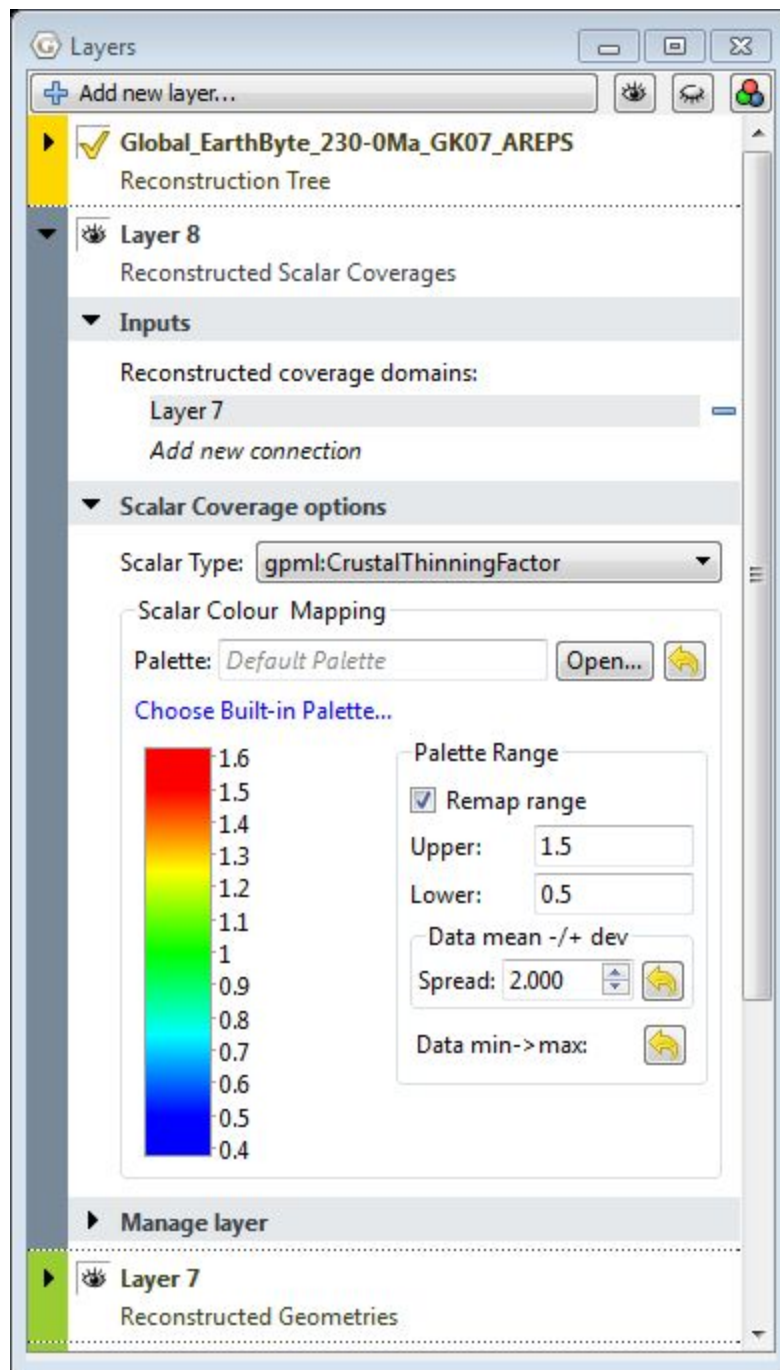


Figure 8: Changing the colour palette range (Step 12)

With the default colour palette, crust that is thicker than at 120 Ma will be yellow/red, while crust that is thinner will be blue.

12. Now change the reconstruction time to 62 Ma (Figure 9).

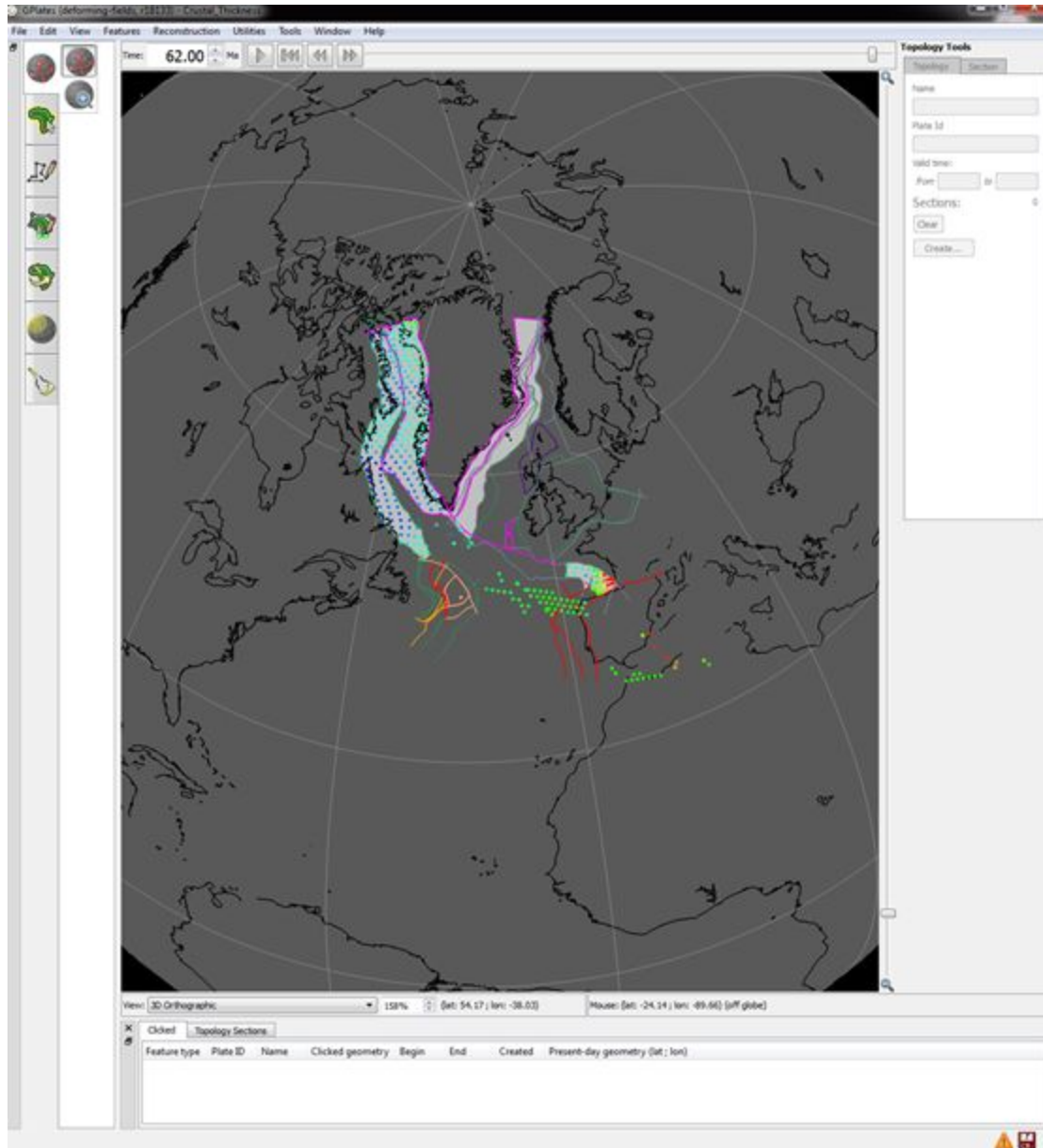


Figure 10: Crustal thickness of North Atlantic

Notice that the points are now all different colours. Based on our colour palette, points that are yellow/red denote a thicker crust than at 120 Ma, those that are blue denote a thinner crust than at 120 Ma, and those that are still green denote that the crustal thickness has not changed since 20

Ma.

13. Play the animation from 120 Ma - 62 Ma and see how the points move and denote changes in crustal thickness.

We can see that the deforming region illustrates rifting between North America and Greenland, the crust is thinned.

There are a range of other colour palette options to choose from if you don't like the red/green/blue default colour range.

14. Expand the Scalar Coverage options under the dark grey layer in the Layer window, and select 'Choose Built-in Palette...' (Figure 11).

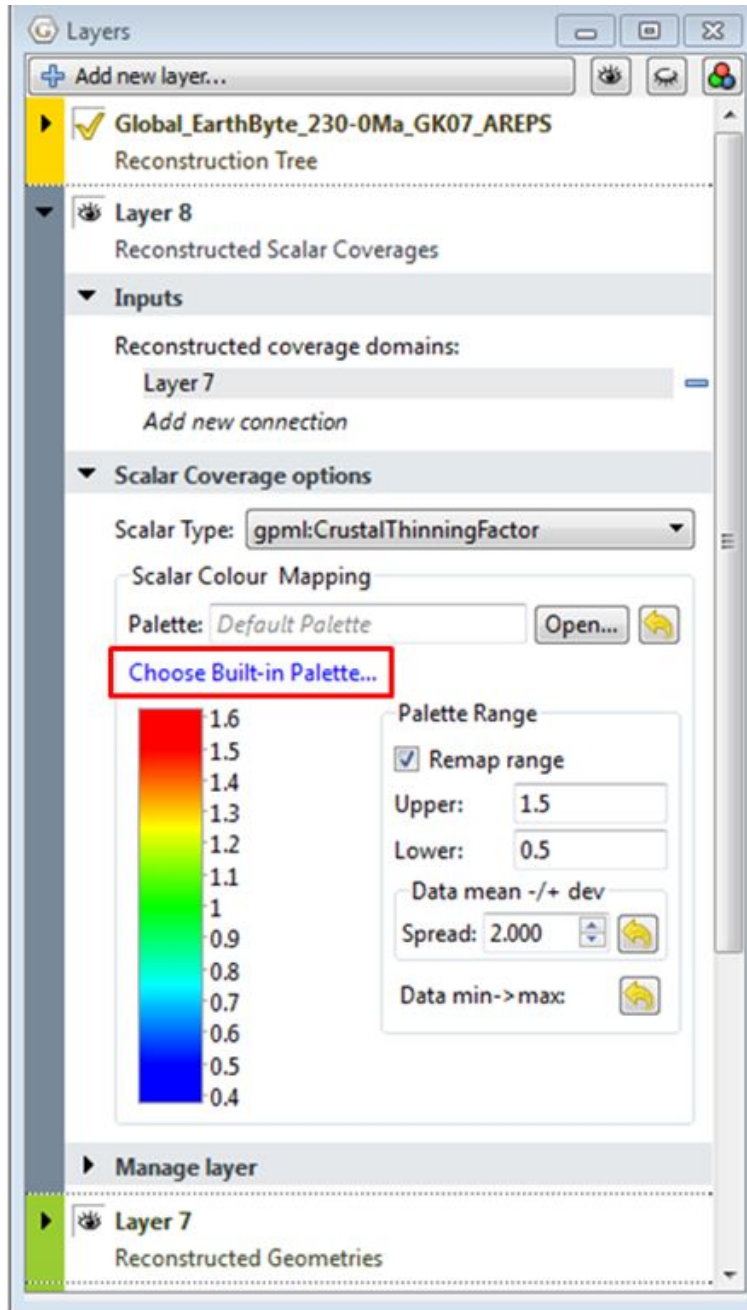


Figure 11: Layer window showing 'Choose Built-in Palette...' option

A new window should open (Figure 12) where you can choose a range of different colour palettes, choose to invert the colour palette (tick 'Invert'), decide on the number of classes and choose to make the colours discrete levels (tick 'discrete').

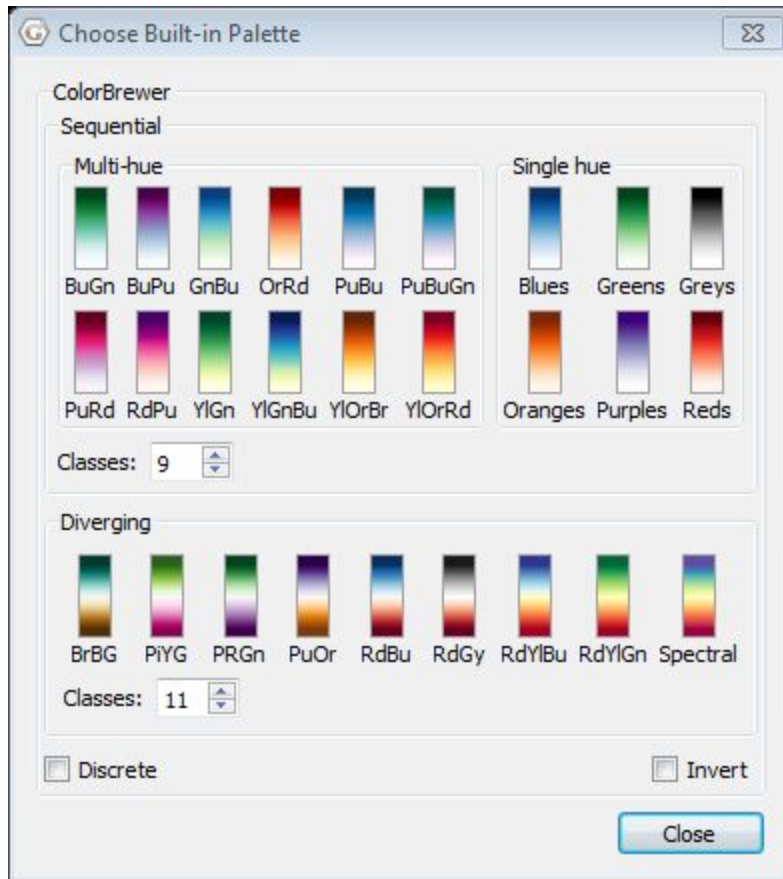


Figure 12: Window showing a range of colour palette options

15. Have a play around with the colours and when you are done with your modifications, click Close.

Don't forget to save your new feature collection with the crustal thickness points!

Note: When specifying the point density in Step 6, we used a value of 6 and got a rather sparse coverage. Using a point density of 8 gives us a more detailed coverage (Figure 13).

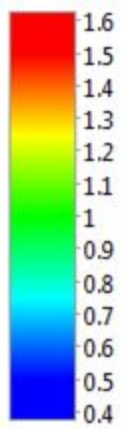
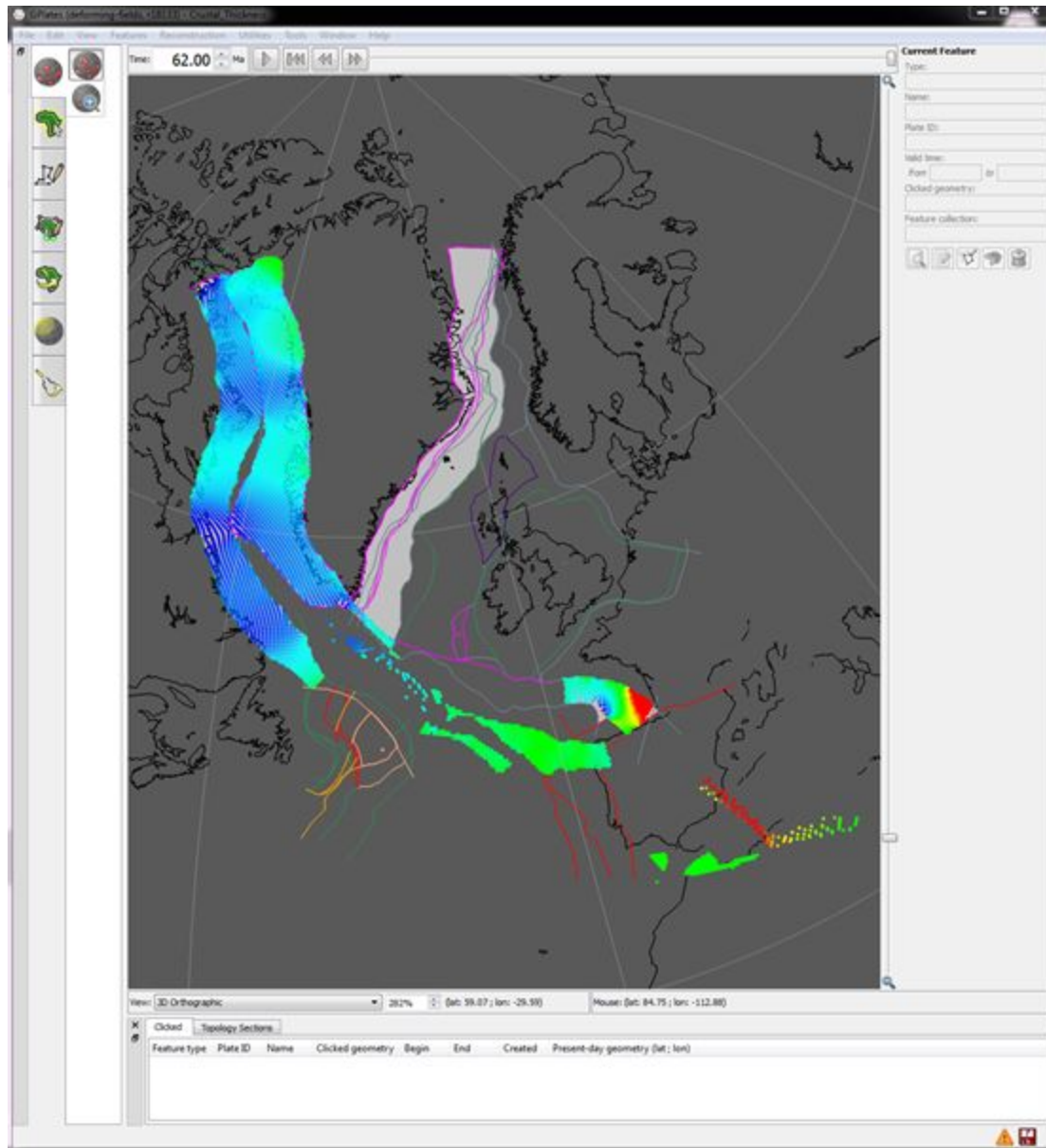
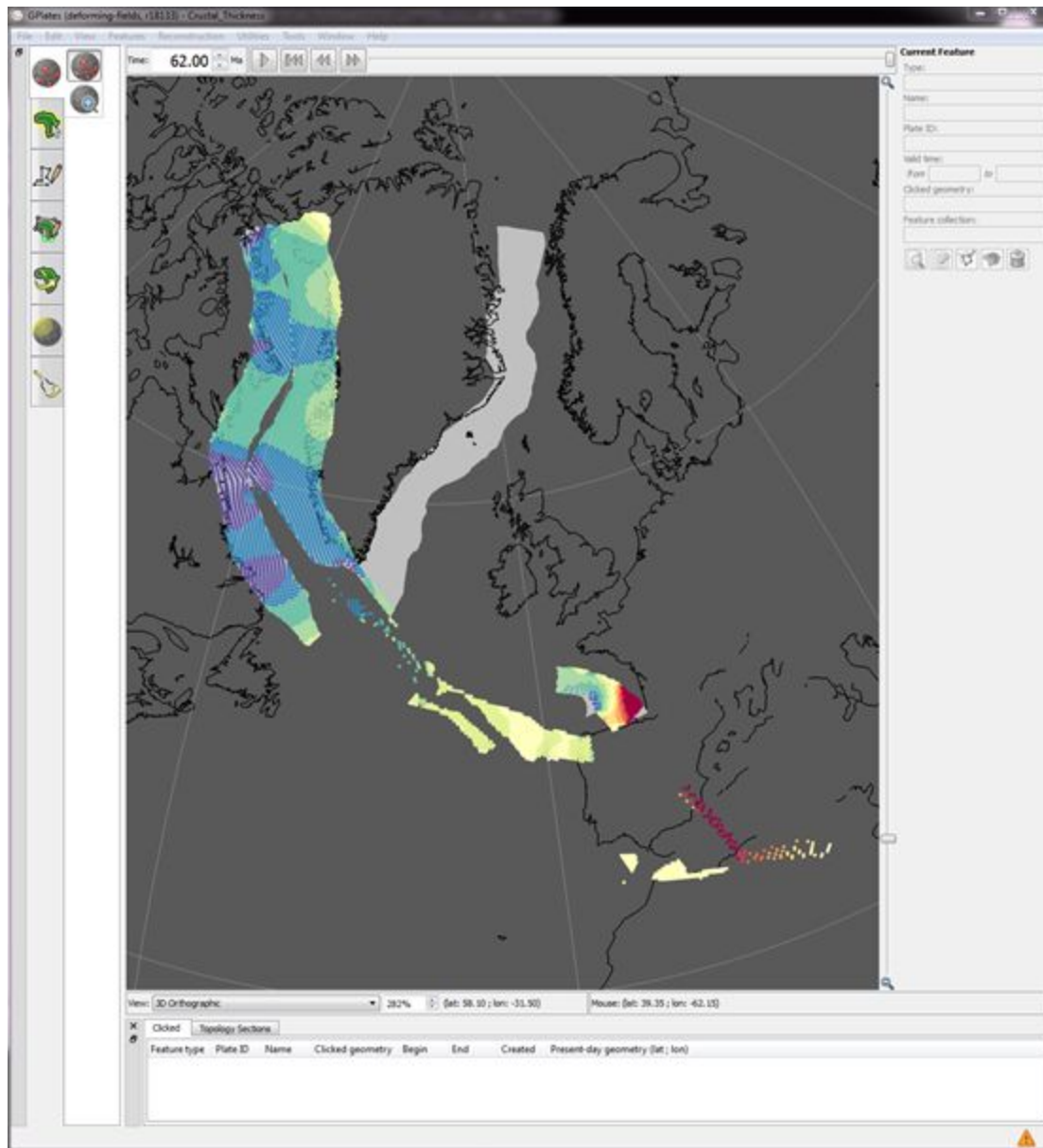


Figure 13: Crustal thickness of North Atlantic deforming region with point density of 8 with

default colour palette showing relative crustal thickness changes

Using a denser point coverage can also make the visualisation of relative crustal thickness change easier, especially if a discrete colour palette is used (Figure 14).



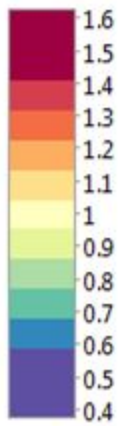


Figure 14: Crustal thickness of North Atlantic deforming region with point density of 8 and modified colour palette (Discrete, Inverted, Spectral)

Exercise 2 – Generate Velocity Points

It is also possible to show the velocities of deformed geometries.

1. Ensure that the project file and the crustal thickness points from either Exercise 1 or 2 are loaded into GPlates (we will use the files from Exercise 1 in this exercise).
2. Change the reconstruction time to 120 Ma.
3. At the top of the Layers window, select 'Add new layer...' and select the light blue Calculated Velocity Fields layer type, then click OK.
4. Expand the options under the newly created layer and under Inputs > 'Velocity domains', add a new connection to the green (reconstructed geometries) layer that represents your crustal thickness points.
5. Under Velocity & Interpolation options, select Calculate velocities 'of domain points'.

Your options should look something like Figure 15

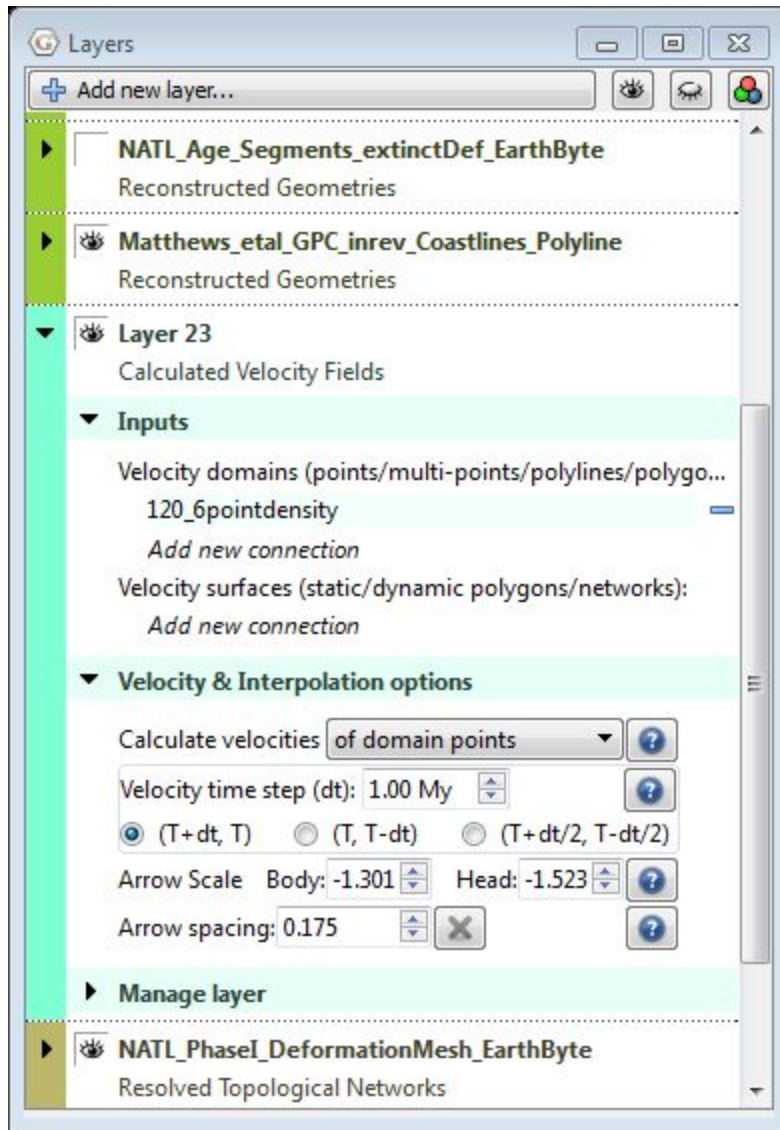


Figure 15: Layer window showing options of the new Calculated Velocity Fields layer

6. Play the animation from 120-62 Ma and see the arrows that appear, describing the motion of the deforming network (Figure 16).

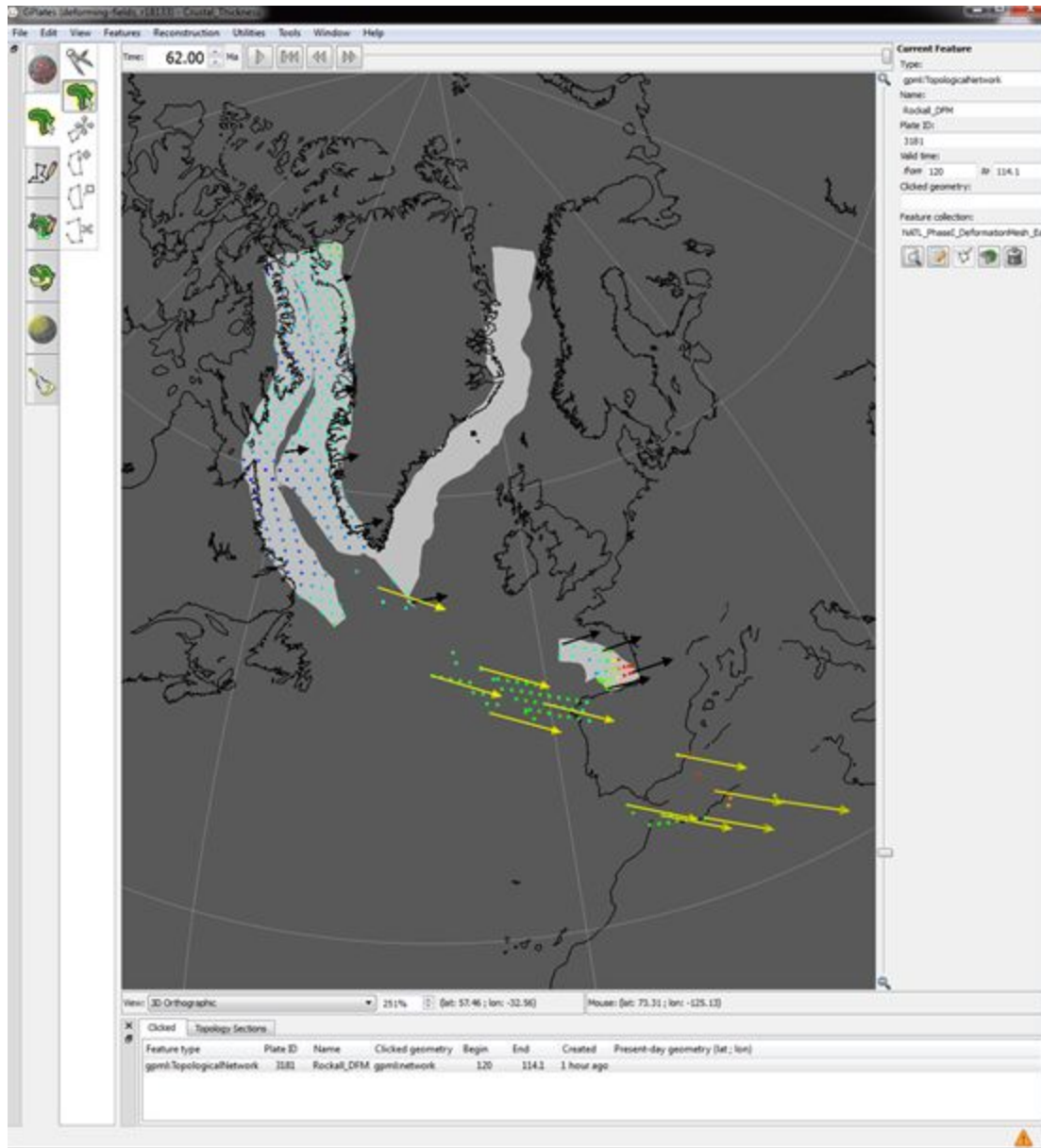


Figure 16: Deforming network and crustal thickness points at 62 Ma showing scalar velocities.

Exercise 3 – Export scalar coverage to files

After following the steps in Exercise 1 to generate scalar coverage points to show crustal thickness through time, we can then export these to files, which can be used at a later time.

1. Make sure that you have the appropriate files loaded into GPlates (dark grey Reconstructed Scalar Coverage layer).
2. Reconstruction > Export > + Add Export
3. Select (Figure 17):
 - A data type to export ('Scalar Coverages')
 - An output file format ('GMT' in this example)
 - Configure Export Options:
 - File Options (Export to a single file)
 - Domain Point Format Options (Longitude/Latitude GMT Default)
 - Include Options (Include dilatation strain rate)
 - Specify Output Filenames (you can change this or leave it as the default)

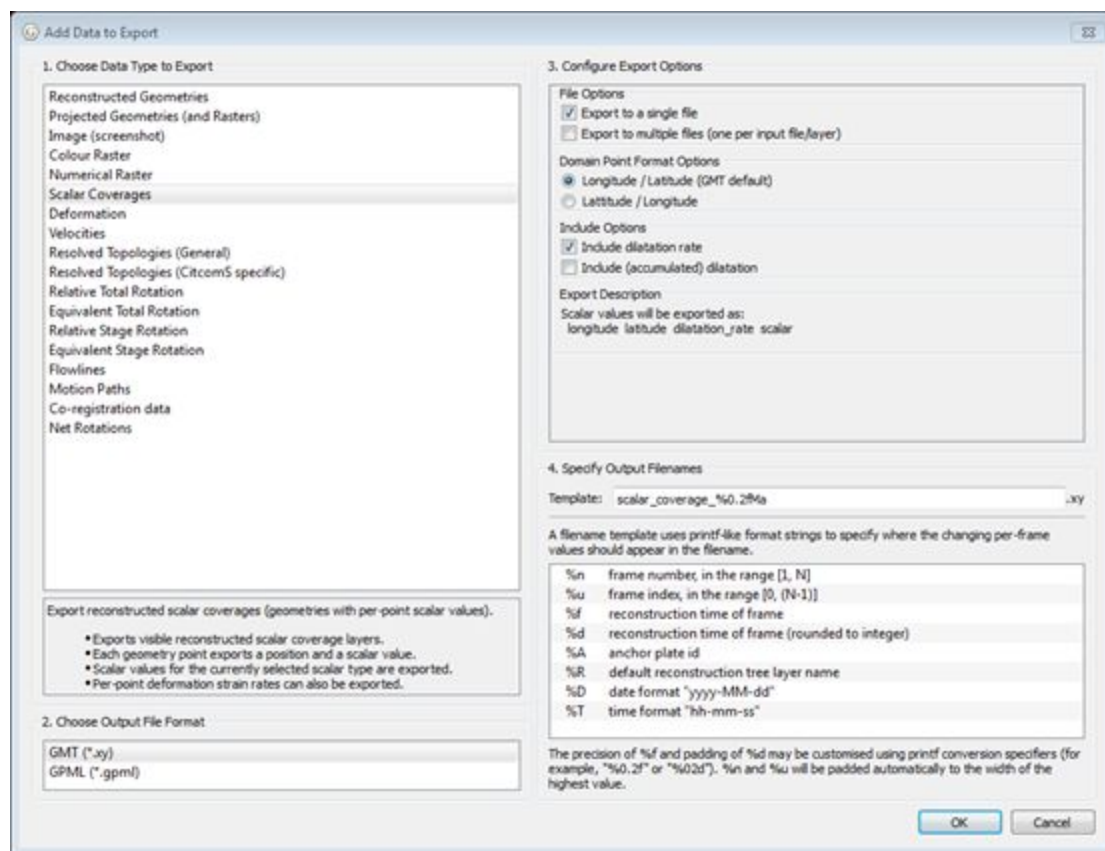


Figure 17: Add Data to Export window for scalar coverage crustal thickness points

3. Click OK and then ensure that we are animating the entire period that the crustal thickness points exist for (120-62 Ma) by changing the times in the Export window (Figure 18).

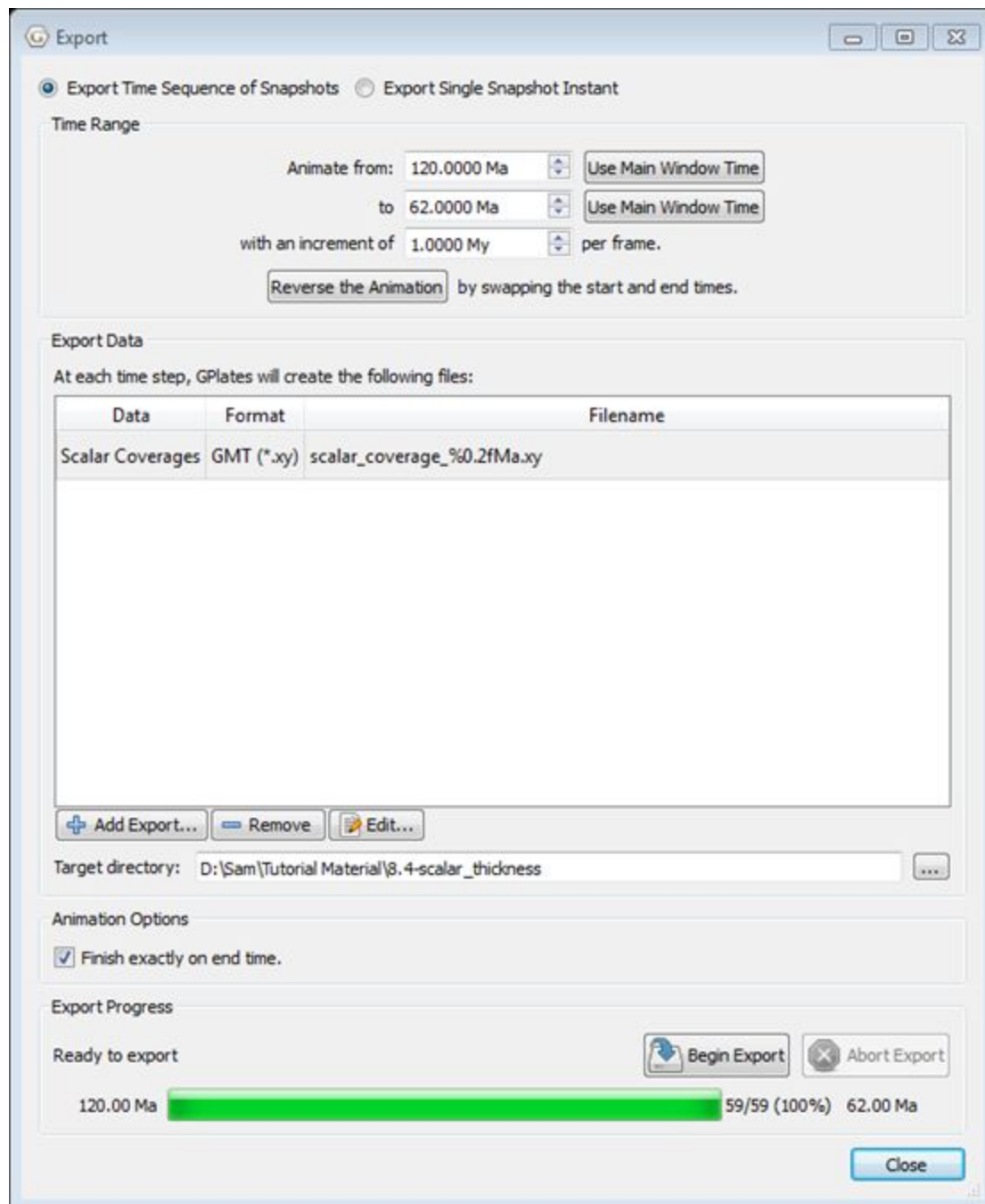


Figure 18: Export window for scalar coverage crustal thickness points

4. Specify the directory where you would like to export these files to and then click 'Begin Export'
5. These files should now be in the target directory for later use

Exercise 4 – Visualising crustal thickness changes in the Arctic

We will use a method similar to that in Exercise 1 to visualise changes in crustal thickness in the Arctic Region, based on a reconstruction by Gion et al. (2017).

Download the files for this exercise from [here](#)

1. If you have the files still loaded in GPlates from previous exercises, close them, or go File > Clear Session
2. Load in all the downloaded files except the Readme by dragging and dropping them onto the globe, or File > Open Feature Collections.
3. Rotate the globe such that the deforming region is in view, and change the reconstruction time to 63 Ma (Figure 19).

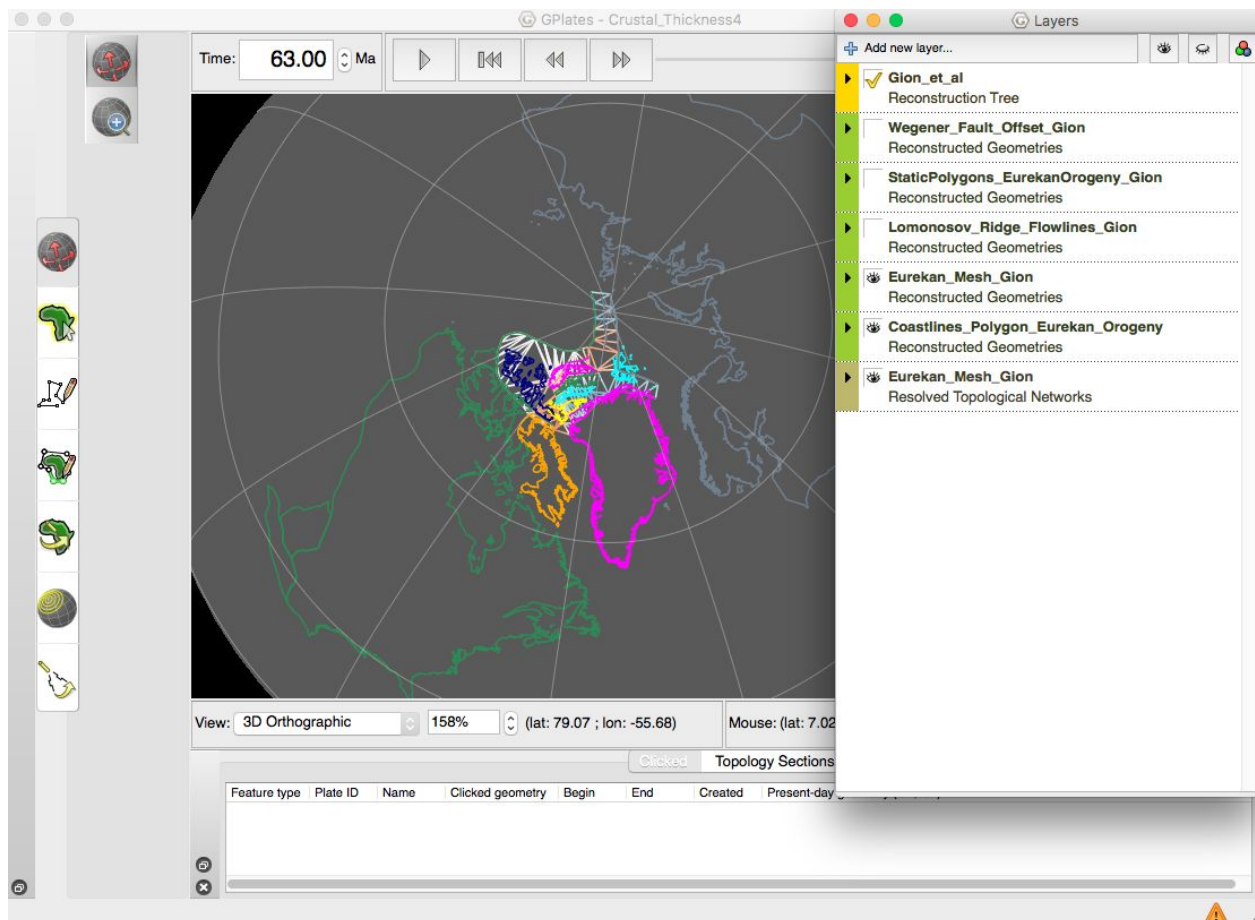


Figure 19: Deforming network in the Arctic Region

4. If your deforming network does not appear as a triangular network, expand the options beneath the gold Resolved Topological Networks layer and beneath Triangulation Colour Mode, select 'Dilatation Strain' (Figure 20).
5. Enable clamping may be ticked as this will constrain the strain rate away from extreme values and decrease computational time (Figure 20).

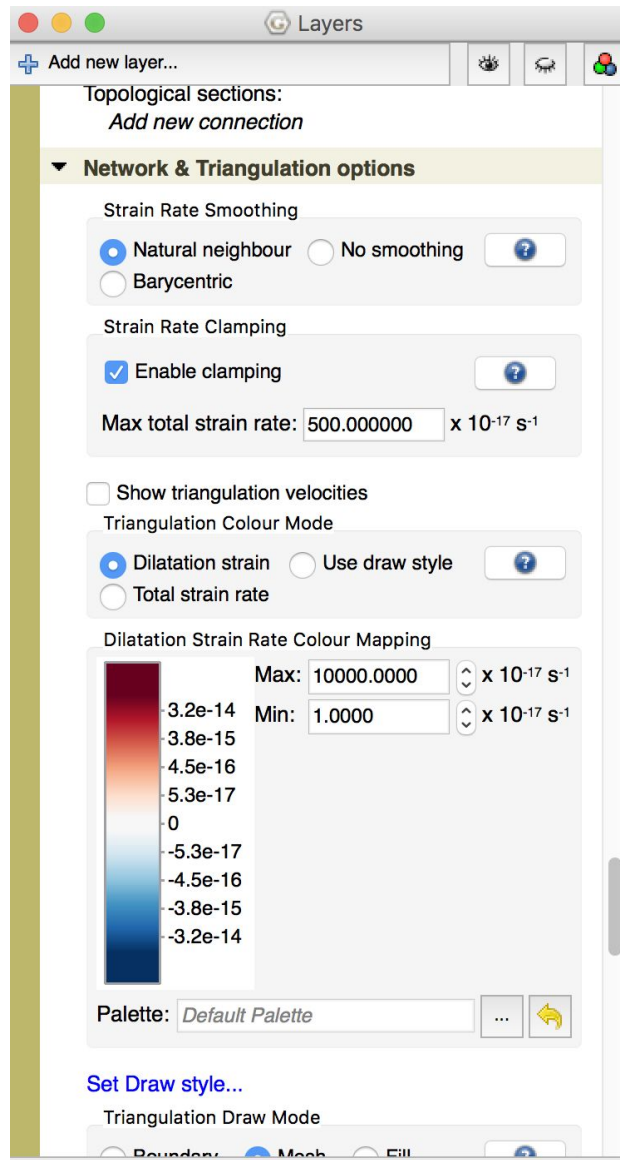


Figure 20: Changing Triangulation Colour Mode of Topological Network and enabling clamping

5. Using the select feature tool, select the deforming network region by clicking anywhere in the triangulated area (the boundary of the region should turn white).

6. Go to Features > Generate Crustal Thickness Points (**before you do this ensure your reconstruction time is 63 Ma).

A new dialog should open where we will specify the parameters for calculating crustal thickness. The parameters are specific to each deforming region.

7. Specify the following parameters (Figure 21):

- Scalar Type = gpml:CrustalThinningFactor
- Density level = 8
- Plate ID = 0 (default)
- Begin time = 63 Ma (this is the time we have reconstructed back to, to generate the points)
- End time = Distant future
- Name = Arctic_Crustal_Thickness (or whatever you'd like to call it)

Generate Crustal Thickness Points

Initial Crustal Thickness

Scalar Type: ?

Thinning factor: ^ v

Uniform Point Distribution

Density level: ^ v Spacing: degrees ?

Random offset: ^ v %

Common Feature Properties

Plate ID: ^ v

Begin (time of appearance): ^ v Ma ☐ Distant Past ?

End (time of disappearance): ^ v Ma ☒ Distant Future

Name:

Figure 21: Specifying crustal thickness parameters

8. Select Next > Create new feature collection > Create

You should now have lots of green points within the deforming network region (Figure 22). You should also note that there are two new layers that have been created - a green Reconstructed Geometries Layer and a dark grey Reconstructed Scalar Coverages Layer (Figure 22).

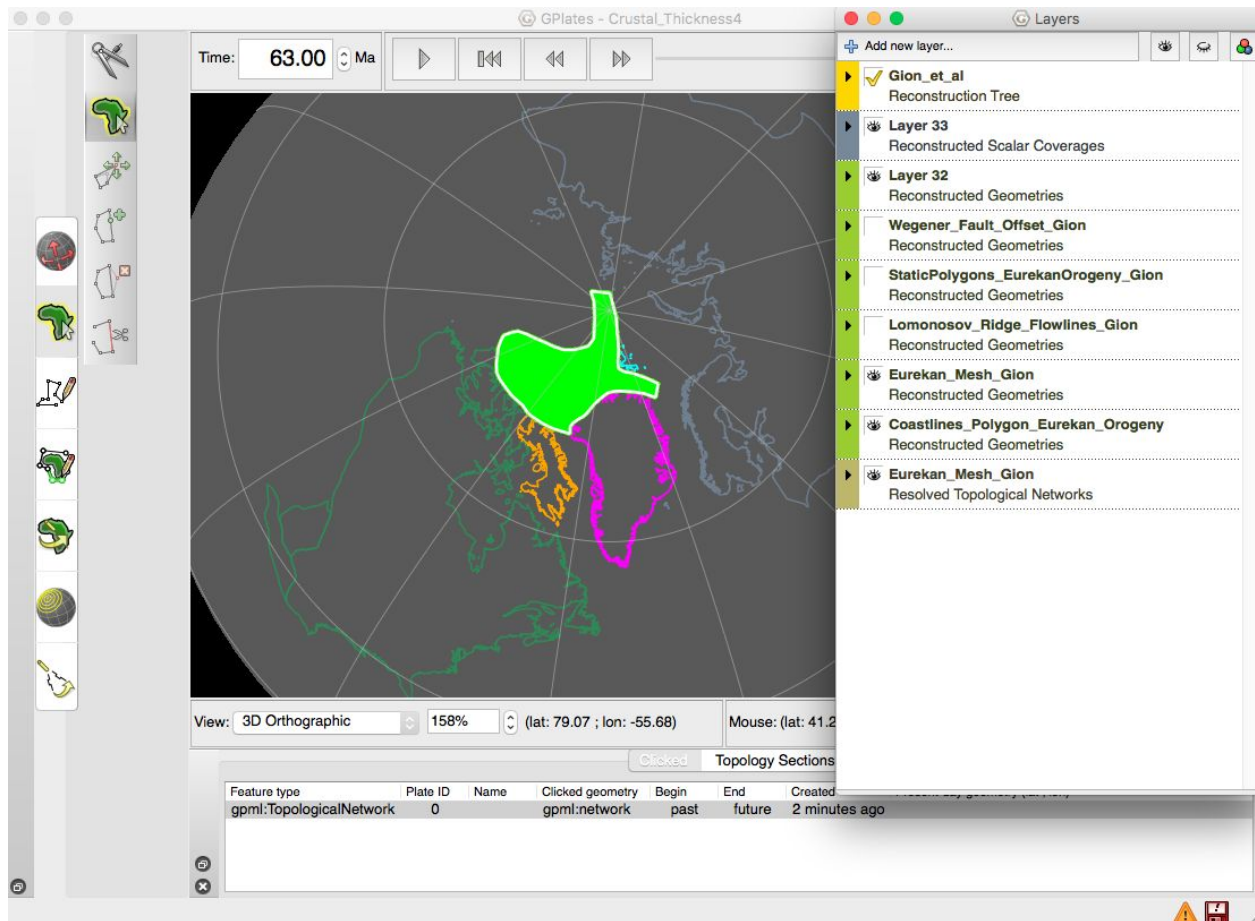


Figure 22: Crustal thickness points that have been generated.

9. In the layer manager window, expand the options beneath the new green Reconstructed Geometries Layer (Figure 23).

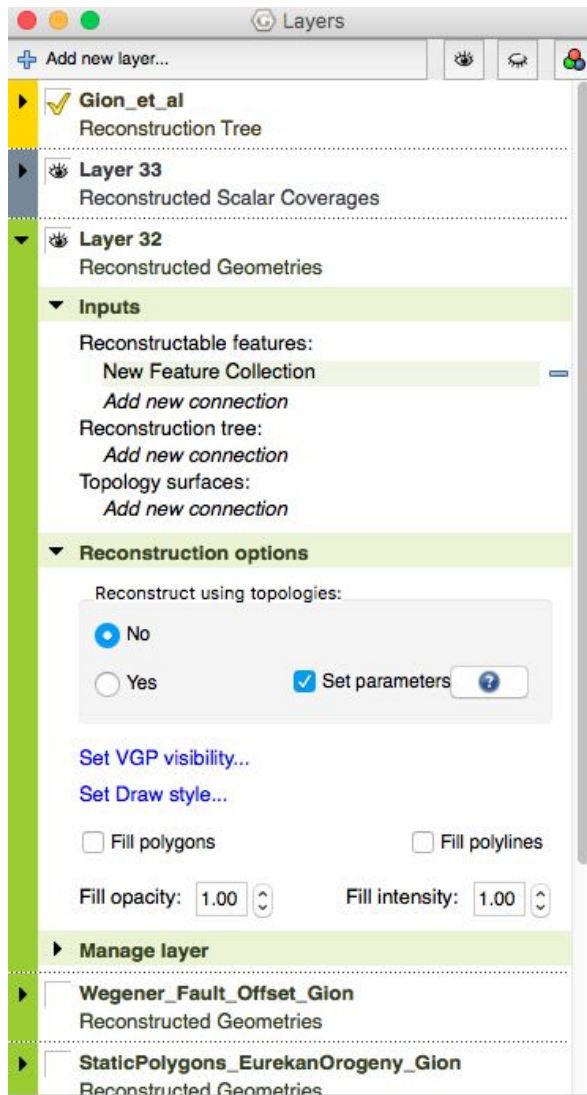


Figure 23: Layer options for our crustal thickness points

10. Under Inputs > Topology Surfaces, add a new connection to the Eureka_Mesh_Gion deforming network (Figure 24).

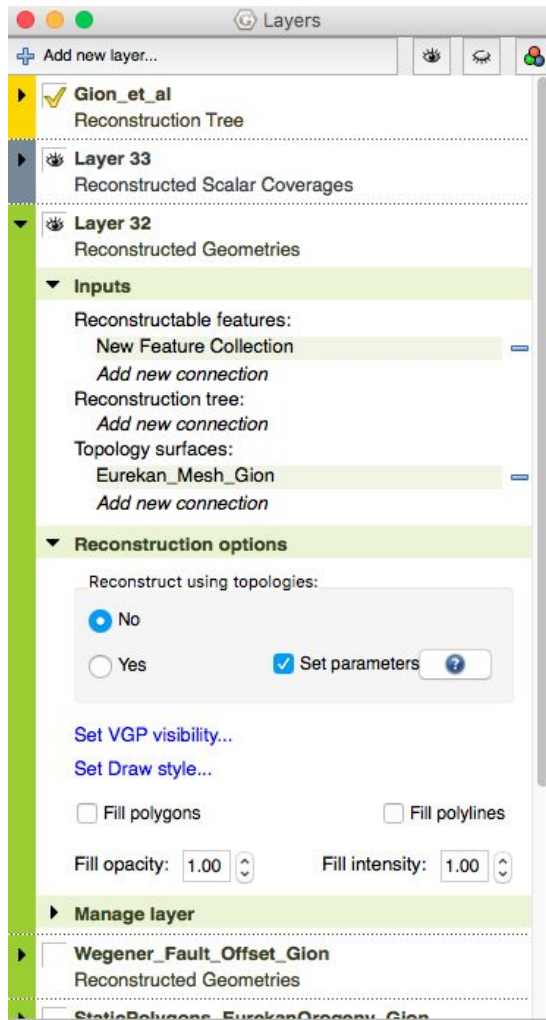


Figure 24: Layer options for our crustal thickness points showing the connection to the topology surface

11. Under Reconstruction Options, select 'Yes' for Reconstruct using topologies. This will bring up a new window where we set Topology Reconstruction Parameters as follows:

- Youngest Age = 0 Ma (default)
- Oldest Age = 63 Ma
- Time Increment = 1 Ma (default)
- Tick "Deactivate points that fall outside a network"

Leave all other options as default (Figure 25) then click OK.

Set Topology Reconstruction Parameters

Choose time span:

Youngest Age Ma

Oldest Age Ma

Time Increment Ma

Reconstruction by topologies *inside* time span.
Reconstruction by plate ID *outside* time span.

☐ Start reconstruction at time of appearance

☒ Detect individual point lifetimes

Threshold velocity delta: cms/yr

Threshold distance to boundary: kms per time increment

☒ Deactivate points that fall outside a network

☒ Tessellate lines:

Point spacing: degrees

Deformed Network Interpolation

☒ Natural neighbour ☐ Barycentric

☒ Show reconstructed feature geometries

☐ Show strain accumulation

Cancel OK

Figure 25: Set Topology Reconstruction Parameters

11. Expand the options under the dark grey Reconstructed Scalar Coverages layer and change the Palette Range to between 1.5 and 0.5, since we are looking at relative changes in crustal thickness and the original value is set as 1 (Figure 26).

Note: the palette range can be changed to any range you'd like however it is recommended that 1 is in the middle since it represents the original crustal thickness at 63 Ma and the colours diverge appropriately.

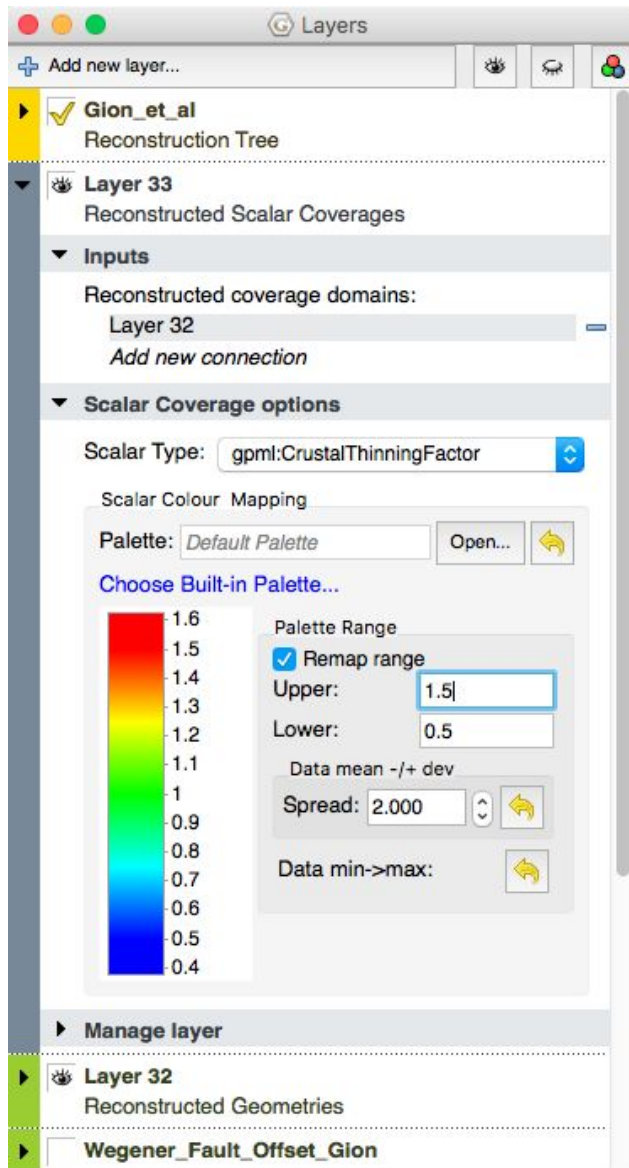


Figure 26: Changing the colour palette range (Step 12)

With the default colour palette, points where the crust is thicker than it was at 63 Ma will be yellow/red, while points where the crust is thinner will be blue.

13. Play the animation from 63-33 Ma and see how the colours of the points change to reflect changes in crustal thickness.

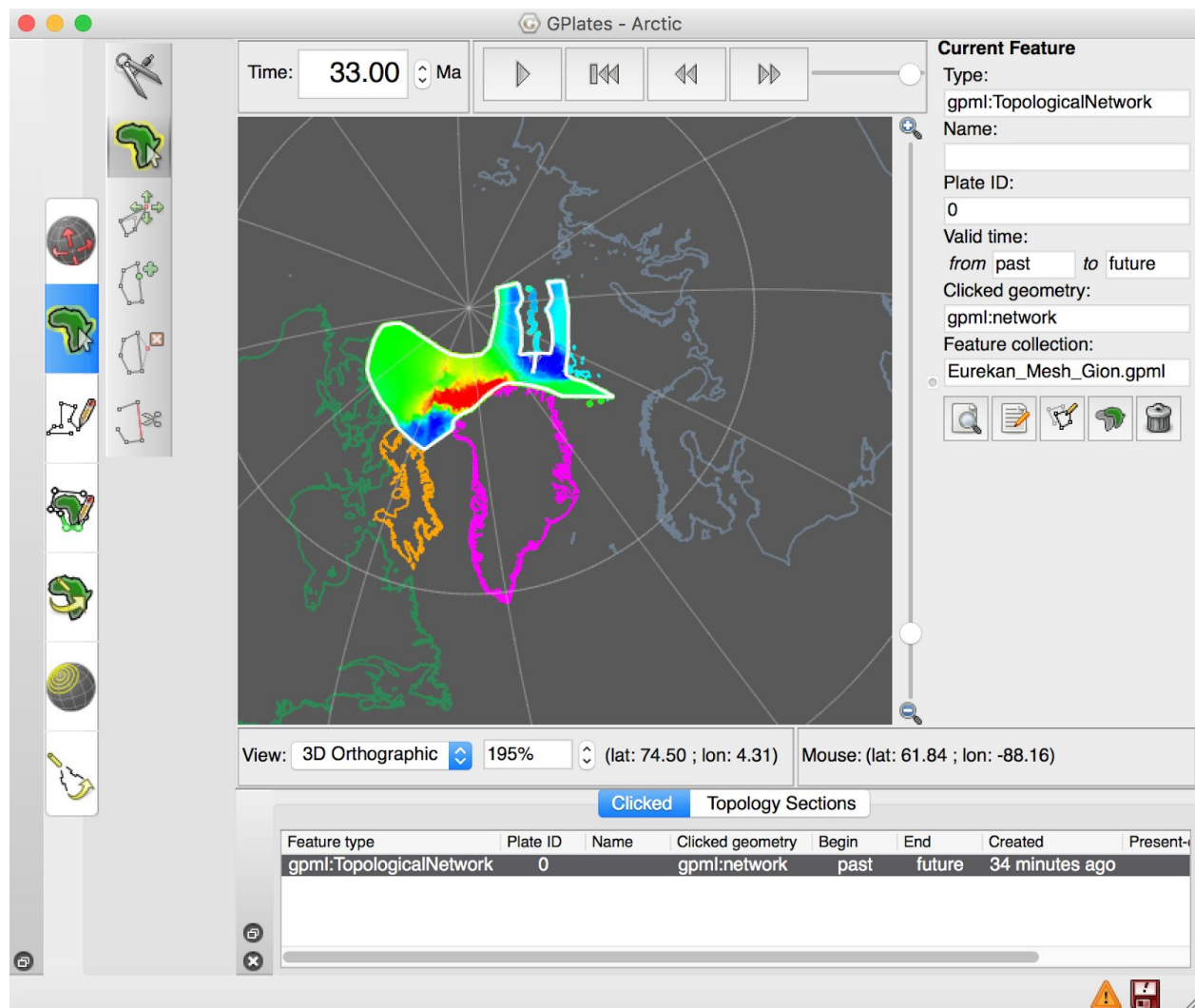


Figure 27: Crustal thickness of Arctic

14. Don't forget to save the new layers you generated!

References

Barnett-Moore, N., Müller, R., Williams, S., Skogseid, J., and Seton, M., 2016, A reconstruction of the North Atlantic since the earliest Jurassic: Basin Research.

Gion, A., Williams, S. and Müller, R. (2017). A reconstruction of the Eurekan Orogeny incorporating deformation constraints. *Tectonics*, 36(2), pp.304-320.

Müller, R. D., Seton, M., Zahirovic, S., Williams, S. E., Matthews, K. J., Wright, N. M., Shephard, G., Maloney, K. T., Barnett-Moore, N., Hosseinpour, M., Bower, D. J., and Cannon, J., 2016, Ocean basin evolution and global-scale plate reorganization events since Pangea breakup, *Annual Review of Earth and Planetary Sciences*, doi:4410.1146/annurev-earth-060115-012211.