Tracking Crustal Thickness Changes

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Updated for GPlates 2.2 and the reconstructions of Müller et al. (2019) by Christopher Alfonso and Behnam Sadeghi

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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 <u>here</u> to download the data bundle for this tutorial.

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

- 1. GPlates project file:
 - 8.4-Crustal_Thickness.gproj
- 2. Rotation file:
 - Muller_etal_2019_CombinedRotations.rot

- 3. Coastlines file:
 - Muller_etal_2019_Global_Coastlines.gpmlz
- 4. Plate boundaries and deforming meshes file:
 - Muller_etal_2019_PlateBoundaries_DeformingNetworks.gpmlz

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 three ways to visualise crustal thickness changes in GPlates 2.2. The first of these is the absolute crustal thickness (gpml:CrustalThickness). When a network of crustal thickness points is generated, an initial uniform crustal thickness value is assigned. By default, this value is set to 40 km, although any value can be specified. Areas which have experienced compression will have increased crustal thickness values, while areas which have experienced extension will have thinner crust.

Relative changes in crustal thickness can be visualised using one of two parameters (gpml:CrustalStretchingFactor and gpml:CrustalThinningFactor). These parameters are defined as follows:

Crustal Stretching Factor
$$=\frac{T_i}{T_t}$$

Crustal Thinning Factor
$$= \frac{T_i - T_t}{T_i} = \frac{-\Delta T}{T_i} = 1 - \frac{T_t}{T_i}$$

Where:

 T_{i} = initial crustal thickness T_{t} = crustal thickness at time t ΔT = change in crustal thickness (i.e. T_{t} - T_{i})

Thus the Crustal Stretching Factor has the range $(0, \infty)$, with values < 1 indicating thickened crust and values > 1 indicating thinned crust. A value of

1 indicates no change in crustal thickness.

Meanwhile, the Crustal Thinning Factor has the range $(-\infty, 1)$, with values < 0 indicating thickened crust and values > 0 indicating thinned crust. A value of 0 indicates no change in crustal thickness.

In all of these cases, the initial time (t = 0) is crucially important, as all calculations are relative to the crustal thickness at this time.

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 `8.4-Crustal_Thickness.gproj' by either dragging and dropping it onto the globe, or File \rightarrow Open Project...
- 2. Rotate the globe such that the North Atlantic is in view at 120 Ma (Figure 1).

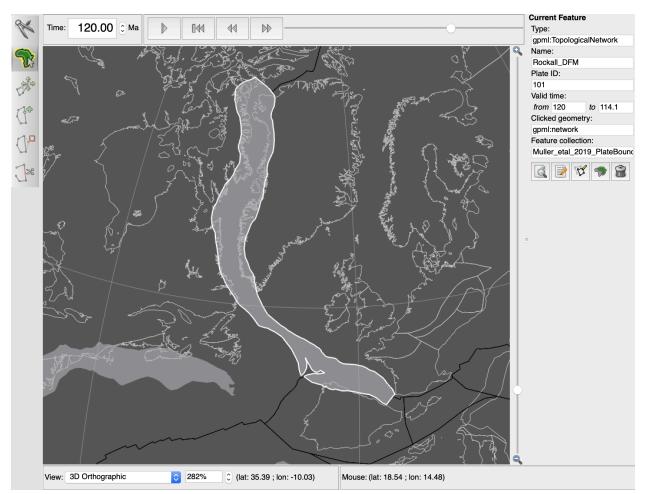


Figure 1: Screenshot of globe focused on North Atlantic at 120 Ma. Deforming meshes are shaded grey, and the North Atlantic deforming mesh ('Rockall_DFM') is selected.

Note the highlighted polygon (outlined in white, shaded in grey). This is a deforming network for the North Atlantic, which we will use to visualise changes in crustal thickness through time.

- 3. **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.
- 4. Using the select feature tool, select the deforming network region by clicking anywhere in the grey shaded area (the boundary of the region should turn white once selected).
- 5. Go to Features \rightarrow Generate Deforming Mesh Points

A new dialog should open where we will specify the parameters for the

calculations to be performed on the deforming mesh (Figure 2). These parameters are defined separately for each deforming region.

	Generate Def	orming Mesh Poir	nts			
Points Region						
Specify the region	n occupied by the po	ints:				
Focused feat	Focused feature boundary					
Latitude/Long	itude extent					
Include rigid ir	nterior blocks					
Start latitude:	90.0000°	0				
End latitude:	-90.0000°					
Start longitude:	-180.0000°					
End longitude:	180.0000°					
🤚 Use Globa	al Extents					
Points Distribution						
Density level: 6	🗘 Spac	ing: 0.625	degrees	8		
Random offset: (0.00 🗘 %					
Previous	ext		Create	Cancel		

Figure 2: Generate Deforming Mesh Points window (Step 5).

Now we will generate the points inside the deforming region that will be used to represent relative changes in crustal thickness.

- 6. Specify the following parameters (Figure 2), then click "Next":
 - Points Region: Focused feature boundary
 - Density level = 6 (default specifies point density in the deforming region. See note at end of this exercise for more information)
 - Spacing will be automatically determined based on density level

- Random offset = 0 % (default)
- 7. In the next window, specify the following parameters (Figure 3), then click "Next":
 - Thickness = 40.0 km (default)
 - Plate ID = 0 (default)
 - Begin time = 120 Ma (the time we reconstructed to when we generated the points)
 - End time = 0 Ma (default)
 - Name = North_Atlantic_Crustal_Thickness (or whatever name you would like to give it)

Generate Deforming Mesh Points
Initial Crustal Thickness
Thickness: 40.00 \$ kms at 120.00 Ma 3
Common Feature Properties
Plate ID: 0
Begin (time of appearance): 120.00 🗘 Ma 🗌 Distant Past 👔
End (time of disappearance): 0.00 C Ma Distant Future
Name: North_Atlantic_Crustal_Thickness
Previous Next Create Cancel

Figure 3: Entering deforming mesh parameters, as described in Step 6.

- 8. In the next window, click "< Create a new feature collection >", then "Create"
- 9. In the next window (Figure 4), we need to specify some final parameters:

- Youngest Age = 0 Ma (default)
- \circ Oldest Age = 120 Ma
- Select "Deactivate points that fall outside a network"
- Leave other options as defaults

🔴 🔿 🕘 💮 🌀	Set Topology Reconstruc	tion Parameters		
_Choose time span				
Youngest Age	0	Ma		
Oldest Age	120	Ма		
Time Increment	1	Ma		
Reconstruction t	by topologies <i>inside</i> time sp	an.		
Reconstruction t	by plate ID outside time spa	ın.		
Start reconstru	uction at time of appearance	9	•	
Detect individu	al point lifetimes		•	
Threshold velo	city delta: 0.70	🗘 cms/yr		
Threshold distance to boundary: 10				
Deactivate points that fall outside a network				
Tessellate line	s:		•	
Point spacing:	0.50 C degrees			
Deformed Networ	k Interpolation			
 Natural neight 	bour Barycentric		•	
Show reconstr	ructed feature geometries			
Show strain ac	cumulation		•	
		Cancel	ОК	

Figure 4: Entering further deforming mesh parameters, as described in Step 8.

10. Click "OK", and your network of points will be created (this may take a moment)

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.

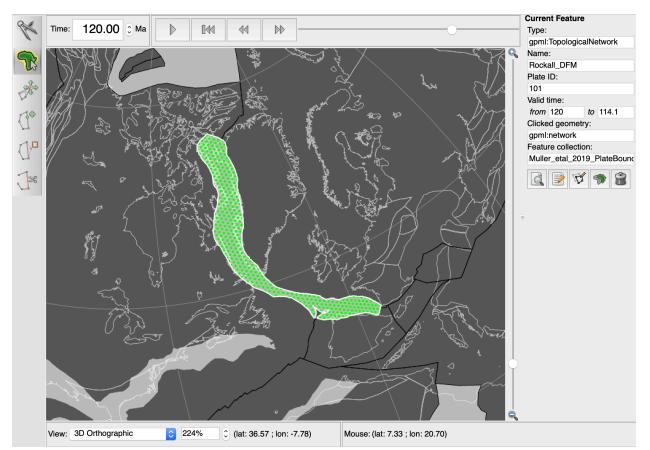


Figure 5: Newly generated crustal thickness points (green) within the deforming region (grey).

11. If it is not already visible, open the Layers window (Window \rightarrow Show Layers... or Cmd/Ctrl+L)

You should notice that two new layers have been produced - a green one (reconstructed geometries) and a dark grey one (reconstructed scalar coverages). These will have automatically been assigned generic names (e.g. "Layer [n]") for the moment.

12. Expand the options for the green reconstructed geometries layer (Figure 6).

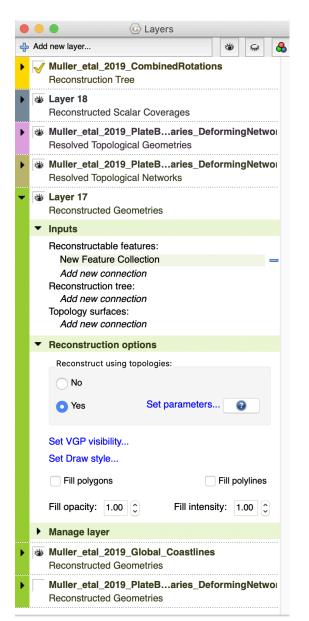


Figure 6: Layer options for our crustal thickness points.

13. Under Inputs \rightarrow Topology surfaces, add a new connection to the gold-coloured Muller_etal_2019_PlateBoundaries_DeformingNetworks (Figure 7).

		G Layers
÷	Add	new layer 😻 😞 🖁
۲	V	Muller_etal_2019_CombinedRotations Reconstruction Tree
Þ	*	Layer 18 Reconstructed Scalar Coverages
•	*	Muller_etal_2019_PlateBaries_DeformingNetwor Resolved Topological Geometries
Þ	*	Muller_etal_2019_PlateBaries_DeformingNetwor Resolved Topological Networks
-	\$	Layer 17 Reconstructed Geometries
	•	Inputs
		Reconstructable features: New Feature Collection Add new connection Reconstruction tree: Add new connection Topology surfaces: Add new connection
	_	Muller etal 2019 PlateBoundaries DeformingNetworks
	•	Muller_etal_2019_PlateBoundaries_DeformingNetworks
		No
		• Yes Set parameters ?
		Set VGP visibility Set Draw style
		Fill polygons Fill polylines
		Fill opacity: 1.00 C Fill intensity: 1.00 C
	•	Manage layer
•	\$	Muller_etal_2019_Global_Coastlines Reconstructed Geometries day geometry (lat ;
•		Muller_etal_2019_PlateBaries_DeformingNetwor Reconstructed Geometries

Figure 7: Connecting the crustal thickness points to the topology surface

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

14. Expand the options under the dark grey Reconstructed Scalar Coverages layer (Figure 8). Under Scalar Coverage options, set the Scalar Type to gpml:CrustalStretchingFactor. Change the Palette Range to 0.0–2.0, since we are looking at relative changes in crustal thickness, where the original value is defined as 1.

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.

		•	G Layers				
÷	Add	l new layer			*	Ş.	8
•	*	Layer 18 Reconstructed S	Scalar Coverages				
	•	Inputs					۰,
		Reconstructed of points_6 Add new cont	overage domains:				-
	•	Scalar Coverag	e options				
		Scalar Type: g	pml:CrustalStretching	Fac	tor	0	3
l		Palette: Defau Choose Built-in	lt Palette	Op	oen	\$	
		-2.2 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 -0 -0.2	Palette Range Palette Range Upper: 22 Lower: 0 Data mean -/+ d Spread: 2.000 Data min->max:)	•	>	
	•	Manage layer					
۲	*		19_PlateBaries_D ogical Geometries	Defo	ormin	gNet	NOI

Figure 8: Changing the colour palette range (Step 13).

With the default colour palette, crust that has thickened since 120 Ma will be blue, while crust which has thinned will be yellow-red.

15. Change the reconstruction time to 62 Ma (Figure 9).

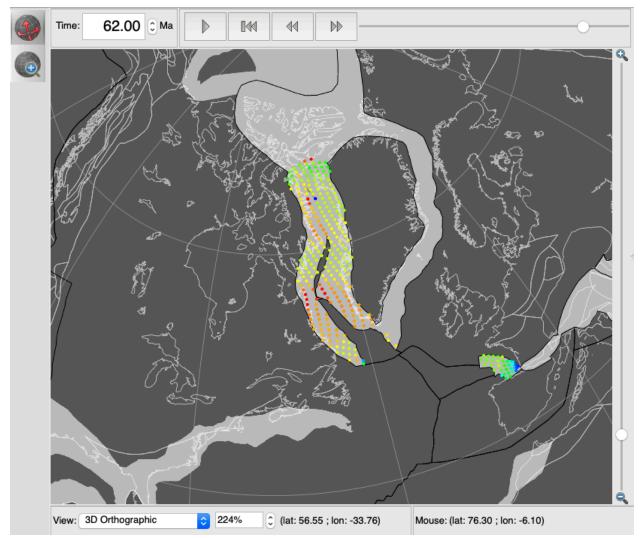


Figure 9: Crustal thickness in the North Atlantic at 62 Ma.

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

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

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

There is also a range of other colour palette options to choose from other than default red-green-blue:

17. Expand the Scalar Coverage options under the dark grey layer in the Layer window, and select 'Choose Built-in Palette...' (Figure 10).

•	•	Layers
÷	Add	new layer 😻 😞
۲	V	Muller_etal_2019_CombinedRotations Reconstruction Tree
•	4	Layer 18 Reconstructed Scalar Coverages
	•	nputs
		Reconstructed coverage domains: Layer 17 = Add new connection
	•	Scalar Coverage options
		Scalar Type: gpml:CrustalStretchingFactor
		Scalar Colour Mapping
		Palette: Default Palette Open
		Choose Built-in Palette
		1.6 Palette Range 1.5 Pemap range 1.4 Upper: 1.5 1.3 Lower: 0.5 1.1 Data mean -/+ dev 1 Spread: 2.000 0.8 0.7 Data min->max: 0.6 0.5 0.4
	•	Manage layer
•	*	Muller_etal_2019_PlateBaries_DeformingNetwo Resolved Topological Geometries
•	*	Muller_etal_2019_PlateBaries_DeformingNetwor Resolved Topological Networks
•	*	Layer 17 Reconstructed Geometries
•	*	Muller_etal_2019_Global_Coastlines Reconstructed Geometries

Figure 10: Layer window showing 'Choose Built-in Palette...' option.

This will open the Choose Built-in Palette window (Figure 11), where you can choose from a range of different colour palettes. You can also choose to invert the colour palette (tick 'Invert'), as well as making the colour palette discrete, with a given number of classes (tick 'Discrete' and enter a value for 'Classes').

	G Choose Built-in Palet	tte
ColorBrewer Sequential		
Multi-hue		Single hue
BuGn BuPu GnB	u OrRd PuBu PuBuGn	Blues Greens Greys
PuRd RdPu YIG	n YIGnBu YIOrBr YIOrRd	Oranges Purples Reds
Classes: 9 🗘		
Diverging		
BrBG PiYG PI	RGn PuOr RdBu RdGy	RdYlBu RdYlGn Spectral
Classes: 11 🗘		
Discrete		Invert
		Close

Figure 11: The Choose Built-in Palette window, showing the range of colour palette options.

18. Experiment with the different colour palette options, then when you are satisfied with your choices, click "Close".

Don't forget to save your new feature collection containing 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. Although it may take longer to compute, using a point density of 8 gives us a more detailed coverage (Figure 12).

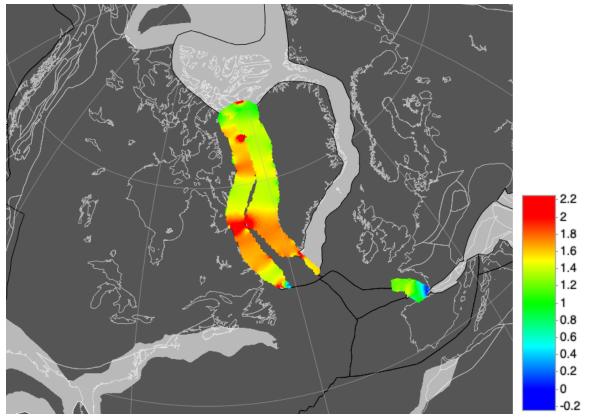


Figure 12: Crustal thickness of North Atlantic deforming region with point density of 8 with default colour palette showing relative crustal thickness changes.

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 13).

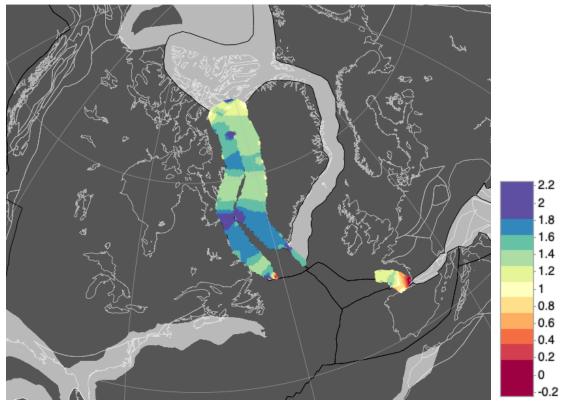


Figure 13: Crustal thickness of North Atlantic deforming region with point density of 8 and modified colour palette (Discrete, Spectral).

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 Exercise 1 are loaded into GPlates.
- 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 \rightarrow '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 14

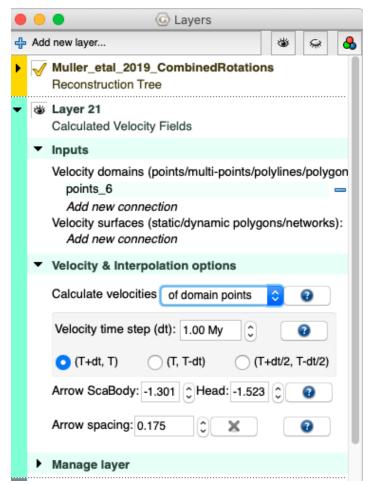


Figure 14: Layer window showing options of the new Calculated Velocity Fields layer.

6. Play the animation from 120–62 Ma and see the arrows that appear, describing the motion of the deforming network (Figure 15).

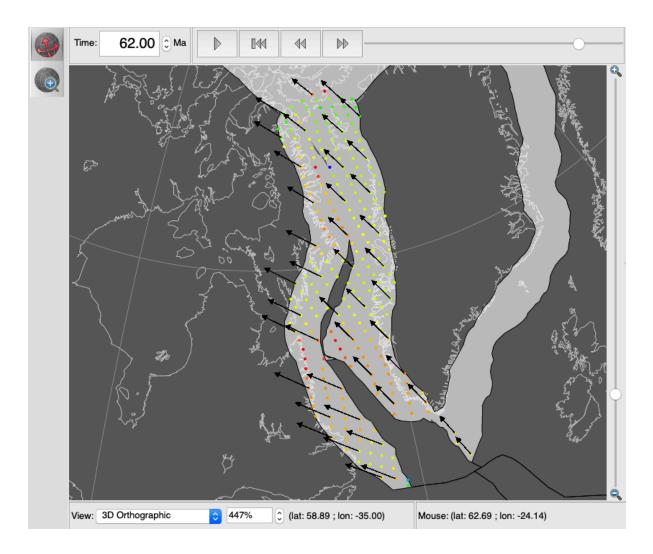


Figure 15: Deforming network and crustal thickness points at 62 Ma showing scalar velocities.

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 \rightarrow Export \rightarrow + Add Export

- 3. Select (Figure 16):
 - 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 Strain Rate Options (Include dilatation strain rate)
 - Specify Output Filenames (you can change this or leave it as the default)

I. Choose Data Type to Export	3. Configure Export Options
Reconstructed Geometries Projected Geometries (and Rasters) Image (screenshot)	Export to duringle files (one per input file/layer)
Colour Raster Numerical Raster	Domain Point Format Options
Scalar Coverages Deformation	 Longitude / Latitude (GMT default) Lattitude / Longitude
Velocities Resolved Topologies (General)	Include Strain Options
Resolved Topologies (CitcomS specific)	Include dilatation strain
Relative Total Rotation Equivalent Total Rotation	Include Strain Rate Options
Relative Stage Rotation Equivalent Stage Rotation	 Include dilatation strain rate (1/sec) Include total strain rate (1/sec)
Flowlines Motion Paths	Export Description
Co-registration data Net Rotations	Scalar values will be exported as: longitude latitude dilatation_strain_rate scalar
	4. Specify Output Filenames Template: scalar coverage %0.2fMa
Export reconstructed scalar coverages (geometries with per- point scalar values).	Template: scalar_coverage_%0.2fMa .x A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename.
Export reconstructed scalar coverages (geometries with per- point scalar values). Exports visible reconstructed scalar coverage layers. 	A filename template uses printf-like format strings to specify where the changing
point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename.
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer)
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. Per-point deformation strain and strain rate can also be 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer) %A anchor plate id
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer)
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. Per-point deformation strain and strain rate can also be exported. 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer) %A anchor plate id %R default reconstruction tree layer name
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. Per-point deformation strain and strain rate can also be 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer) %A anchor plate id %R default reconstruction tree layer name %D date format "yyyy-MM-dd"
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. Per-point deformation strain and strain rate can also be exported. 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer) %A anchor plate id %R default reconstruction tree layer name %D date format "yyyy-MM-dd" %T time format "hh-mm-ss" The precision of %f and padding of %d may be customised using printf conversior specifiers (for example, "%0.2f" or "%02d"). %n and %u will be padded
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. Per-point deformation strain and strain rate can also be exported. Choose Output File Format 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer) %A anchor plate id %R default reconstruction tree layer name %D date format "yyyy-MM-dd" %T time format "hh-mm-ss"
 point scalar values). Exports visible reconstructed scalar coverage layers. Each geometry point exports a position and a scalar value. Scalar values for the currently selected scalar type are exported. Per-point deformation strain and strain rate can also be exported. Choose Output File Format 	A filename template uses printf-like format strings to specify where the changing per-frame values should appear in the filename. %n frame number, in the range [1, N] %u frame index, in the range [0, (N-1)] %f reconstruction time of frame %d reconstruction time of frame (rounded to integer) %A anchor plate id %R default reconstruction tree layer name %D date format "yyyy-MM-dd" %T time format "hh-mm-ss" The precision of %f and padding of %d may be customised using printf conversio specifiers (for example, "%0.2f" or "%02d"). %n and %u will be padded

Figure 16: Add Data to Export window for scalar coverage crustal thickness points.

4. Click OK and then ensure that we are animating the entire period that the crustal deformation is occurring (120-62 Ma) by changing the times in the Export window (Figure 17).

	G	Export	
Export Time Sequence	of Snapshots	Export Single Snapshot Ins	tant
Time Range			
Export f	to 62.0000 Ma	Use Main W	
with an increme Revers		oper frame. y swapping the start and end	d times.
Export Data			
At each time step, GPlat	es will create the fol	lowing files:	
Data	Format	Filename	
Add Export = Re Target directory: /User	move 📝 Edit s/Shared/GPlates_e	xport	
Export Options			
Finish exactly on end	l time.		
Export Progress			
Ready to export		Begin Export	Abort Export
120.00 Ma			62.00 Ma
			Close

Figure 17: Export window for scalar coverage crustal thickness points.

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

Exercise 4 – Visualising crustal thickness changes in the Arctic

We will now use a method similar to that in Exercise 1 to visualise changes in crustal thickness in the Arctic Region, based on the reconstruction of Müller et al. (2019).

- 1. If you have the files still loaded in GPlates from previous exercises, close and reopen GPlates, or go File \rightarrow Clear Session.
- 2. As in Exercise 1, load the GPlates project file `8.4-Crustal_Thickness.gproj'.
- 3. Rotate the globe such that the Arctic region is in view, and change the reconstruction time to 68 Ma (Figure 18).

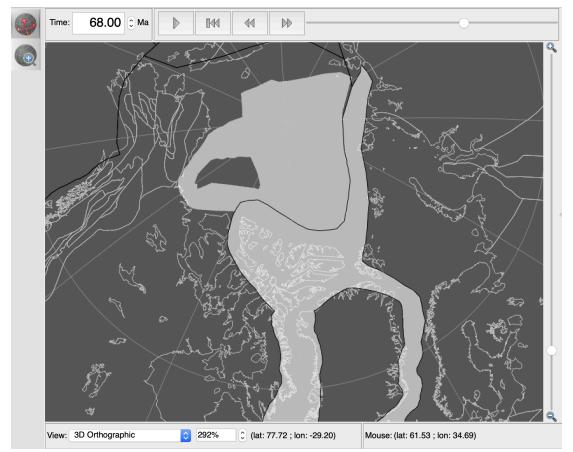


Figure 18: Deforming networks of the Arctic Region at 63 Ma.

4. Expand the options beneath the gold Resolved Topological Networks

layer and select the following options (Figure 19):

- Under Triangulation Draw Mode, select 'Mesh'
- Under Triangulation Colour Mode, select 'Dilatation strain'
- Under Strain Rate Clamping, select 'Enable clamping' (this will constrain the strain rate to remove extreme values and reduce computation time)

•	•	G Layers
÷	Add	new layer 👑 📯 🐣
		Strain Rate Clamping
		Enable clamping
		Max total strain rate: 500.000000 x 10-17 s-1
		Rift Stretching
		Exponential stretching constant: 1.000
		Strain rate resolution:)0000 x 10-17 s-1
		Refinement threshold (degrees): 1.100
		Show triangulation velocities Triangulation Colour Mode Dilatation strain Use draw style Total strain rate Strain rate style
		Total strain rate Strain rate style
		Dilatation Strain Rate Colour Mapping
		Max: 3000.0000 (c) x 10-17 s-1 1.1e-14 1.8e-15 2.7e-16 4.3e-17 -4.3e-17 -2.7e-16 -1.8e-15 -1.1e-14 Palette: Default Palette
		Set Draw style Triangulation Draw Mode Boundary O Mesh Fill
		Fill rigid interior blocks (uses draw style)
		Fill opacity: 0.60 C Fill intensity: 1.00 C

Figure 19: The options outlined in Step 4 have been selected.

The view should now appear as in Figure 20.

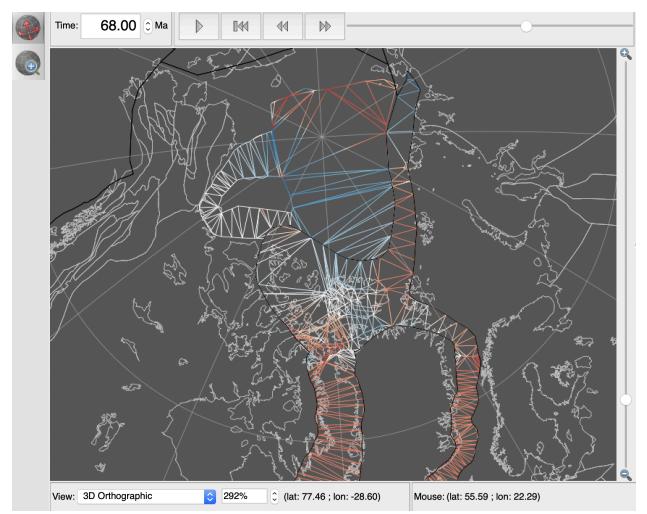


Figure 20: Deforming regions of the Arctic, visualised as meshes and coloured by dilatation strain.

- Using the select feature tool, select the EllesmereIsland_Deformation_Network feature, to the north of Greenland, by clicking on the triangulated mesh (the boundary of the region should turn white).
- 6. After ensuring the reconstruction time is 68 Ma, go to Features \rightarrow Generate Deforming Mesh Points.

As in Exercise 1, a new window will open, where we will specify the parameters for calculating crustal thickness.

- 7. Under 'Points Region', select 'Focused feature boundary'. Under Points Distribution, set 'Density level' to 8. Select 'Next'.
- 8. In the next window, specify the following parameters (Figure 21):
 - Initial crustal thickness = 40 km (default)
 - Plate ID = 0 (default)
 - Begin time = 68 Ma
 - End time = Distant Future
 - Name = whatever name you would like, e.g.
 "EllesmereIsland_Crustal_Thickness"

Generate Deforming Mesh Points
Initial Crustal Thickness
Thickness: 40.00
Common Feature Properties
Plate ID: 0
Begin (time of appearance): 68.00 🗘 Ma Distant Past 👔
End (time of disappearance): 0.00 🔅 Ma 🗸 Distant Future
Name: Ellesmerelsland_Crustal_Thickness
Previous Next Create Cancel

Figure 21: Specifying crustal thickness parameters (Step 8).

- 9. Click 'Next', select '< Create a new feature collection >', and click 'Create'.
- 10. In the next window, specify the following parameters, and leave the others as default:
 - Youngest Age = 0 Ma

- Oldest Age = 68 Ma
- Tick 'Deactivate points that fall outside a network'
- 11. Click 'OK'. The points may take a while to generate.

You should now have lots of green points within the deforming network region (Figure 22). As in Exercise 1, 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).

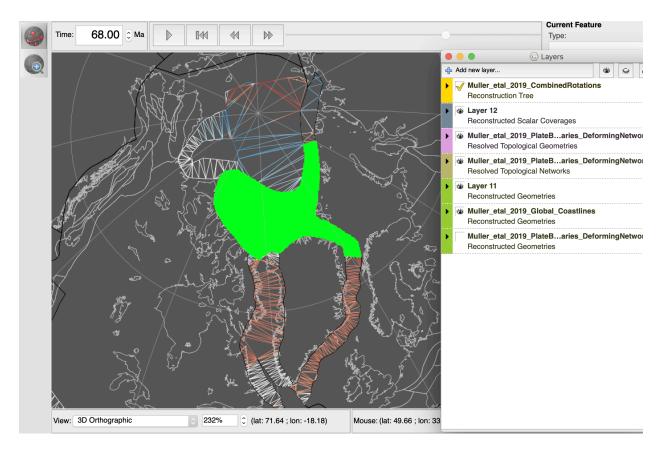


Figure 22: The newly-generated crustal thickness points.

12. In the Layers window, expand the options beneath the new green Reconstructed Geometries Layer. Under 'Inputs', add a new Topology surfaces connection to the brown Resolved Topological Networks layer (Figure 23).

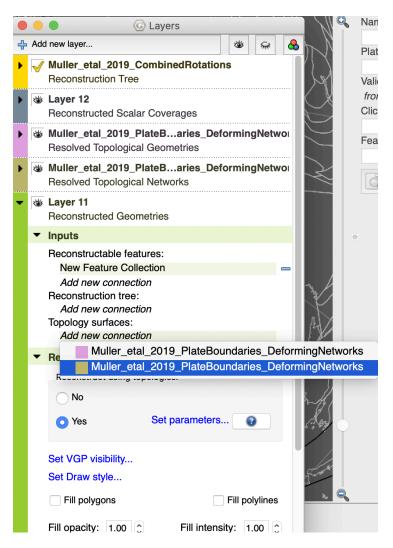


Figure 23: Adding the connection to the Resolved Topological Networks layer.

13. Expand the options under the dark grey Reconstructed Scalar Coverages layer. Set the Scalar Type to gpml:CrustalStretchingFactor and change the Palette Range to between 1.8 and 0.2, since we are looking at relative changes in crustal thickness and the original value is set as 1 (Figure 24).

N.B. 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 68 Ma and the colours diverge appropriately.

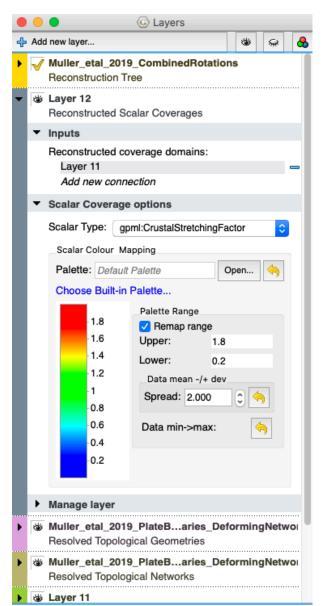


Figure 24: Changing the colour palette (Step 13).

With the default colour palette, points where the crust is thicker than it was at 68 Ma will be blue, while points where the crust is thinner will be yellow-red.

14. Play the animation from 63-33 Ma and see how the colours of the points change to reflect changes in crustal thickness (Figure 25).

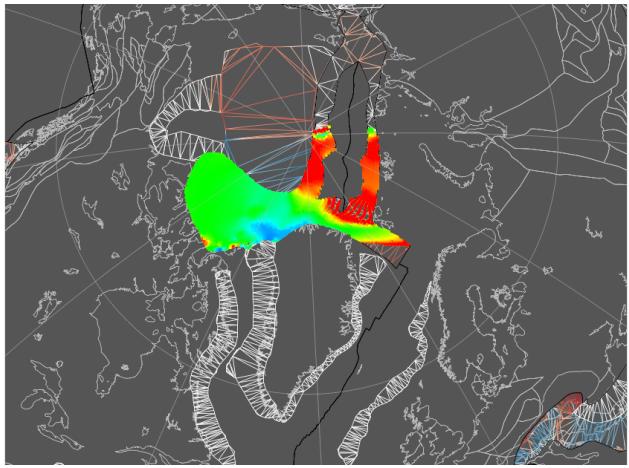


Figure 25: Crustal Stretching Factor in the Arctic region at 20 Ma.

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

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