

Introduction to Paleogeography: Paleogeographic Reconstructions using Raw Paleobiology Data

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Aim

This tutorial is designed to introduce paleogeographic data, and teach the user how to load, prepare and reconstruct fossil data in GPlates.

Background

The following tutorial introduces paleogeography, and the first exercise describes how to load a paleogeography shapefile, using a CPT file to fill by property. The second exercise will explore fossil data, and aims to show how fossil data can be used in helping to determine paleocoastlines. Exercise 3 and 4 describe loading and reconstructing data from the Paleobiology Database in GPlates. The shapefiles provided can be directly loaded into GPlates as Begin/End ages have been assigned.

Note: If importing your own fossil data, create a shapefile of the points in ArcGIS or the open-source equivalent QGIS. Make sure the fossil data has "Begin" and "End" ages representing the age range.

Included Files

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

The tutorial dataset includes the following files:

- Coastlines: Muller_etal_2019_Global_Coastlines.gpmlz
- Rotations: Muller_etal_2019_CombinedRotations.rot
- Static polygons: Muller_etal_2019_Global_StaticPlatePolygons.gpmlz
- Paleogeography of Australia:
Paleogeography_v10/PaleogeographicAtlas_GA_GTS04_V10.shp and associated auxiliary files
- GMT colour palette table (CPT): GA_Paleogeography.cpt

Additionally, shapefiles containing the locations of different types of fossils dating to 200–100 and 100–0 Ma are located in the 'Shapefiles' directory. The different types of fossils are:

- Marine Carbonates
- Marine Siliciclastics
- Terrestrial Fossils
- General Fossils

Finally, although they are not used in this tutorial, the global paleogeographic reconstructions of **Smith et al. (1994)** and **Golonka et al. (2006)** are included (Smith_paleogeography.gpml and Golonka_paleogeography.gpml, respectively) for those who are interested in comparing them to the Australian paleogeography file.

Exercise 1 – Paleogeography

This exercise involves loading the Australian paleogeography shapefile, and using a CPT file to fill by property.

Exercise 1a: Loading the Paleogeography shapefile

1. Download the data bundle for this tutorial and unzip the folder.
2. To load the shapefile go to “File → Manage Feature Collections” (Ctrl/Cmd+M) and click “Open File...”. Navigate to the paleogeographic shapefile and click “Open”.
3. Rotate the globe until you can see the shapefile.

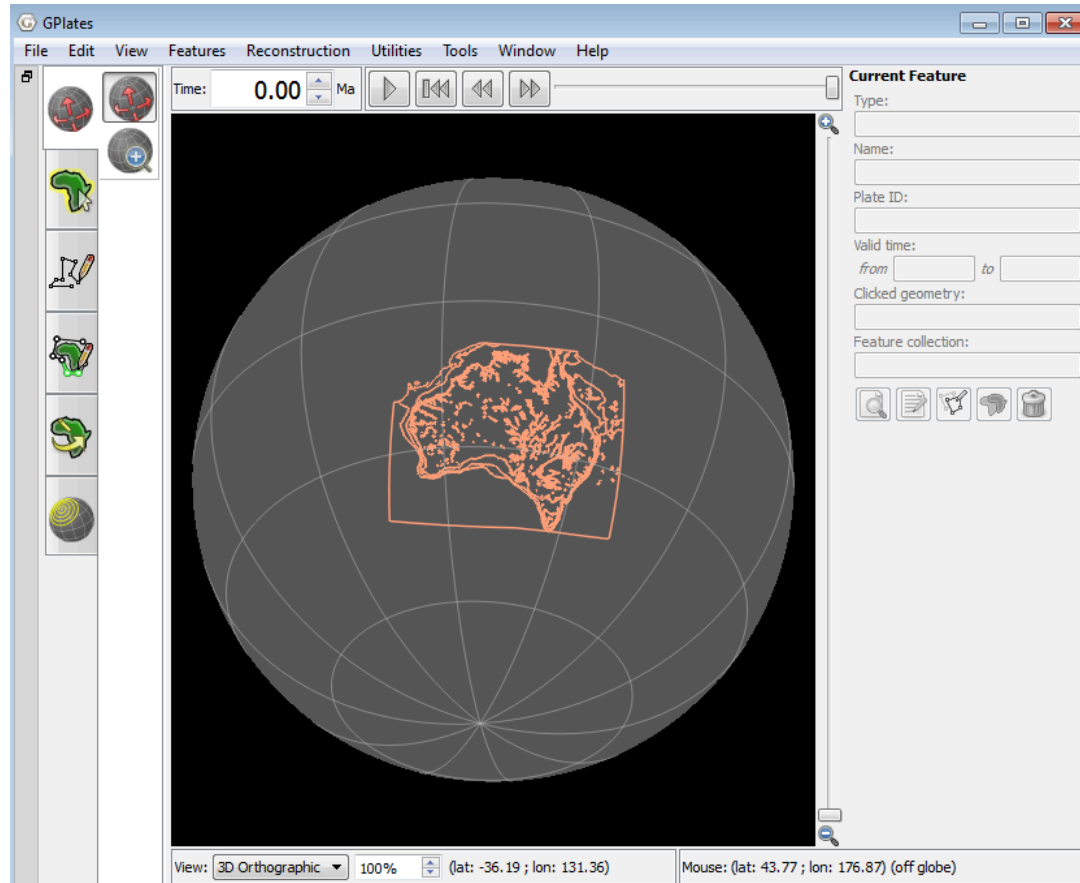



Figure 1: Australian paleogeography shapefile

Exercise 1b: CPT file

This exercise involves using a CPT file to create fill-by-property colouring.

1. Open the Manage Colouring window either by going to “Features → Manage Colouring” or by clicking on the  icon at the top right of the Layers window.
2. Select “ColorByProperty” on the left side of the window, and click “Add...”.

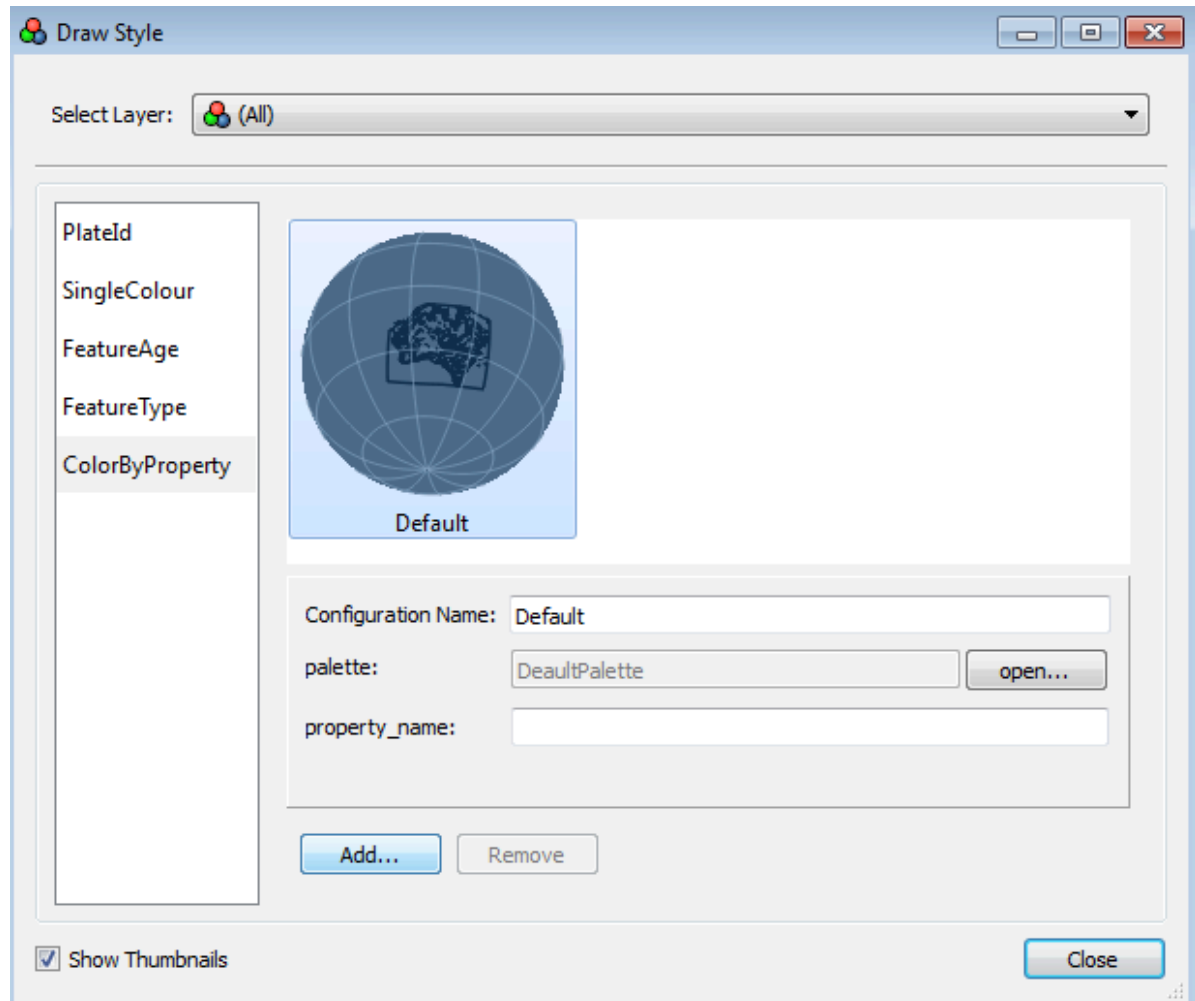


Figure 2: The manage colouring window

3. Next to "Configuration Name:", add an appropriate name (e.g., paleogeography). For "palette:" specify the CPT file. To do this click "open...", navigate to the file (GA_Paleogeography.cpt), and then click "Open". For "property_name:", type in: "gpml:shapefileAttributes:ENVIRONMEN" (without the "T" – shapefile attribute names have a very strict character limit). Then close the window.

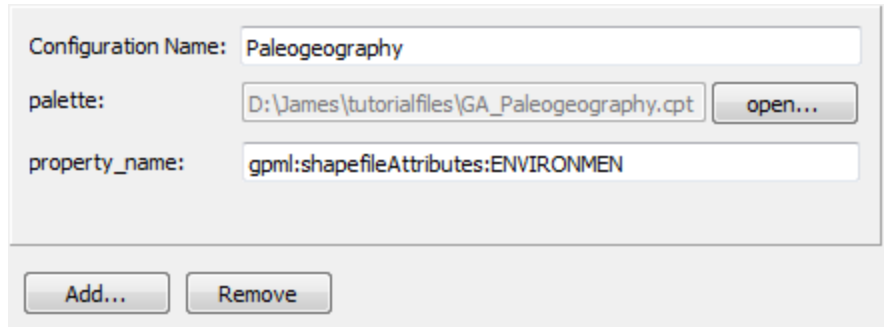


Figure 3: Manage Colouring window – adding CPT

4. The shape file should now be coloured according to property using specified cpt file. To zoom in use the “+” and “-” keys on the keyboard, or scroll the mouse wheel.

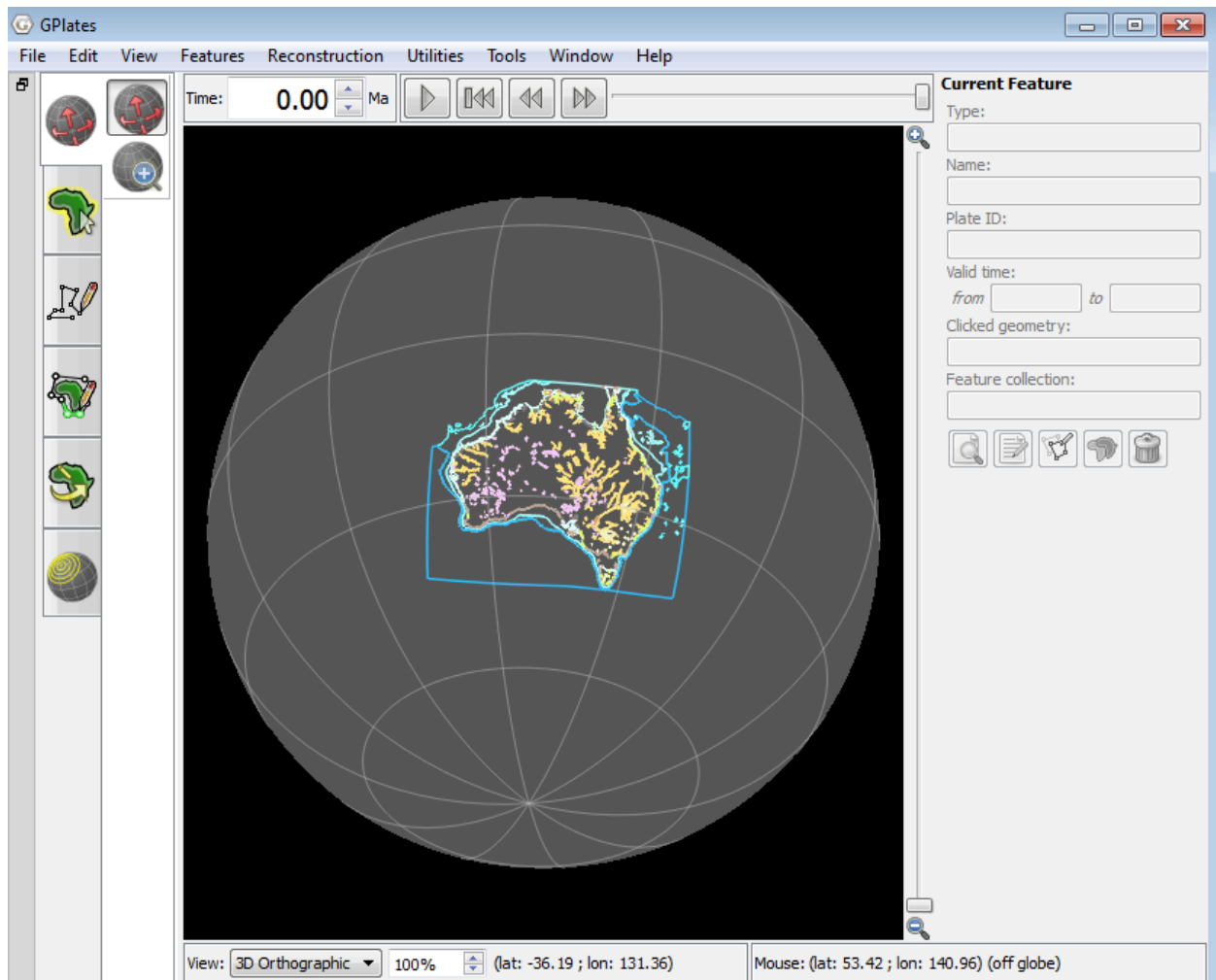


Figure 4: The shapefile coloured using the CPT file.

5. In the Layers window (“Window → Show Layers” or Ctrl/Cmd+L), click on the small arrow to the left of the paleogeographic layer. Under

“Reconstruction Options”, check the box “Fill Polygons”.

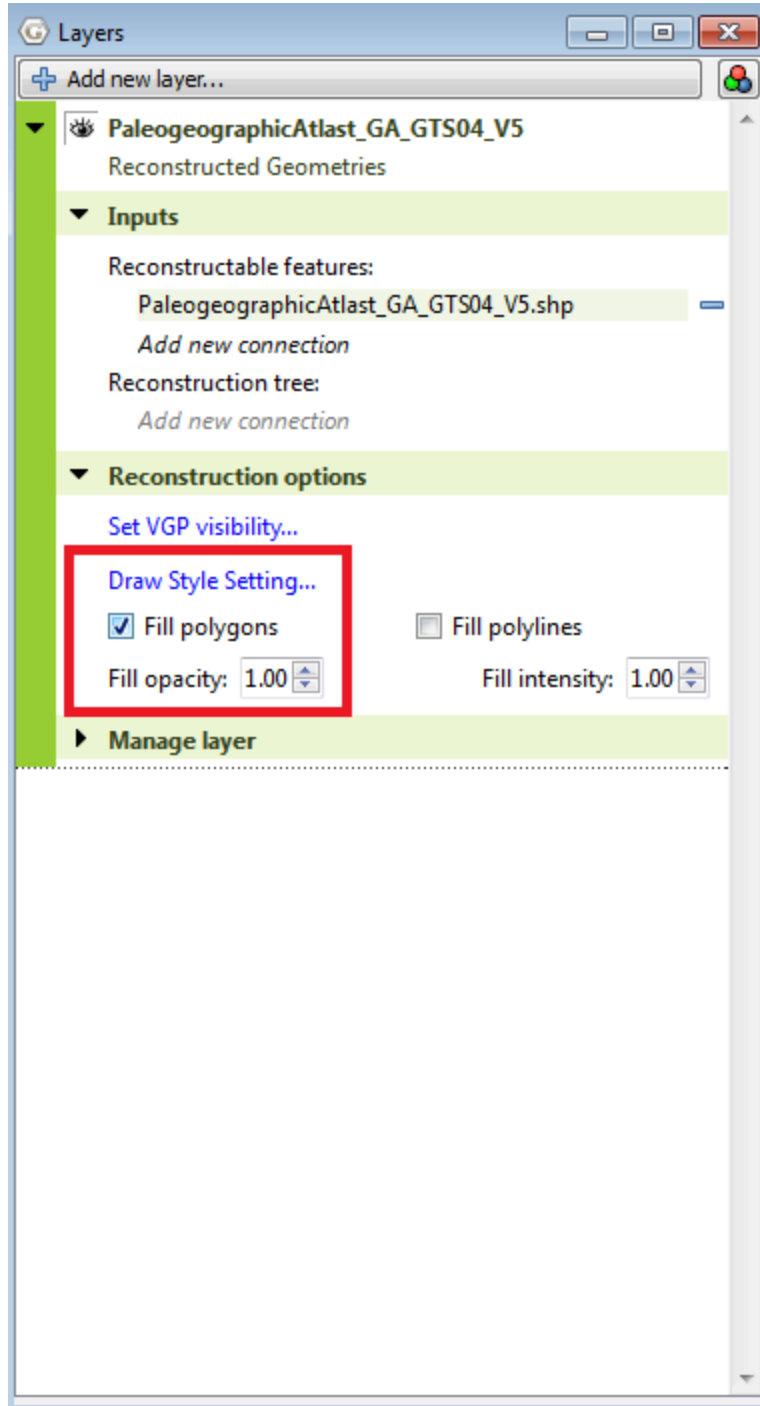


Figure 5: The layers window

Your screen should now appear similar to this (Figure 6):

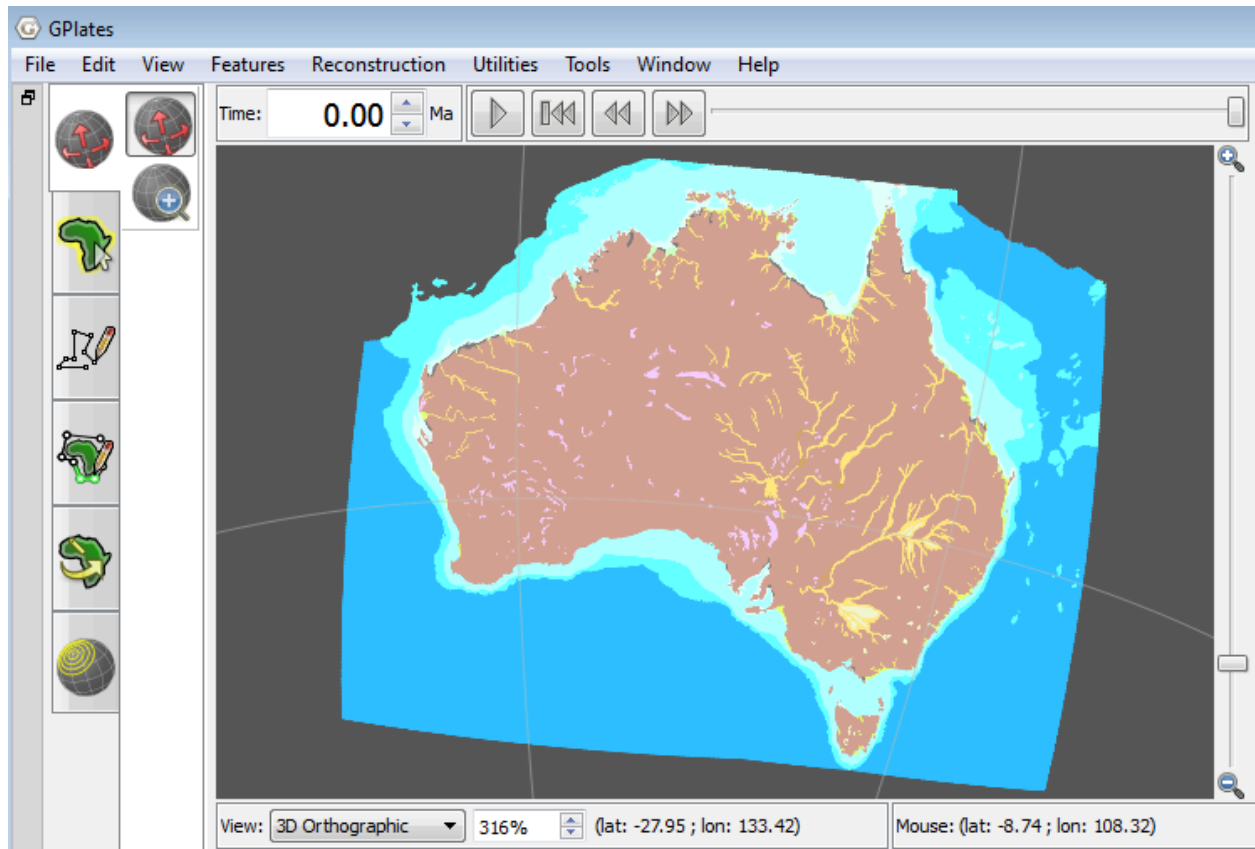


Figure 6: Shapefile with "Fill Polygons" box checked

Exercise 1c: Loading the rotation and paleocoastline file

By loading the rotation file, we can see the paleogeography change over time.

1. Load the rotation file by going to "File → Manage Feature Collections". Navigate to the rotation file and click "Open".
2. Next to "Time:" type in 200 Ma and click the "Play the Animation"



button to see the change over time.

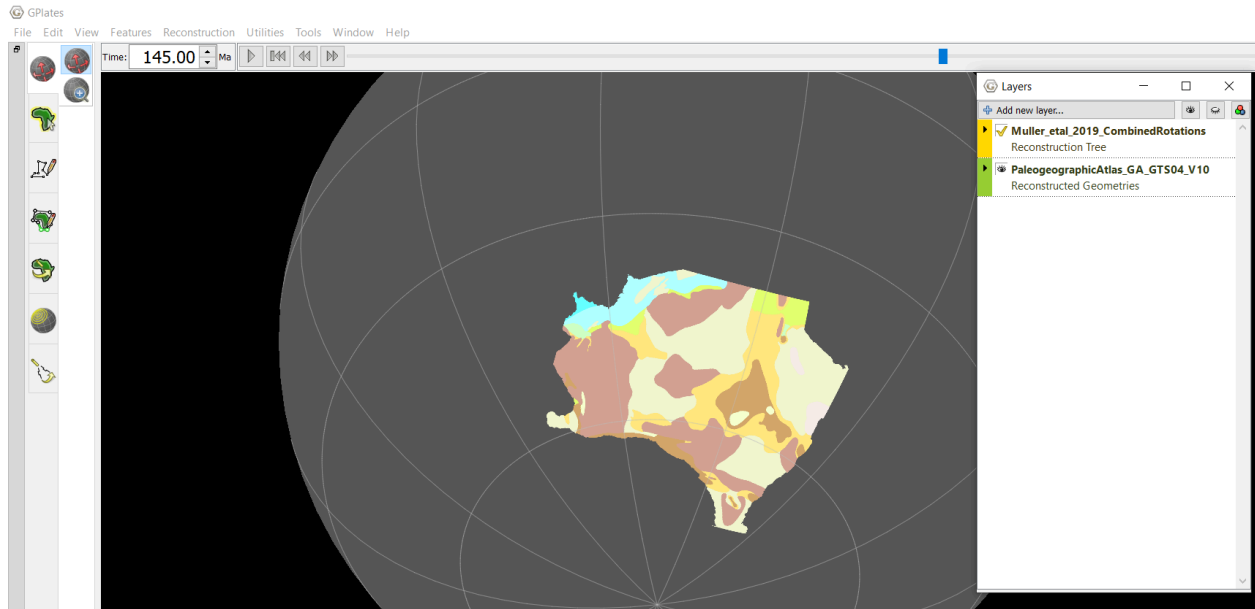


Figure 7: Australian paleogeographic data at 145 Ma.

1. Adding a paleocoastline helps to define the paleogeography. To add the paleocoastline, follow part 1 of this exercise and select the Australian paleocoastline file (Australia_paleogeography.gmpl). The paleocoastline file is a Cretaceous-Cenozoic file, covering 145 Ma to 3 Ma.
2. To change the colour of the coastline, go to "Features → Manage Colouring" (Figure 8). In the top panel select the paleocoastline file we have just loaded and click on "Single Colour" from the options on the left. Select black, and close the window (Figure 9).

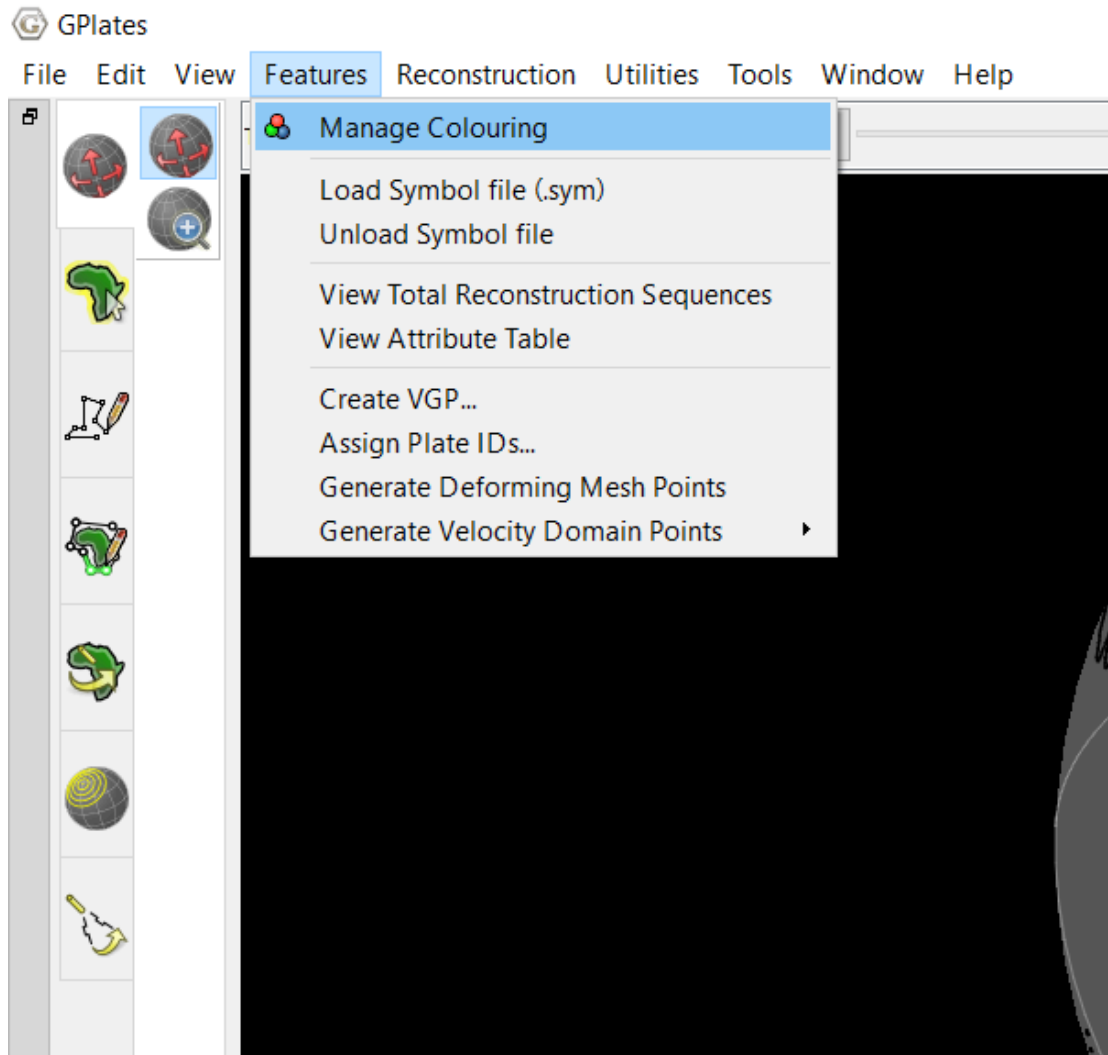



Figure 8. How to change colours.

5. Type in 145 Ma next to "Time:" and replay the animation 

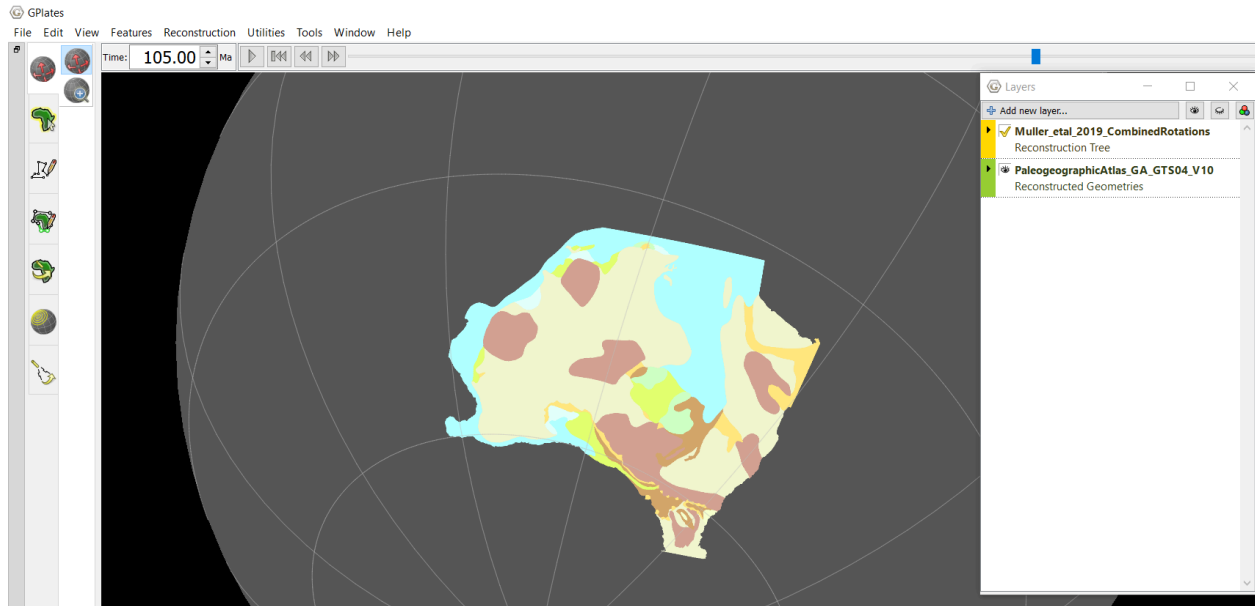


Figure 9: Australian paleogeographic data at 105 Ma with the paleocoastline file loaded.

Exercise 2 – Paleobiology

This exercise will explore fossil data and aims to show how it can be used in helping to determine paleocoastlines.

The exercise introduces the following files:

The 8 paleobiology shapefiles

- 11_100Ma_0Ma_collections_siliciclastic_marine
- 10_200Ma_100Ma_collections_siliciclastic_marine
- 11_100Ma_0Ma_collections_terrestrial
- 10_200Ma_100Ma_collections_terrestrial
- 11_100Ma_0Ma_collections_general
- 16_200Ma_100Ma_collections_general
- 11_100Ma_0Ma_collections_carbonate_marine
- 10_200Ma_100Ma_collections_carbonate_marine

Exercise 2a: Importing the fossil shapefiles

1. Go to “File → Manage Feature Collections → Open File”, and navigate to the paleobiology shapefiles included with this tutorial - select these files and click “Open” (hold down Ctrl/Cmd to select more than one at a time).
2. When you open the shapefiles you will see the window shown in Figure 10 for each file.

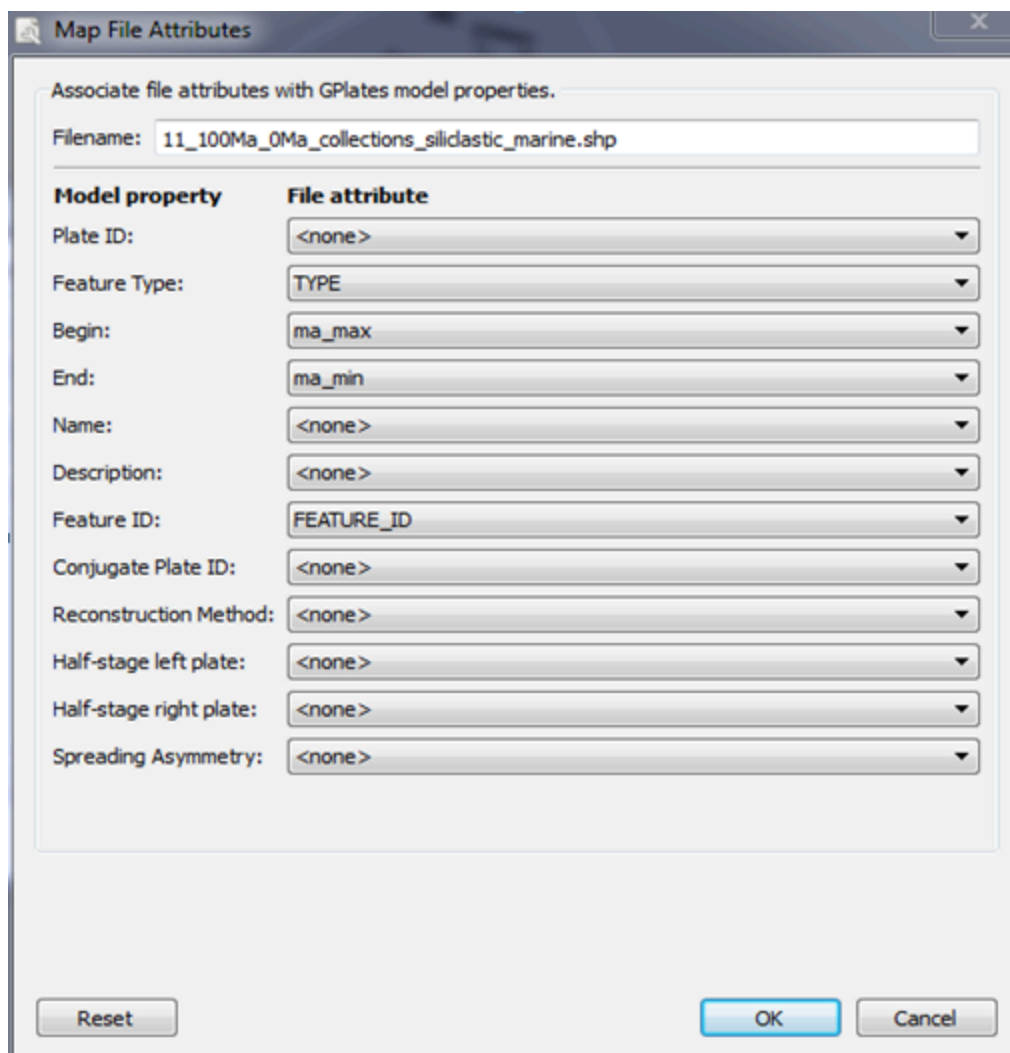


Figure 10: Shapefile attributes window

Two fields in this window need to be changed for each file:

- Begin → ma_max
- End → ma_min

Then press "OK".

3. The fossil data will appear as coloured dots – these are coloured according to plate ID by default. In order to more easily distinguish between the different types of fossil data it is a good idea to give each type a different colour. To do this go to "Features > Manage Colouring", select an individual paleobiology file, click on "SingleColour", and select a colour. There are two files for each (200Ma_100Ma and 100Ma_0Ma) – choose the same colour for the same fossil type (i.e., make both carbonate marine files the same colour etc.).
4. Type in 145 Ma next to "Time:" and play the animation. Pay attention to the paleobiology around the area of the Australian inland sea.
5. When animating forward from 145 Ma we see an increase of fossil data points at 125 Ma, and then a significant increase at 112 Ma (use the double arrows to move back and forth at 1 Ma intervals).

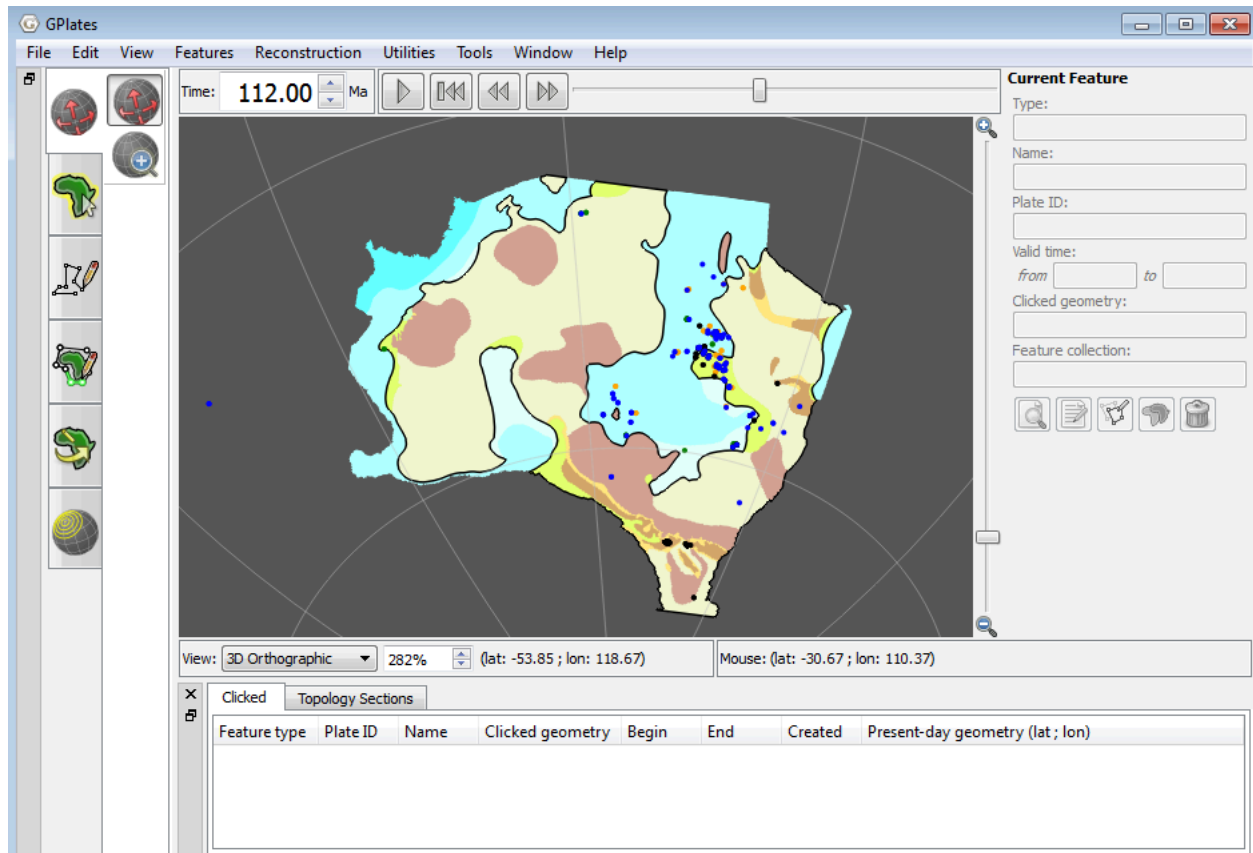


Figure 11: Australian paleogeography and paleobiology at 112 Ma.

Exercise 2b: Editing the paleocoastline

As an exercise, we will now edit the paleocoastline taking into account the paleobiology data.

1. Type in 109 Ma next to "Time:" and press "Return".

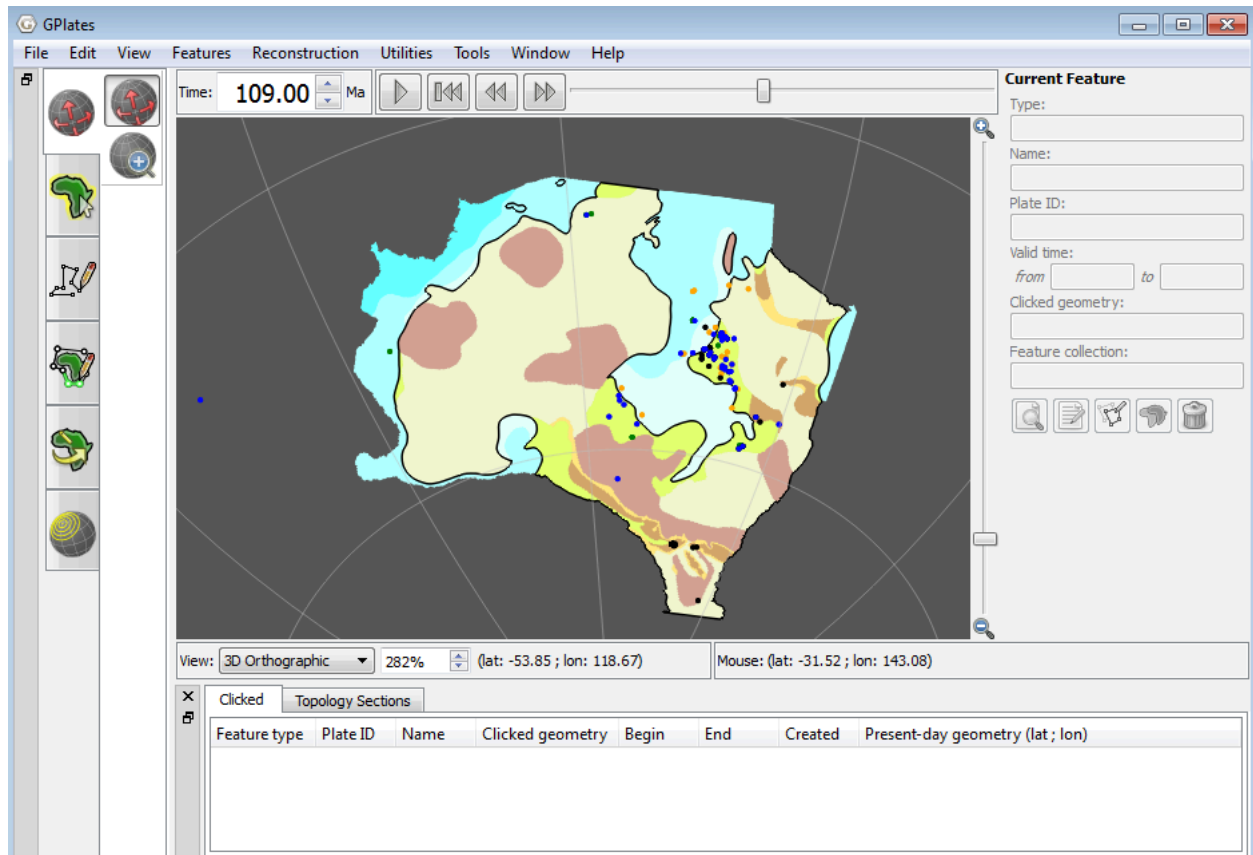


Figure 12: Australian paleogeography and paleobiology data at 109 Ma.

2. The yellow area with the cluster of paleobiology points (to the east of the inland sea) is defined as "Coastal depositional paralic". This definition can be seen by using the "Select Feature" tool, clicking on the yellow polygon and then selecting the "Query Feature" tool 1. (to the right of the screen). This definition of the region fits, with the large number of both marine and terrestrial fossil points in the area.
3. As an exercise, we will edit the paleocoastline by redefining this section to be part of the inland sea. This coastline change is consistent with both [Golonka et al. \(2006\)](#) and [Smith et al. \(1994\)](#). For interest, both of these paleocoastline files (both global datasets) are included in the tutorial data bundle. These both define a larger epicontinental sea at this time than we have here.
4. Choose the "Select Feature" tool from the left hand side, and select

the paleocoastline. Once selected it should appear white. If it is hard to select, try switching off the paleogeography layer by clicking on the eye in the Layers window next to "PaleogeographicAtlas_GA_GTS04_V10". Once you have selected the coastline, switch this layer back on. To the right of the screen you can see that this coastline is valid from 110 Ma to 106 Ma. Any edits we make will be in place for this time.

5. Click on the 'Move Vertex' tool. With this tool selected you will see the individual vertices of the paleocoastline. Click and drag the individual vertices to reposition them. For this exercise, we will redefine the paleocoastline to be on the other side of the yellow region, creating a larger inland sea

The 'Delete Vertex Tool' can be used to remove any points, and the 'Insert Vertex' tool can add any additional vertices. To make it easier to see, zoom in on the region, using the '+' and '-' keys or the mouse scroll wheel.

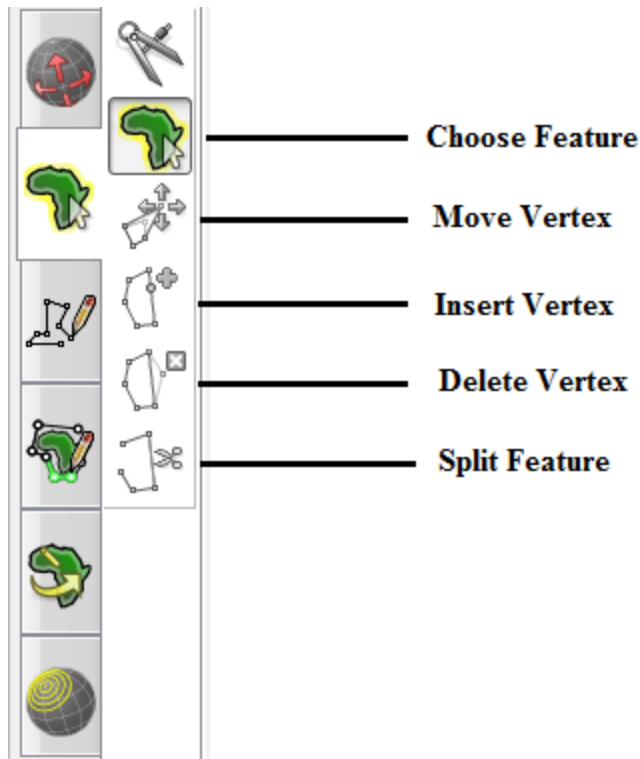


Figure 13: The GPlates toolbar

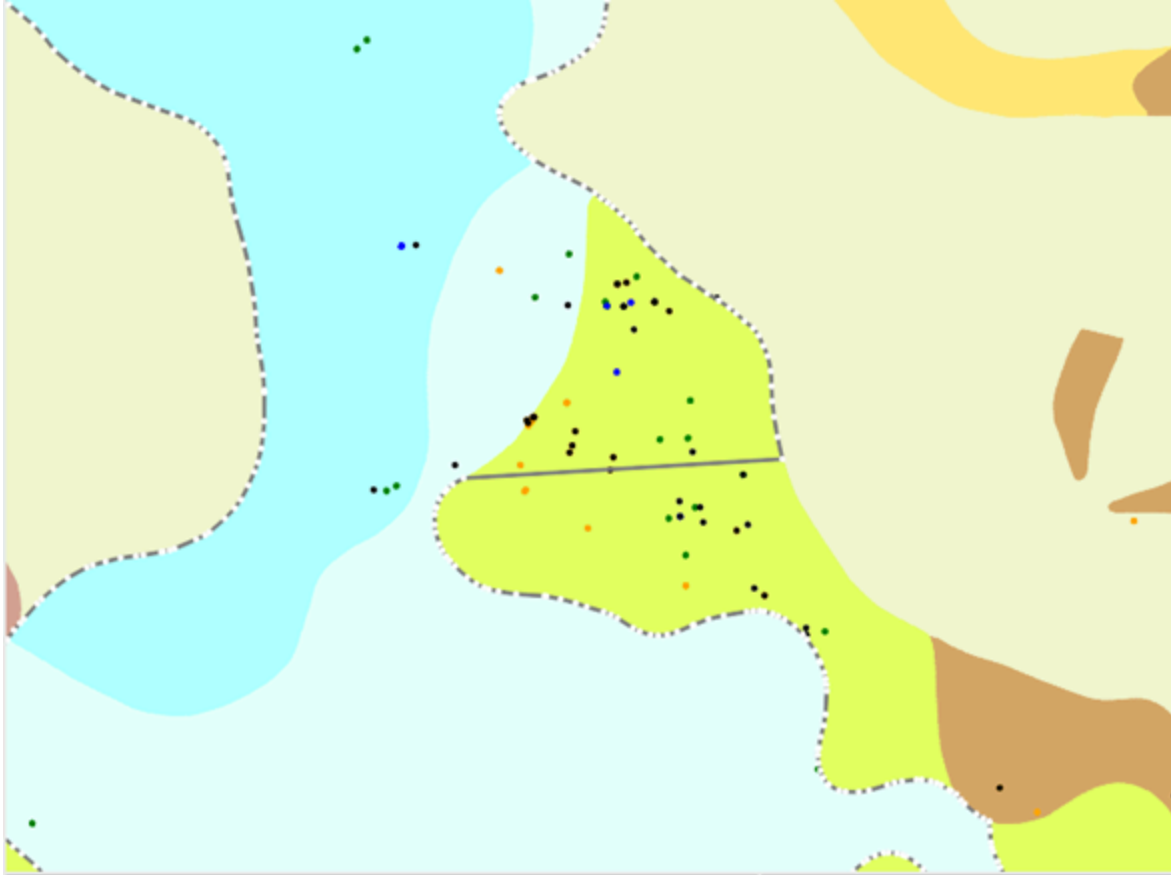


Figure 14: Zoomed in image - editing the paleocoastline of the Australian inland sea.

When you are happy with the new paleocoastline, click the "Select Feature" tool again.

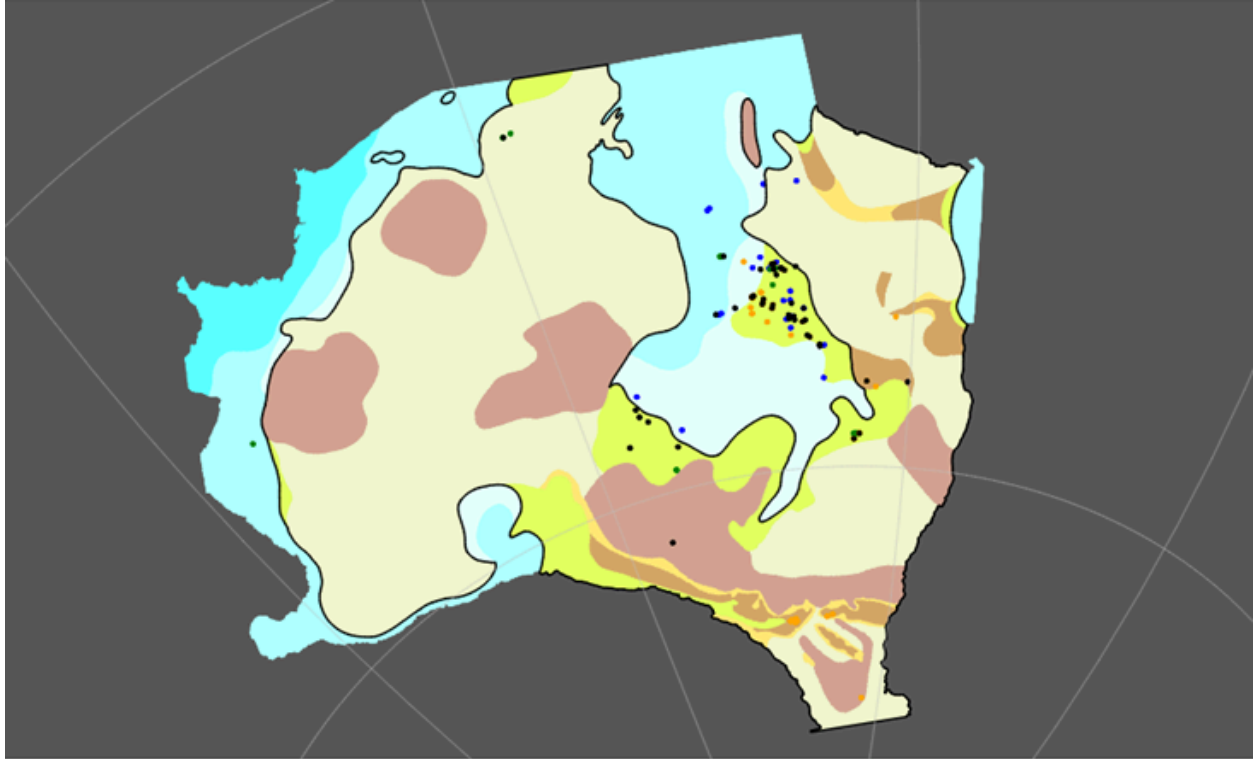


Figure 15: New paleocoastline, 109 Ma

6. Type in 145 again into "Time:", and "Play Animation" with the new paleocoastline.

Exercise 3 – Loading and preparing raw fossil data for reconstruction

1. If you are coming from Exercise 2, click File → Clear Session.
2. In GPlates, click File → Open Feature Collection... → Navigate to the tutorial data and select the marine carbonates shapefile 11_100Ma_0Ma_collections_carbonate_marine.shp (Figure 16)

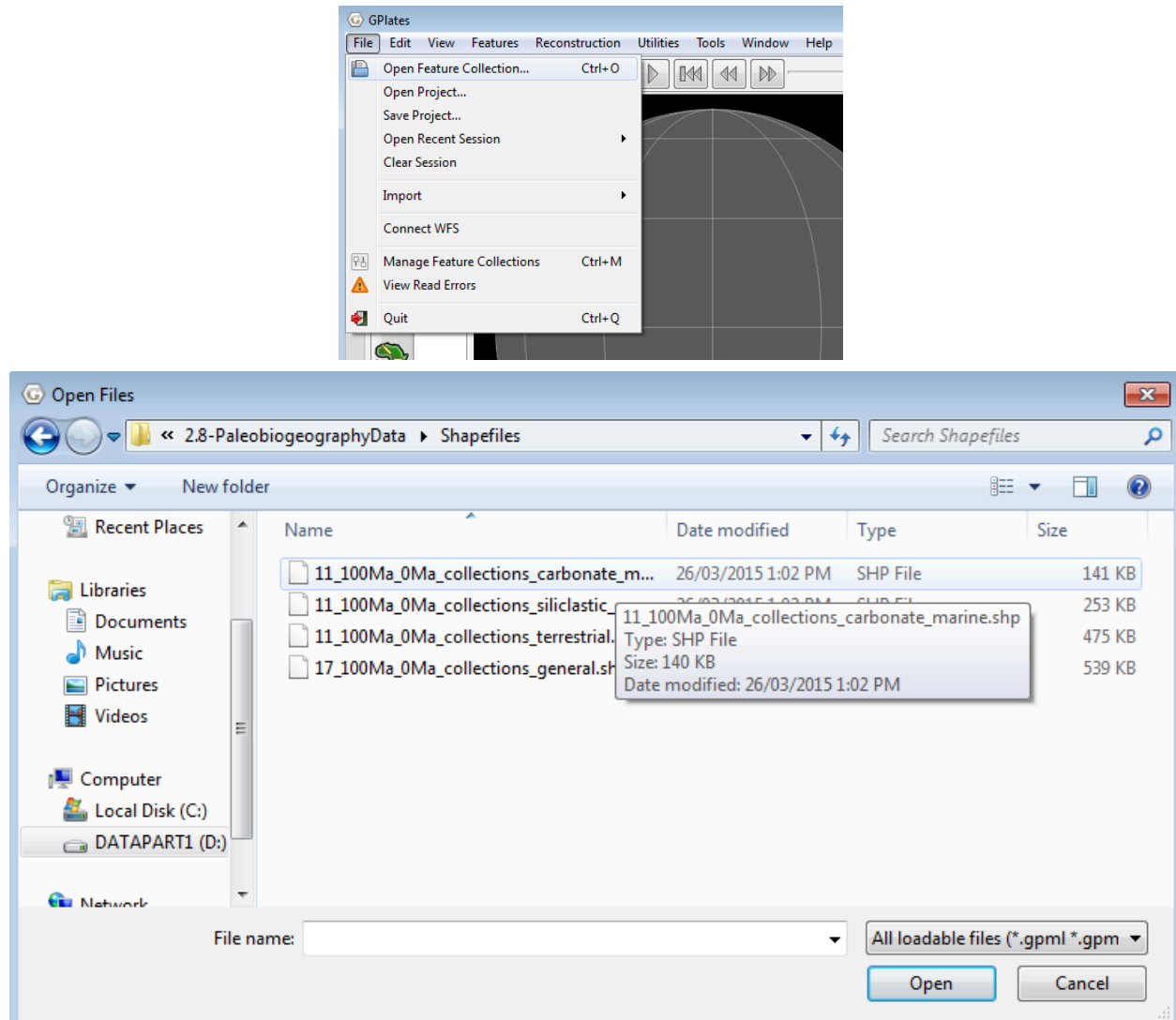


Figure 16. Open files in GPlates

3. The first time the shapefile is loaded, GPlates will ask you what properties it should associate with the different shapefile attributes (Figure 17a). If you have completed Exercise 2, you will have already loaded this shapefile into GPlates and can skip this step. Otherwise, make sure you assign **Begin: ma_max** and **End: ma_min**, otherwise your fossil data will exist at all times. You can also attach fields that represent 'Name' and 'Description' of each datapoint, if so desired (Figure 17b). Click OK (this may sometimes take a few seconds, do not quit!).

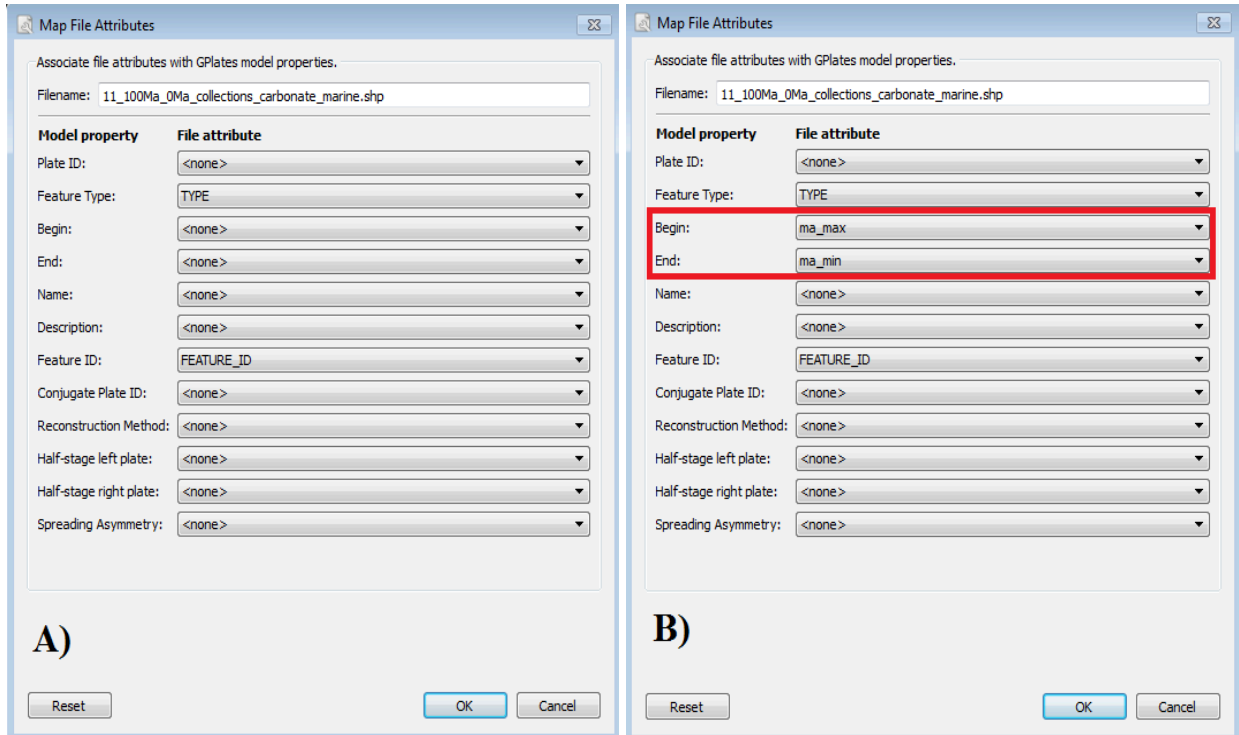


Figure 17. Assigning shapefile attributes in GPlates. (a) The 'Associate shapefile attributes with GPlates model properties' window with default settings and (b) with Begin and End attributes defined as ma_max and ma_min respectively

Note: If an attribute is assigned incorrectly we can change the associated properties by File > Manage Feature Collections > 'Configure' (the first option next to the shapefile in question).

4. The fossils will appear as yellow dots on the globe. You may like to add the coastlines file so we can see the fossil locations with more context. If we slide the time slider back to 100 Ma, we will see these fossil points appear and disappear, indicating that we've assigned their ages correctly. However, they do not yet move because they need to be linked to the plate motions.
5. Select any fossil point to see how no Plate ID has been assigned yet. We will need to cookie-cut (i.e., Assign Plate IDs) to the fossil data, in order to get them to reconstruct according to our rotation file. Here we will use the polygons provided in the tutorial data bundle; alternatively, your own polygons with associated Plate IDs could be used.

Load the static polygons by clicking on File → Open Feature Collection → Navigate to the tutorial data bundle directory and load the static polygons file (Muller_etal_2019_Global_StaticPlatePolygons.gpmlz).

You will now also see some coloured polygons in the GPlates main window. (Figure 18).

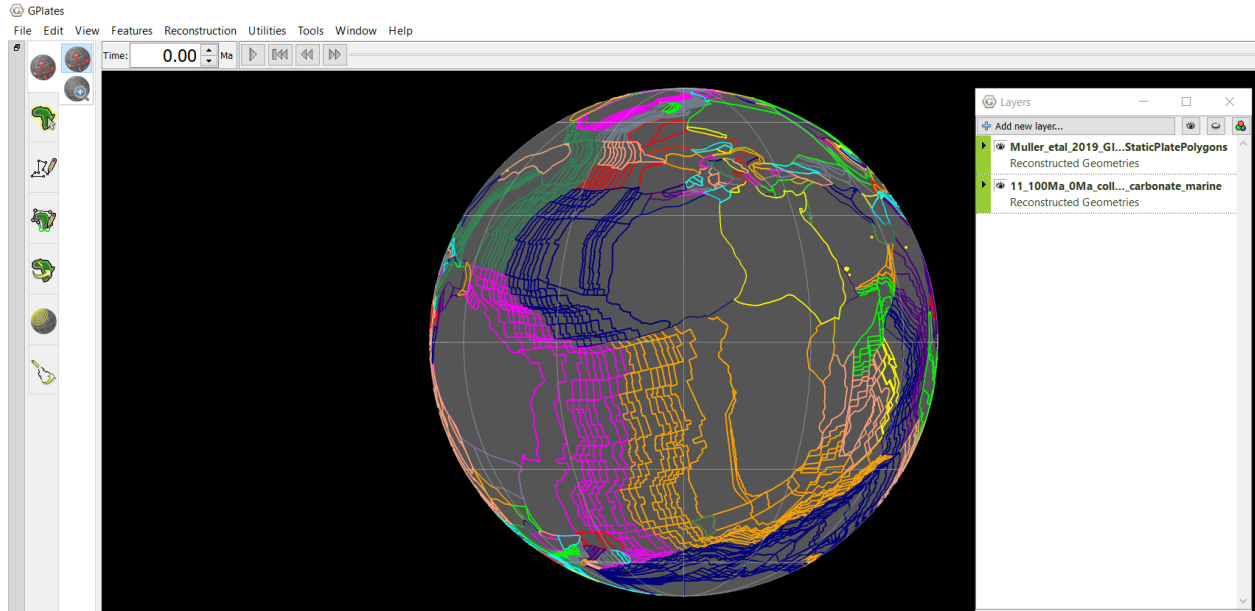


Figure 18. Static polygons in GPlates (coloured by Plate ID) and fossil data points with no Plate IDs assigned.

6. To assign Plate IDs, go to Features → Assign Plate IDs... (Figure 19)

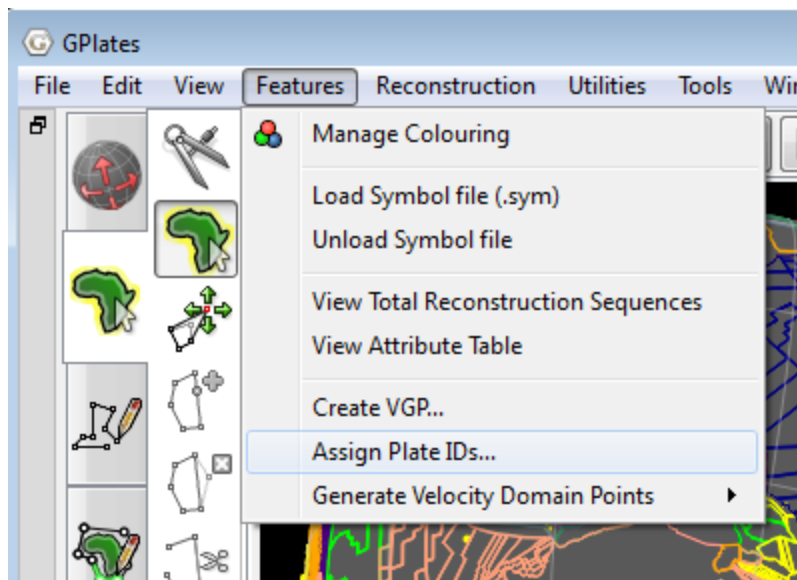


Figure 19. Features menu

7. Specify the partitioning layer: this is generally a file containing static polygons, in this case the

Muller_etal_2019_Global_StaticPlatePolygons.gpmIz file. Click Next.

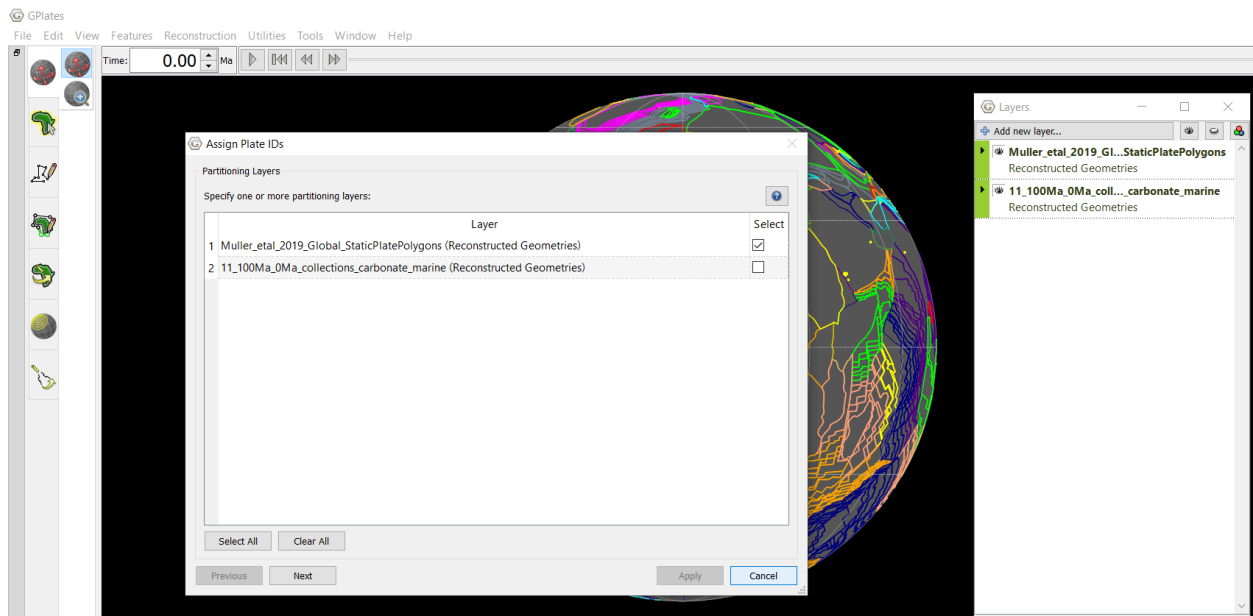


Figure 20. Select partitioning layers in the Assign Plate IDs process

8. Specify the layer layers to be partitioned. In the example, it is the carbonate marine data from 100 Ma to 0 Ma. Click Next.

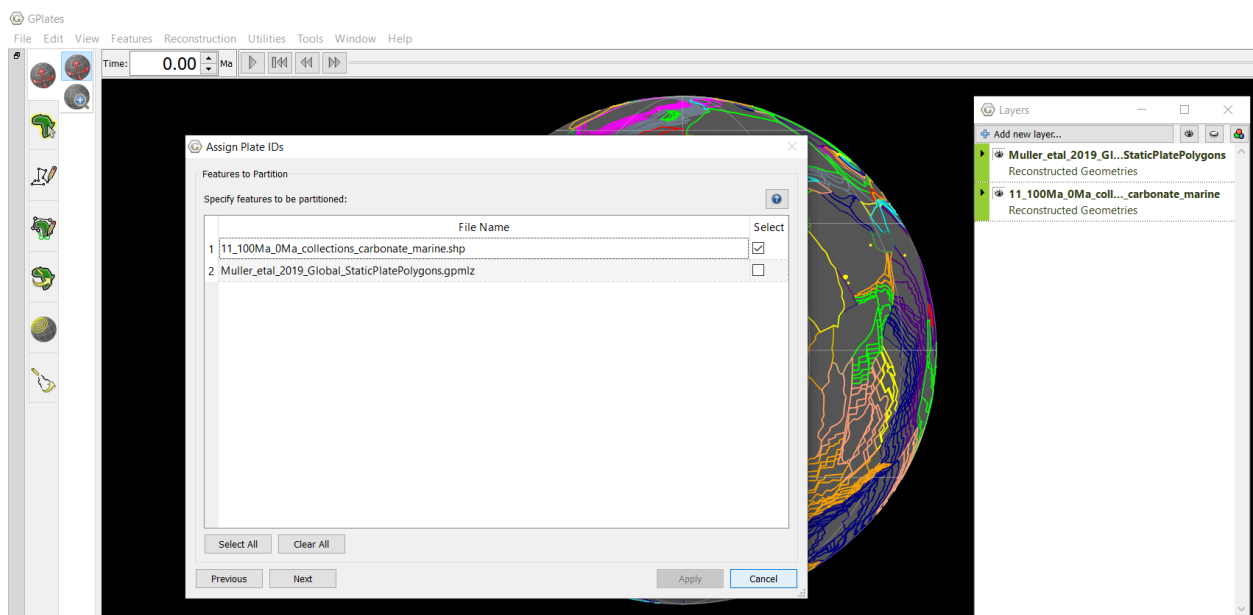


Figure 21. Assign the feature to be partitioned in the Assign plate ID process

9. The next screen allows you to decide whether you want to cookie-cut

your data at present-day or some other reconstruction time. For the purposes of reconstructing fossils and other similar data, where you have the locations of the data points at the present day, you would normally choose 'Present Day'.

Leave other options as their defaults (Figure 22) and click Apply.

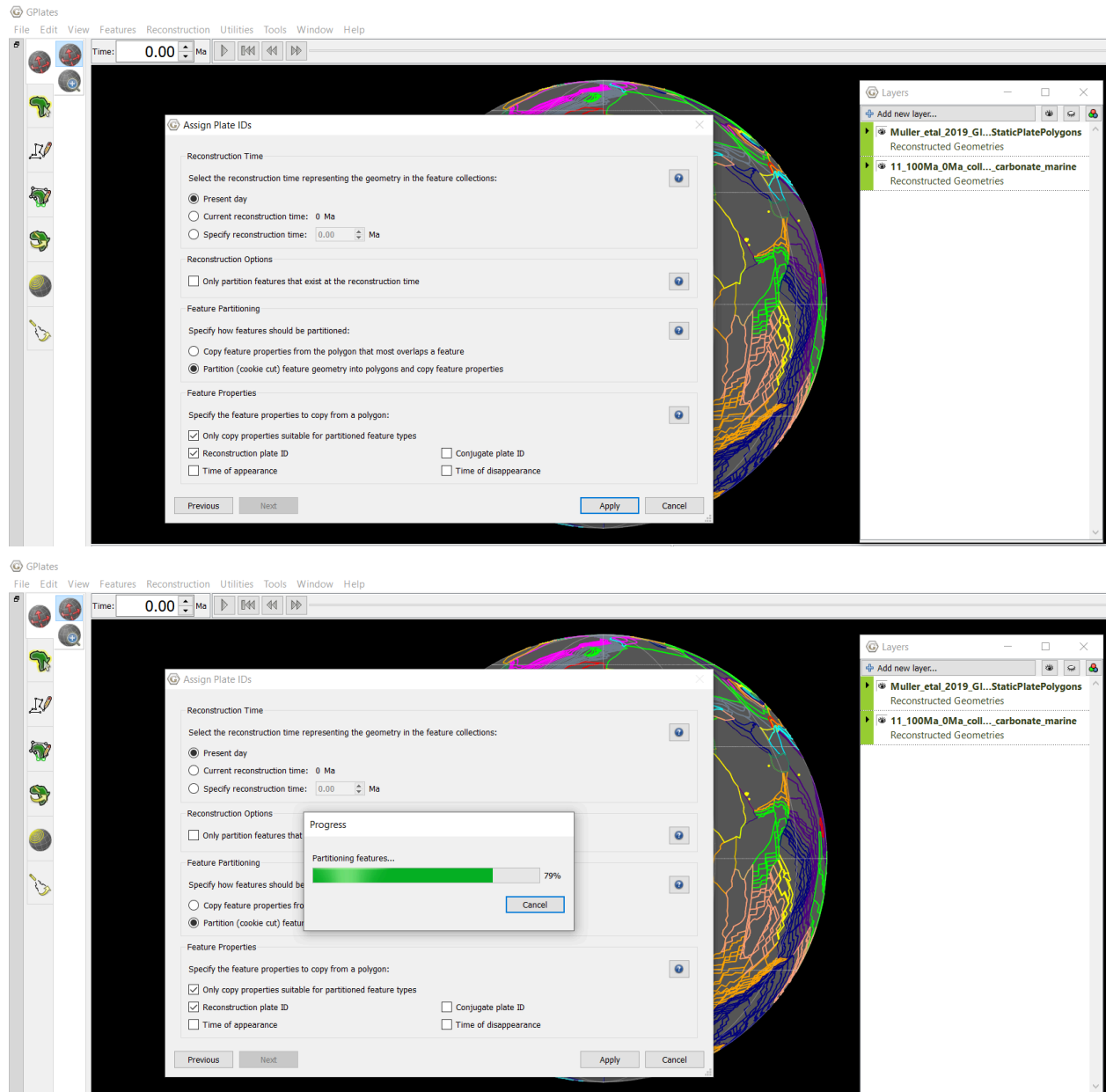


Figure 22. Options required for Assigning Plate IDs for fossil data

10. Your data is now ready to reconstruct. If you deselect the Static Polygons in the Layers window, you will see the data points will now

have a range of colours, assigned by Plate ID (Figure 23).

11. Save the changes to your shapefile, or save out to a new shapefile or other format in File → Manage Feature Collections → “Save As” or “Save A Copy”

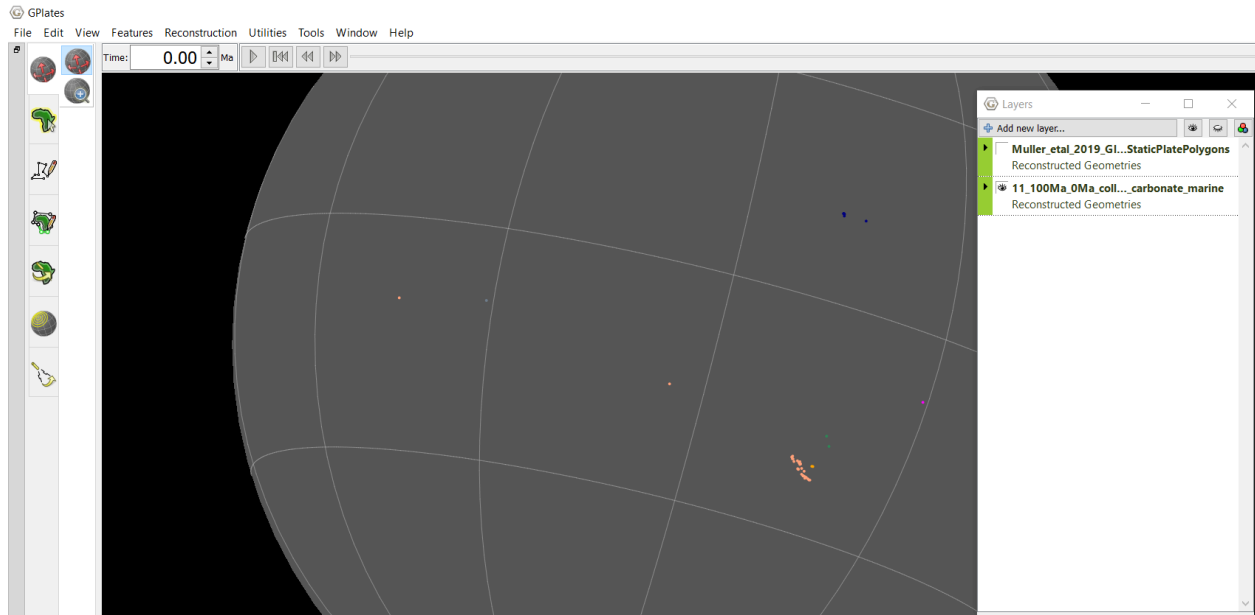


Figure 23. Fossil Data assigned by Plate ID

Exercise 4 – Reconstructing the fossil data

1. Continuing from Exercise 3, load the plate motion model included in the tutorial data bundle by clicking on File → Open Feature Collection... and selecting the following files (Figure 24):
 - Muller_etal_2019_CombinedRotations.rot
 - Muller_etal_2019_Global_Coastlines.gpmlz

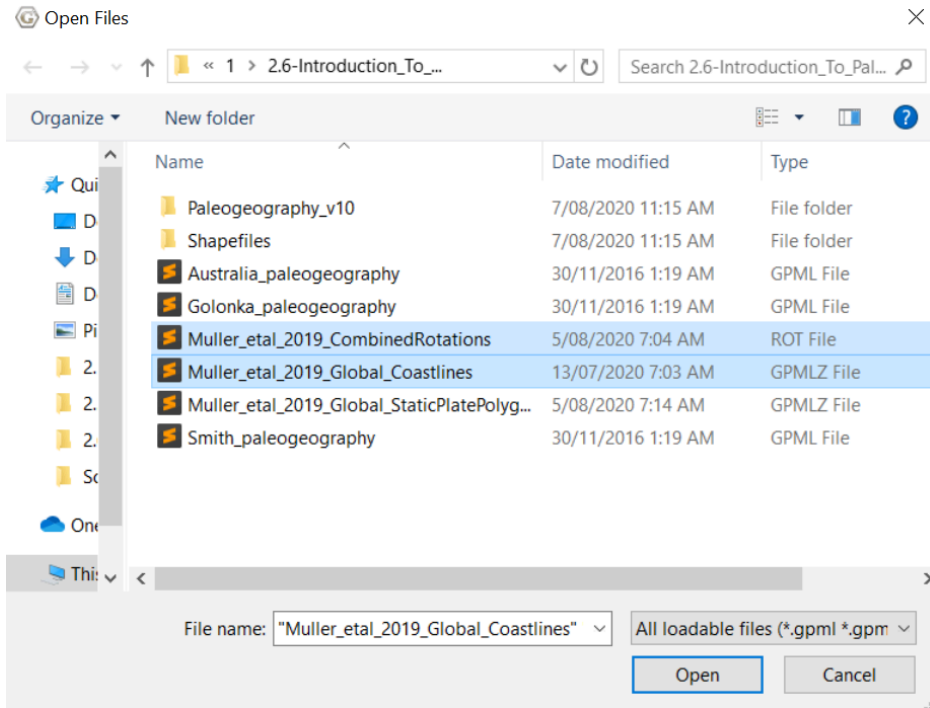


Figure 24. Open plate motion model files in GPlates

2. We can repeat steps 1-8 for the remaining fossil shapefiles (siliciclastic, terrestrial, and general). We can cookie cut multiple shapefiles at once by ticking multiple features (this is one of the most useful and efficient features on GPlates).

Once we have a full range of environments uploaded, it is more useful to colour the fossil environment groups based on a single colour, rather than Plate ID: Go to Feature → Manage Colouring → select layer (i.e., a single shapefile layer) and 'Single Colour'. Choose the colour of your choice.

We should also colour the coastline a single colour (e.g., grey).

3. You can now reconstruct to any desired time, and choose to export the results as images (e.g., *.jpg files) or many other file types (e.g. GMT .xy files).

Go to Reconstruction → Export → Select your time range (100 Ma – 0 Ma) → Click "Add Export Type" and choose Colour Raster → (*.jpg) or any other image type. Configure your image resolution if desired. Click OK, and then click "Begin Export". GPlates will output your data into your specified directory.

Note: It is common to export Reconstructed Geometries as GMT XY or ESRI

Shapefiles to create detailed maps.

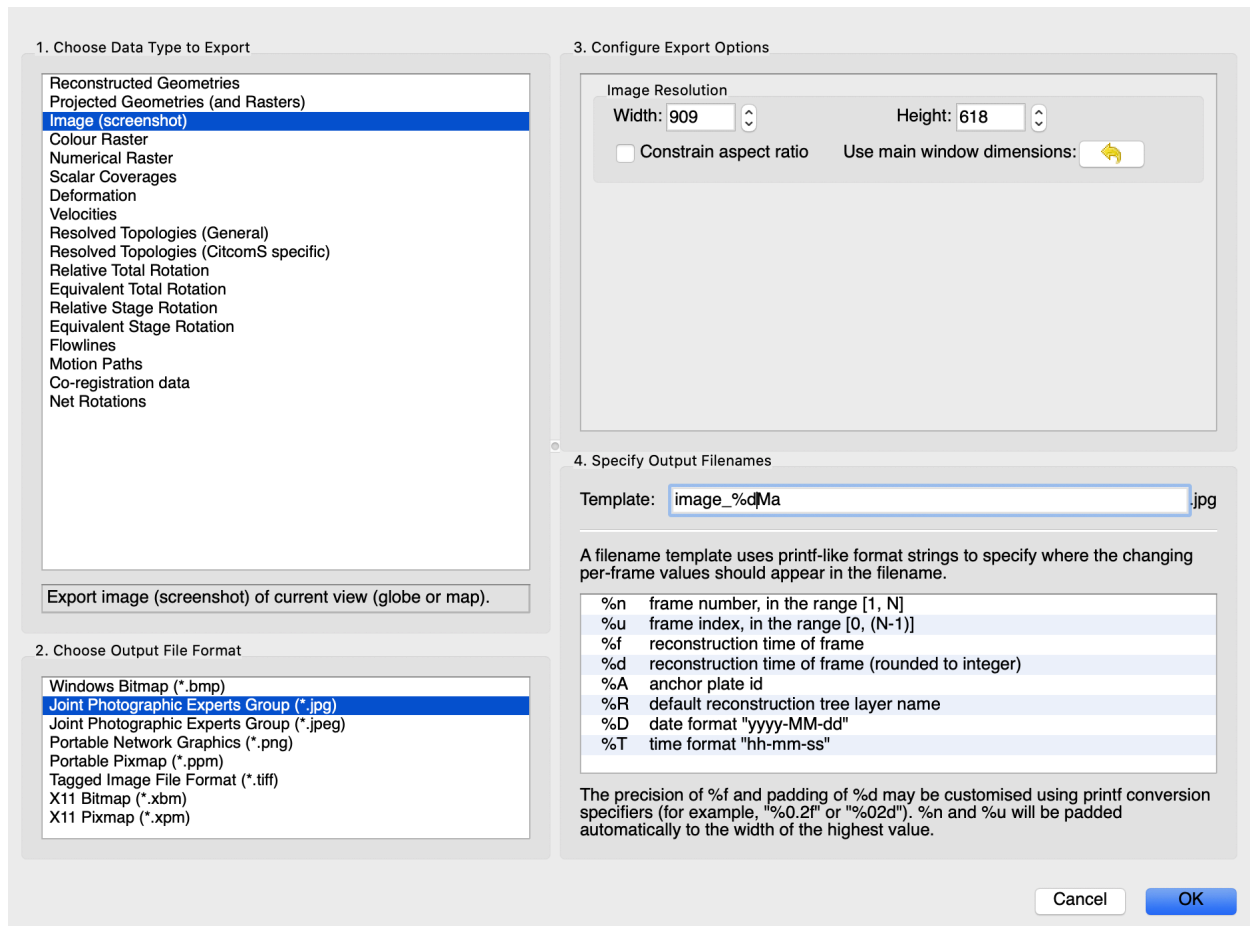
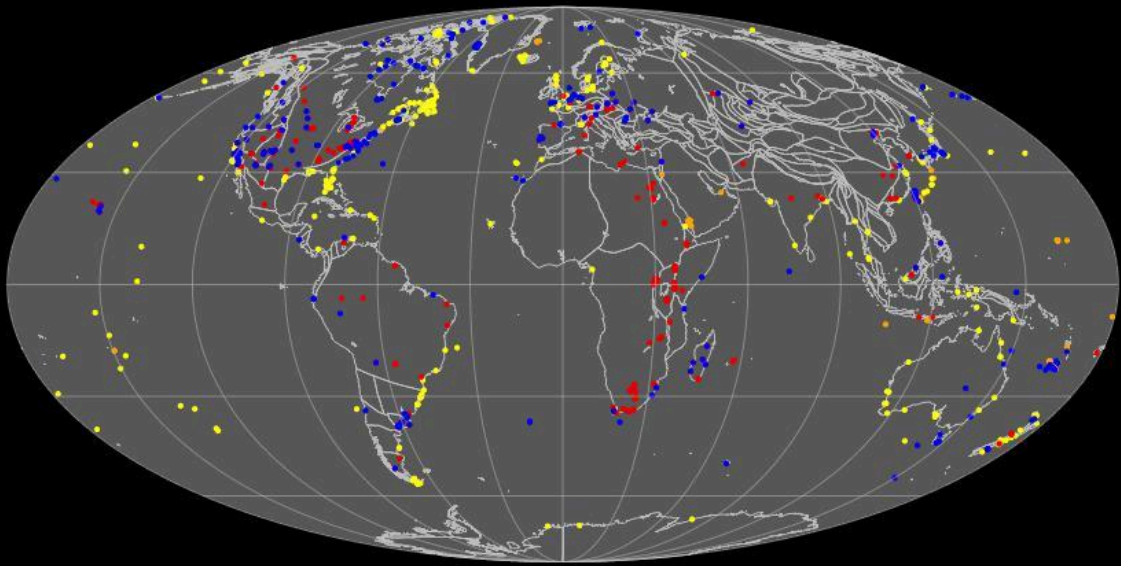


Figure 25. Export animations as image files such as JPGs

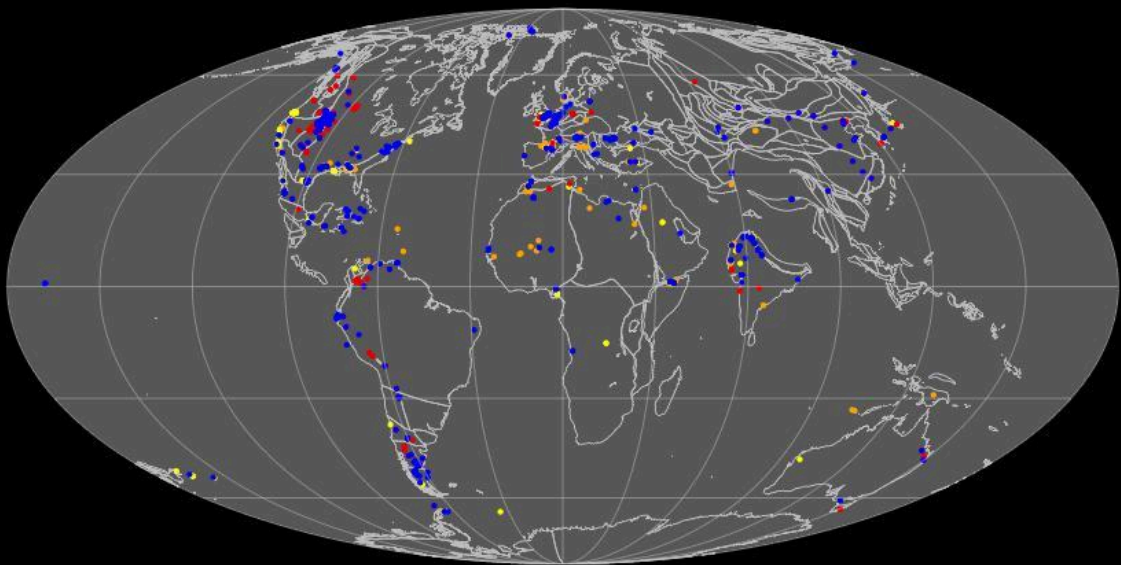
4. Now that we can have reconstructed fossil data, we can see how the fossil environment (i.e. paleogeography) relates to our reconstructions.

- Terrestrial (Red) – General (Blue) – Siliciclastic (yellow) – Carbonates (Orange)

0 Ma



50 Ma



100 Ma

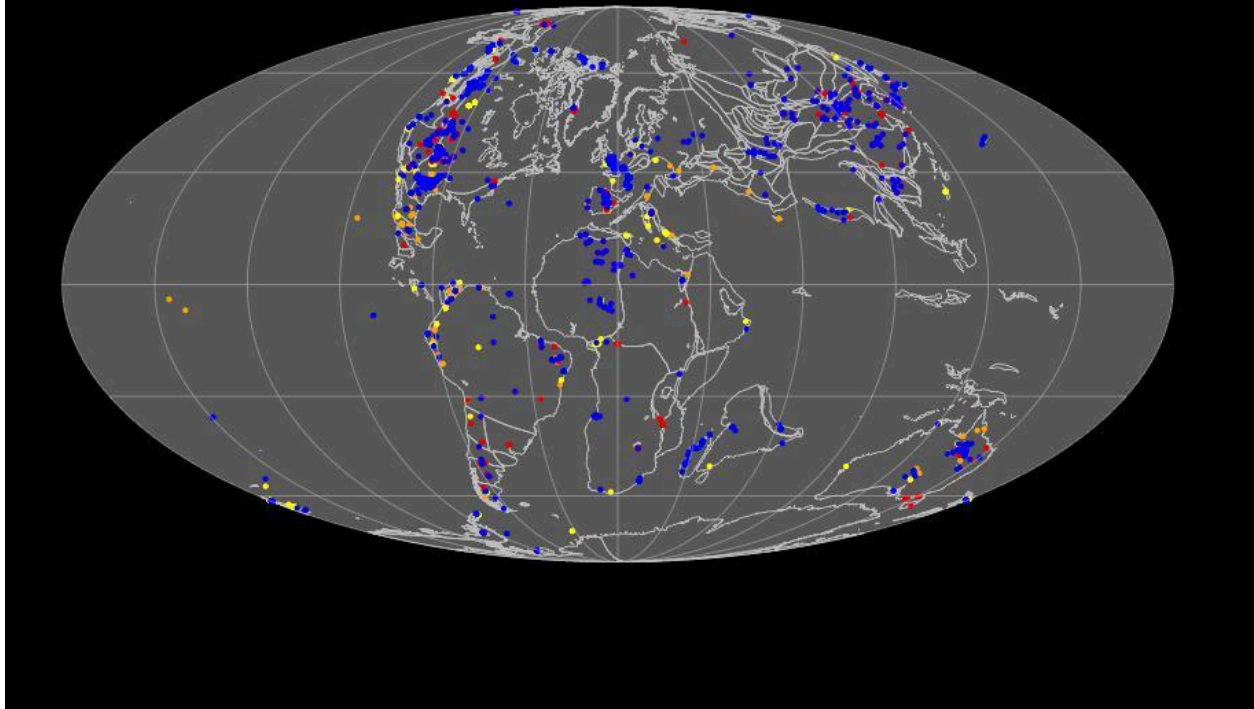


Figure 26. Reconstructed fossil data at 0 Ma, 50 Ma and 100 Ma. The terrestrial fossils are coloured red, general fossils blue, siliciclastic fossils yellow and carbonate fossils orange.

References

Golonka, J., Krobicki, M., Pajak, J., Giang, N.V., and Zuchiewicz, W., 2006, Global Plate Tectonics and Paleogeography of Southeast Asia. Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Arkadia, Krakow, Poland.

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](https://doi.org/10.1029/2018tc005462).

Smith, A.G., Smith, D.G., and Funnell, B.M., 1994, Atlas of Mesozoic and Cenozoic coastlines, Cambridge University Press, 99 pp.