

Flowlines and Motion Paths

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Aim

This tutorial is designed to teach the user how and when to use the flowline and motion path features in GPlates.

Included Files

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

The tutorial dataset (2.3-Flowlines_and_Motion_paths.zip) includes the

following files:

Rotation model file: Muller_etal_2019_CombinedRotations.rot

Coastline file: Muller_etal_2019_Global_Coastlines.gpmlz

Continent-Ocean Boundary (COB) file:
Muller_etal_2019_Global_COBLineSegments.gpmlz

Spreading ridge file: Muller_etal_2019_Ridges.gpmlz

Global gravity anomaly raster: Gravity_World.jpg

Hotspot file: HS_triangles.dat

Hawaiian-Emperor Seamount Chain file: HawaiianEmperorChain.gpml

Fracture zone file: Fracture_Zones_SEPacific.gpml

This tutorial dataset is compatible with GPlates 2.2.

Background

Flowlines

Flowlines are half stage rotations that are calculated by GPlates based on the rotation file you are using. They are used to track plate motion away from spreading ridges. Features like fracture zones are real-world examples of flowlines.

Motion Paths

Motion paths show the absolute motion of a feature in GPlates based on the rotation file you are using. They can be used to track the absolute motion of any feature, but are particularly useful for features like hotspots, as you can compare the motion path produced by your rotation file to the actual hotspot track.

Exercise 1A - Creating and Using Flowlines

1. Open GPlates

2. File > Open Feature Collection...(Figure 1) > select the Rotation Model File, the Coastline File, the COB File, and the Spreading Ridge File from the data bundle for this tutorial:

- Muller_etal_2019_CombinedRotations.rot
- Muller_etal_2019_Global_Coastlines.gpmlz
- Muller_etal_2019_Global_COBLineSegments.gpmlz
- Muller_etal_2019_Ridges.gpmlz

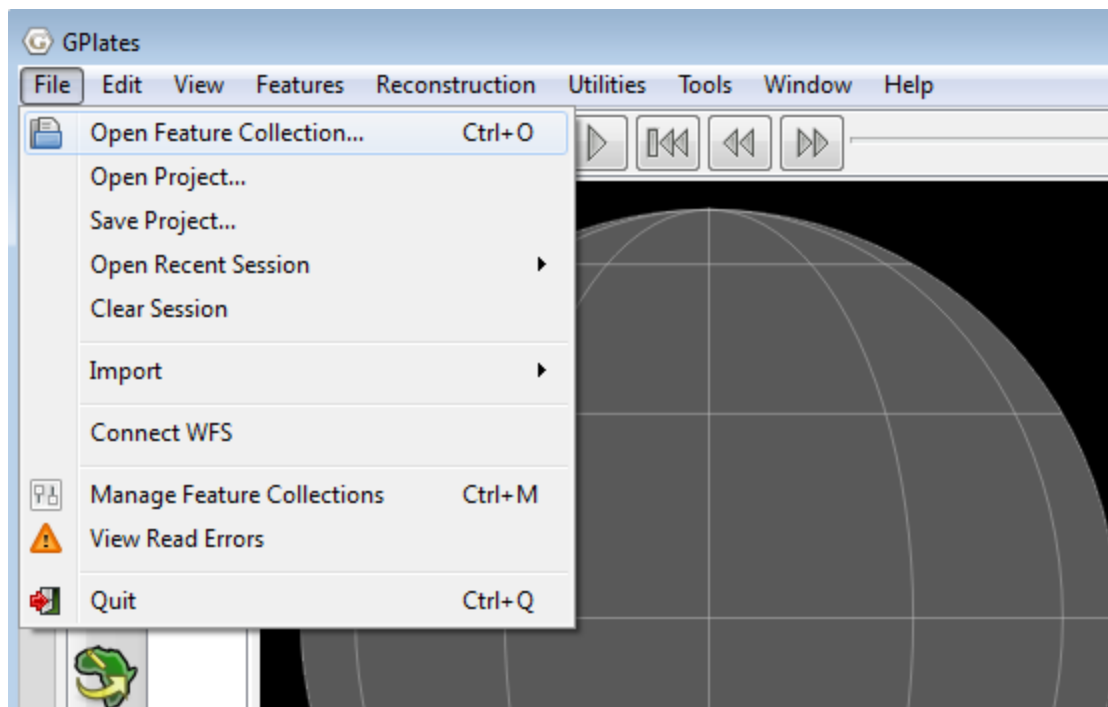


Figure 1: Step 2 - How to open a feature collection from the menu bar.

3. Rotate the globe so that the spreading ridge between South America and Africa is centered on your screen (Figure 2).

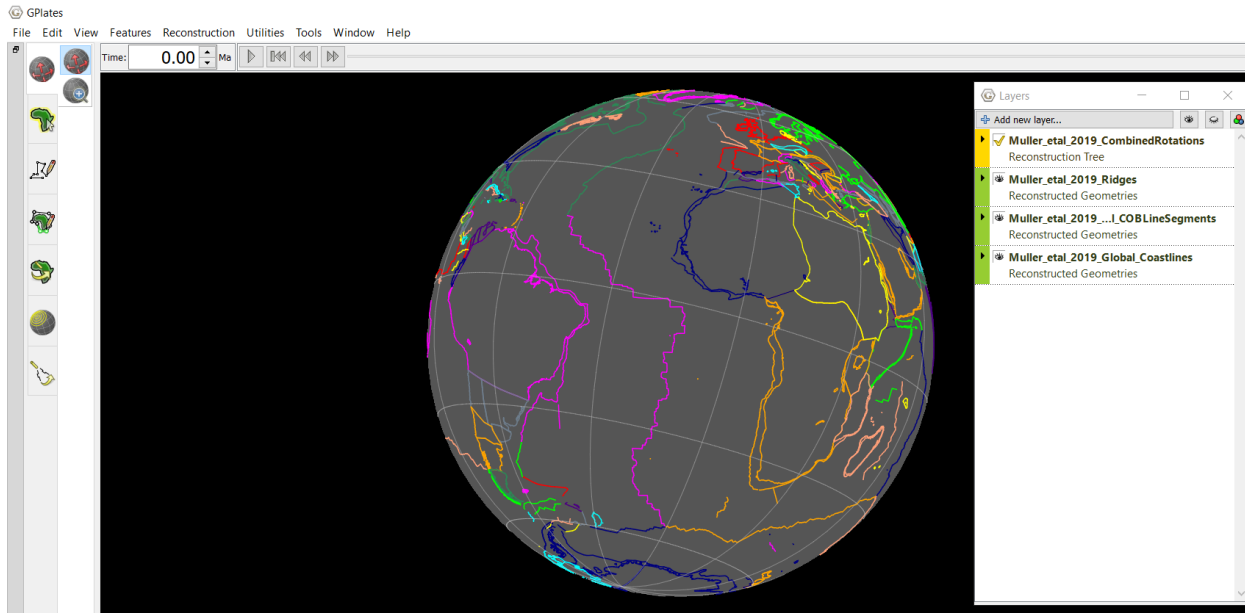


Figure 2: View of spreading ridge between South America and Africa

4. Select the *Digitisation* workflow tab and the *Digitise New Multi-point*

Geometry tool  from its submenu. Use this to create a point located on the spreading ridge. Then click on the Create Feature button on the right side of the globe (Figure 3).

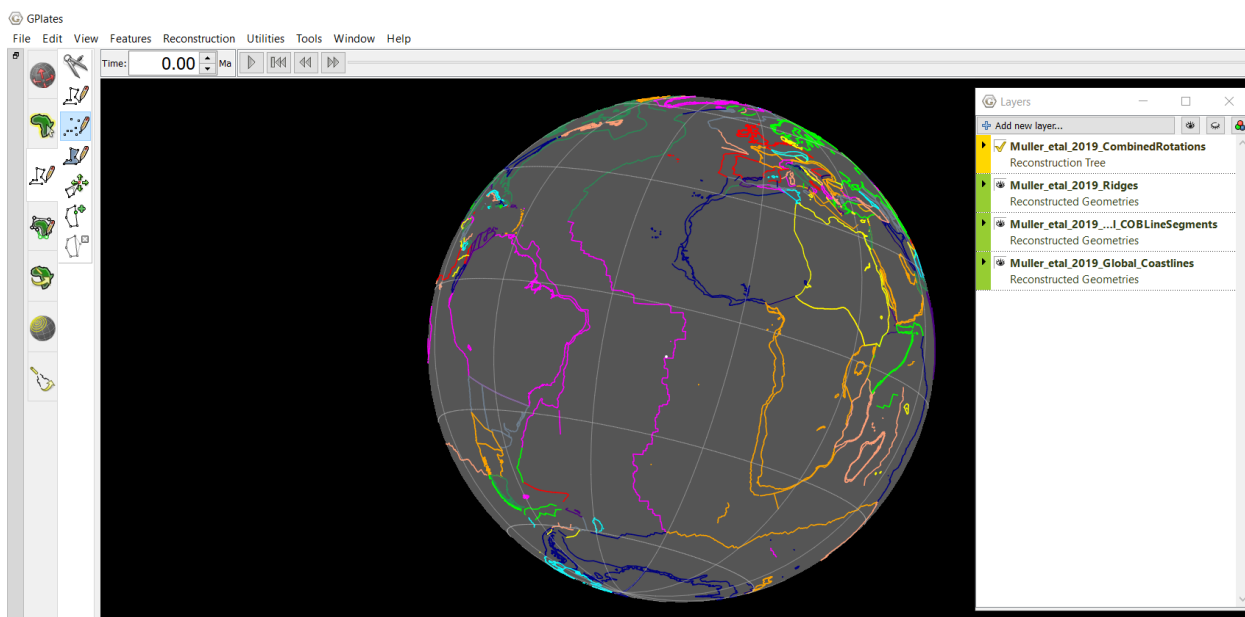


Figure 3: Digitised point on the spreading ridge with the Digitisation workflow tab expanded

This will open up the Create Feature menu.

5. Choose your “Feature Type” to be “Flowline” (Figure 4) from the list and click Next.

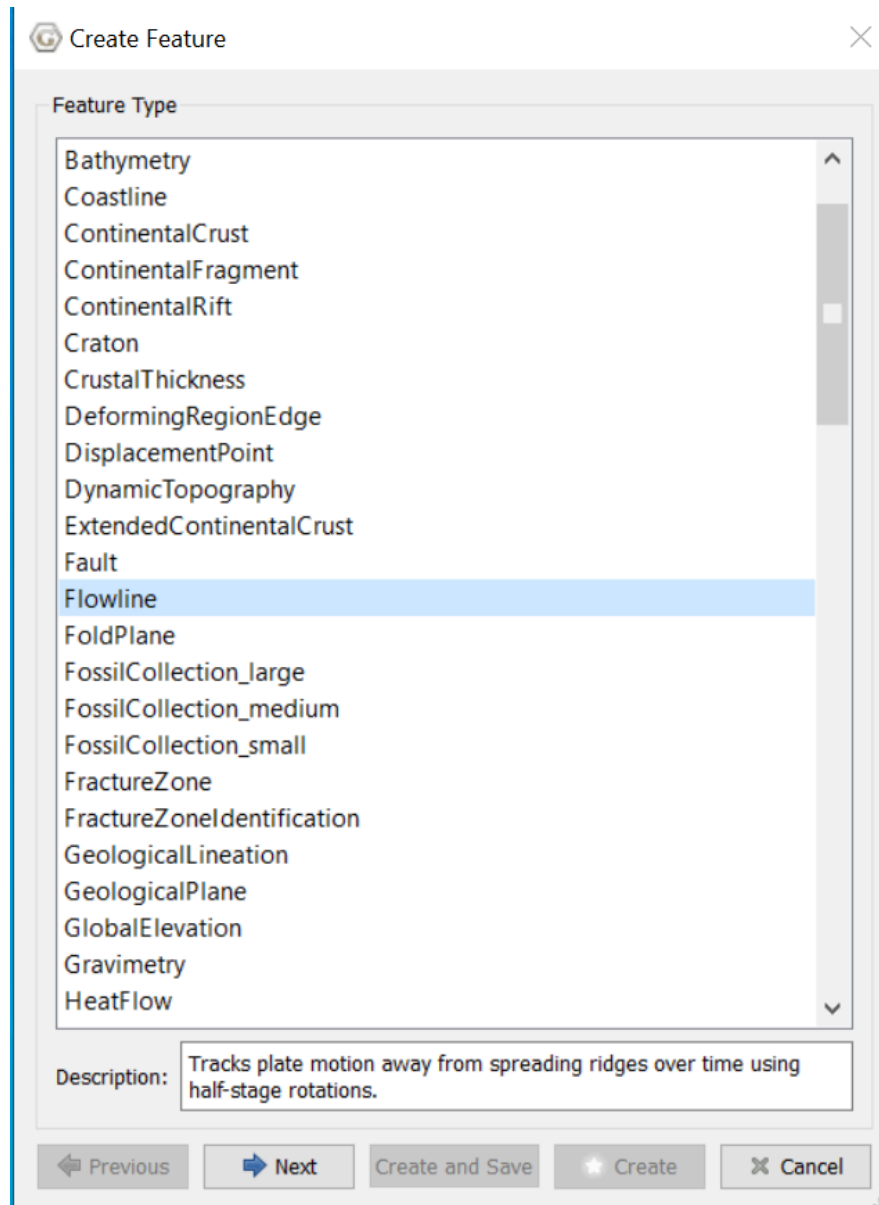


Figure 4: Create Feature menu with gpml:Flowline highlighted

6. In this window you can fill in the properties of your point. Leave the 'Interpret provided geometries' option as *Spreading centre(s)*. Under Common Properties, fill in the following fields (Figure 5):

Left Plate ID: 201 (South America)

Right Plate ID: 701 (Africa)

Begin (time of appearance): 120 Ma

End (time of disappearance): 0 Ma
Name: 201-701 flowline

Click Next

The 'Create Feature' dialog box is shown with the following sections and fields:

- Geometry Property:** A question 'Which property best indicates the geometry's purpose?' is followed by a list box containing 'seedPoints'.
- Customise Geometry:** A section titled 'Interpret provided geometries as:' with three radio button options: 'Spreading centre(s)' (selected), 'Left-plate end-point(s)', and 'Right-plate end-point(s)'.
- Common Properties:**
 - 'Reconstruction Method:' is a dropdown menu set to 'Half Stage Rotation'.
 - 'Left Plate ID:' is a text box with '201' and a spinner.
 - 'Right Plate ID:' is a text box with '701' and a spinner.
 - 'Begin (time of appearance):' is a text box with '120' and a spinner, followed by 'Ma' and a checkbox for 'Distant Past'.
 - 'End (time of disappearance):' is a text box with '0.00' and a spinner, followed by 'Ma' and a checkbox for 'Distant Future'.
 - 'Name:' is a text box containing '201-701 Flowline'.
- Buttons:** At the bottom are 'Previous', 'Next', 'Create and Save', 'Create', and 'Cancel' buttons.

Figure 5: Create Feature menu - flowline properties

7. A new menu will appear. Select *gpml:times* and press '+Add'. This will bring up a new window where we can add our flowline increment times.

Under *Insert multiple times* fill

From: 120 Ma

To: 0 Ma

in steps of: 10 My

Press Insert single time as 120 first. Now you have two time samples. Otherwise you get an error saying the time sequence should contain at least two time samples. Then, press the Insert button under *Insert multiple times*. This should populate the Times section from 0 to 120 in increments of 10 (Figure 6). Press OK to return to the previous window.

Add/Edit Property

Property Name:

Type:

Edit gpml:Array

	Time (Ma)	Actions
1	0	  
2	10	
3	20	
4	30	
5	40	

Insert single time

Time: Ma

Insert multiple times

From: Ma

to: Ma

in steps of: My

Figure 6: Create Feature menu - geometry and reconstruction times

8. Review the properties of the flowline in *Existing properties*.

These should be:

gml:name - 201-701 Flowline

gml:validTime - 120 - 0

gpml:reconstructionMethod - HalfStageRotation

gpml:leftPlate - 201

gpml:rightPlate - 701

gpml:times - this will appear blank, however if you select 'Edit', the previous array will appear and can be modified if necessary.

Select Next.

9. Choose <Create a new feature collection> then click Create.

10. A coloured flowline (in GPlates 2.2; grey in versions previous to 1.3) with arrows indicating direction of plate motion at that time appears, with a yellow point indicating the position of the spreading ridge (Figure 7). You can reconstruct this flowline through time; enter 120 in the time dialog box, and then use the slider or the arrows to move forward through time to see the flowline as it is created.

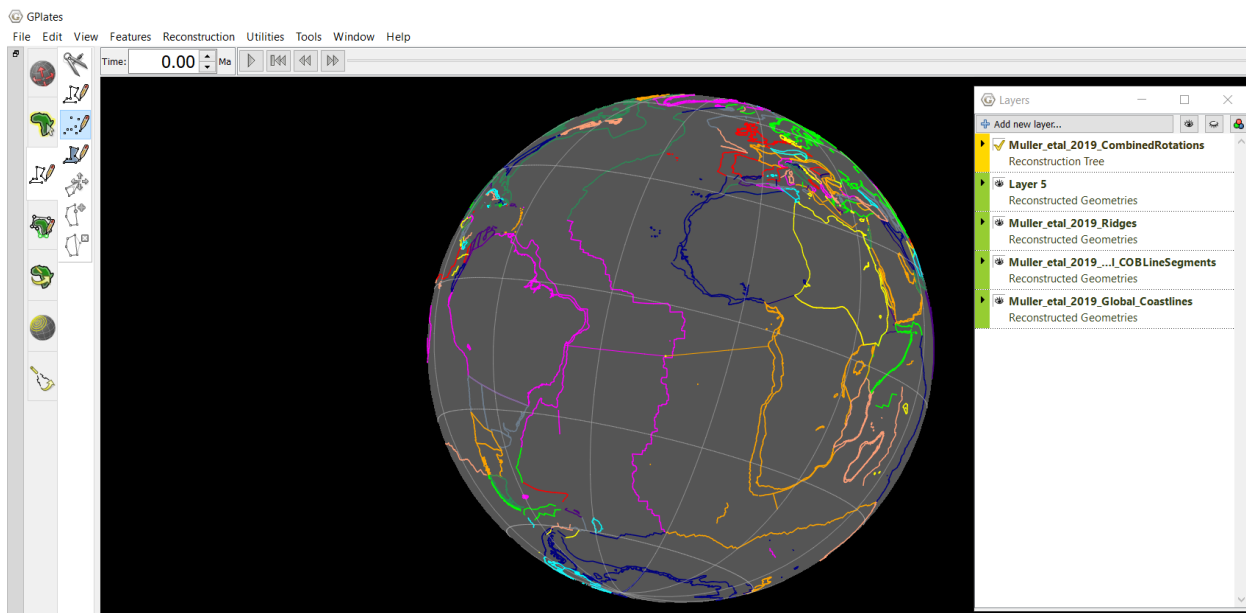


Figure 7: Flowline between South America and Africa.

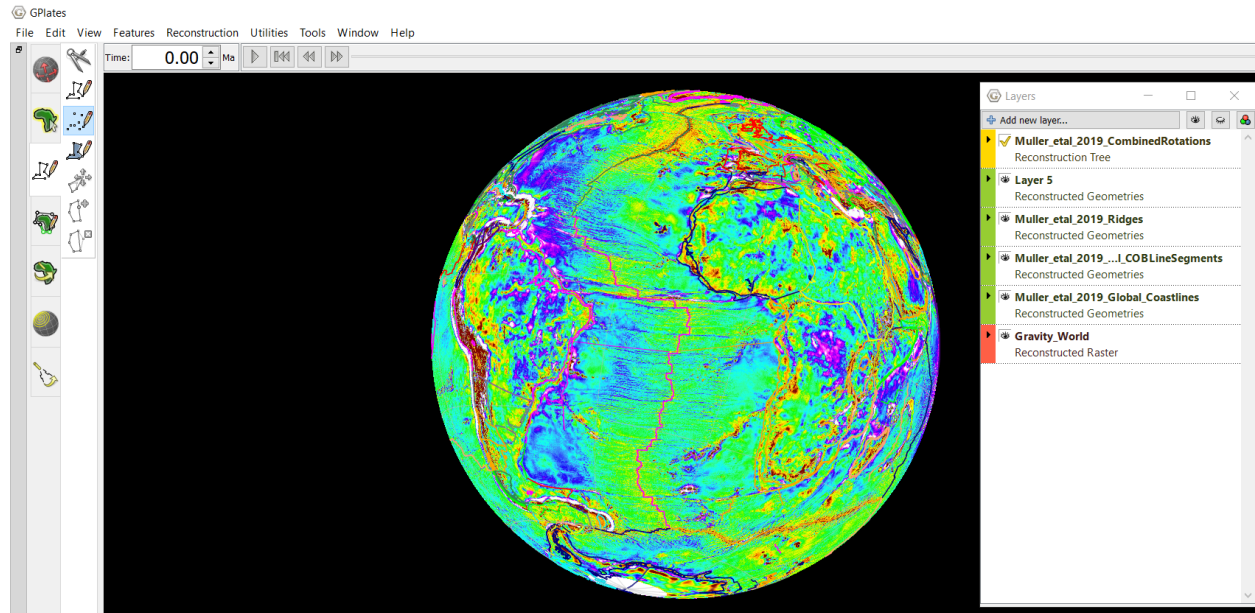
11. If you are satisfied with your flowline, don't forget to save it!

We can also compare computed flowlines with observed fracture zones by comparing the flowline we just digitised with the fracture zones on the global gravity anomaly raster (fracture zones are a real world example of flowlines).

12. To load the gravity anomaly raster go to File > Import > Import Raster... > then select Gravity_World.jpg
Leave as band_1 > Next
Leave as global extent > Next
Create new feature collection > Finish (Figure 8).

13. Rotate the globe so that you can see the flowline we just created between South America and Africa. Notice how the flowline matches up with the fracture zones in the gravity anomaly raster. The flowline may be difficult to see due to the bright colours of the raster - we can adjust the opacity and intensity of the raster in the layer manager.

Figure 8: Digitised flowlines aligning with fracture zones in the global gravity anomaly raster (Step 13)



14. Have a go at digitising another flowline or two to see how they match up with other fracture zones in the region (Figure 9).

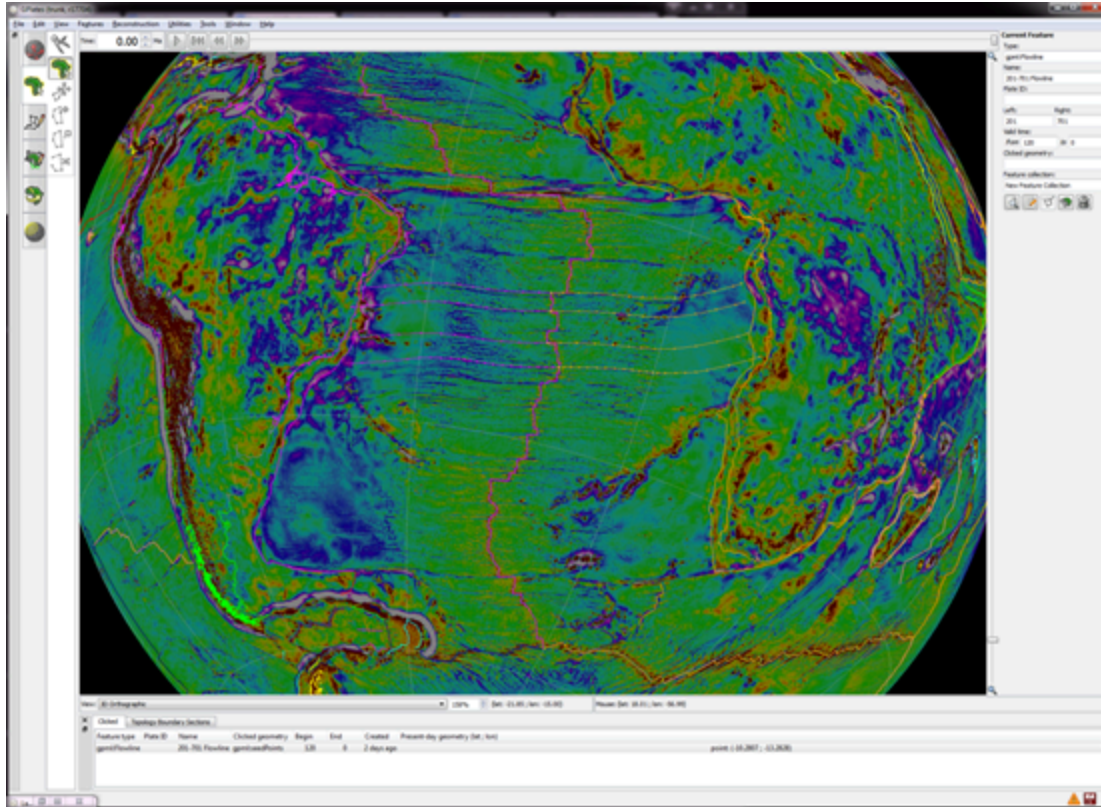


Figure 9: Various flowlines that align with fracture zones on the gravity anomaly raster (Step 14)

Note: You can also create flowlines using continent-ocean boundaries (COBs) instead of the spreading ridge. To do this, in Step 4 instead of digitising a point on the spreading ridge, choose a point on a COB. Continue with steps 5 and 6 as above, then for Step 7 under "Interpret provided geometries as:" choose either "Left-plate end-points(s)" or "Right-plate end-points" depending on which plate you have placed your point. Follow the rest of the directions as above.

Note: You can create multiple flowlines at the same time, provided all of the points have the same geometry, i.e., they must all be points on a spreading centre, or all on the left plate, or all on the right plate.

Exercise 1B - Creating a flowline at a reconstructed time

Sometimes it is useful to create flowlines that do not originate from present-day spreading centres (i.e., MORs), for example, to follow the motion of a fracture zone. In this exercise, we will create a flowline ensuring a seedpoint coincides with the end of a fracture zone, so we can easily

compare the motion described by the flowline and fracture zone (Note: fracture zones are real-world cases of flowlines that incorporates all the complexities of seafloor spreading, including spreading asymmetry, which may not be captured in plate motion models.)

1. If not already open, open GPlates
2. Go to File > Open Feature Collection (as in Exercise 1A), and select the following files:
 - Muller_etal_2019_CombinedRotations.rot
 - Muller_etal_2019_Global_Coastlines.gpmlz
 - Muller_etal_2019_Global_COBLineSegments.gpmlz
 - Muller_etal_2019_Ridges.gpmlz
 - Fracture_Zones_SEPacific.gpml
3. Rotate the globe so that the East Pacific Rise (EPR) is centred on your screen (Figure 10).

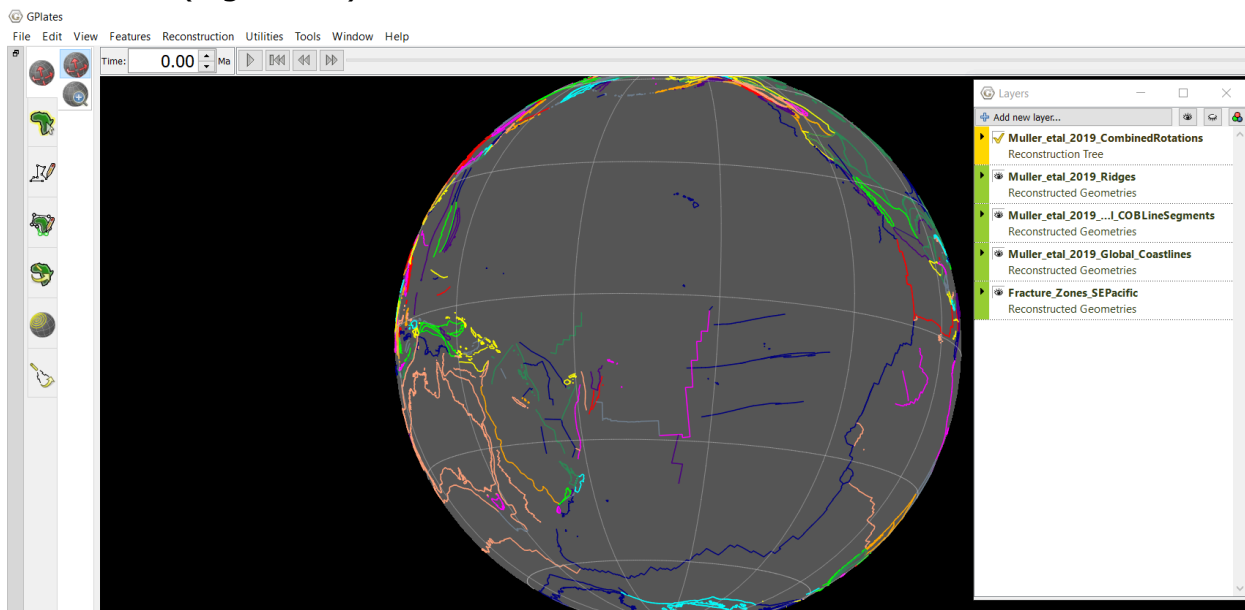


Figure 10: View of the Pacific-Nazca (EPR) spreading system at present day

4. Reconstruct back in time using the time slider at the top (Figure 11). In this case we will reconstruct to 20.1 Ma, since the oldest segment of the fracture zones in question (on the Pacific Plate) are associated with this age.

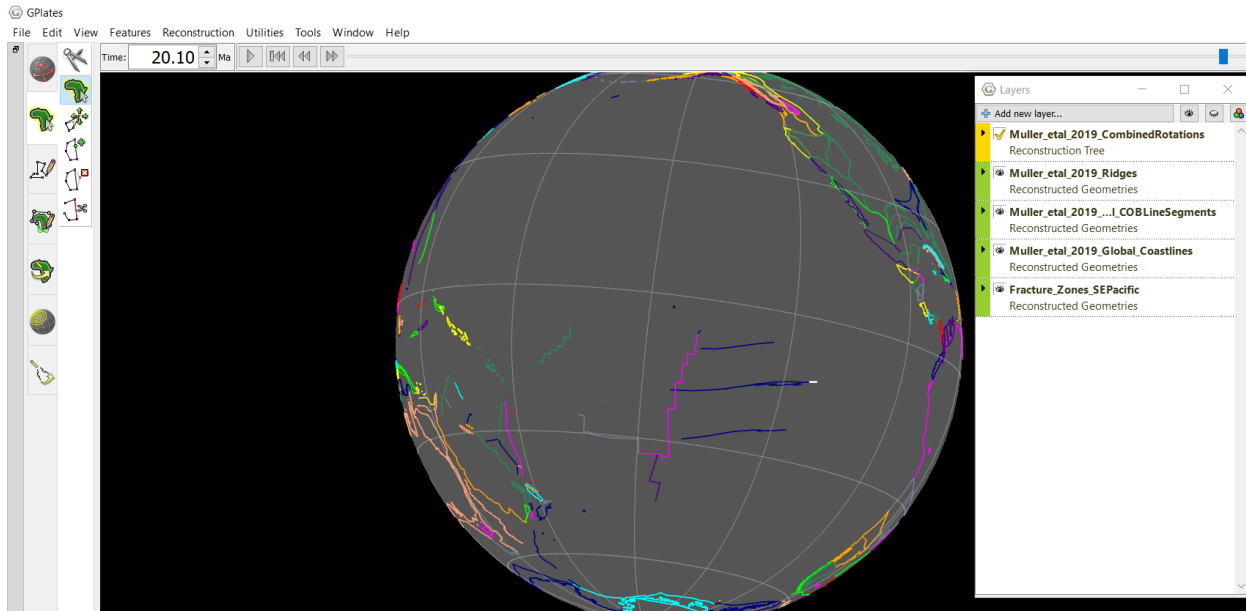


Figure 11: View of the Eastern Pacific reconstructed at 20.1 Ma and the Marquesas FZ, where we will create our seed point.

5. Select the *Digitisation* workflow tab and the *Digitise New Multi-point*

Geometry tool  from its submenu. Use this to create a feature **on the youngest edge** of the fracture zone, then click on the *Create Feature* bottom on the lower right side of the globe (Figure 12). This will open up the Create Feature menu.

Note: We are still working at a reconstructed time in GPlates.

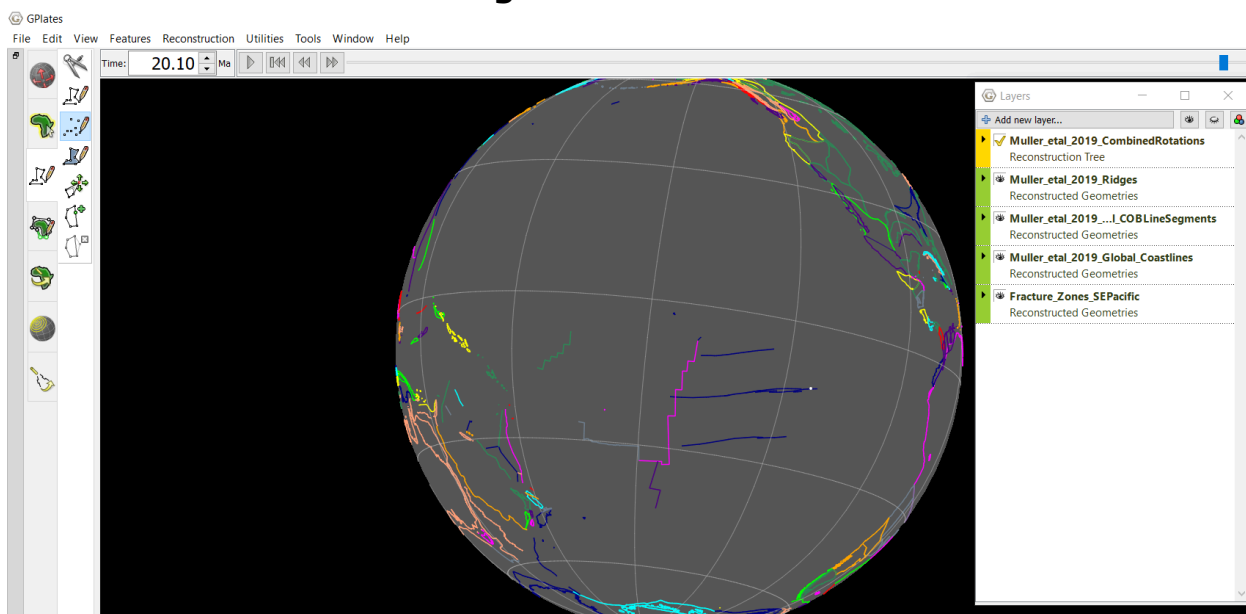


Figure 12: Digitised seed-point on the fracture zone end at 20.1 Ma

6. From the Create Feature menu, choose your feature type to be *Flowline* from the list (Figure 13). Click Next.

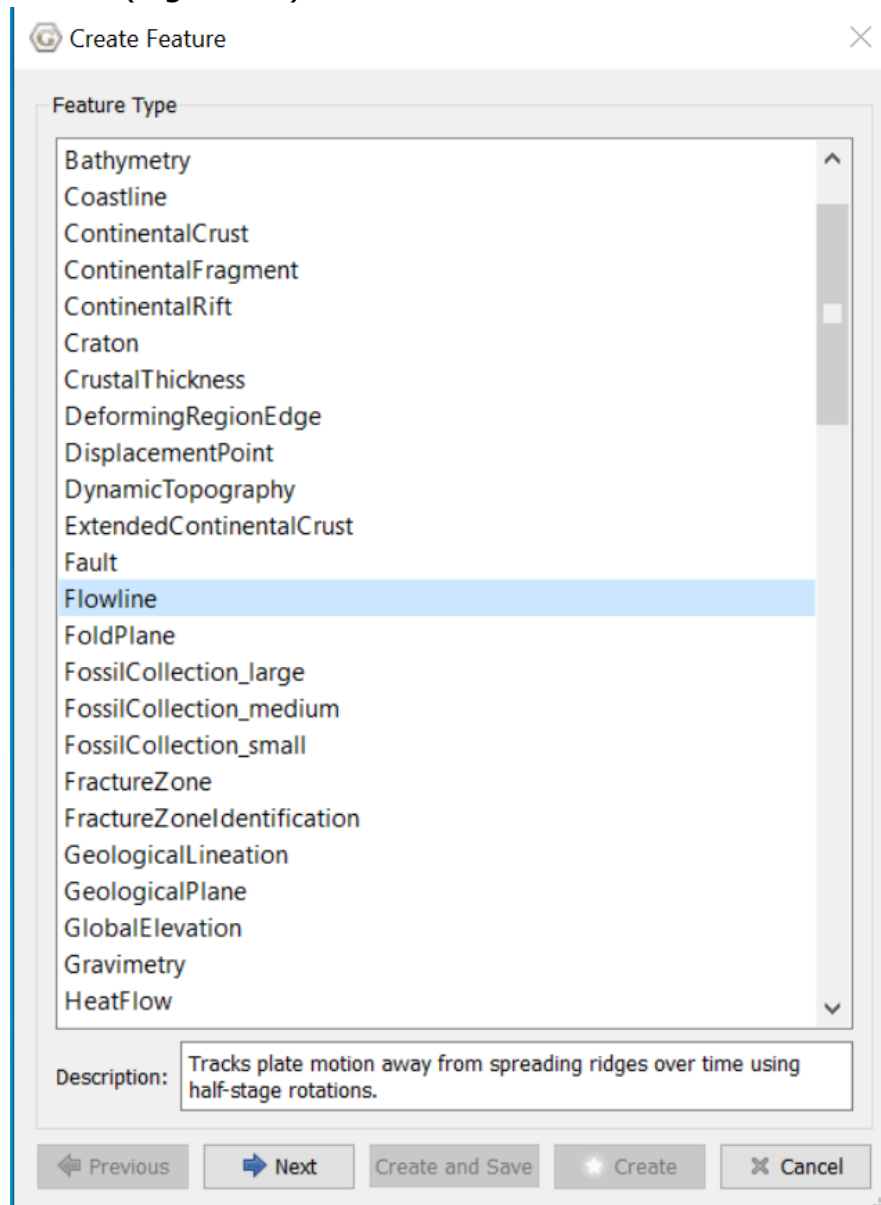


Figure 13: Create feature menu with flowline feature type highlighted

7. Leave the 'Interpret provided geometries' option as *Spreading centre(s)*. Under Common Properties, fill in the following fields (Figure 14):

Left Plate ID: 901

Right Plate ID: 911

Begin (time of appearance): 85 Ma

End (time of disappearance): 20.1 Ma

Name: 901-911 flowline

Click Next. Note that the end time (time of disappearance) is the same as our current reconstruction time.

The image shows a software window titled "Create Feature". It contains three main sections: "Geometry Property", "Customise Geometry", and "Common Properties".

- Geometry Property:** A text box contains "seedPoints".
- Customise Geometry:** A section titled "Interpret provided geometries as:" with three radio buttons: "Spreading centre(s)" (selected), "Left-plate end-point(s)", and "Right-plate end-point(s)".
- Common Properties:**
 - "Reconstruction Method:" is a dropdown menu set to "Half Stage Rotation".
 - "Left Plate ID:" is a text box with "901".
 - "Right Plate ID:" is a text box with "911".
 - "Begin (time of appearance):" is a text box with "85.00" Ma, followed by a checkbox for "Distant Past" (unchecked).
 - "End (time of disappearance):" is a text box with "20.10" Ma, followed by a checkbox for "Distant Future" (unchecked).
 - "Name:" is a text box with "901-911 Flowline".

At the bottom, there are five buttons: "Previous", "Next", "Create and Save", "Create", and "Cancel".

Figure 14: Create flowline feature menu, with common properties filled out

8. A new menu will appear – highlight *gpml:times* and select 'Add'. This will bring up a new window where we can add our flowline increment times (Note: If *gpml:times* does not appear under *Available Properties*, look under *Existing Properties* in the lower half of the window. Highlight it, and click *Edit*). Press Insert single time as 85 first. Now you have two time samples. Otherwise you get an error saying the time sequence should contain at least two time samples. Then, under *Insert Multiple Times*, fill:
From: 85.00 Ma
To: 0 Ma
in steps of: 5.00 My

Press Insert – this will populate the Times section from 0 to 85 Ma in increments of 5 Myr (Figure 15). Press OK to return to the previous window.
Note: The flowline time increments are created until **0 Ma**, even though we are creating the flowline at some time in the past. This is needed for proper stage pole interpretation.

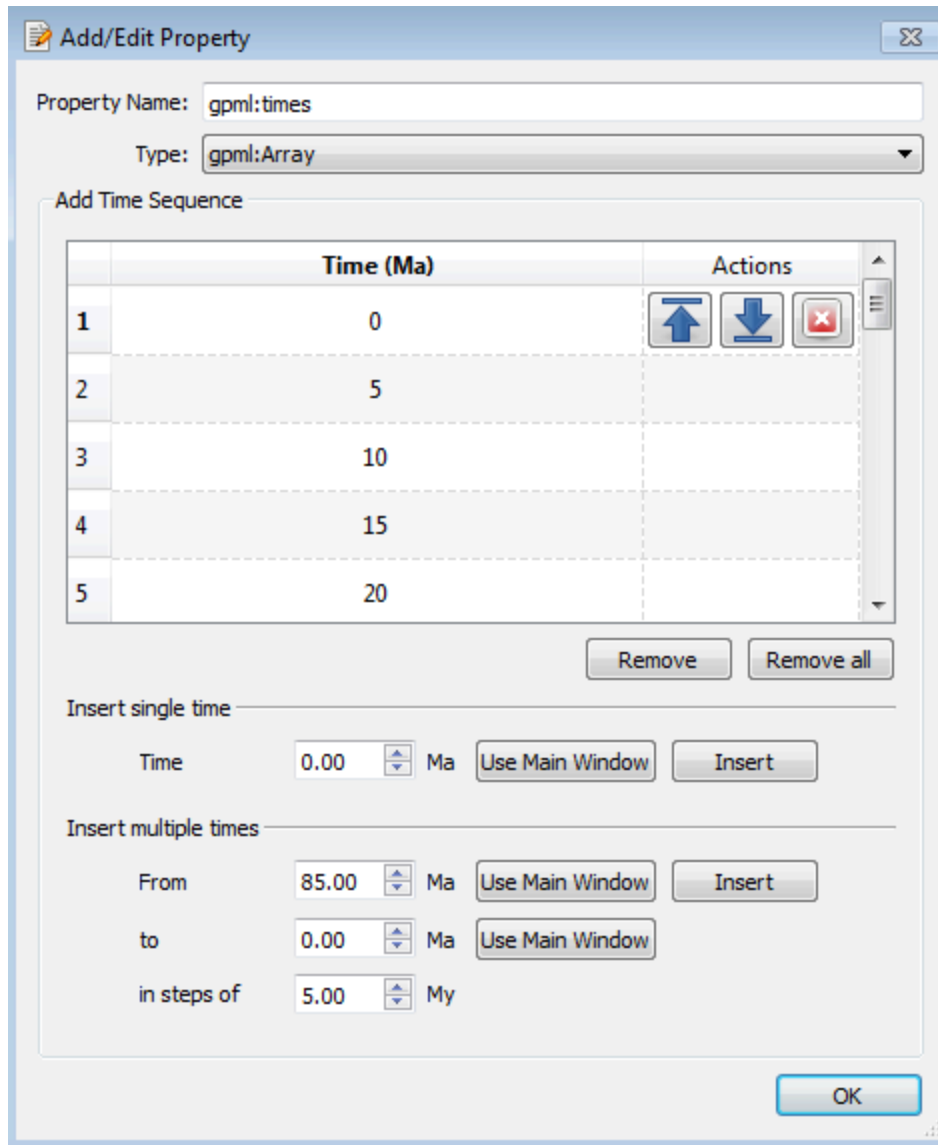


Figure 15: Flowline times array menu, with multiple times (5 myr increments) inserted.

9. Review the properties of the flowline in *Existing Properties*:

These should be:

gml:name - 901-911 flowline

gml:validTime - 85 – 20.1

gpm1:reconstructionMethod - HalfStageRotationVersion3

gpm1:leftPlate - 901

gpm1:rightPlate - 911

gpm1:times - this will be blank, however if you select 'Edit', the array will popup and can be edited if needed.

Select Next.

10. Choose a feature collection for the new flowline – in this case we will

select

< Create a new feature collection >

Press Create

11. Your flowline will appear coloured (based on Plate ID), and will have a seedpoint (yellow point) at the edge of the fracture zone (Figure 16). We can reconstruct this flowline through time, from 85 Ma to 20.1 Ma, however this flowline will not appear at present day (0 Ma) since it was not included in its *Valid Time* properties assigned in Step 7.

By creating the flowline in this manner, we can easily compare the motions of the fracture zones (real-world flowlines) and our modelled flowlines, and see where refinements to our plate motions can be made.

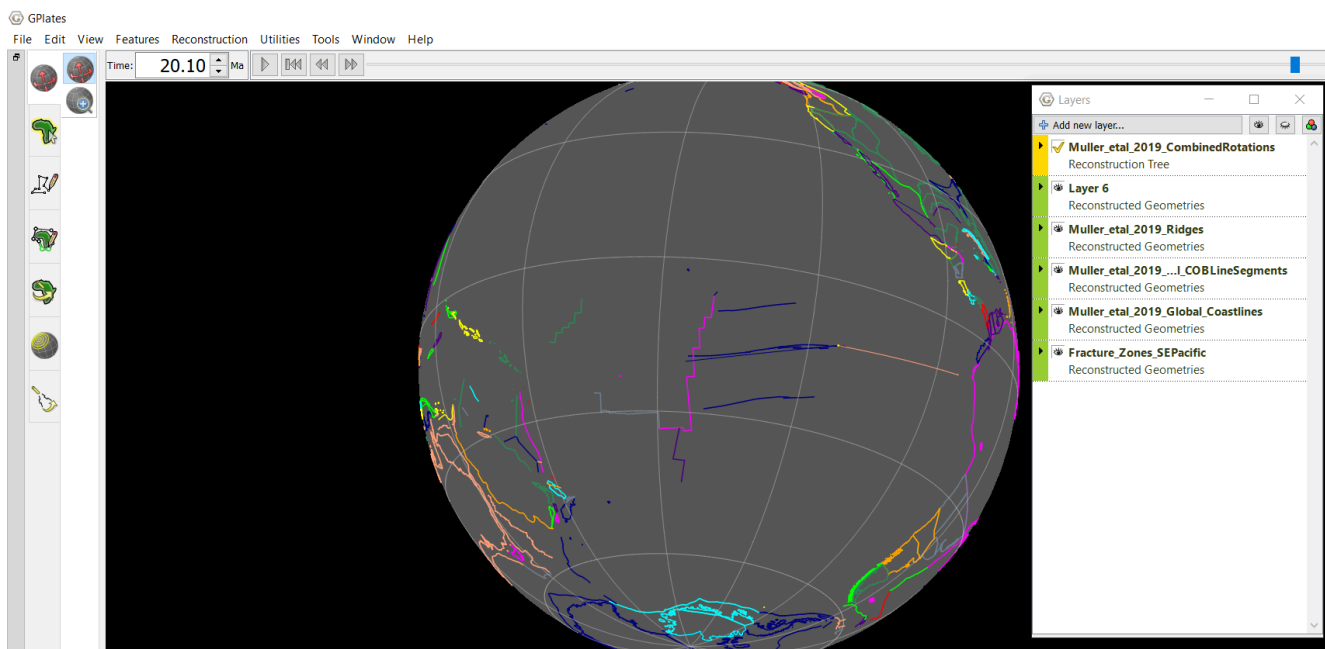


Figure 16: 911-901 (NAZ-PAC) flowline at 20.1 Ma

Exercise 2 - Creating and Using Motion Paths

1. If not done already, open GPlates.
2. File > Open Feature Collection as done above, and select the Rotation Model File, the Coastline File, the Hotspot File, and the Hawaiian-Emperor Seamount Chain File from the data bundle for this tutorial:

- Muller_etal_2019_CombinedRotations.rot
- Muller_etal_2019_Global_Coastlines.gpmlz
- HS_triangles.dat
- HawaiianEmperorChain.gpml

3. Rotate the globe so that the Hawaiian-Emperor seamount chain in the Pacific Ocean is centered on your screen (Figure 17). There should be a triangle indicating a hotspot at the end of the Hawaiian Island chain.

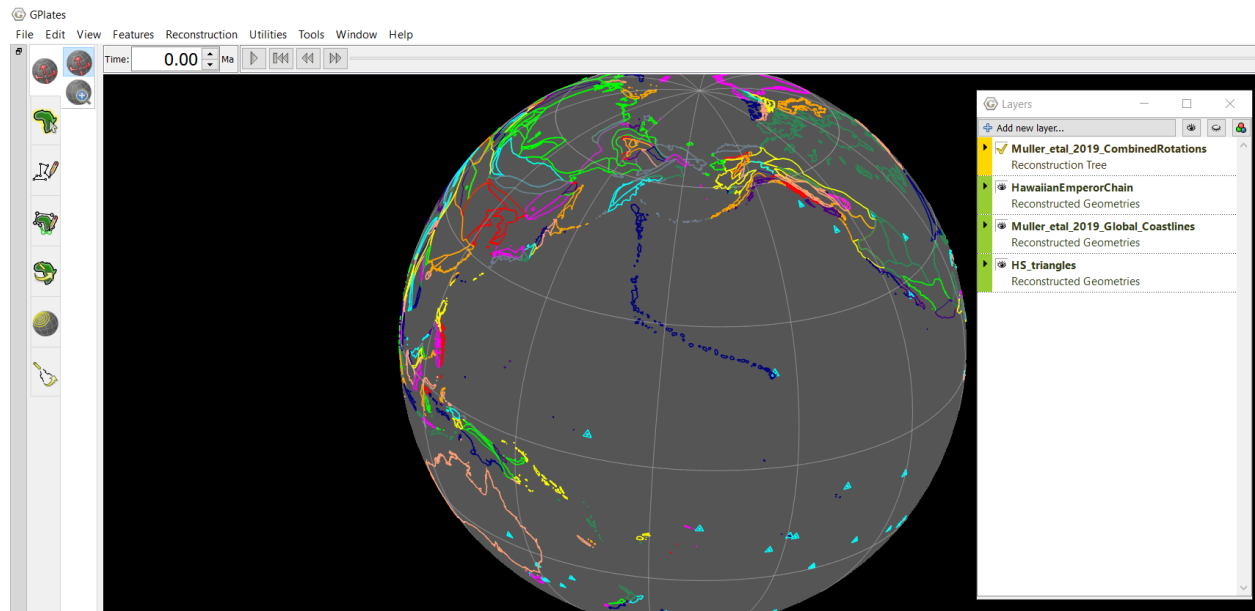


Figure 17: View of Hawaiian-Emperor seamount chain and present day hotspots (blue triangles)

4. Select your Digitize New Multi-point Geometry tool  and use it to create a point located on the Hawaiian hotspot triangle. Then click on the Create Feature button on the right side of the globe (Figure 18).

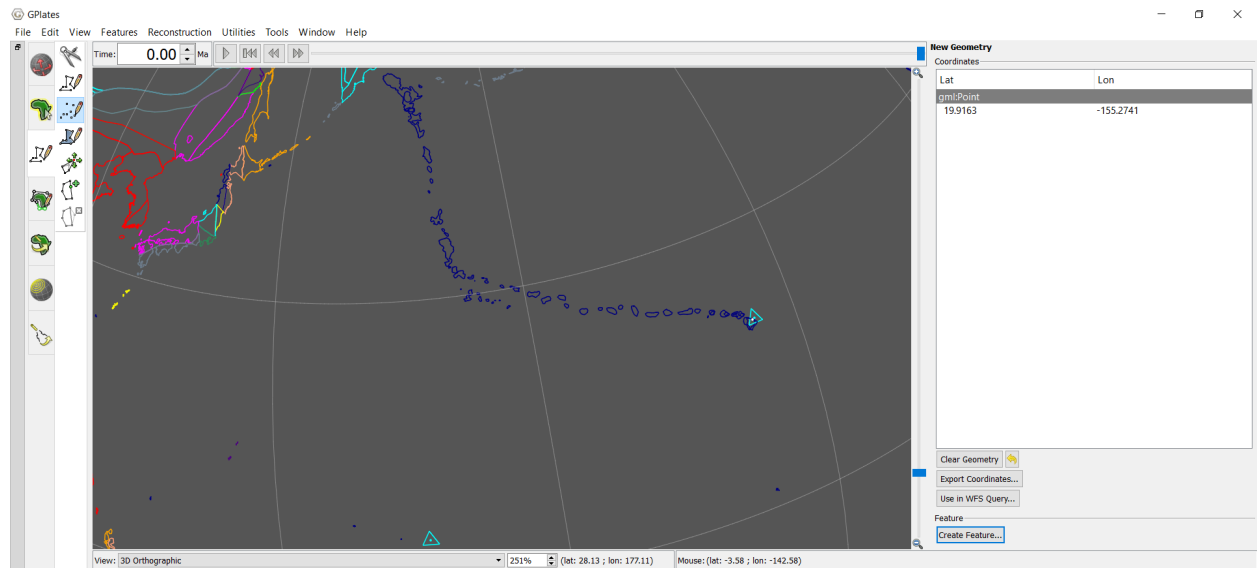


Figure 18: View of digitised geometry on Hawaiian hotspot and New Geometry sidebar

This will open up the Create Feature menu (Figure 19).

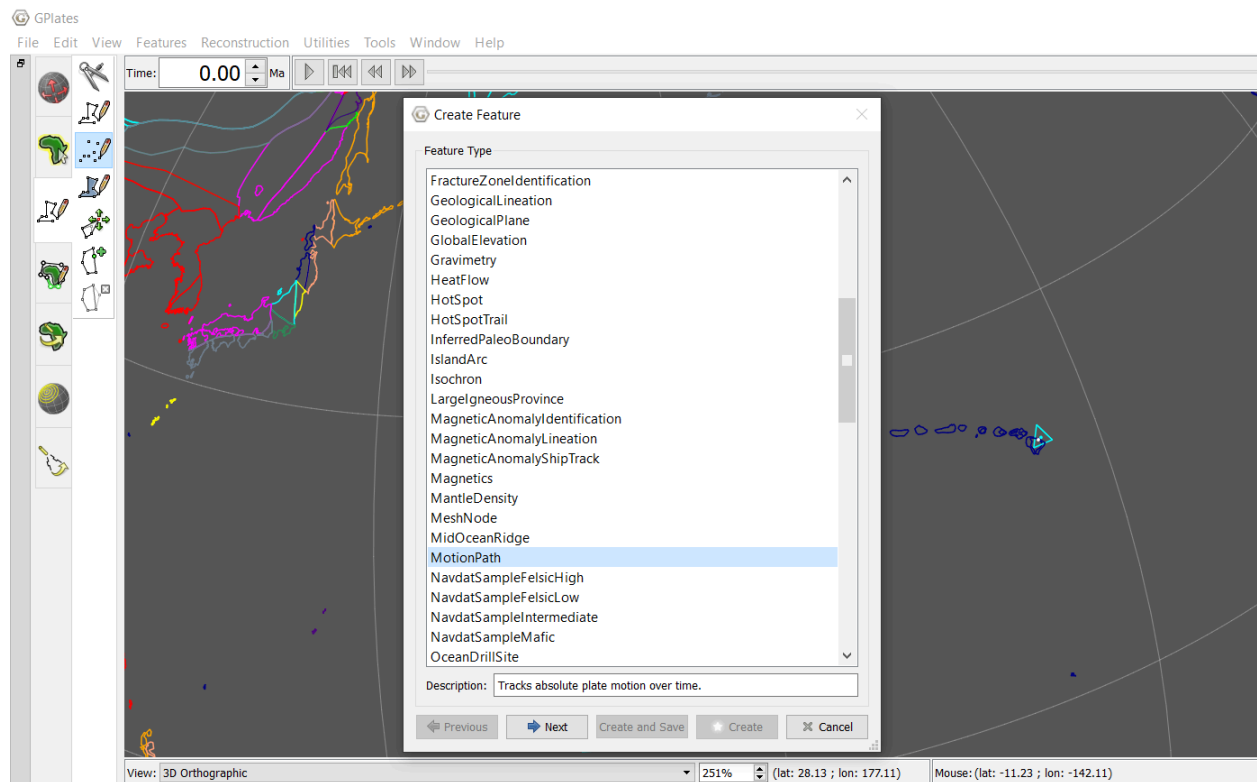


Figure 19: Create Feature menu

5. Choose your "Feature Type" to be "gpml:MotionPath" from the list and

click Next.

6. In this window you fill in the properties of your point. Fill in the following fields (Figure 20):

Plate ID: 0 (Spin axis, incorporating the mantle reference frame)

Relative Plate ID: 901 (the plate we wish to calculate motion relative to, in this case the Pacific plate)

Begin (time of appearance): 80 Ma

End (time of disappearance): Distant future

Name: Hawaiian Emperor Hotspot Path

Then click Next.

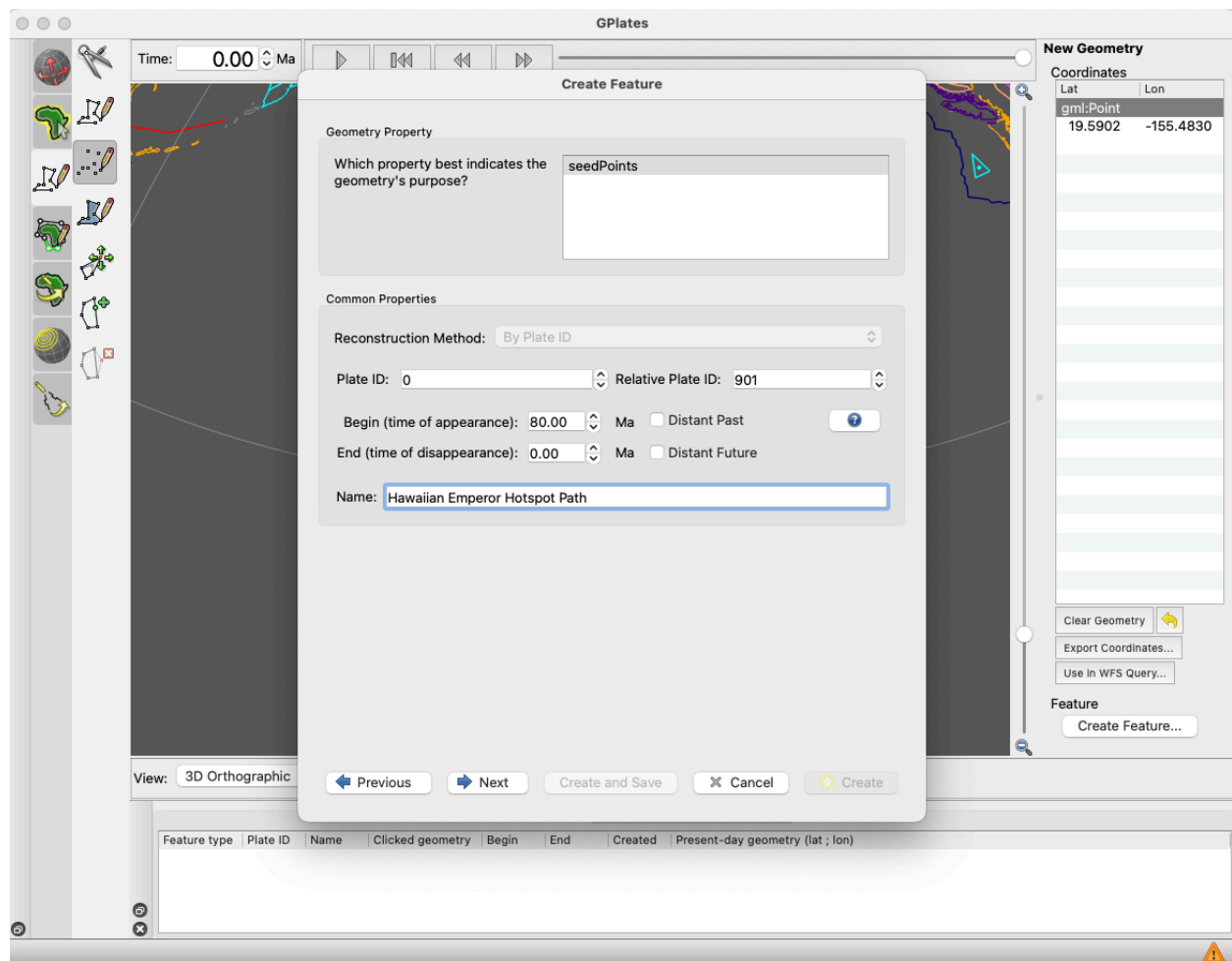


Figure 20: Create Feature menu - motion path properties

7. Click on the property *gpmi:times* and click "+Add". Under the "Insert multiple times" section, fill

From: 80 Ma

to: 0 Ma

in steps of: 5 My

Click the "Insert" button in this section. This should populate the chart in this window (Figure 21). Click "OK", then "Next".

Add/Edit Property

Property Name:

Type:

Edit gpml:Array

	Time (Ma)	Actions
1	0	  
2	5	
3	10	
4	15	
5	20	

Insert single time

Time Ma

Insert multiple times

From Ma

to Ma

in steps of My

Figure 21: Create Feature menu - relative plate id and reconstruction times

8. Choose <Create a new feature collection> then click Create.

9. A line showing the motion path of the hotspot relative to the Pacific plate should appear. Note how it follows the Hawaiian-Emperor seamount chain (Figure 22). As with flowlines you can reconstruct this motion path through time; enter 80 in the time dialog box, and then use the slider or the arrows

to move forward through time to see the motion path as it is created.

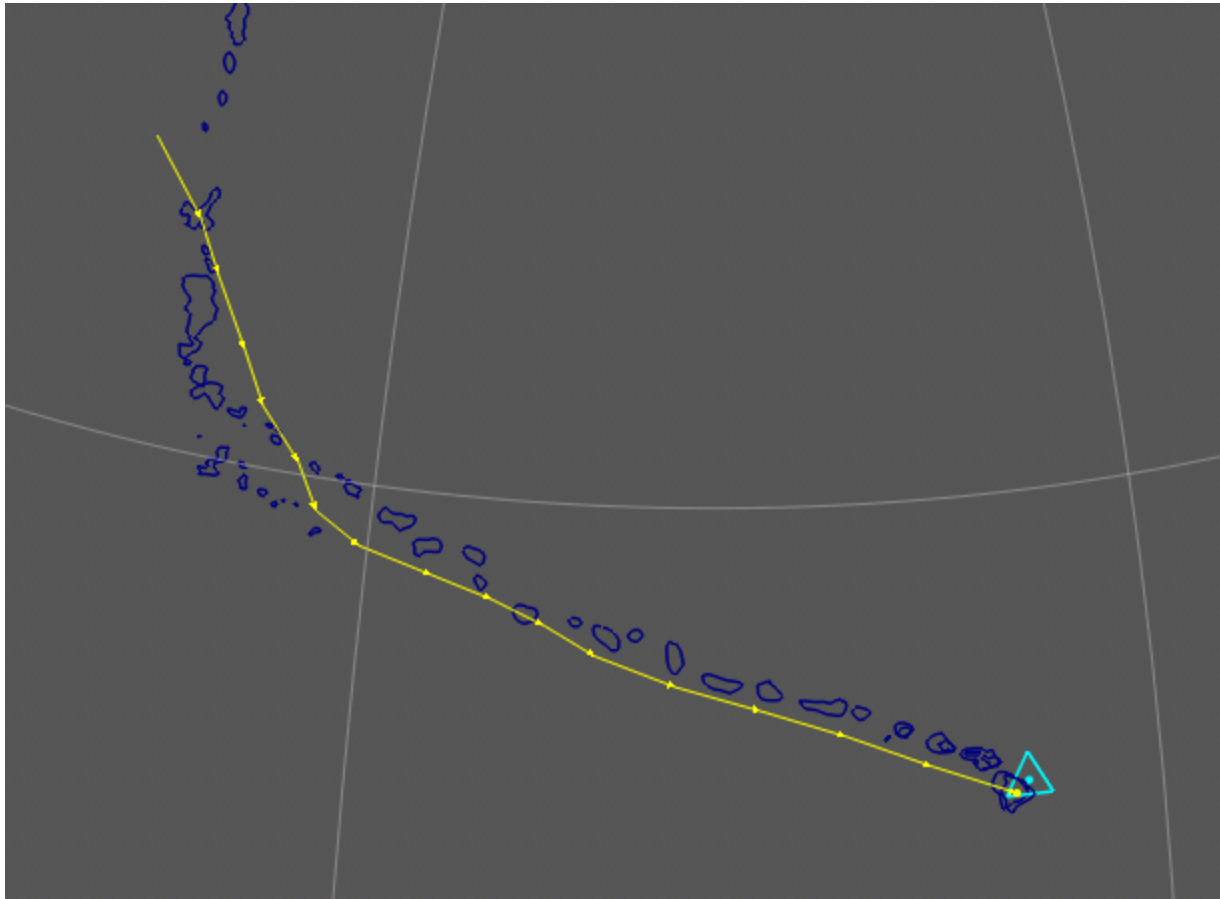


Figure 22: Motion path of the Hawaiian hotspot along the Hawaiian-Emperor seamount chain

10. If you are satisfied with your motion path, don't forget to save it!

Note: You can create multiple motion paths at the same time, provided all of the points have the same plate IDs and relative plate IDs. Keep in mind, there are specific regional mantle or hotspot reference frames that could improve the fit to the seamount chain - which means you may need to use different plate ID pairs.