Creating Features in GPlates

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

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Aim

This tutorial is designed to teach the user how to digitise features, including: (1) Exporting their coordinates, and (2) Adding them to Feature Collections. Screenshots have been included to illustrate how to complete new steps within each exercise.

Included Files

Click here to download the data bundle for this tutorial.

The tutorial dataset (1.5-Creating_Features.zip) includes the following files:

Coastlines: Muller_etal_2019_Global_Coastlines.gpmlz

Rotation file: Muller_etal_2019_CombinedRotations.rot

Static Polygon files: Muller_etal_2019_Global_StaticPlatePolygons.gpmlz

Dynamic Polygon files: Muller_etal_2019_PlateBoundaries_DeformingNetworks.gpmlz

Locations of volcanoes from around the world (USGS data): volcanoes.gpml

Gravity Anomaly Grids - Global and the Australian Region (these are from the 18.1 Sandwell and Smith 1-min Gravity Anomaly dataset): Gravity_AUS.jpg and Gravity_World.jpg

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

This tutorial dataset is compatible with GPlates 2.2.

Background

GPlates enables the user to digitise features on the globe and add them to new or existing feature collections. Creating features in GPlates is a useful way to highlight relationships between multiple data sets. GPlates supports polylines, polygons and multi-point geometries. These features can then be assigned a feature type (e.g., Craton, Fault, Basin, Volcano), and various feature properties (e.g., age of appearance and disappearance). When combined with a rotation file, features can be digitised at any time in the past and then reconstructed backwards and forwards through time.

Feature collections can be saved in a number of date-file formats, including PLATES4 line (*.dat *.pla), GPlates Markup Language (*.gpml) and ESRI shape files (*.shp). Additionally feature data can be exported in the GMT xy (*.xy) format.

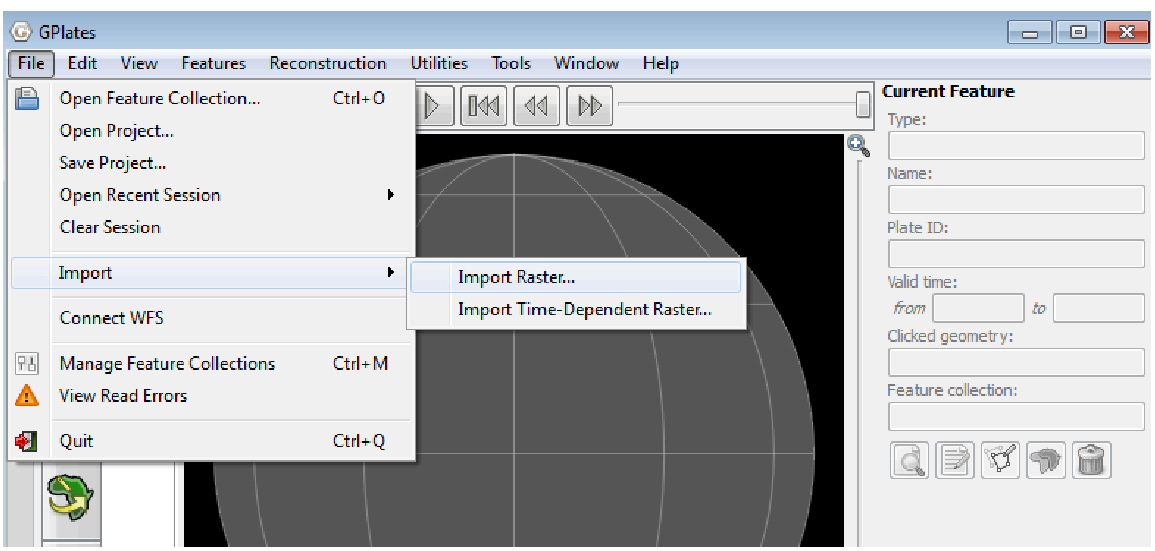
See the GPlates online manual for further information:
www.gplates.org/user-manual/Creating_Features.html

Exercise 1 – Importing Global Rasters

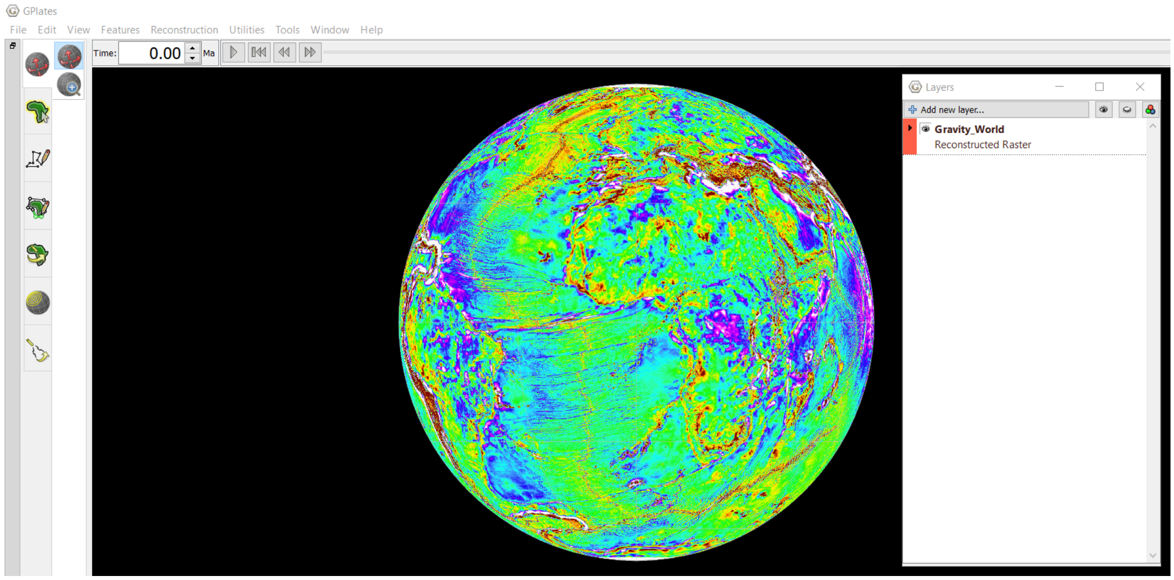
It is useful to be able to import present-day rasters into GPlates as this enables you to identify boundaries of tectonic elements that can then be assigned plate IDs and other feature data. In this exercise we will be importing a global raster image showing gravity anomaly data.

1. Open GPlates

2. File → Import → Import Raster… (Figure 1) → locate and select **Gravity_World.jpg** in the Creating_New_Features data bundle → Open → Next → Next → Finish (The region and extent of this jpg will load correctly into GPlates by default).



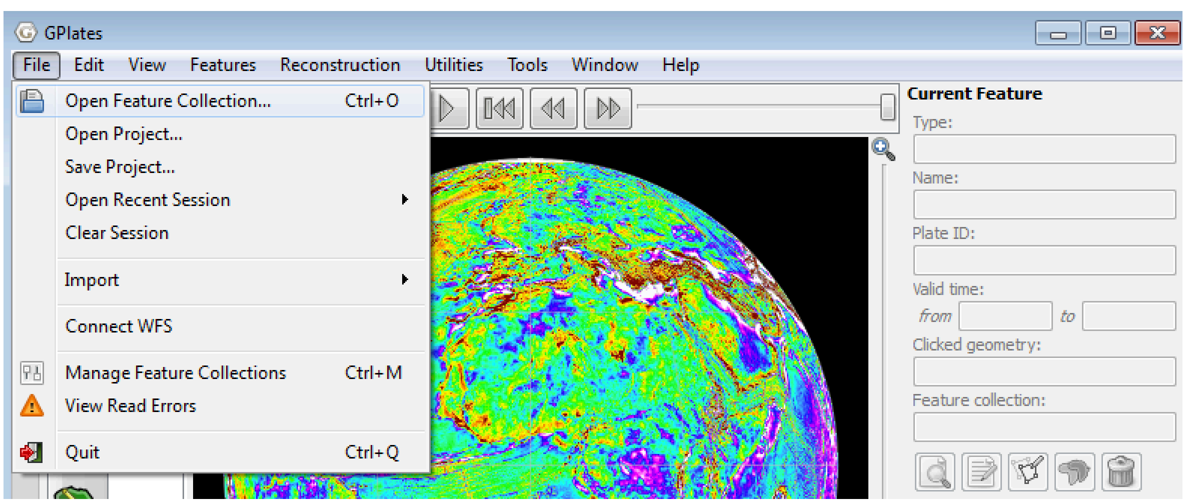
A



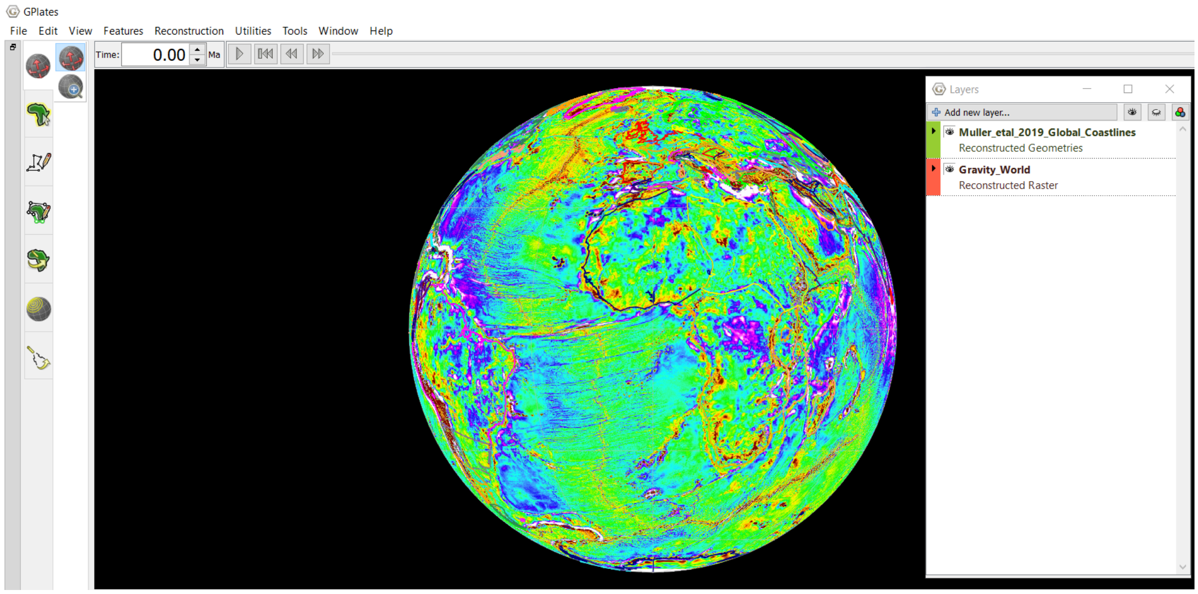
B

Figure 1. Step 2 - How to open a raster image from the menu bar: A) Before, and B) After.

3. File → Open Feature Collection… (Figure 2) → locate and select **Muller_etal_2019_Global_Coastlines.gpmlz** in the '1.5-Creating_Features' data bundle → Open



A



B

Figure 2. Step 3 – How to open a feature collection from the menu bar: A) Before, and B) After.

Note that the coastlines will not always match up perfectly as coastlines are a function of present-day sea-level, whereas the transition from continental to oceanic crust (the Continent-Ocean Boundary – COB) may be hidden below sea-level.

Regional rasters can also be loaded into GPlates, see Appendix.

Exercise 2 – Digitising a Polyline

In this exercise we will digitise the subduction zone that spans the western margin of South America. Subduction zones form at sites of plate convergence, where one plate is being thrust into the mantle beneath another plate (the overriding plate); currently the Nazca and Antarctic plates are being subducted beneath South America. We will use the global gravity raster from EXERCISE 1 to help us constrain the location of subduction. In gravity images, subduction zones produce a distinctive positive-negative pair. In our gravity image these will present as roughly adjacent bands of white and dark red.

1. If not done already, as above: File → Open Feature Collection… (Figure 3) → locate and select **Muller_etal_2019_Global_Coastlines.gpmlz** in the

‘1.5-Creating_Features’ data bundle → Open

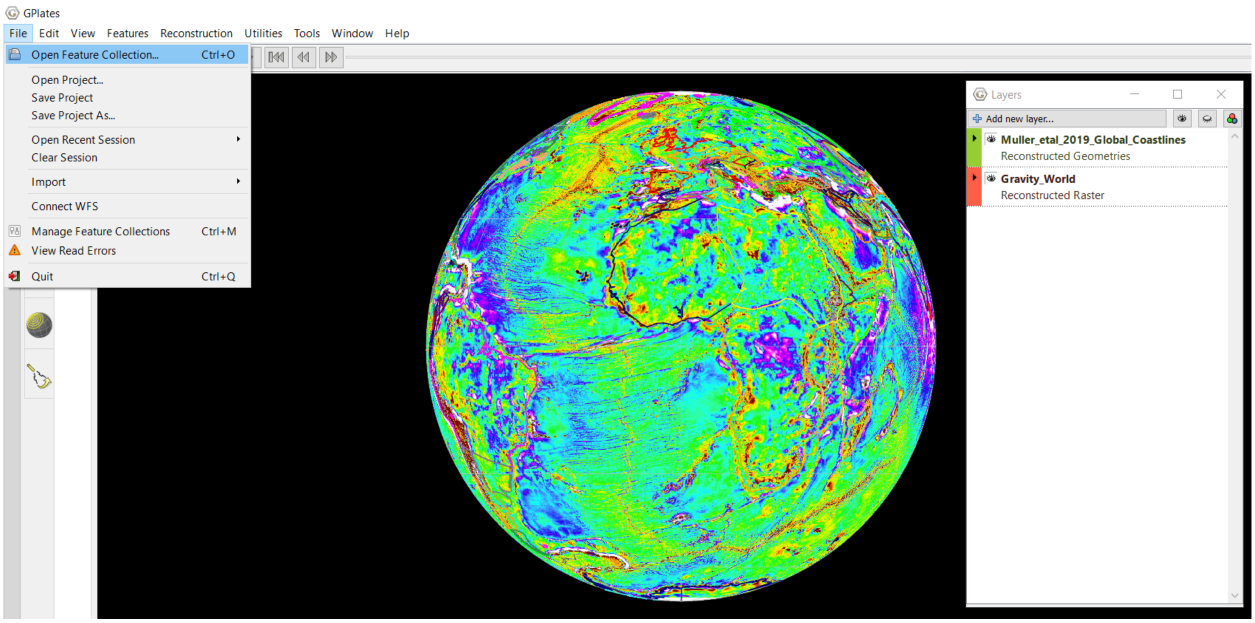


Figure 3. How to load Feature Collections into GPlates from the Menu Bar.

Now that the coastlines are displayed in GPlates, rotate the globe so that South America is in view (Figure 4). You may need to change the colouring of the coastlines with Features → Manage Colouring in order to view them clearly. We suggest that you colour the coastlines black.

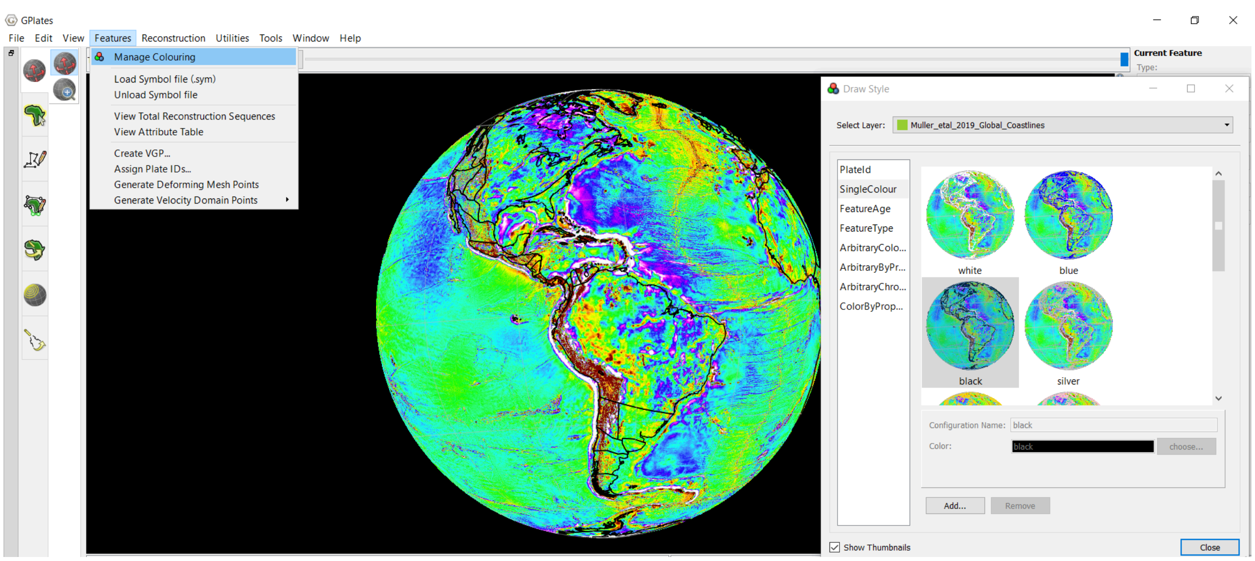
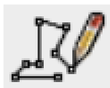
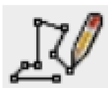


Figure 4. Gravity data for the South American region.

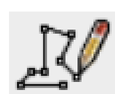
GPlates has three different digitisation tools, all located in the Digitisation menu  of the Tool Palette (left of the main window):

(1)  Digitise New Polyline Geometry – a series of non-intersecting lines that form an open polygon; essentially a line formed by the connection of a series of two or more points.

(2)  Digitise New Multi-point Geometry – a collection of points.

(3)  Digitise New Polygon Geometry – a series of lines that form a closed circuit.

The choice of tool will reflect the feature being created. We will use a polyline to create our subduction zone.

2. Click the Digitise New Polyline Geometry icon 

Once the digitisation tool has been selected, every mouse click on the globe will create a new point along the polyline.

First have a think about where you are going to digitise your subduction zone. Keep in mind:

· Coastlines reflect present day sea level, they do not necessarily reflect the boundary between continental and oceanic crust, or the boundary between two plates.

· Negative gravity anomalies occur adjacent to trenches due to relatively lighter (less-dense) crust plunging into denser mantle.

Let’s now have a go at digitising. Your subduction zone should look something like Figure 5 below. Note that in Figure 5 the gravity raster has been turned off to make the subduction zone polyline clearer in the image.

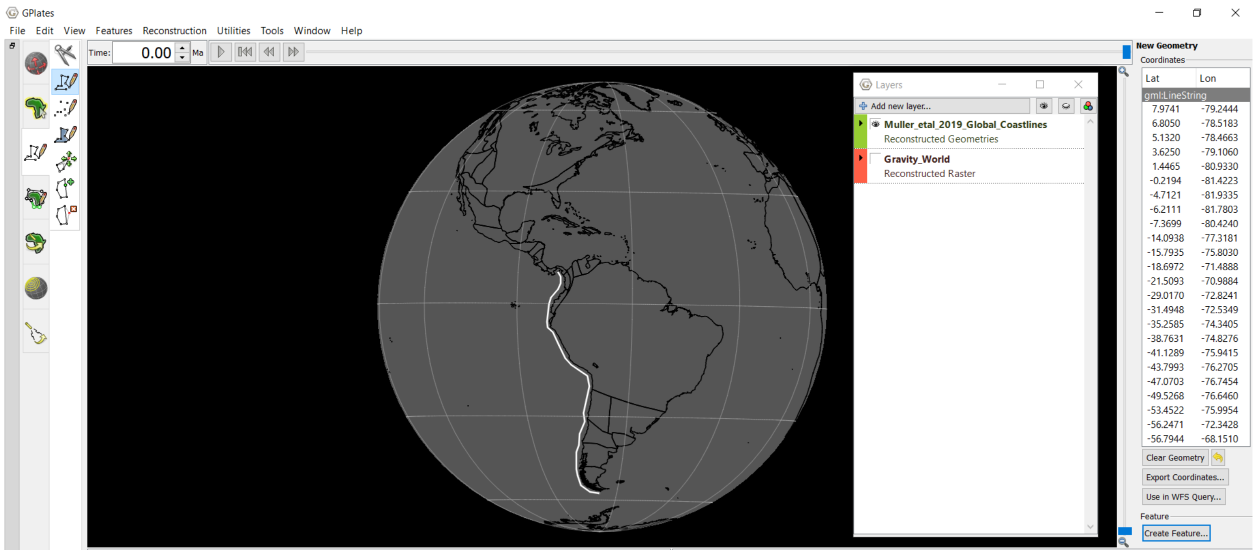


Figure 5. South American subduction zone (white line).

You will notice that the coordinates of each point can be seen in the New Geometry Table on the right hand side of the globe (Figures 5 and 6).

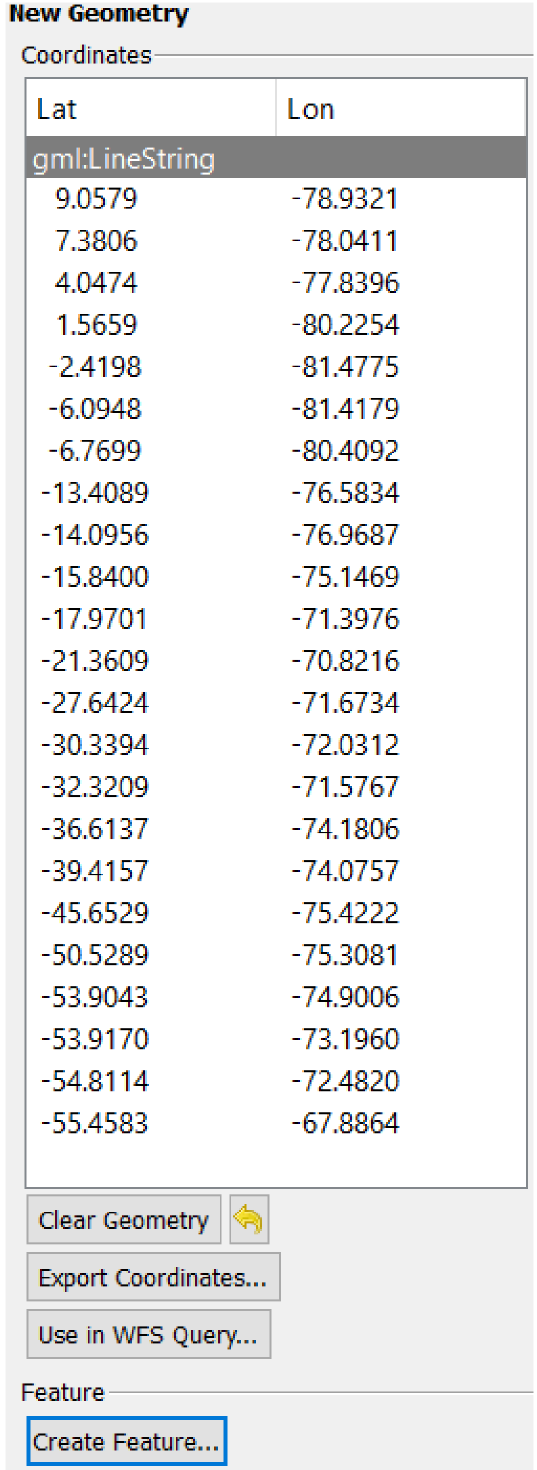
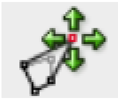
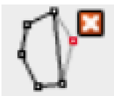


Figure 6. New Geometry table showing the coordinates of each participating point of the polyline.

If you don't like the shape of your polyline you can move the existing vertices, add new ones or delete them all together. These actions require the geometry editing tools from the Tool Palette.

 Move vertex - simply click and drag the point you wish to move to a new location.

 Insert vertex - click on the line (that connects the vertices) at the location that you wish to add the new vertex.

 Delete vertex – click on the point that you would like to remove.

Alternatively, if you wish to clear the whole polygon click the Clear button in the New Geometry table, situated below the column of polygon coordinates (Figure 6).

When you select one of these editing tools, the vertices along the polyline become highlighted ready for modification (Figure 5). Additionally, by hovering the cursor over one of the vertices, its coordinates become highlighted in the New Geometry table (Figure 7).

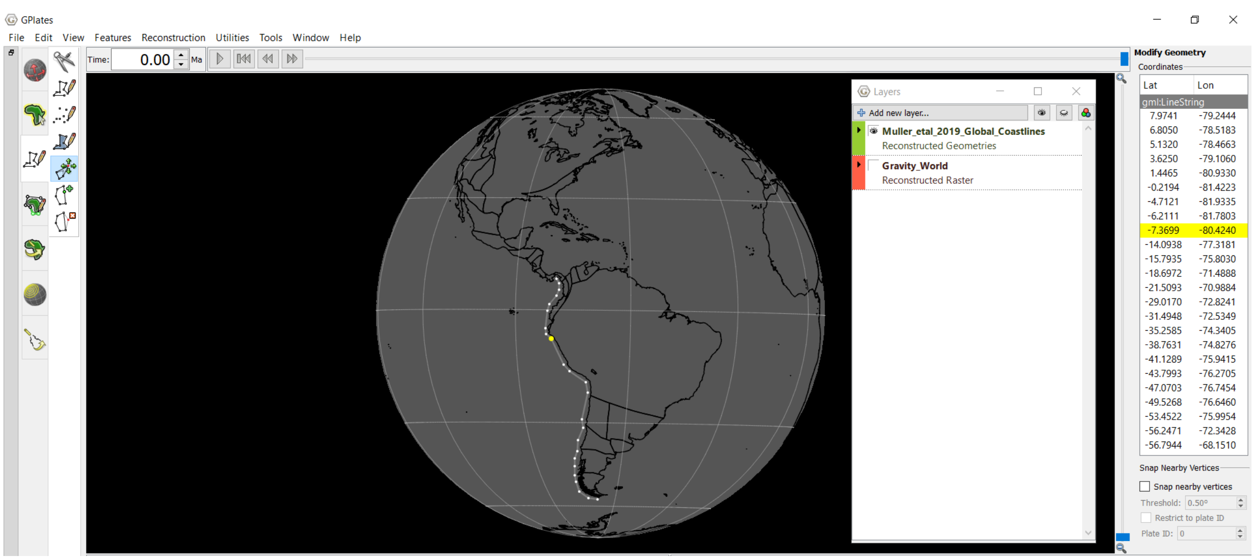
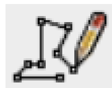


Figure 7. View of the main window while the cursor is hovering over one of the central

vertices (yellow).

Once you are happy with the shape and placement of your polygon you can export the geometry; create a file that contains the coordinates of these vertices. If you have edited the line you will need to click the Digitise New Polyline Geometry tool  again in order to bring up the 'Export Coordinates' option under the New Geometry table. We will export our data in the Generic Mapping Tools (GMT) format, which consists of a list of longitudes and latitudes.

3. Click Export Coordinates… (from the New Geometry table on the right side of the globe) and select the select the following options that appear in the Export Coordinates window:

a. Format: Generic Mapping Tools (GMT)

b. Coordinate order: Longitude, Latitude (by default GMT reads coordinates in this order)

c. Tick Include additional terminating points for polygon.

d. Export To: File

→ Export (Figure 8)

e. Select the destination and name of the file that you will save → Save

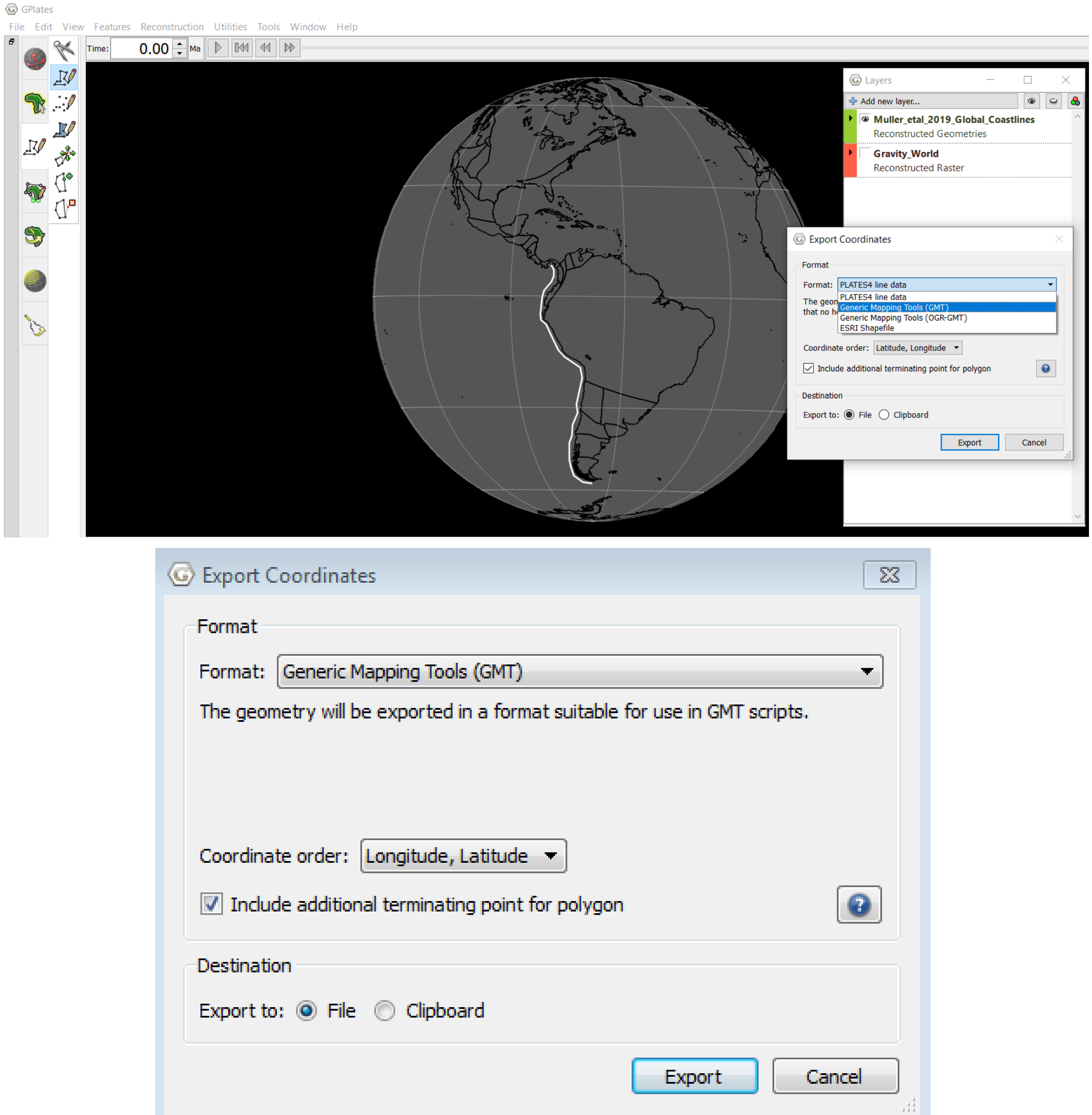
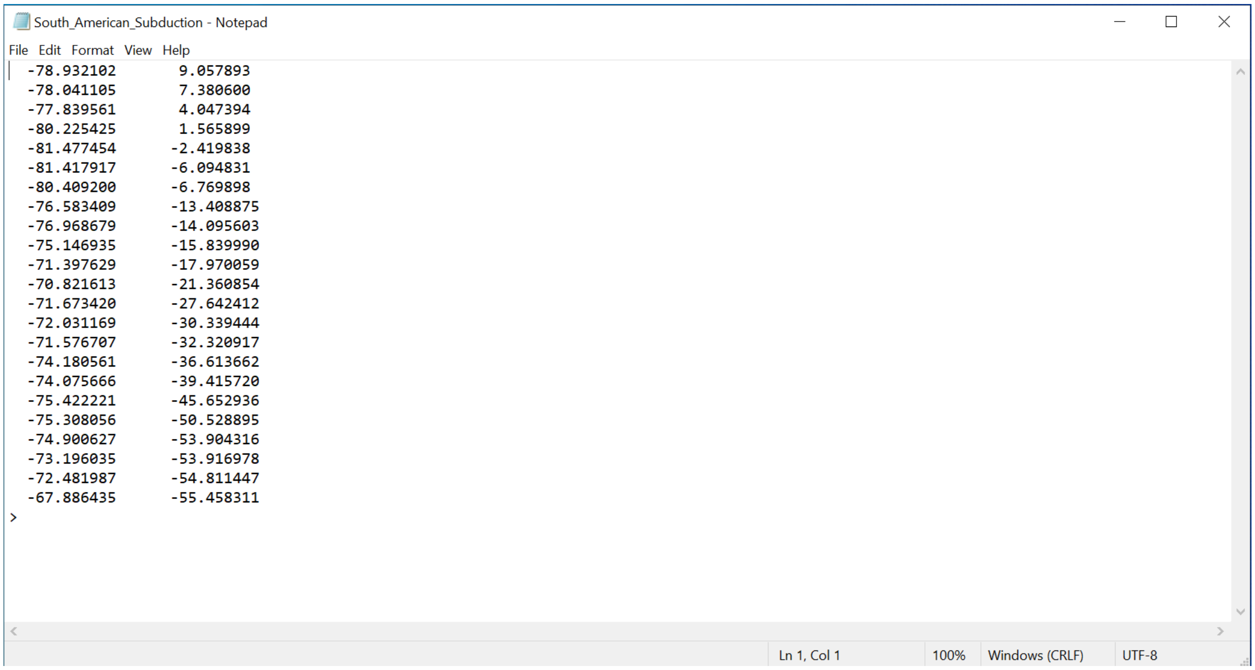


Figure 8. The Export Coordinates window, showing an example of exporting in the GMT file format.

Navigate to the file that you just created so that you can see what the output looks like. You can open it using Notepad on Windows, or some other simple text editor. (In some cases you may need to “right click” the file and select the app with which to open it.) You should see a simple list of longitudes and latitudes with a ‘>’ sign beneath the last longitude entry (Figure 8). If you wanted to you could now plot these data in GMT.



South_American_Subduction - Notepad

File Edit Format View Help

```
 -78.932102       9.057893
 -78.041105       7.380600
 -77.839561       4.047394
 -80.225425       1.565899
 -81.477454      -2.419838
 -81.417917      -6.094831
 -80.409200      -6.769898
 -76.583409      -13.408875
 -76.968679      -14.095603
 -75.146935      -15.839990
 -71.397629      -17.970059
 -70.821613      -21.360854
 -71.673420      -27.642412
 -72.031169      -30.339444
 -71.576707      -32.320917
 -74.180561      -36.613662
 -74.075666      -39.415720
 -75.422221      -45.652936
 -75.308056      -50.528895
 -74.900627      -53.904316
 -73.196035      -53.916978
 -72.481987      -54.811447
 -67.886435      -55.458311
>
```

Ln 1, Col 1 | 100% | Windows (CRLF) | UTF-8

Figure 9. GMT formatted file containing the coordinates of the South American subduction zone.

Now, in order to reconstruct our subduction zone and continue to be able to load it into GPlates we need to "create" the feature and add it to a feature collection – either a new or existing one.

4. Create Feature… (below the New Geometry table)

The Create Feature window will now appear in the centre of the screen. The first screen will enable you to choose the feature type (Figure 10).

5. gpml:SubductionZone → Next

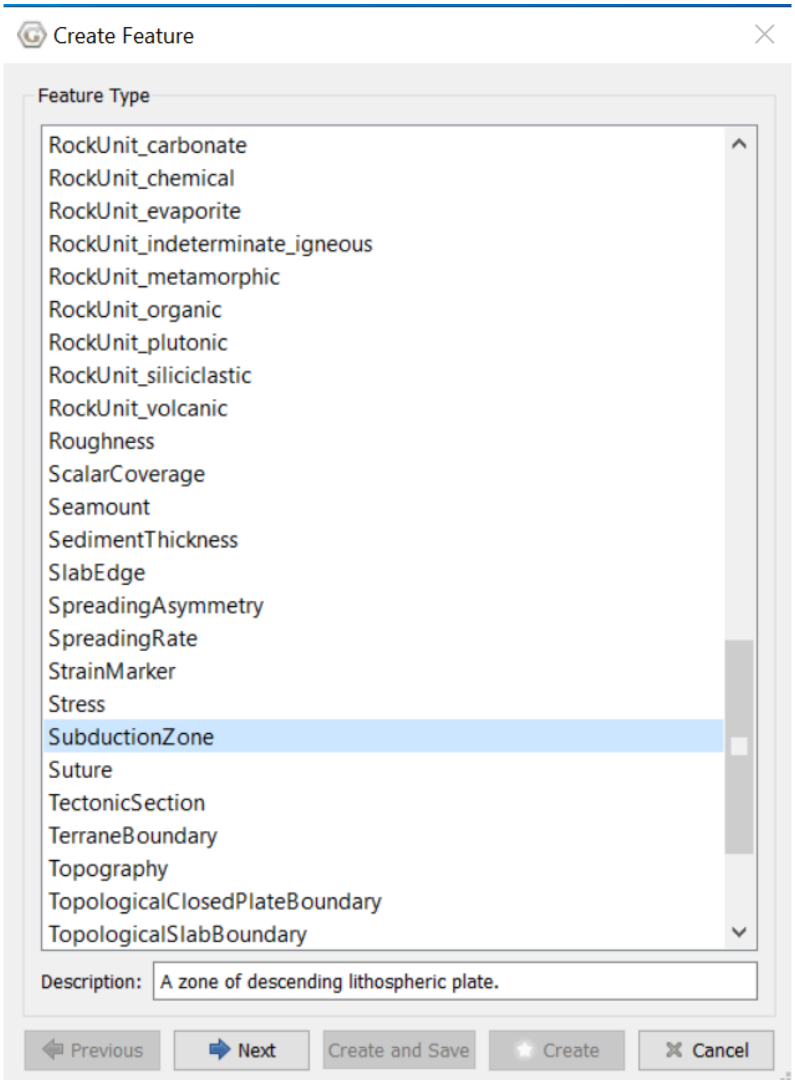


Figure 10. Selecting feature type from the Create Feature window.

The next Create Feature window enables you to assign some basic properties to your feature.

6. Assign geometry to property: Centre line (leave the default option)

*What Plate ID should be assigned to your subduction zone?

The Plate ID will dictate how the feature reconstructs through time. That is, how it will rotate relative to other plates. Ask yourself: What plate should my subduction zone be attached to? For now we will leave the ‘conjugate Plate

ID’ as "None."

You want your subduction zone to be attached to South America (201).

7. Plate ID: 201 → Begin (time of appearance): 300 Ma* → End (time of disappearance): tick the Distant Future box → Name: South America SZ (or a name that you think best describes your feature) → (Figure 11) → Next → Next.

*We will assign a Begin age of 300 Ma as this defines the limit of EarthByte’s current plate model and the subduction zone has been active since at least this time.

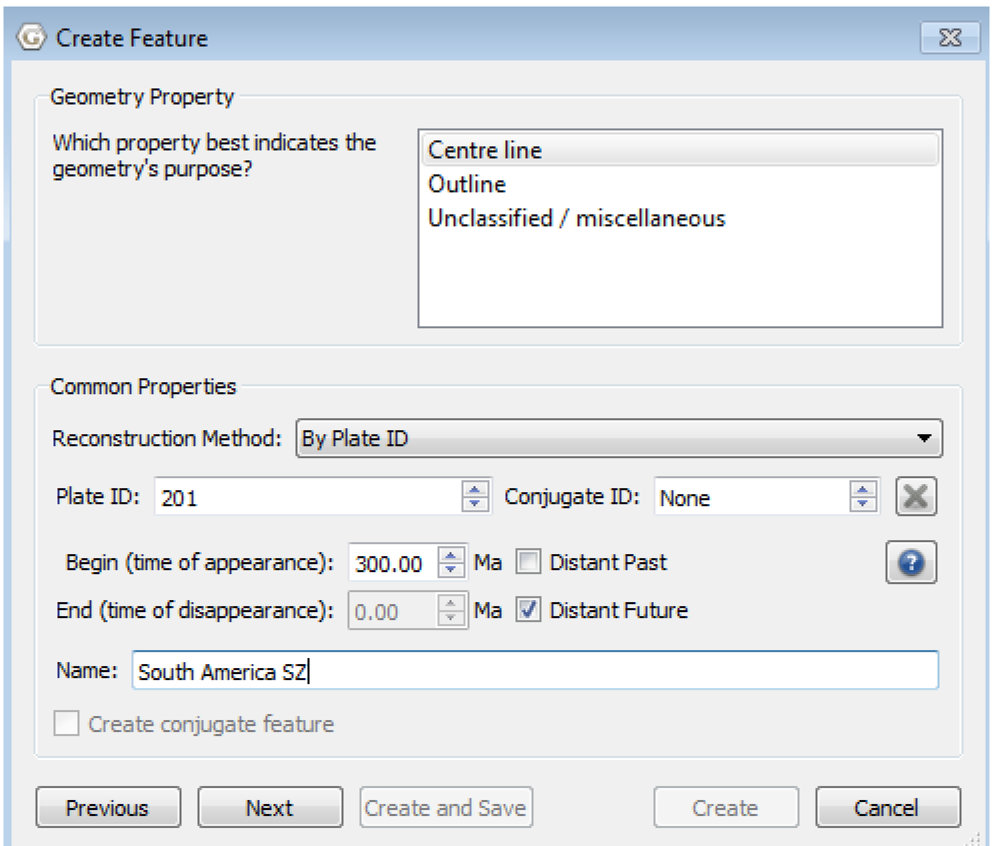


Figure 11. Assigning basic properties to a feature using the Create Feature window.

Now you are ready to add your feature to a feature collection. You may add features to existing or new feature collections. We will add our subduction zone to a new feature collection.

8. < Create a new Feature Collection > → Create (Figure 12)

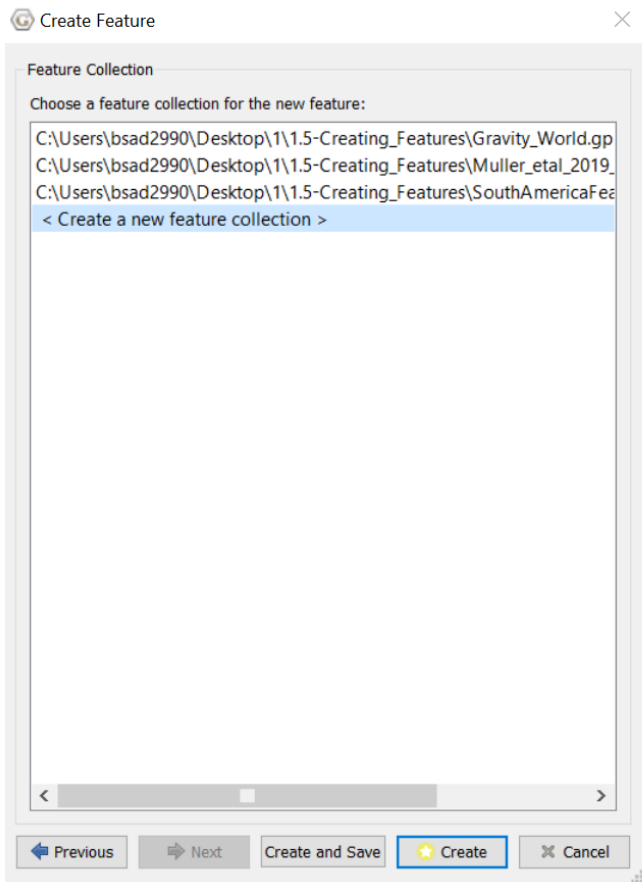


Figure 12. New features can be added to existing or new feature collections.

This creates an unsaved feature collection which you must now save with a new name, using the Manage Feature Collections window.

Open the Manage Feature Collections window and locate your new Feature Collection which should be highlighted in yellow.

9. Choose the ‘Save As’ option  in the Actions column (far right) → choose an appropriate name for your feature collection e.g., SouthAmericaFeatures → keep the GPlates Markup Language format (gpml) → Save (Figure 13)

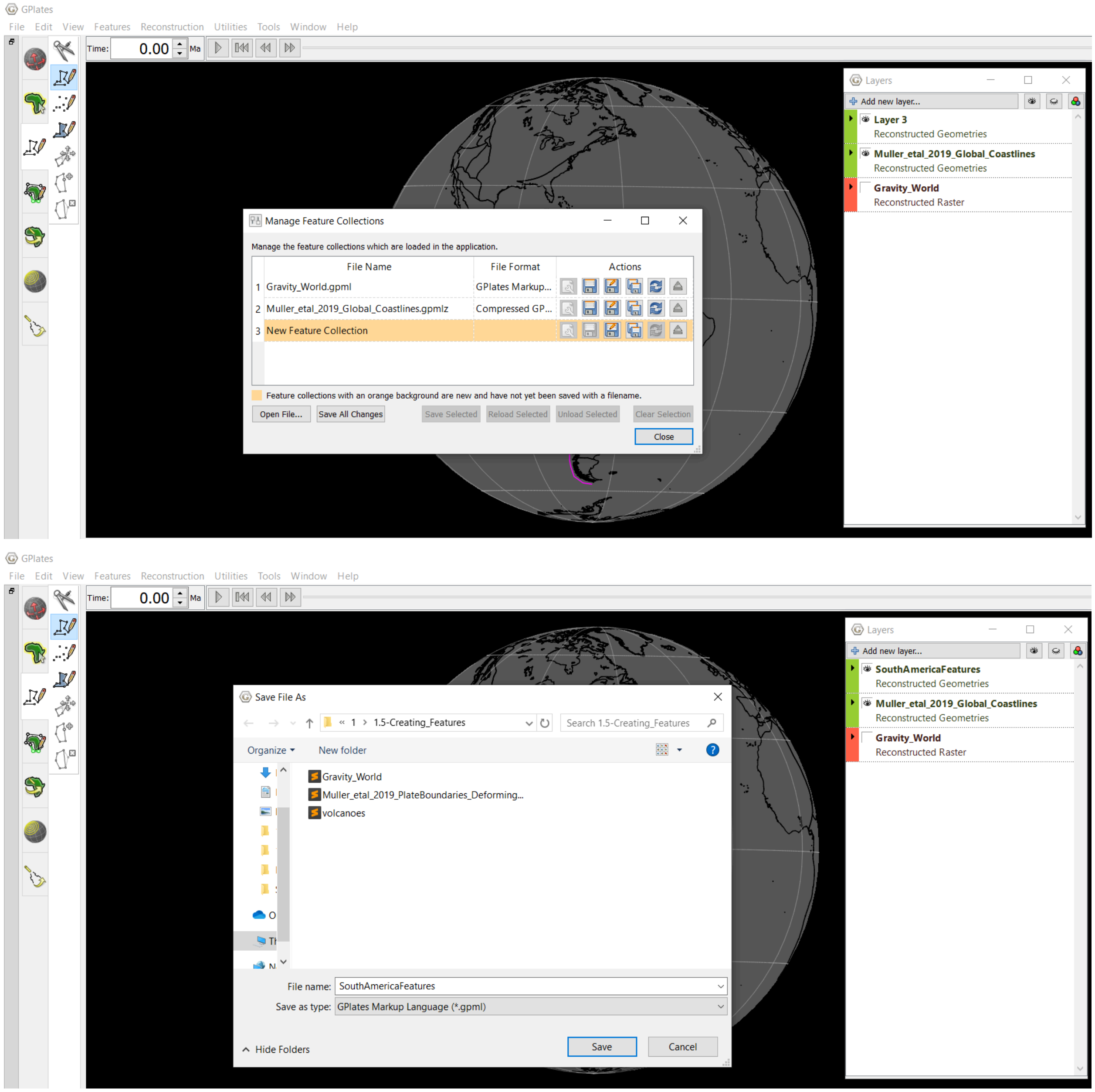


Figure 13. Saving a new feature collection.

Now that your feature has been created use the Choose Feature tool  to query your subduction zone. It contains all the property information you provided (Figure 14).

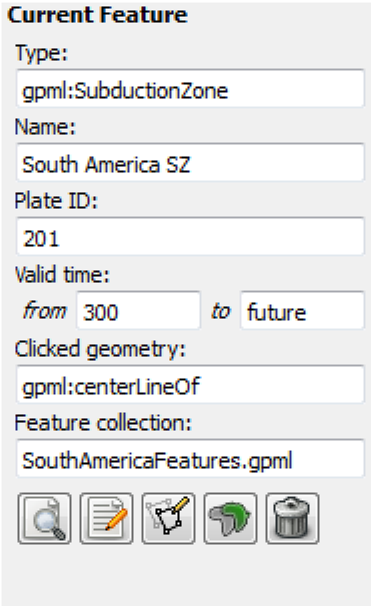


Figure 14. Feature information for the newly created South America subduction zone.

We will now load a rotation file into GPlates and reconstruct our subduction zone through time. This will show you that the subduction zone is indeed staying attached to South America, as dictated by the assigned plate ID of 201.

10. File → Manage Feature Collections → Open File… → locate and select **Muller_etal_2019_CombinedRotations.rot** from the '1.4-Creating_Features' data bundle → Open

Now that you have loaded in the rotation file, use the Time and/or Animation controls (located above the globe in the main window – Figure 15) to reconstruct South America through time. You should notice that your subduction zone is moving fixed to the continent.

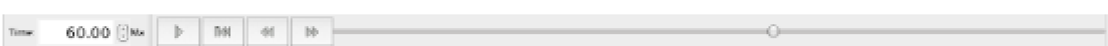


Figure 15. Time and Animation controls in the main window. You may use these controls to manually enter a time, move the slider to reconstruct the globe or animate from a selected time to the present.

Exercise 3 – Cookie Cutting

GPlates allows "cookie cutting", that is, data can be clipped using polygon geometries whereby a subset of the polygon's features is copied over to the clipped data. For example, plate IDs can be assigned to a data set using a plate-polygon geometries, the plate IDs will then be assigned according to which plate polygon the individual features are enclosed by. The polygons that can be used to intersect the data may be in the form of non-topological features (static polygons) or 'TopologicalClosedPlateBoundary' features (dynamically closing polygons). Two plate polygon files (that outline tectonic plates) are currently available to the user: (1) a set of static (present-day) plate polygons and (2) a set of dynamically closing plate polygons (See below).

1. Muller et al. (2019) Static Polygon Files (**Muller_etal_2019_Global_StaticPlatePolygons.gpmlz**)

These polygons represent the boundaries of present day plates as well as presently preserved palaeo-plate boundaries. The polygons are broken up by age over the ocean floor based on the Müller et. al. (2019) present day age grid. Plates that have been created or destroyed in the past are not incorporated into this model.

Static polygons allow plate IDs to be assigned to other sets of data and to reconstruct raster data. These polygons, and the set of isochrons defining the age of the ocean floor, are consistent with the grid of seafloor age described here.

This dataset is compatible with the EarthByte present day coastline file. The file can be loaded into GPlates, other GIS software (such as ArcGIS, PaleoGIS, Quantum GIS, GRASS GIS, SAGA GIS, etc.) as well as technical computing programs such as MATLAB.

2. Muller et al. (2019) Dynamic Polygon Files (**Muller_etal_2019_PlateBoundaries_DeformingNetworks.gpmlz**)

These polygons represent continuously closing plates from 250 Ma to the present. Unlike the present day polygons listed above, these polygons dynamically change shape as the plate boundaries evolve. Plates that once existed in the past are incorporated.

A topological network of plate polygons with dynamic geometries are provided for the last 200 Ma. These data are provided in gpml (GPlates native) format and so require GPlates to be effectively visualised. Further information of this collection of data can be found here. The Dynamic polygons are consistent with Muller et al. 2019.

This dataset is best used for any global plate kinematic analysis, as boundary layer input into mantle convection software such as CitcomS and can be used to assign plate identifications to your dataset. The plate polygons are available as GPML (GPlates Markup Language) files, which can be manipulated and translated to other formats with GPlates. The data are also available as static polygons in 1 Myr intervals.

We will now assign plate IDs to a global set of volcanoes using present-day plate polygons. Let's first turn off the gravity raster and the feature collection containing your digitised subduction zone from the previous exercise

11. In the Layers window, turn the visibility of the gravity raster and the 'SouthAmericaFeatures' layer off by clicking on the 'Eye' icon.

12. File → Open Feature Collection… → locate and select **volcanoes.gpml** from the '1.5-Creating_Features' data bundle → Open

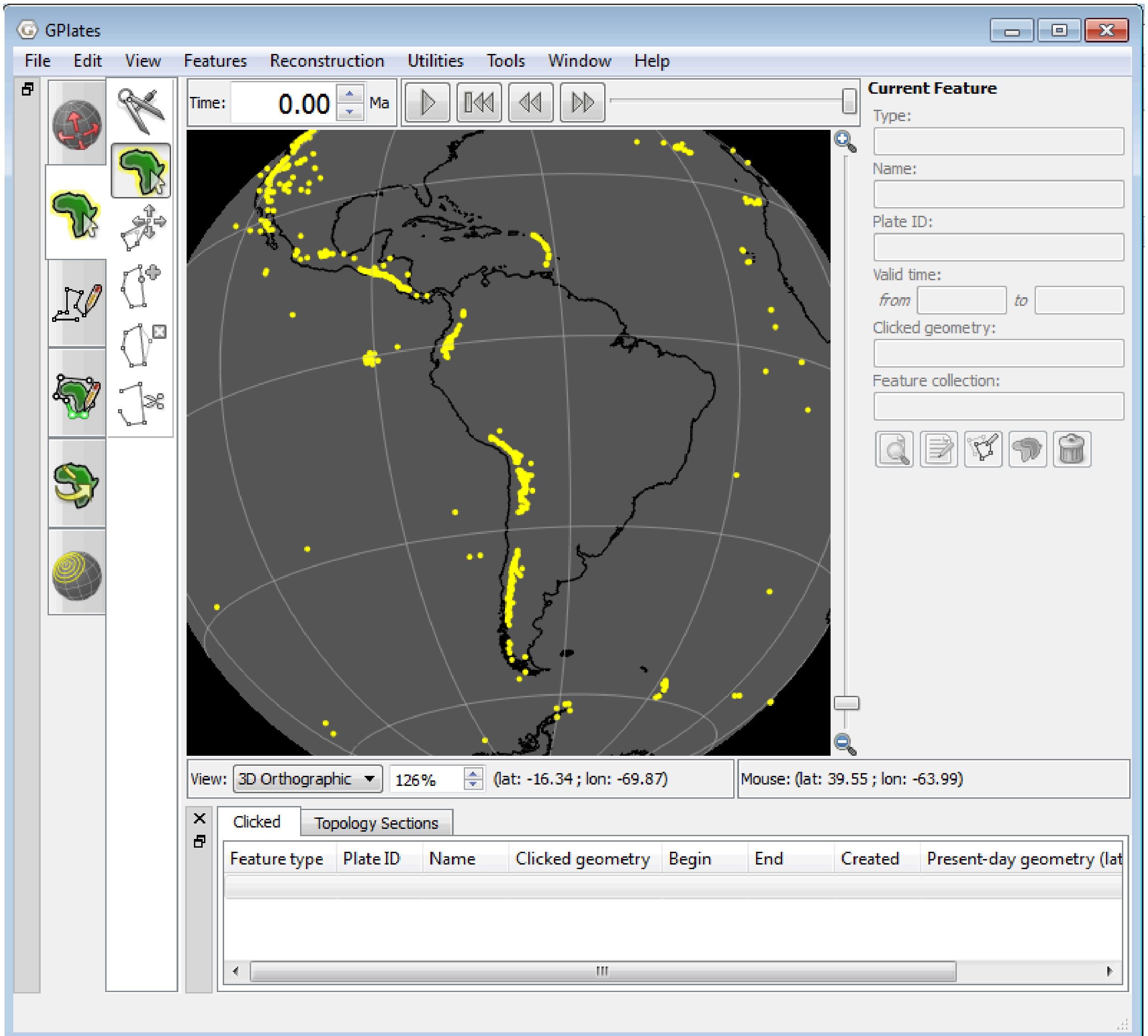


Figure 16. View of South America showing volcano locations (yellow).

You will notice that all the volcanoes are coloured yellow. If you query one of the volcanoes you will see that it does not have a plate ID. We will use cookie cutting to assign plate IDs.

Finally let's load a plate polygon file.

13. File → Manage Feature Collections → Open file… → select **Muller_etal_2019_Global_StaticPlatePolygons.gpmlz** from the data bundle → Open (Figure 17)

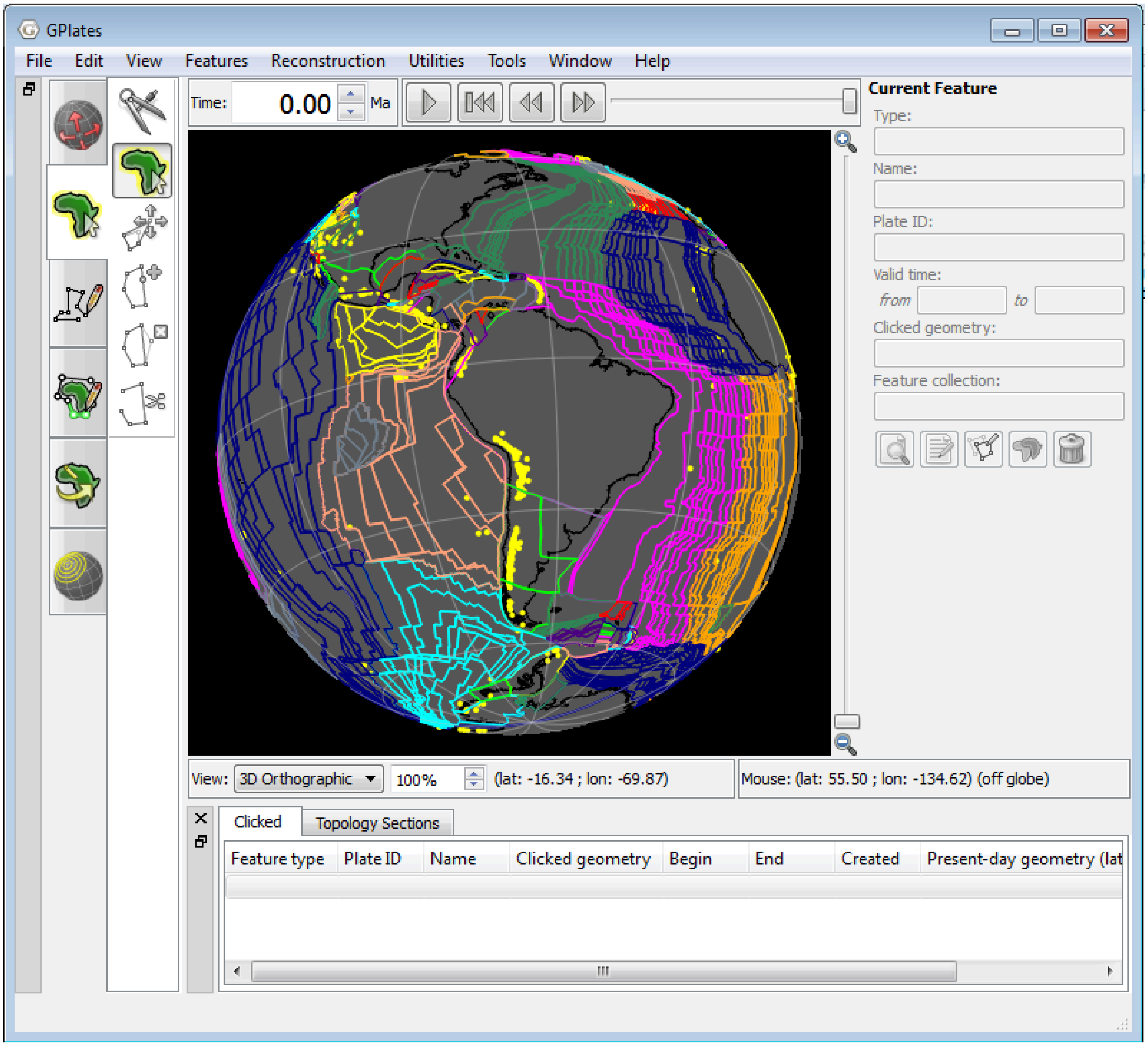


Figure 17. Volcano data and the Seton et al. (2012) set of static plate polygons are displayed on the globe.

14. Features → Assign Plate IDs… (Figure 19)

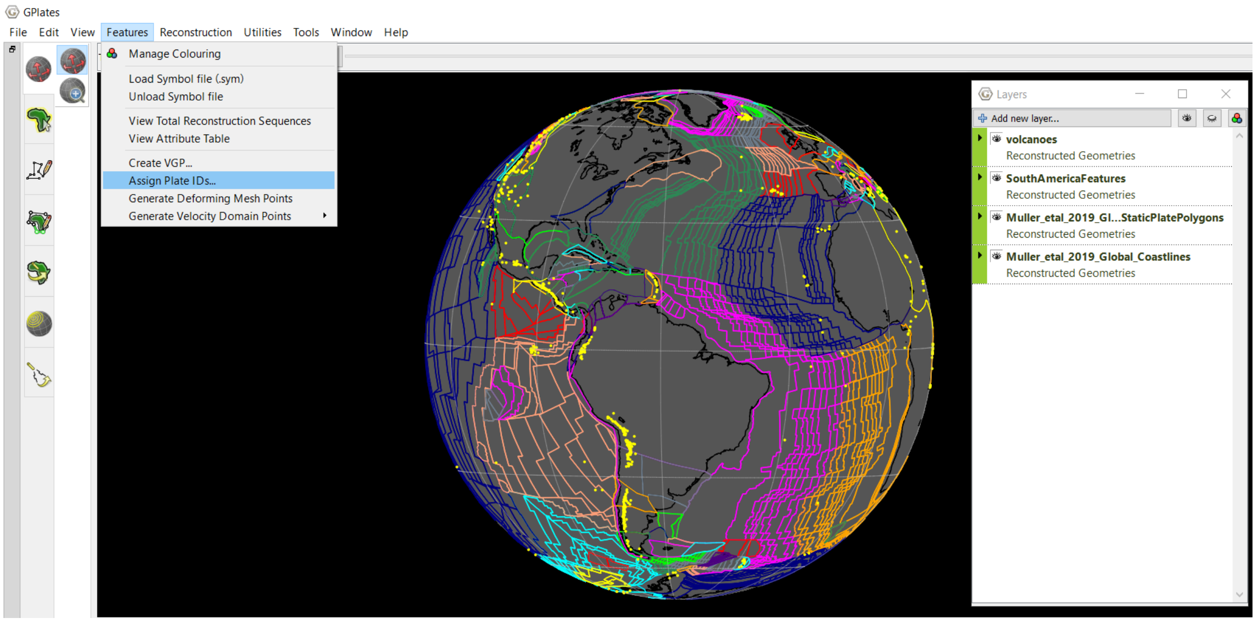


Figure 18. "Cookie cutting" is achieved using the Assign Plate IDs window.

15. In the dialog that opens, tick the plate polygon file that you wish to you to cut the volcanoes data → Next (Figure 19)

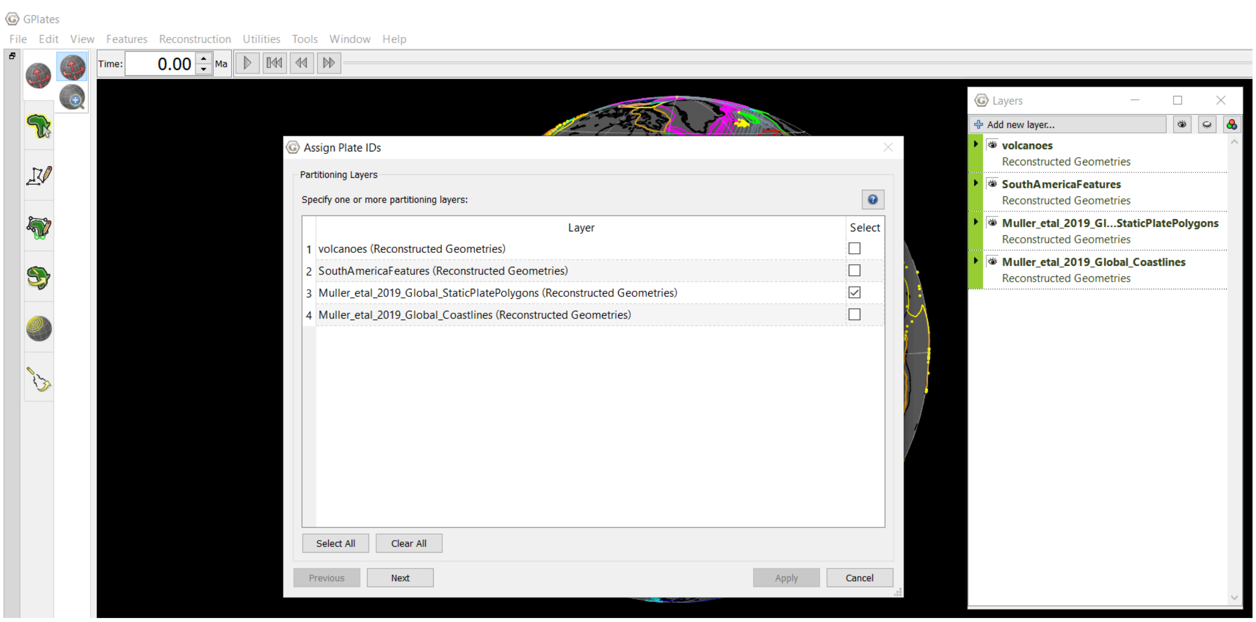


Figure 19. The first step in cookie cutting is to select the plate polygon file you wish to use to cut the data.

16. Now select the file you wish to cookie cut, i.e. the volcanoes file → Next

(Figure 20)

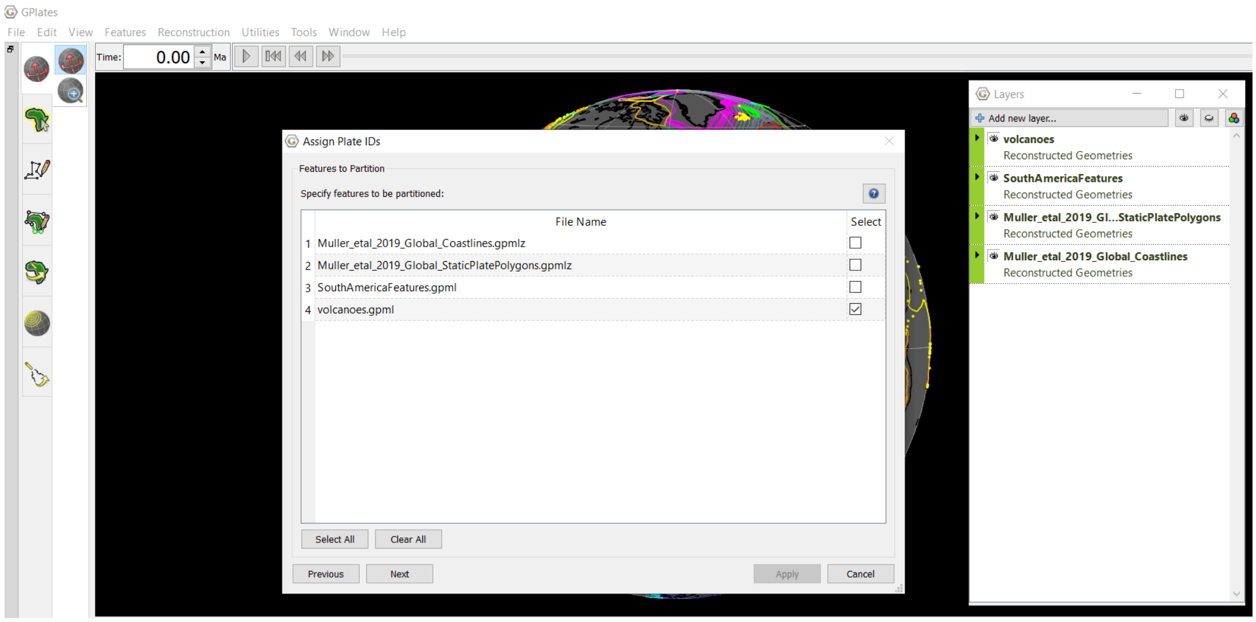


Figure 20. The second step in cookie cutting data is choosing the dataset to cut.

17. In the final window you must choose the cookie cutting specifications. We are only interested in cutting our data set according to present-day plate boundaries, so choose Present Day for Reconstruction Time (top box). In the Feature Partitioning box (middle) select the cookie cutting option. We only wish to copy over Plate IDs from the plate polygon file, so in the final box only select Reconstruction plate id → Apply (Figure 21)

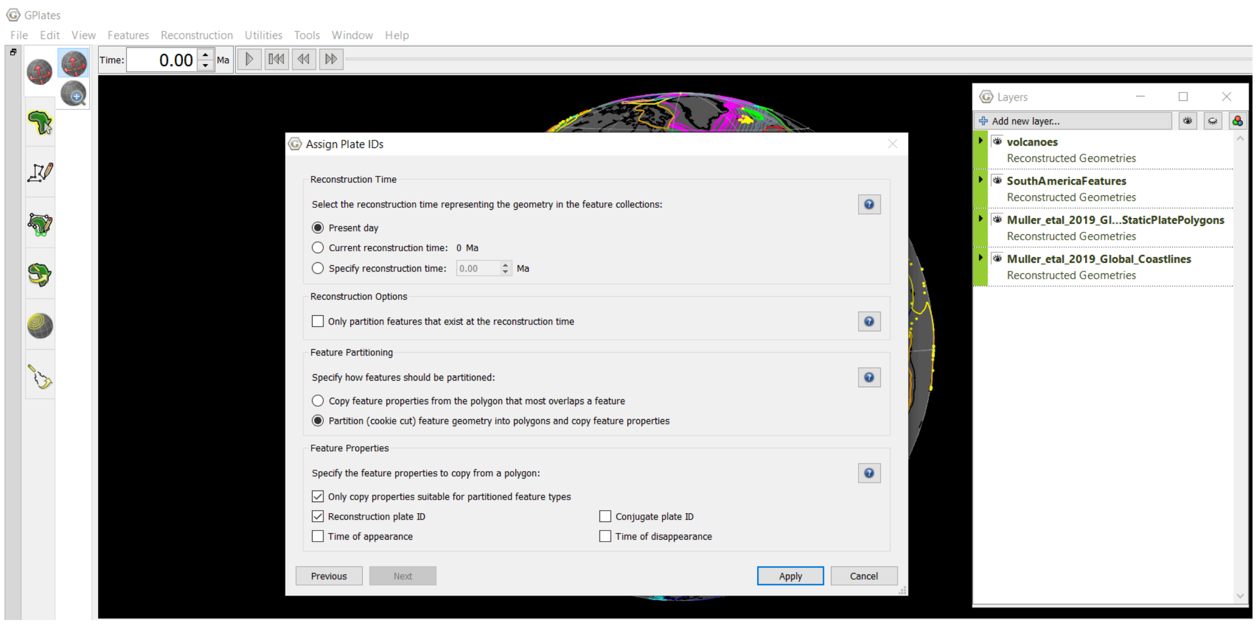


Figure 21. Specifying how you wish to clip your data.

Once GPlates has finished partitioning your data, you will see that the volcanoes have now been assigned plate IDs, and therefore they are coloured according to the plate that belong to (Figure 22).

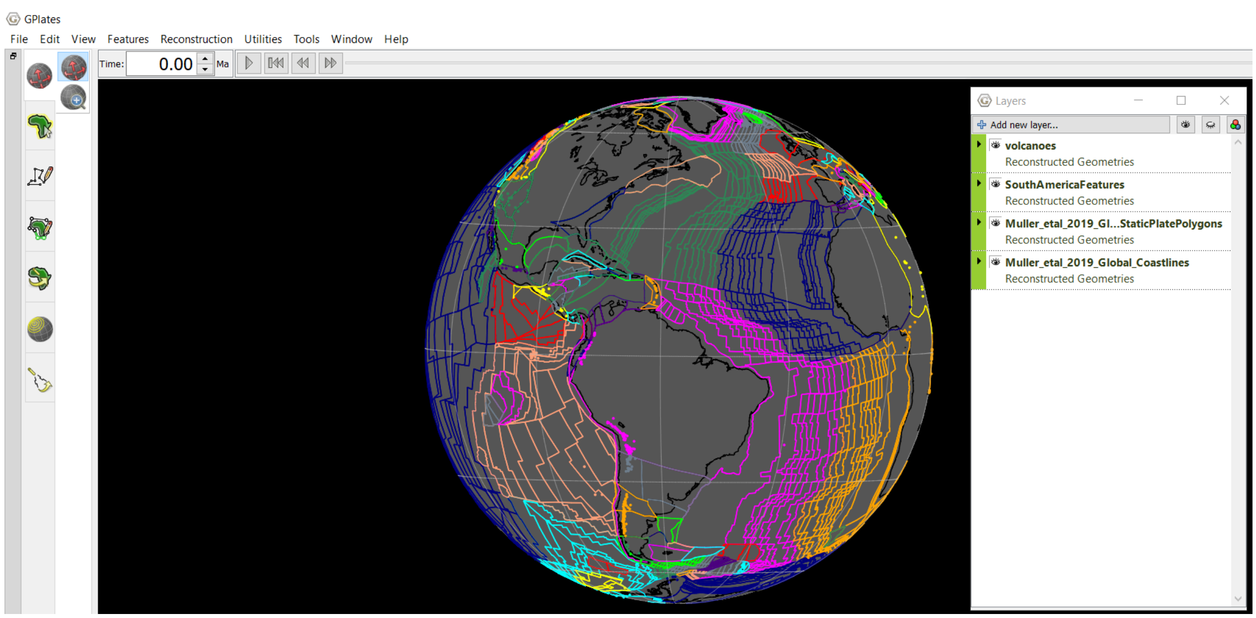


Figure 22. Volcanoes now posse plate IDs as indicated by their colouring.

If you reconstruct the globe back through time you will see that the volcanoes move fixed to the plates that belong to. Notice the red Save error icon in the bottom right hand corner of the screen - remember that you must save your data file to preserve this plate ID assignment.

References

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. Fifty Years of Plate Tectonics: Then, Now, and Beyond.

Appendix

Importing Regional Rasters

In this exercise we will be importing a regional raster image showing gravity anomaly data. It extends from 100°E to 180°E, and 60°S to the equator.

1. File → Import → Import Raster… → locate and select Gravity_AUS.jpg in the Importing_Rasters data bundle → Open (Figure 23) → Next

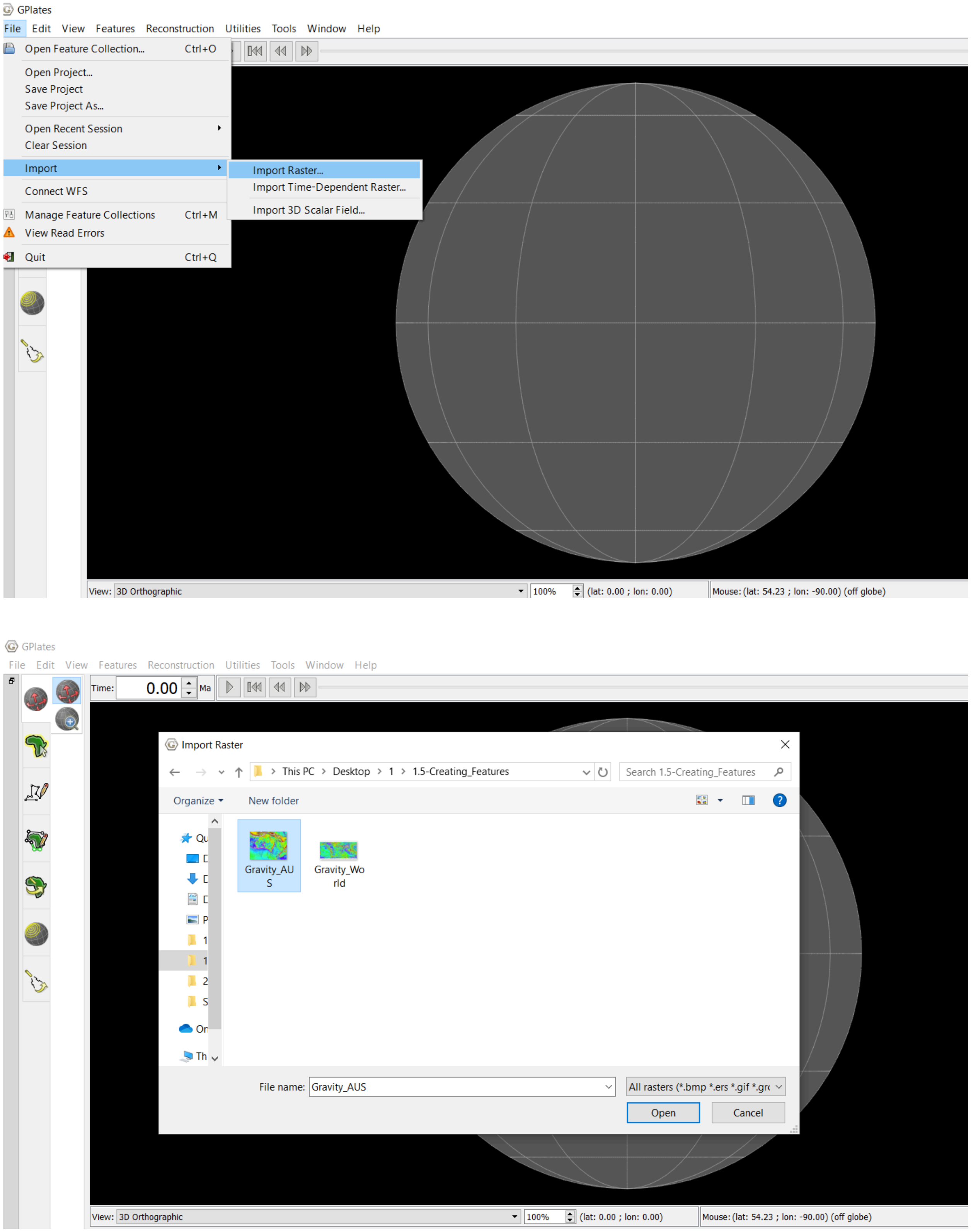


Figure 23. Remember - How to open a raster from the menu bar.

GPlates needs to be told the surface extent of your raster image, otherwise it will assume it is a global raster, or alternatively it will set its extent to that of the previous raster you had loaded into GPlates during the same session (Figure 24).

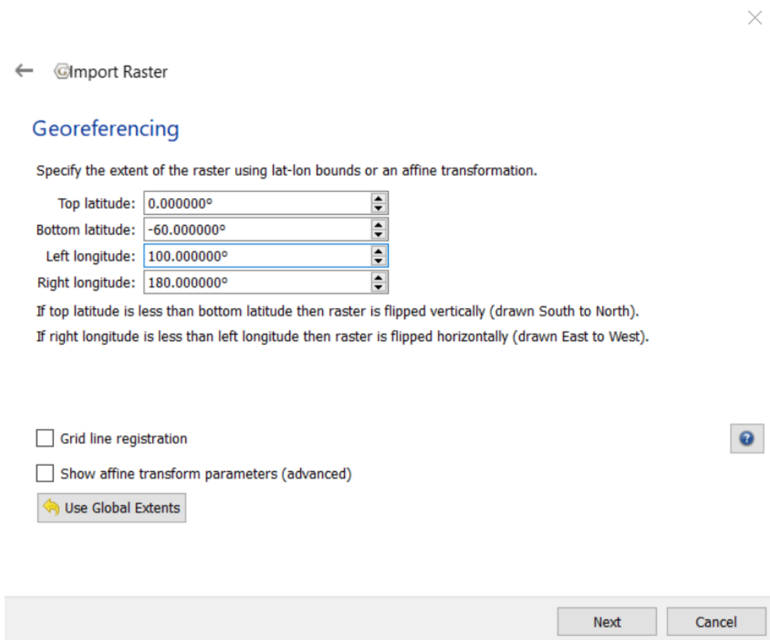


Figure 24. How to 'Set Raster Surface Extent…' following on from 'Import Raster'.

2. Next → Finish. Your raster will now be positioned correctly (Figure 25).

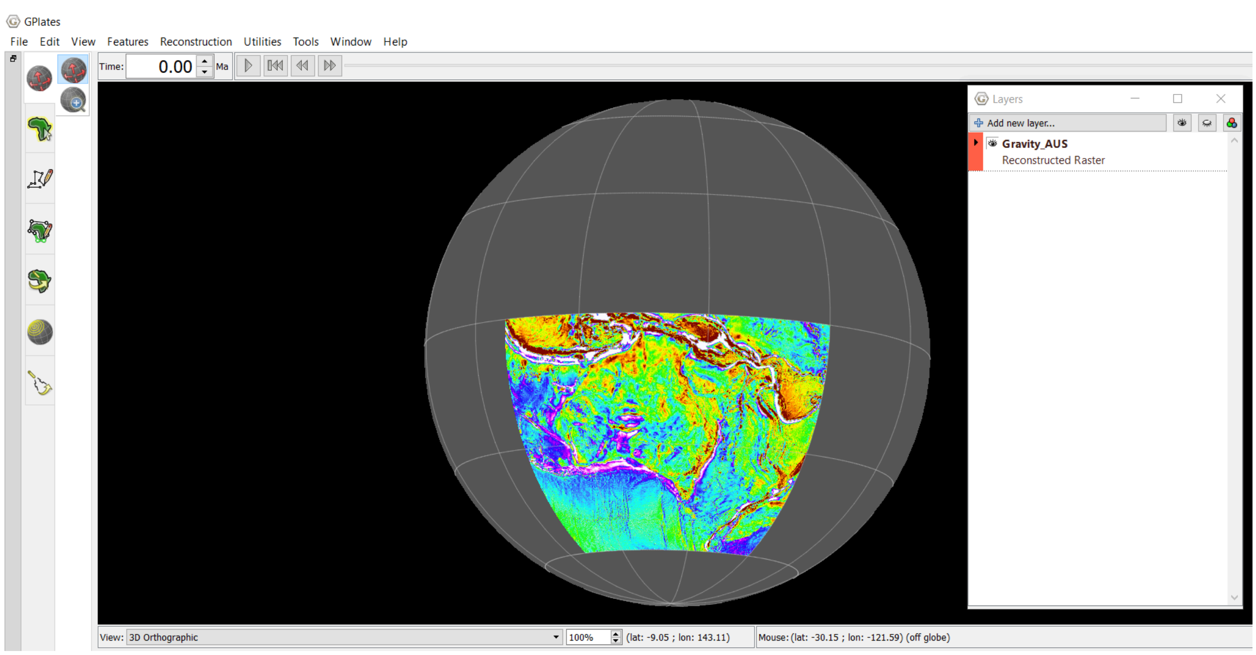


Figure 25. Correctly positioned gravity data for the Australian region.