Plotting Palaeogeographical Maps in R: an Example

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- Deep Time Maps (https://deeptimemaps.com)

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- Deep Time Maps (https://deeptimemaps.com)
- Paleomap Project (http://scotese.com)

GPlates (https://www.gplates.org/) reconstructs palaeogeography at arbitrary time.

Automatic map plotting

- ▶ NonaR/paleoMap (https://github.com/NonaR/paleoMap)

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- NonaR/paleoMap (https://github.com/NonaR/paleoMap)
- LunaSare/gplatesr (https://github.com/LunaSare/gplatesr)

GPlates Web Service

▶ https://gws.gplates.org/

```
coastline_gws_url <-
  "http://gws.gplates.org/reconstruct/coastlines/?time=155&
polygons_gws_url <-
  "http://gws.gplates.org/reconstruct/static_polygons/?time

kimmeridgian_coastlines <-
  rgdal::readOGR(coastline_gws_url) %>%
    broom::tidy()
kimmeridgian_polygons <-
  rgdal::readOGR(polygons_gws_url) %>%
    broom::tidy()
```
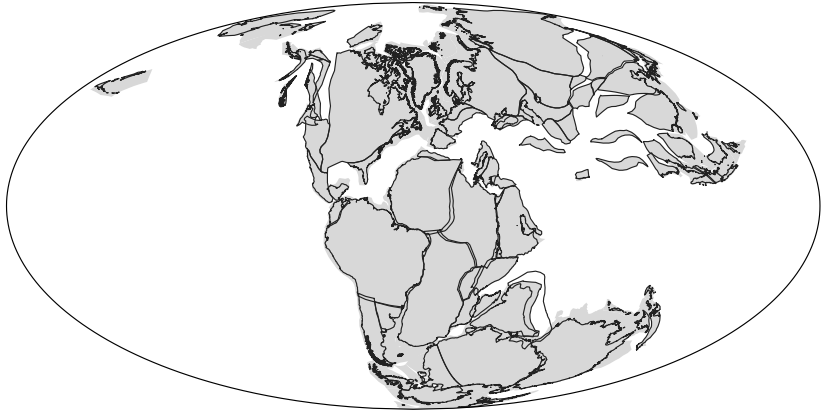
Figure 1: **Outlines of continental plates in the Kimmeridgian (155 Ma).** Data downloaded from the GPlates web service.

True Palaeogeographical Outlines

GPlates web service gives:

▶ outlines of plates from the model

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True Palaeogeographical Outlines

GPlates web service gives:

- ▶ outlines of plates from the model
- ▶ modern coastline outlines
- ▶ I want *ancient coastal outlines* instead

- ▶ GPlates software has more models
- ▶ Including Cao et al. (2017) palaeogeographical reconstructions

```r
map_layers <-
  c(
    "Land"              = "#FFD23A",
    "Mountain"          = "#FF8D51",
    "Shallow marine"    = "#45D8FF"
  )
```

1. Load data into GPlates
2. Export for desired
3. Load into R and plot

But showing the separate layers (land, mountain, shallow marine, ice) doesn't work easily with `geom_map`.

▶ have to add a new geom for every layer:

```
ggplot() +
  geom_map() +
  geom_map() +
  geom_map() ...
```

Instead I assign names to the layers (land, mountain...) and use
`geom_polygon` to plot.

NB:

- ▶ The data has 'groups' and 'subgroups' to close off the
  polygons, otherwise shapes may cross the whole globe.
- ▶ Some difficultly with the plotting order means arranging the
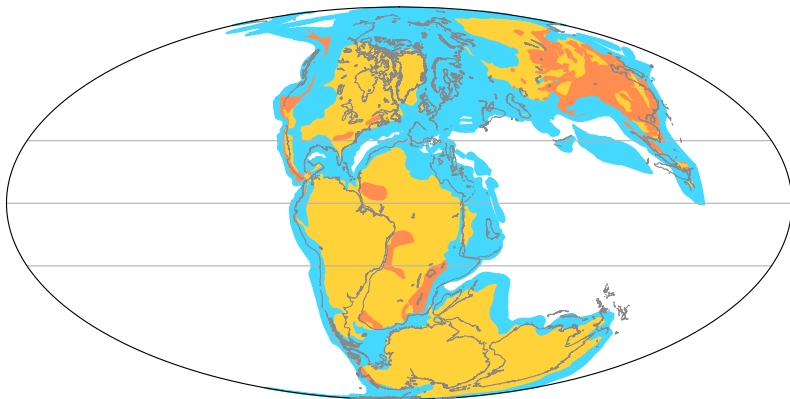 plotting order in be marine > land > mountain > ice – use
  factors.
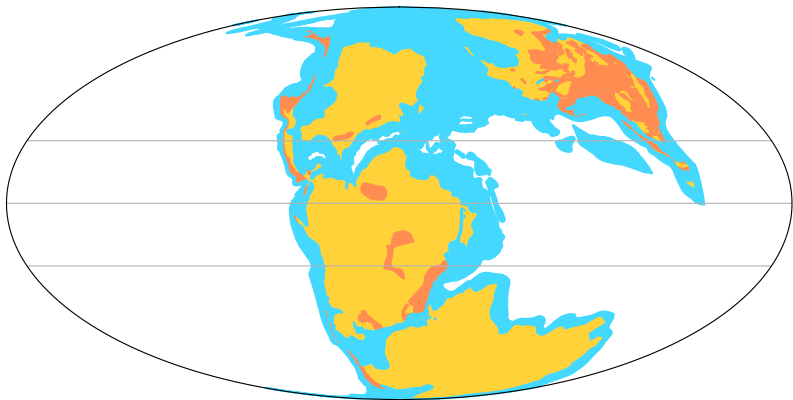
Palaeogeography ▮ Land ▮ Mountain ▮ Shallow marine

Figure 2: **Palaeogeography in the Kimmeridgian (155 Ma).**

I also wanted to add coastlines to show where modern countries are, but not the full plates from the web service.

- ▶ use coastlines reconstructed polylines

Figure 3: **Palaeogeography in the Kimmeridgian (155 Ma).** Outlines of modern coastlines (where known) are included in grey.

Add Fossil Occurrences
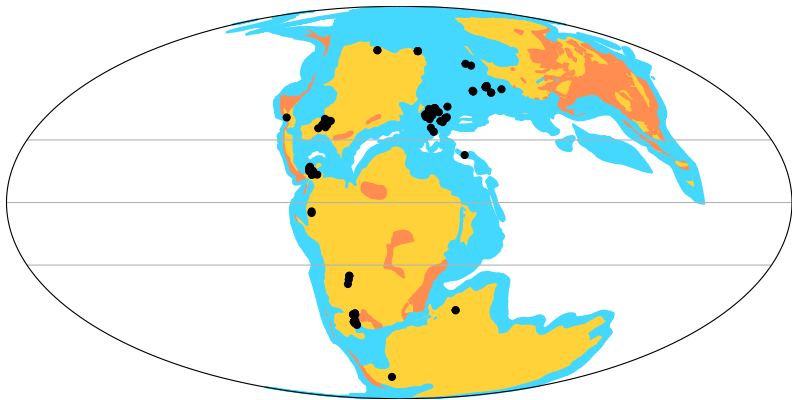
Now to add some fossil occurrences.

Of course it's ichthyosaurs, because I have no imagination:

- ▶ Callovian–Tithonian (166-145 Ma)
- ▶ all levels, taxonomy – no filtering

```
pbdb_url <-
  "https://paleobiodb.org/data1.2/occs/list.csv?base_name=1

occ_ichthyosaurs <-
  read_csv(pbdb_url)
```

Use `geom_point` to overlay this on the base map.

Figure 4: **Occurrences of ichthyosaurs from the Callovian–Tithonian.** Palaeogeographical map shows the distribution of land in the Kimmeridgian (155 Ma).

Palaeogeography   Land   Mountain   Shallow marine

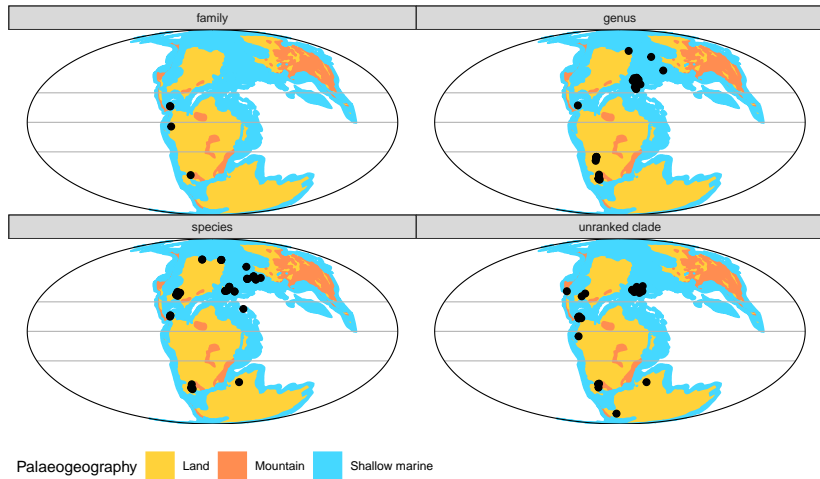These plots can also be split automagically using *facets.*

Figure 5: **Occurrences of ichthyosaurs in the Callovian–Tithonia separated by identified rank.** Palaeogeographical maps shows distribution of land in the Kimmeridgian (155 Ma).