

# <sup>1</sup> TopoChronia: A QGIS plugin for the creation of fully quantified palaeogeographic maps

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## Software

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## <sup>7</sup> Summary

<sup>8</sup> Reconstructing the palaeogeography and palaeotopography of the Earth has been a challenge  
<sup>9</sup> since the advent of the plate tectonics theory in the 1960s. With the development of  
<sup>10</sup> geographic information systems (GIS), many plate tectonics models have been created and  
<sup>11</sup> allowed researchers to reconstruct the movements of plates back in time (up to 1 billion years  
<sup>12</sup> for some models), based on geological evidence found in the present-day Earth.

<sup>13</sup> We present TopoChronia, a QGIS plugin that converts input data from plate tectonic models  
<sup>14</sup> into quantified and synthetic topography. This plugin is optimized to work with the PANALESIS  
<sup>15</sup> model, because it is the only one currently providing sufficient information in terms of geological  
<sup>16</sup> features to reconstruct a fully quantified topography.

## <sup>17</sup> Statement of need

<sup>18</sup> Most of the plate tectonic models and reconstructions use the standalone GPlates software  
<sup>19</sup> ([Gurnis et al., 2012](#)), which allows users to move plates in time steps and export geospatial data  
<sup>20</sup> layers. These layers can later be used in GIS software, such as the QGIS plugin TerraAntiqua  
<sup>21</sup> ([Aminov et al., 2023](#)), to reconstruct palaeotopography. Other models such as PANALESIS  
<sup>22</sup> ([Vérard, 2019](#)), are created and have processing functionalities that use commercial GIS  
<sup>23</sup> software (ArcGIS). A preliminary version of the code to generate topography of the Earth  
<sup>24</sup> based on PANALESIS past was developed as an ArcGIS extension, written in Visual Basic  
<sup>25</sup> .NET but never published. It is now fully updated as a QGIS plugin in Python.

<sup>26</sup> Constraining the palaeotopography is critical in fields such as climate and mantle dynamics  
<sup>27</sup> modelling, as the elevation of land and bathymetry of oceans are used to set the initial conditions  
<sup>28</sup> of models ([Bello et al., 2015; Ragon et al., 2023](#)). Quantifying the Earth's topography and  
<sup>29</sup> its evolution also allows to estimate the volume of rocks being eroded, for instance through  
<sup>30</sup> sediment discharge ([Lyster et al., 2020](#)), as weathering or silicate rocks is a key controlling  
<sup>31</sup> factor of CO<sub>2</sub> concentration in the atmosphere over geological time scales ([Macdonald et al.,](#)  
<sup>32</sup> [2019; Molnar & England, 1990](#)).

<sup>33</sup> The traditional method to create palaeotopographic maps ([Scotes, 2021](#)) is to use present-day  
<sup>34</sup> geological evidence, rotate them back to their past location and derive semi-quantitative  
<sup>35</sup> elevation typical of the environment they depict. Another method is to take the present-day  
<sup>36</sup> Earth topography of an area of interest as it is, and rotate it back in time to its past location  
<sup>37</sup> ([Aminov et al., 2023](#)). These methods have limitations, including that present-day features are  
<sup>38</sup> the result of millions of years of plate movements and cannot be "copy-pasted" as such, and  
<sup>39</sup> that one time step might not be coherent with the previous and next ones.

<sup>40</sup> We provide here an open-source plugin to reconstruct palaeotopography and palaeogeography  
<sup>41</sup> "from scratch" using the PANALESIS model, which is based on present-day geological evidence

and uses a dual-control approach, meaning that one reconstruction is based on the state of the Earth in the previous time-step, and influences the next step. Synthetic values for elevations are generated in nodes (points) related to geological settings and based on their present-day counterparts (Vérand, 2017). The output maps of TopoChronia can be used for modelling purposes and to reconstruct sea-level curves, over the Phanerozoic and beyond [Vérand et al. (2015);franziskakis2025a].

## Functionalities

TopoChronia is divided into three main parts:

### 1. Check Configuration

- Assess input data files (geometry, field names, values)
- Perform manual corrections if necessary, for wrongly named fields
- Define output folder path
- Extract available reconstruction ages

### 2. Create Node Grid

- Select input lines from plate model file
- Convert mid-oceanic ridge and isochron features and interpolate a preliminary raster for oceans
- Convert all other features (abandoned arcs, continents, cratons, lower subduction, upper subduction, passive margin wedges, continent sides, hot-spots, other margins, rifts, and collision zones)
- Merge all nodes and clean to avoid clashing between features

### 3. Interpolate to Raster

- Interpolate global raster
- Calculate oceanic volume under sea-level (elevation below 0m)
- Calculate required sea-level increase to match present-day oceanic volume
- Correct water load using Airy's model to adjust for sea-level increase
- Perform final raster interpolation with new sea-level

Each reconstruction will yield the following outputs:

- A palaeogeographic map in geotiff format with cylindrical equal-area projection (ESRI:54034): raster\_final\_filled\_{age}.tif
- A text file summarizing sea-level information **before** water load correction (initial volume and area, added water column, sea-level increase and subsidence): water\_load\_correction\_summary.txt
- A text file summarizing sea-level information **after** water load correction: water\_load\_correction\_summary\_f.txt
- All nodes both in EPSG:4326 and ESRI:54034 projections: all\_nodes\_{age}.geojson and reproj\_all\_nodes\_{age}.geojson
- All other processing products from line to points for each setting.

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