# Plate Tectonics

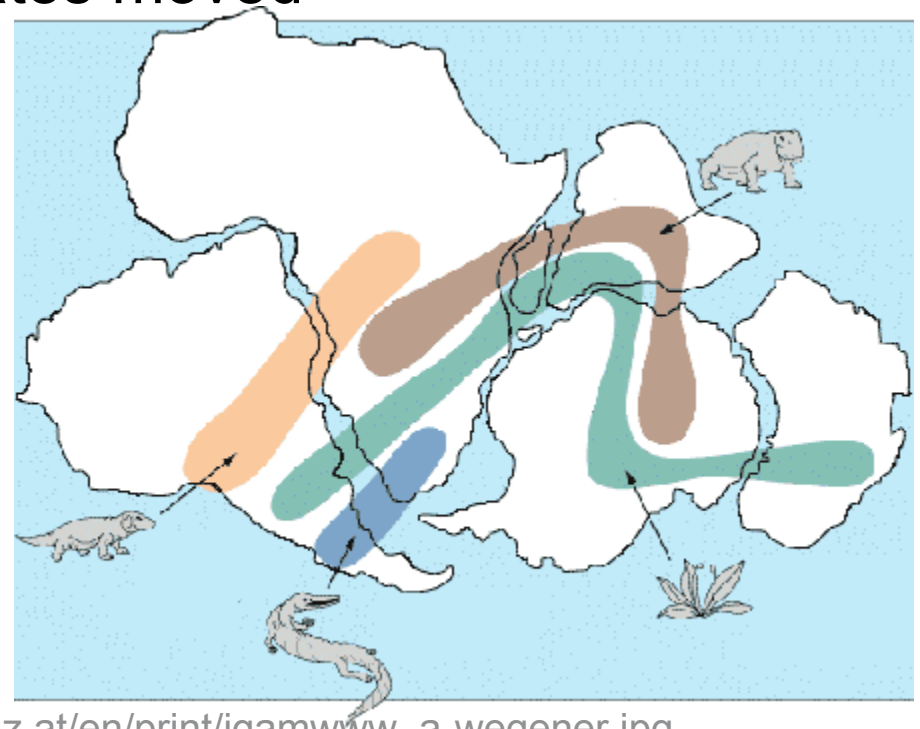
Jessica Kim
Ashley Kennard
Lindsey Stancliff

Research Mentor: Alex Copley
Professor Jean-Philippe Avouac

Friday, July 24, 2009
California Institute of Technology
Summer Research Connection

# Alfred Wegener

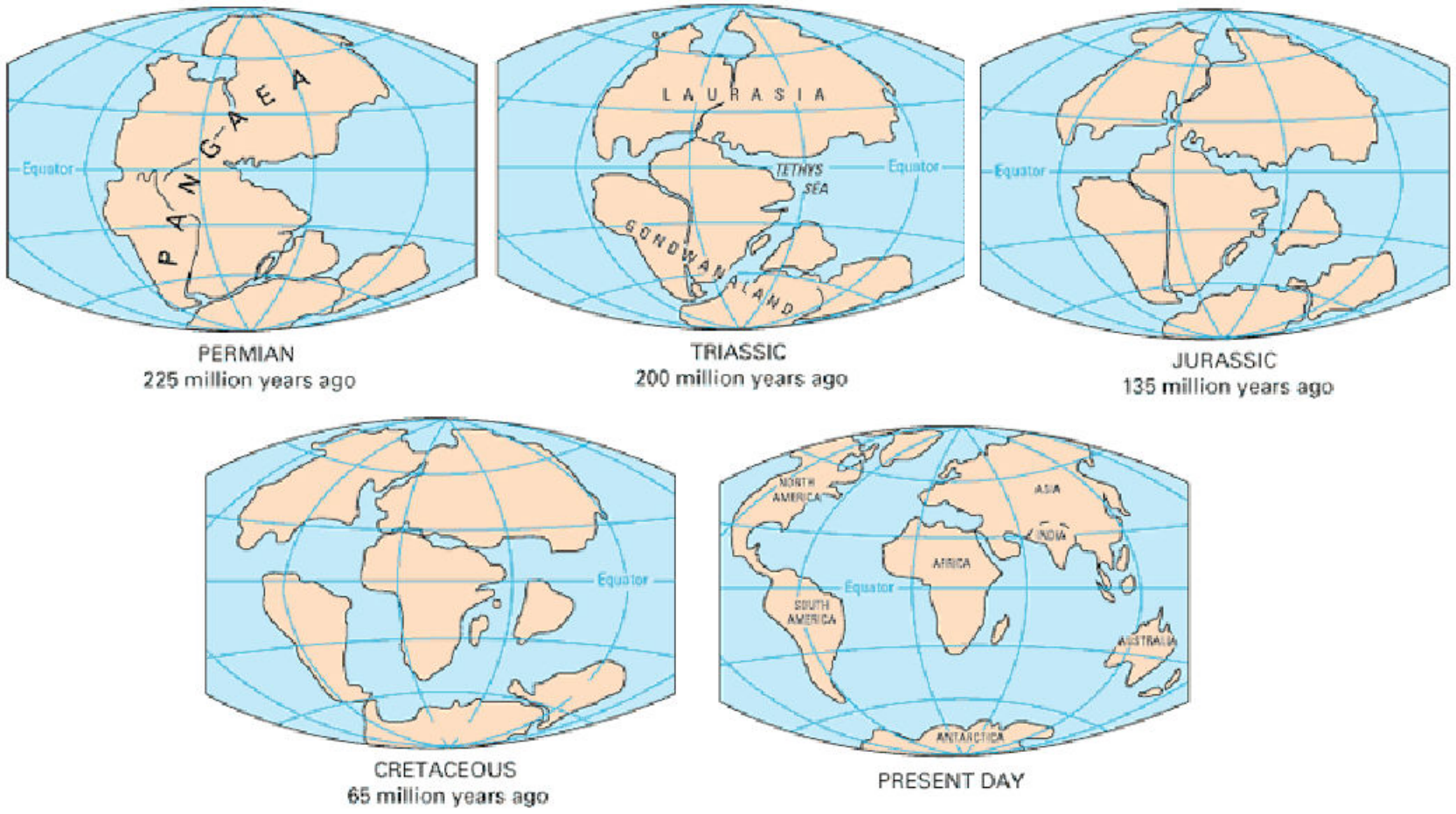
- Trained as an Arctic Meteorologist
- 1912, published the theory of "continental drift"
  - Common geology and fossils between continents
  - Could not find how the plates moved



Source of Alfred Wegener Image: http://www.uni-graz.at/en/print/igamwww_a-wegener.jpg

Source of Pangea Map: http://www.visionlearning.com/library/modules/mid65/Image/VLObject-829-021205011253.gif

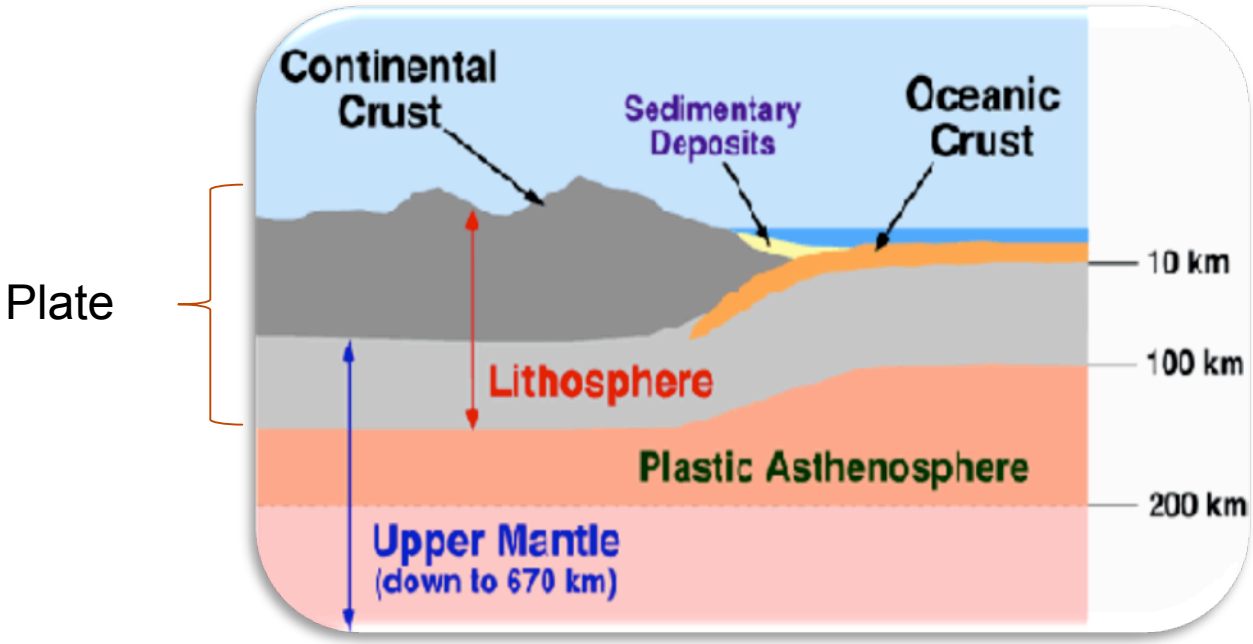
# Pangaea to Today




Source of time lapse plate positions:
http://www.platetectonics.com/book/images/Pangaea.gif

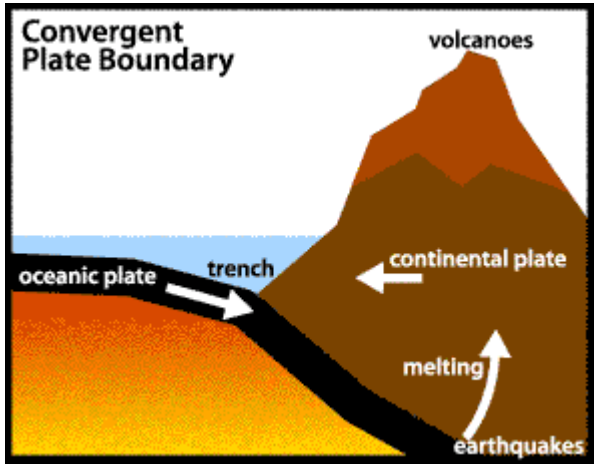
# Plate Tectonics – the motion of the plates on the surface of the Earth

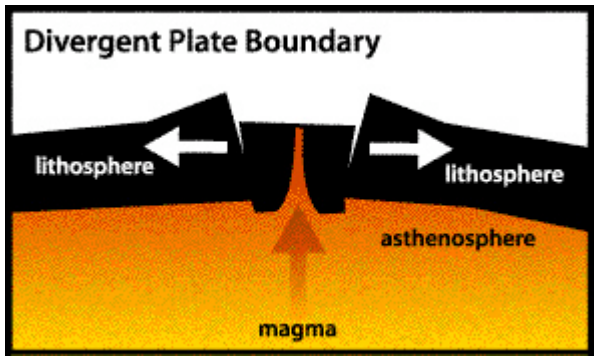
- Lithosphere = crust + the top (cooler) part of the upper mantle.




Source of Image: http://www.physicalgeography.net/fundamentals/images/lithosphere.gif

# How plates move

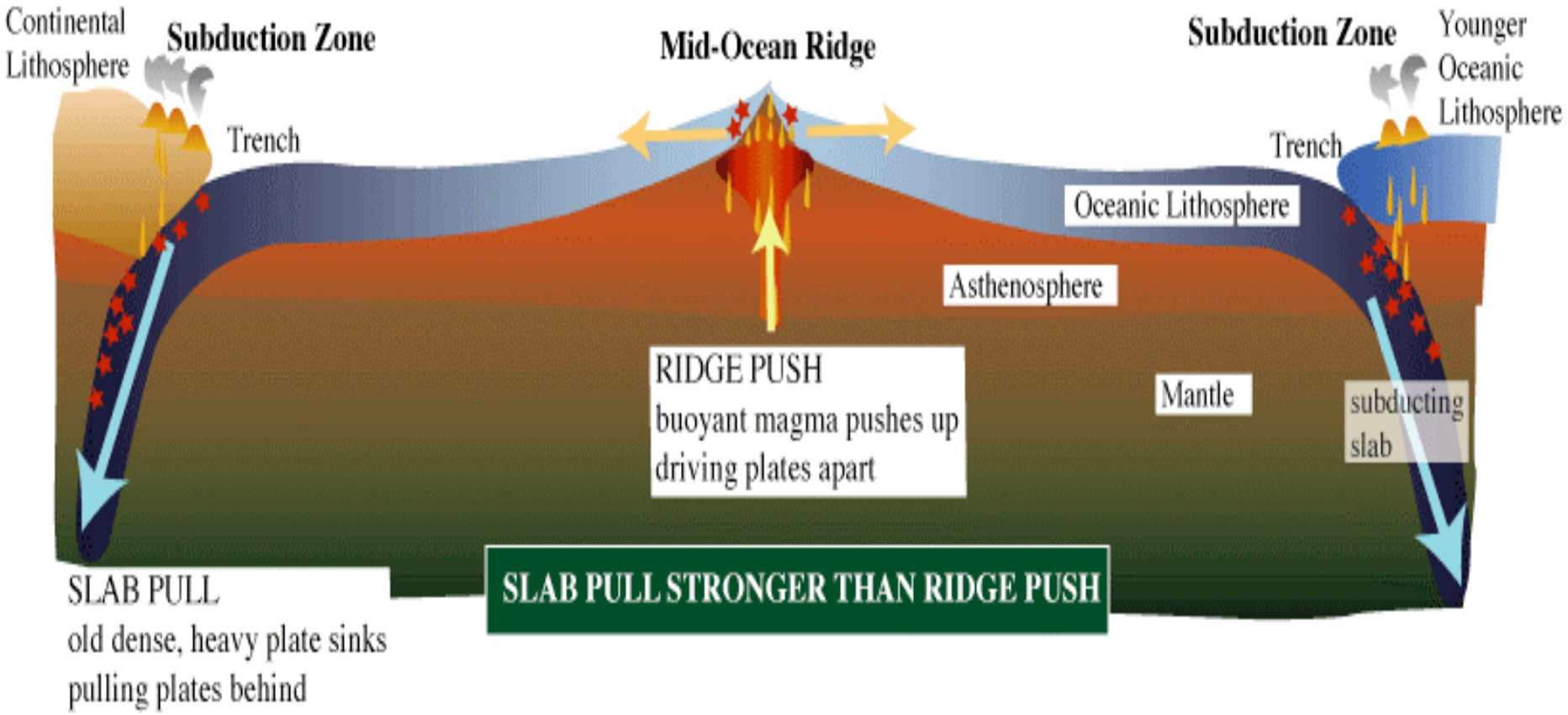




Source of Divergent Plate Boundary:
http://www.cotf.edu/ete/images/modules/msese/earthsysflr/EFPlateP3.gif
Source of Convergent Plate Boundary:
http://www.cotf.edu/ete/images/modules/msese/earthsysflr/EFPlateP2.gif

# What influences the motion of plates?




Source of diagram: http://quakeinfo.ucsd.edu/~gabi/sio15/supps/slab-ridge.gif

# Goals

- Create better visual aides for plate tectonics
  - from 2-D maps to 3-D animation
    - Hemispheres
      - Color coded and updated motion
    - Zoom in on Asia

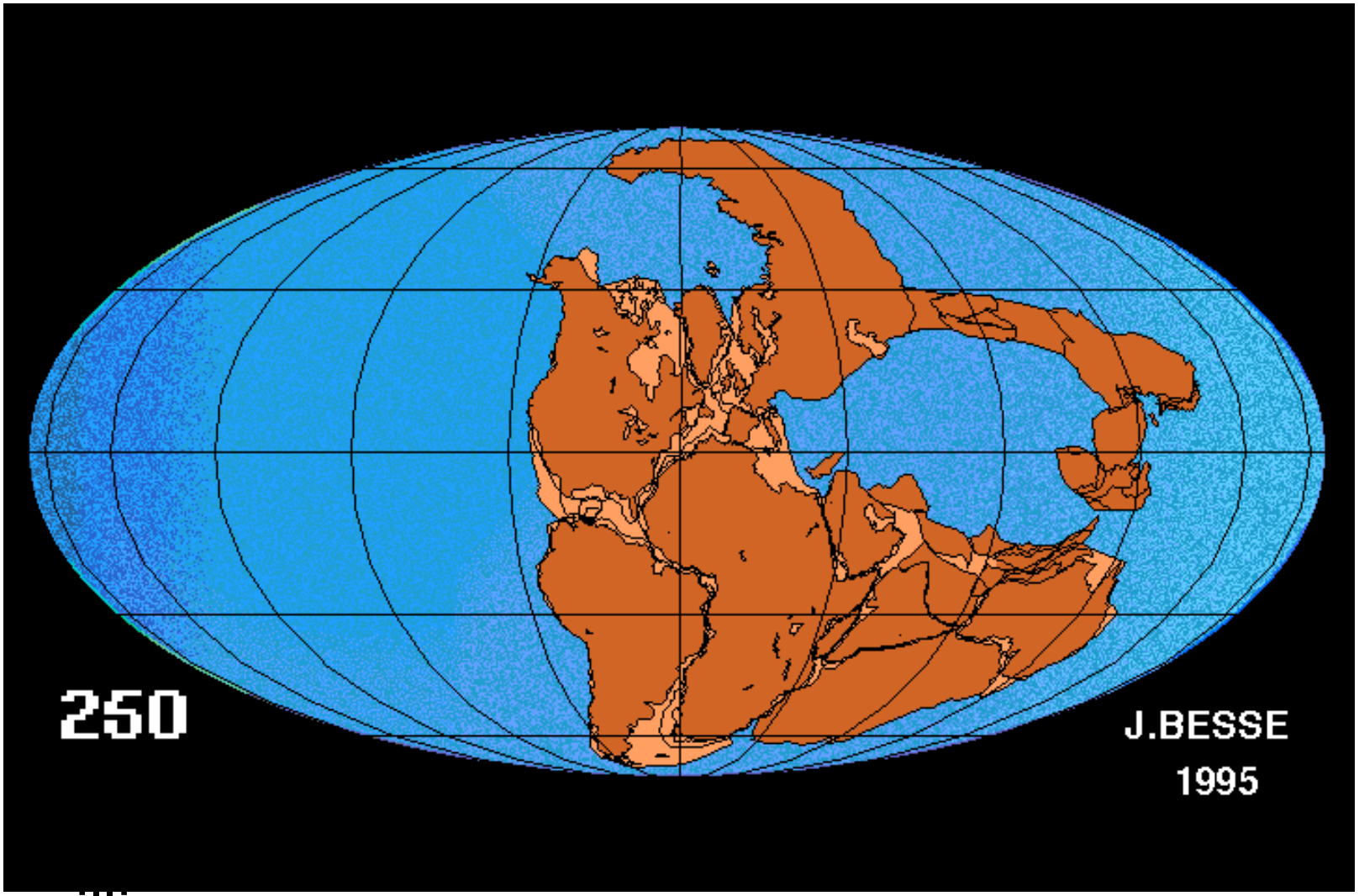
- Generate template that can be built upon for GPlates

# Goals

- Create better visual aides for plate tectonics
  - from 2-D maps to 3-D animation
    - **Hemispheres**
      - **Color coded and updated motion**
    - Zoom in on Asia

- Generate template that can be built upon for GPlates

# Pre-existing Animation

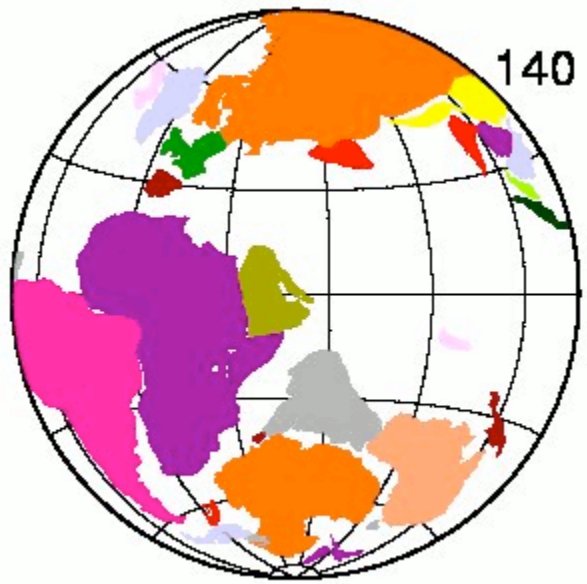



million years ago

Source of animation: http://tectonics.caltech.edu/outreach/highlights/sumatra/what.html

# A better hemisphere animation

Animation to show the location of the continents from 140 million years ago to today.



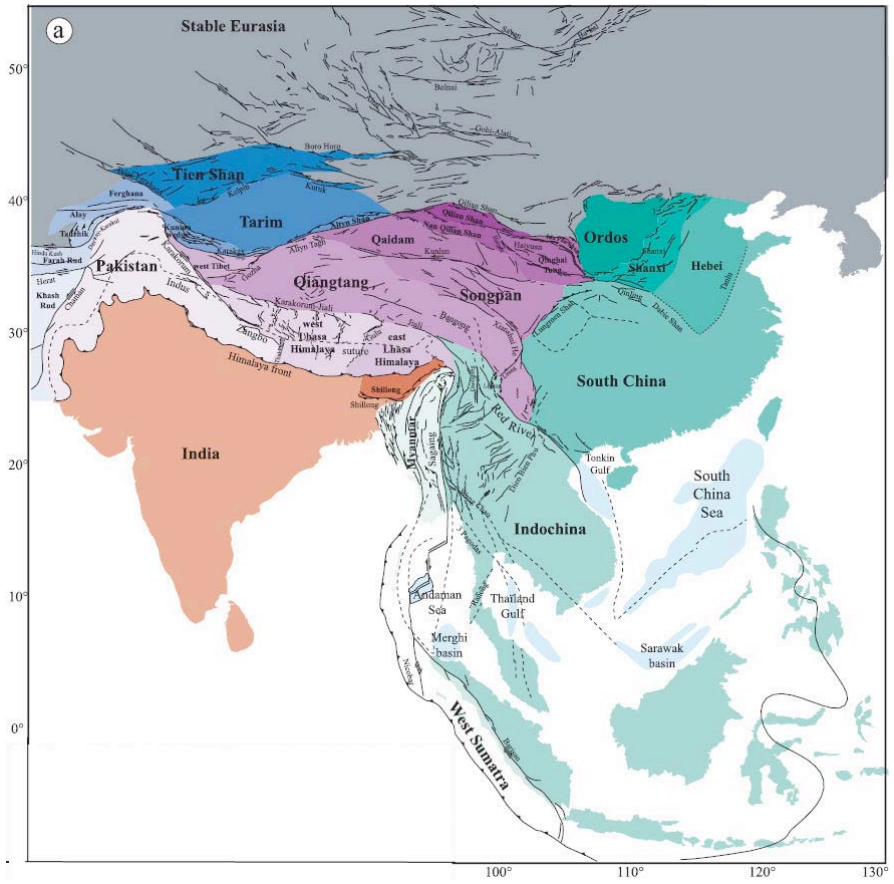
# Goals

- Create better visual aides for plate tectonics
  - from 2-D maps to 3-D animation
    - Hemispheres
      - Color coded and updated motion
    - **Zoom in on Asia**

- Generate template that can be built upon for GPlates

# New Information about Eurasia Plates
# The 2-D Map

A. Replumaz & P. Tapponnier (2003)



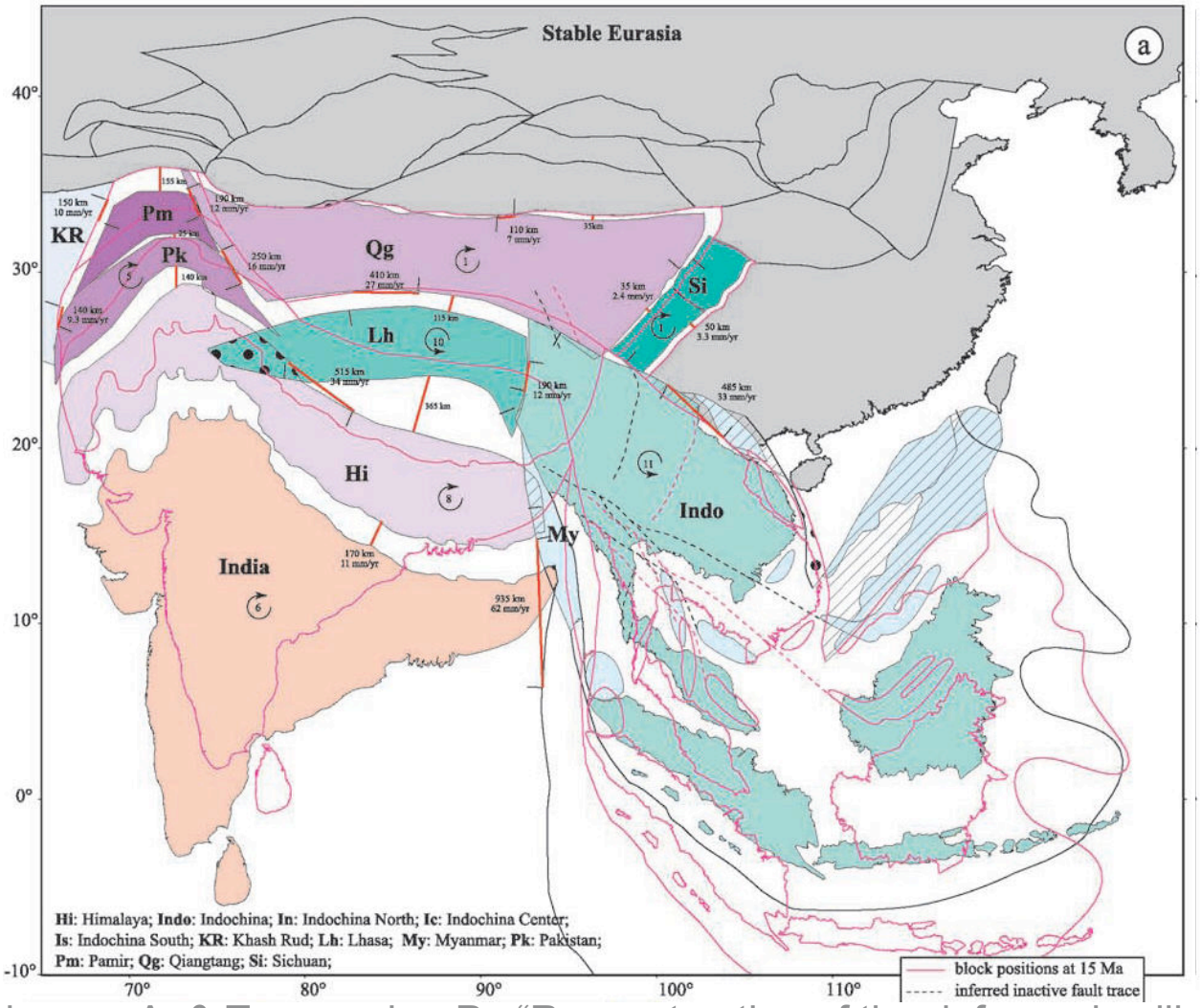

ETG 1 - 8 REPLUMAZ AND TAPPONNIER: BLOCKS RECONSTRUCTION OF ASIA

Table 2. Step-by-Step Euler Poles, Block Motions Relative to Siberia

| Block | Latitude Pole | Longitude Pole | Angle of Rotation | References |
|---|---|---|---|---|
| | | *Time Step 0–5 Ma, 25 Blocks* | | |
| India | 24.4 | 17.7 | −2.5 | *DeMets et al.* [1994] |
| Tarim | 43.5 | 95.7 | 3.2 | *Avouac and Tapponnier* [1993] |
| Ordos | 42.2 | 117 | −2.5 | *Zhang* [1994] |
| South China | 6.5 | 101.4 | 1.6 | |
| Hebei | 58.3 | 139.8 | −1.5 | |
| Shanxi | 57.2 | 133.1 | −1.2 | |
| Qilian | 32.3 | 102.3 | 6.3 | |
| Qiangtang | 20.5 | 99.5 | 6.7 | |
| Sungpan | 16.6 | 105.2 | 2.8 | |
| Nan Qilian | 30.8 | 103.2 | 5.4 | |
| Qinghai Tung | 31.9 | 103.1 | 5.5 | |
| Qaidam | 30 | 105.6 | 4.7 | |
| East Lhasa-Himalaya | 30.7 | −16.3 | −1.3 | |
| West Lhasa-Himalaya | 34.3 | 9.7 | −1.4 | |
| West Tibet | 38.3 | 74.7 | −14.3 | |
| Kunlun wedge | 39.8 | 105.5 | 2.9 | |
| Altyn Shan | 43.3 | 96.7 | 4.5 | |
| Ferghana | 32.6 | 66.2 | −2.2 | |
| Alay | 37.7 | 67 | −4.4 | |
| Tadjik | 37.2 | 69.1 | −13.5 | |
| Pakistan | −0.4 | 154.2 | 1.3 | |
| Shillong | −16.9 | 174.3 | 2.1 | |
| Myanmar | 15.9 | 124.8 | 4.2 | |
| Indochina | 18.2 | 104.3 | 3.3 | |
| West Sumatra | 21.3 | 111.2 | 3.3 | |
| | | *Time Step 5–10 Ma, 21 Blocks* | | |
| India | −11.5 | −133.6 | 5.1 | *Patriat and Achache* [1984] |
| Tarim | 43.5 | 95.7 | 2.5 | *Avouac and Tapponnier* [1993] |
| Ordos | 42.2 | 117 | −2.5 | *Zhang* [1994] |
| Southeast Asia | 10.5 | 120.2 | 2 | |
| Hebei | 10.6 | 101.1 | 1.3 | |
| Shanxi | 57.2 | 133.1 | −1.2 | |
| Qiling | 23.6 | 106.7 | 3.8 | |
| Qilian | 32.5 | 101.3 | 3.3 | |
| Qiangtang | −16.9 | 120.4 | 2 | |
| Sungpan | −5.2 | 122.7 | 1.9 | |
| Nan Qilian | 31.1 | 101.9 | 3.1 | |
| Qinghai Tung | 29.9 | 102 | 2.3 | |
| Qaidam | 30.4 | 100.4 | 6 | |
| Himalaya | −0.1 | 164.3 | 1.5 | |
| Kunlun wedge | 27.8 | 121.5 | 1.2 | |
| Altyn Shan | 39.3 | 93.8 | 7.3 | |
| Ferghana | 32.6 | 66.2 | −2.2 | |
| Alay | 37.7 | 67 | −4.4 | |
| Tadjik | 37.2 | 69.1 | −13.5 | |
| Myanmar | 5.4 | 39.7 | −4.6 | |
| West Sumatra | 12.9 | 127.9 | 2.2 | |
| | | *Time Step 10–15 Ma, 14 Blocks* | | |
| India | 21.5 | 27.7 | −2.7 | *Patriat and Achache* [1984] |
| Tarim | 43.5 | 95.7 | 1.3 | *Avouac and Tapponnier* [1993] |
| Southeast Asia | 26.3 | 1.1 | −0.6 | |
| Qiangtang | 46.5 | −4.7 | −1.4 | |
| Sungpan | 47.9 | 6.3 | −1.1 | |
| Qaidam | 32.1 | 102.5 | 2.8 | |
| Himalaya | 3.9 | 125.6 | 1.8 | |
| Kunlun wedge | 33.1 | 86.2 | 8.1 | |
| Altyn Shan | 38.5 | 93.6 | 4.2 | |
| Ferghana | 36.3 | 68.7 | −3.5 | |
| Alay | 37.5 | 67.7 | −3.5 | |
| Tadjik | 36.1 | 67.5 | −3.5 | |
| Myanmar | 0 | 180 | 2.2 | |
| West Sumatra | 17.2 | −170.7 | 1.7 | |
| | | *Time Step 15–30 Ma, 8 Blocks* | | |
| India | 14.4 | 36.7 | −8.5 | *Patriat and Achache* [1984] |
| Indochina | 5.3 | 86.2 | 10.7 | from *Briais et al.* [1993] |
| Pamir | −1.8 | 160.5 | 1.4 | |
| Pakistan | 26.9 | 50.5 | −4.8 | |
| Sichuan | 44.5 | 120 | −0.9 | |
| Qiangtang | 57.5 | 81.1 | −1.9 | |

Source: Replumaz, A. & Tapponnier, P., “Reconstruction of the deformed collision zone Between India and Asia by backward motion of lithospheric blocks”, Journal of Geophysical Research, Vol. 108, No. B6, 2003.

# Original Data Presented the Old Way



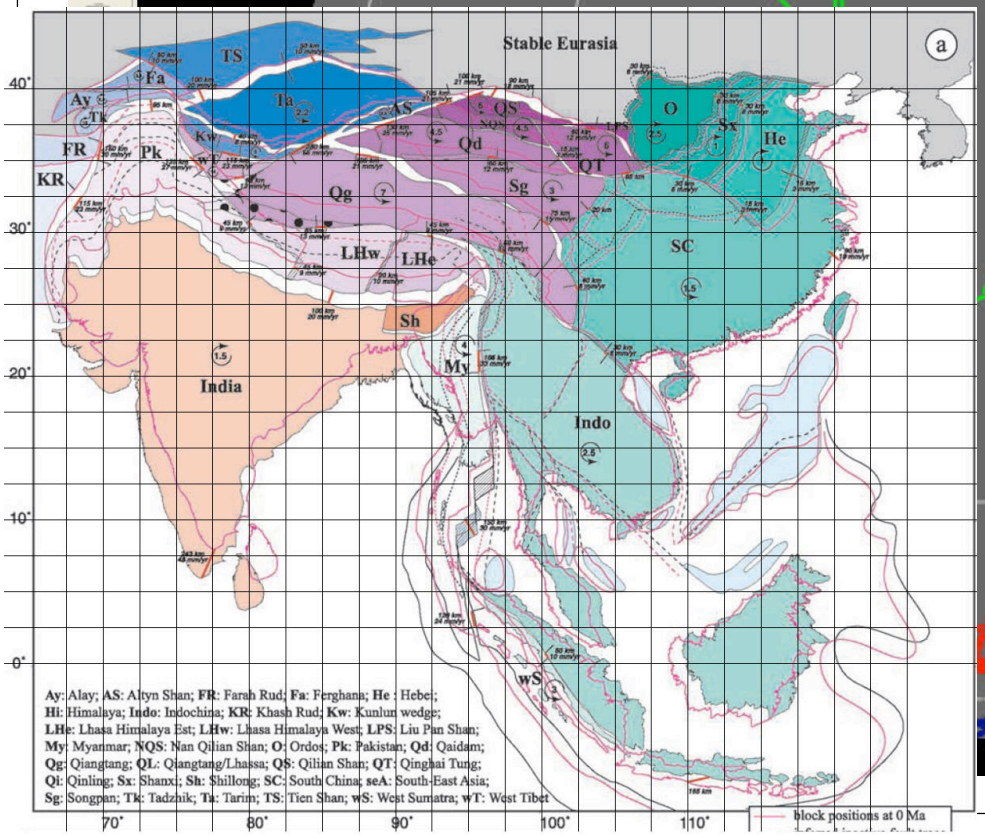

Source: Replumaz, A. & Tapponnier, P., "Reconstruction of the deformed collision zone Between India and Asia by backward motion of lithospheric blocks", Journal of

# GPlates

Free Software developed by scientists from the geology community from around the world for plate tectonic applications. (gplates.org)

University of Sydney
Norwegian Geological Survey
Caltech

Mark Turner

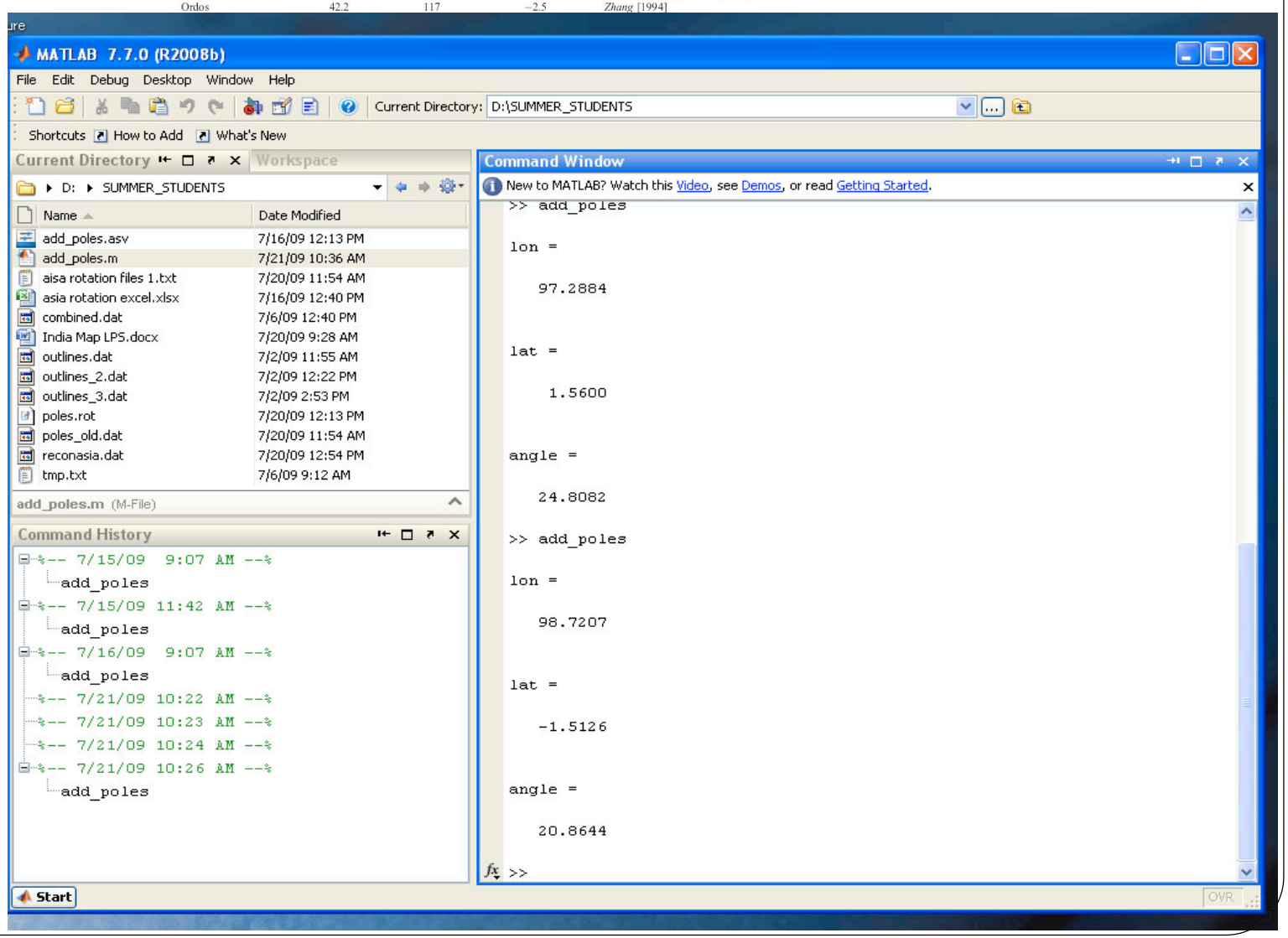


# MATLAB - used to calculate new poles



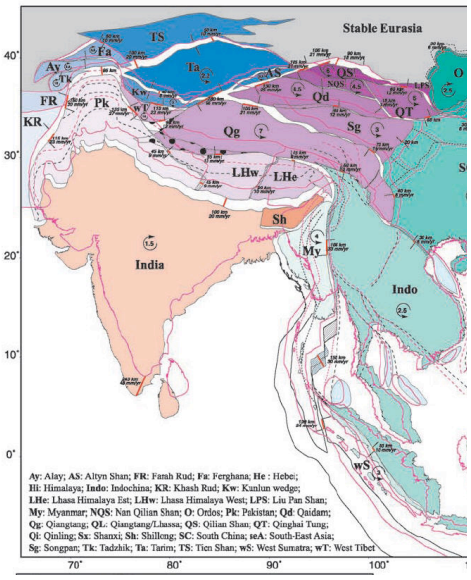
Table 2. Step-by-Step Euler Poles, Block Motions Relative to Siberia

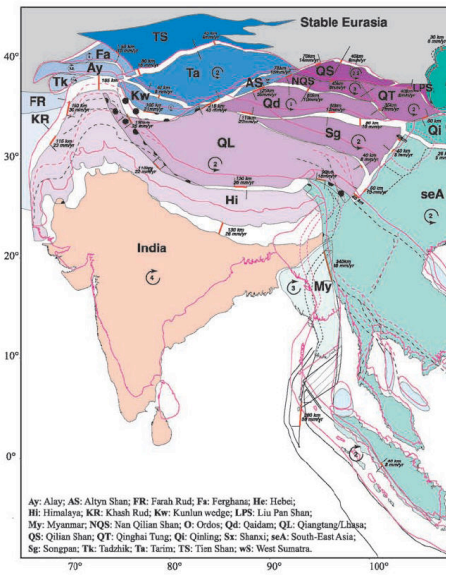
| Block | Latitude Pole | Longitude Pole | Angle of Rotation | References |
|---|---|---|---|---|
| | | *Time Step 0–5 Ma, 25 Blocks* | | |
| India | 24.4 | 17.7 | −2.5 | *DeMets et al.* [1994] |
| Tarim | 43.5 | 95.7 | 3.2 | *Avouac and Tapponnier* [1993] |
| Ordos | 42.2 | 117 | −2.5 | *Zhang* [1994] |

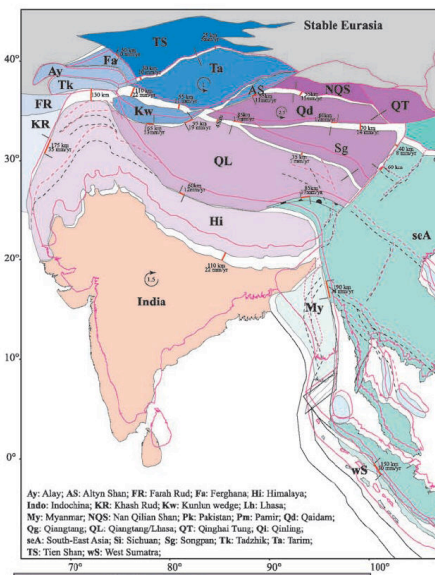


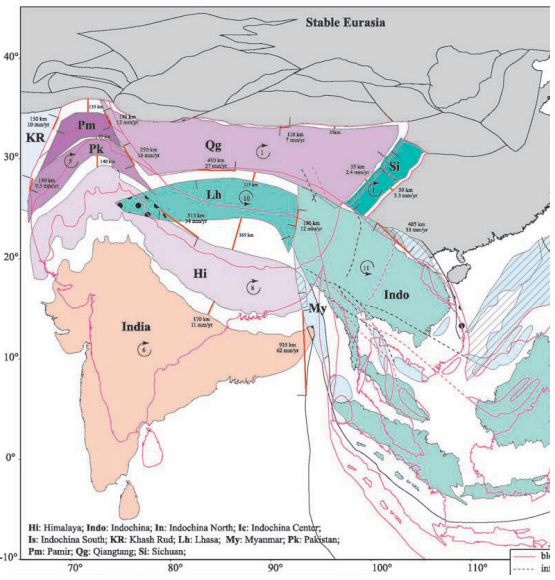
# Computed Poles of Rotation

| | 5 million years ago | | | | 10 million years ago | | | | 15 million years ago | | | | 30 million years ago | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plate Name** | **Latitude** | **Longitude** | **Angle of Rotatior** | **Combined Plates 1** | **Latitude** | **Longitude** | **Angle of Rotatior** | **Combined Plates 1** | **Latitude** | **Longitude** | **Angle of Rotatior** | **Combined Plates 3** | **Latitude** | **Longitude** | **Angle of Rotation** | |
| India | 24.4 | 17.7 | -2.5 | India | -15.7581 | -142.6868 | 7.3702 | India | -17.495 | -145.0888 | 10.0354 | India | -16.9463 | 177.6976 | 15.3385 | |
| Tarim | 43.5 | 95.7 | 3.2 | Tarim | 43.4999 | 95.7 | 5.7 | Tarim | 43.4998 | 95.7 | 7 | Eurasia | 43.4998 | 95.7 | 7 | |
| Ordos | 42.2 | 117 | -2.5 | Ordos | -42.1999 | -62.9998 | 5 | Eurasia | -42.1999 | -62.9998 | 5 | Eurasia | -42.1999 | -62.9998 | 5 | |
| South China | 6.5 | 101.4 | 1.6 | Southeast Asia | 8.9913 | 111.7741 | 3.5512 | Southeast Asia | 4.6687 | 119.665 | 3.7427 | Eurasia | 4.6687 | 119.665 | 3.7427 | |
| Hebei | 58.3 | 139.8 | -1.5 | Hebei | -51.0861 | 63.7046 | 1.3257 | Eurasia | -51.0861 | 63.7046 | 1.3257 | Eurasia | -51.0861 | 63.7046 | 1.3257 | |
| Shanxi | 57.2 | 133.1 | -1.2 | Shanxi | -57.1999 | -46.8998 | 2.4 | Eurasia | -57.1999 | -46.8998 | 2.4 | Eurasia | -57.1999 | -46.8998 | 2.4 | |
| Qilian | 32.3 | 102.3 | 6.3 | Qilian | 32.3535 | 101.9524 | 9.5998 | Eurasia | 32.3535 | 101.9524 | 9.5998 | Eurasia | 32.3535 | 101.9524 | 9.5998 | |
| Qiangtang | 20.5 | 99.5 | 6.7 | Qiangtang | 12.5751 | 104.8272 | 8.2824 | Qiangtang | 5.7687 | 111.5119 | 8.4912 | Qiangtang | -5.3288 | 116.2531 | 7.622 | |
| Lhasa- part of Qiangtang | 20.5 | 99.5 | 6.7 | Qiangtang | 12.5751 | 104.8272 | 8.2824 | Qiangtang | 5.7687 | 111.5119 | 8.4912 | Lhasa | 3.7803 | 100.6134 | 18.6073 | |
| Sungpan | 16.6 | 105.2 | 2.8 | Sungpan | 8.0691 | 112.6405 | 4.5672 | Sungpan | -1.7575 | 121.549 | 4.7853 | Qiangtang | -22.9016 | 131.8712 | 4.4211 | |
| Nan Qilian | 30.8 | 103.2 | 5.4 | Nan Qilian | 30.8916 | 102.7209 | 8.4996 | Nan Qilian | 30.8916 | 102.7209 | 8.4996 | Eurasia | 30.8916 | 102.7209 | 8.4996 | |
| Qinghai Tung | 31.9 | 103.1 | 5.5 | Qinghai Tung | 31.298 | 102.8041 | 7.7988 | Qinghai Tung | 31.298 | 102.8041 | 7.7988 | Eurasia | 31.298 | 102.8041 | 7.7988 | |
| Qaidam | 30 | 105.6 | 4.7 | Qaidam | 30.1461 | 102.6783 | 10.6918 | Qaidam | 30.5477 | 102.598 | 13.4905 | Eurasia | 30.5477 | 102.598 | 13.4905 | |
| East Lhasa-Himalaya | 30.7 | -16.3 | -1.3 | Himalaya | -14.2772 | 163.8541 | 2.7012 | Himalaya | -14.2772 | 163.8541 | 2.7012 | Himalaya | -22.2834 | -142.9441 | 9.7351 | |



# Sample input for Gplate plate motions

```
924   10.0   -37.2   -46.9     2.4   936 !Shanxi
924   15.0   -37.2   -46.9     2.4   936 !Shanxi
924   20.0   -37.2   -46.9     2.4   936 !Shanxi
925                              0   936 !Hebei
925                              5   936 !Hebei
925                              3   936 !Hebei
925                              3   936 !Hebei
925   30.0   -51.1    63.7     1.3   936 !Hebei
926    0.0     0.0     0.0     0.0   936 !Altyn Shan
926    5.0                     4.5   936 !Altyn Shan
926   10.0                    11.8   936 !Altyn Shan
926   15.0    40.2    94.7    16.0   936 !Altyn Shan
926   20.0    40.2    94.7    16.0   936 !Altyn Shan
927    0.0     0.0                   936 !India
927    5.0    24.4
927   10.0   -15.8   -142.7    7.4   936 !India
927   15.0   -17.5   -145.1   10.0   936 !India
927   20.0   -16.9    177.7
928    0.0     0.0     0.0
928    5.0    -0.4    154.2     1.3   936 !Pakistan
928   10.0    -0.2    159.6     2.8   936 !Pakistan
928   15.0    -0.2    159.6     2.8   936 !Pakistan
928   20.0   -18.7   -144.3     9.4   936 !Pakistan
929    0.0     0.0     0.0     0.0   936 !Pakistan
929    5.0   -16.9    174.3     2.1   936 !Shillong
929   10.0   -10.0    169.9     3.5   936 !Shillong
929   15.0   -10.0    169.9     3.5   936 !Shillong
929   20.0   -13.1   -156.7    11.3   936 !Shillong
930    0.0     0.0     0.0     0.0   936 !Lhasa Himalaya West
930    5.0    34.3     9.7    -1.4   936 !Lhasa Himalaya West
930   10.0   -17.1    175.1     2.7   936 !Lh
930   15.0   -17.1    175.1     2.7   936 !Lh
930   20.0   -22.3   -140.7    10.1   936 !Lhasa Himalaya West
931    0.0     0.0     0.0     0.0   936 !Lhasa Himalaya East
931    5.0    30.7   -16.3     -1.3   936 !Lhasa Himalaya East
931   10.0   -14.3    163.9     2.7   936 !Lhasa Hi
931   15.0   -14.3    163.9     2.7   936 !Lhasa Hi
931   20.0   -22.3   -142.9     9.7   936 !Lhasa Hi
932    0.0     0.0     0.0     0.0   936 !Tadzhik
932    5.0    37.2    69.1   -13.5   936 !Tadzhik
932   10.0   -37.2   -110.9    27.0   936 !Tadzhik
932   15.0   -37.6   -111.1    12.3   936 !Tadzhik
932   20.0   -37.6   -111.1    12.3   936 !Tadzhik
```

Assigned Plate Numbers

Latitude

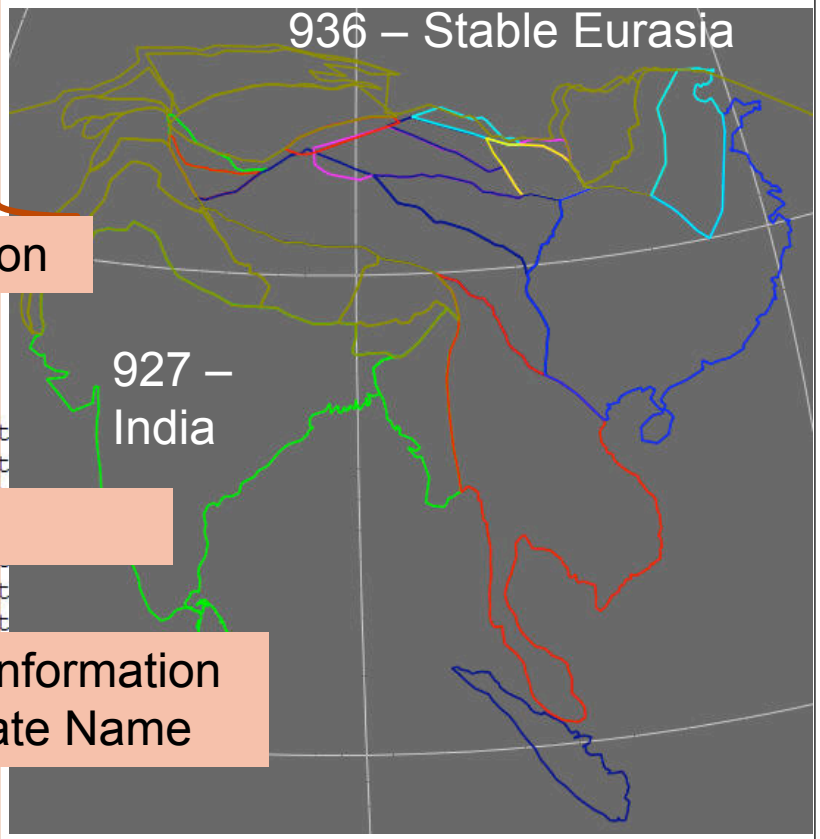
Longitude

Millions of Years

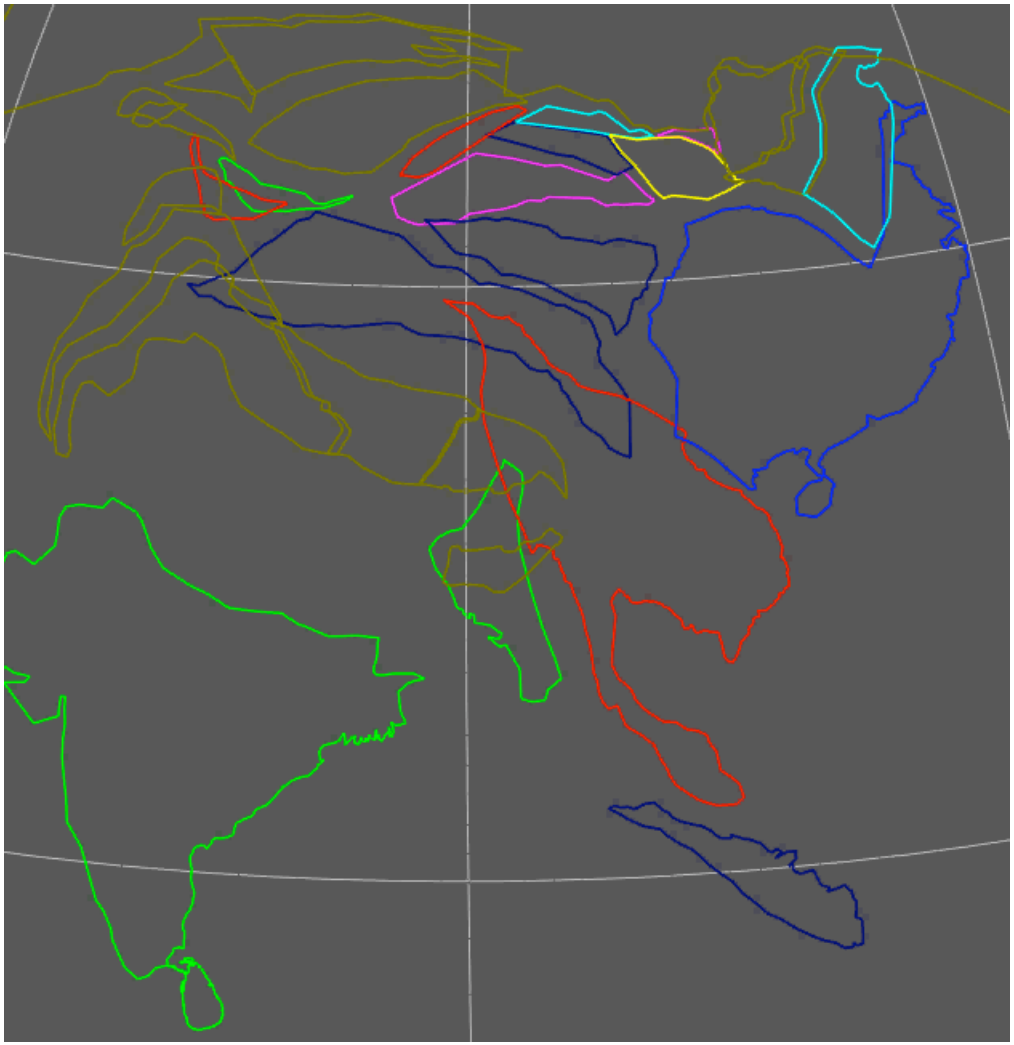
Angle of Rotation

Fixed Plate

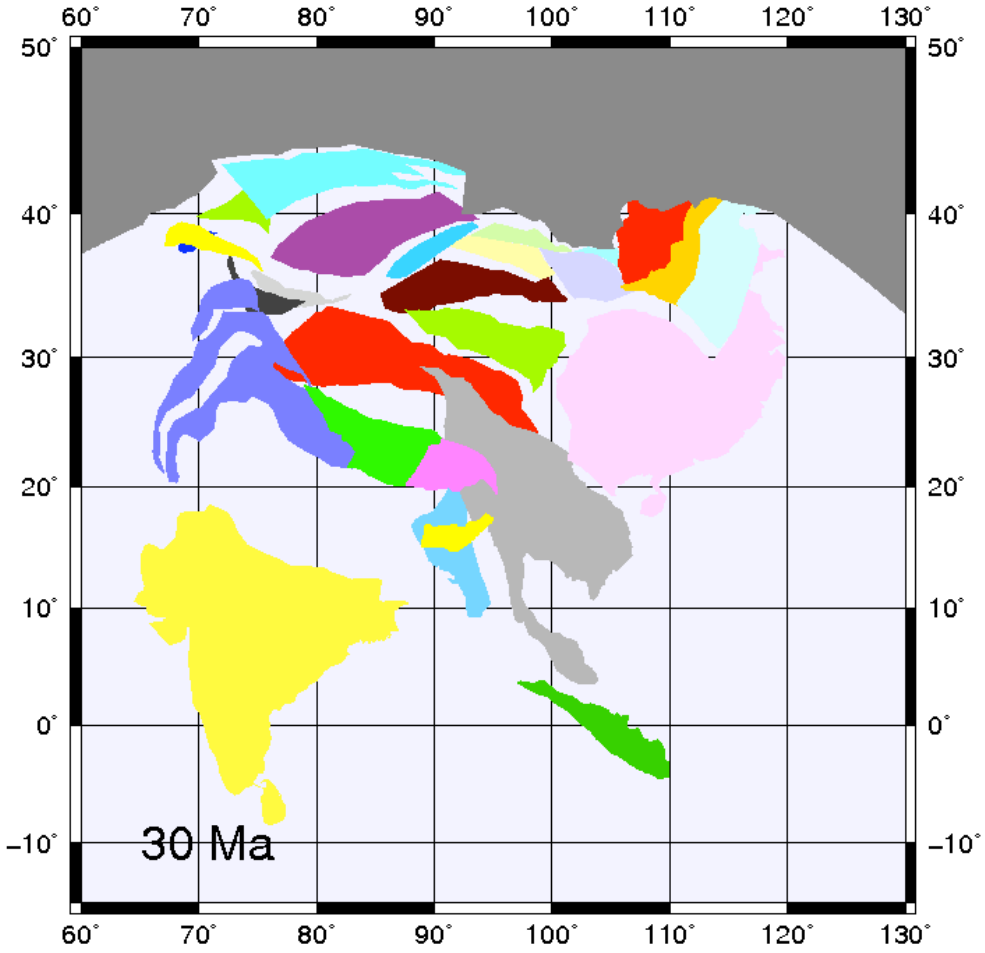
Extra Information like Plate Name



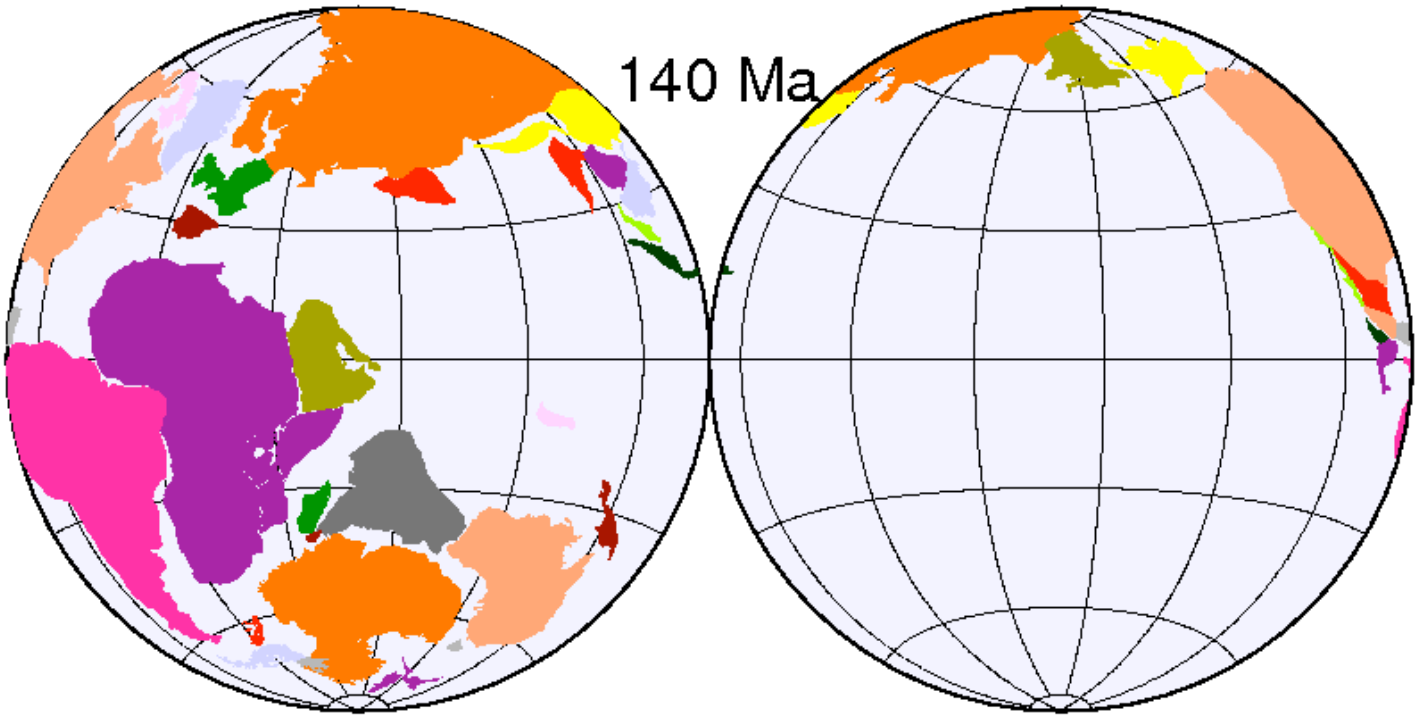
# Animation to Date



# Animation to Date



# Animation to Date



# Goals

- Create better visual aides for plate tectonics
  - from 2-D maps to 3-D animation
    - Hemispheres
      - Color coded and updated motion
    - Zoom in on Asia

- **Generate template that can be built upon for GPlates**

# Acknowledgements

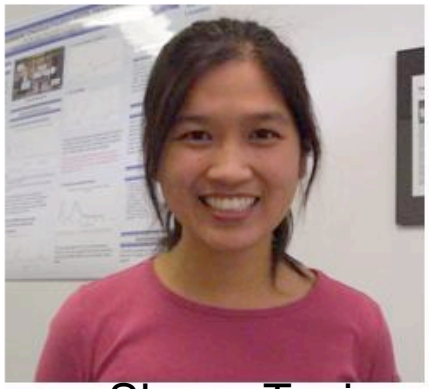

- Siemens Foundation, Howard Hughes Medical Institute, and Pasadena Independent Schools Foundation


Jean-Philippe Avouac
Professor of Geology
Director,
Tectonics Observatory

Alex Copley
Postdoctoral Scholar in Geology

Laurie Kovalenko
Education and
Public Outreach

James Maloney



Sherry Tsai