Linking Observations to Subduction Process Modelling

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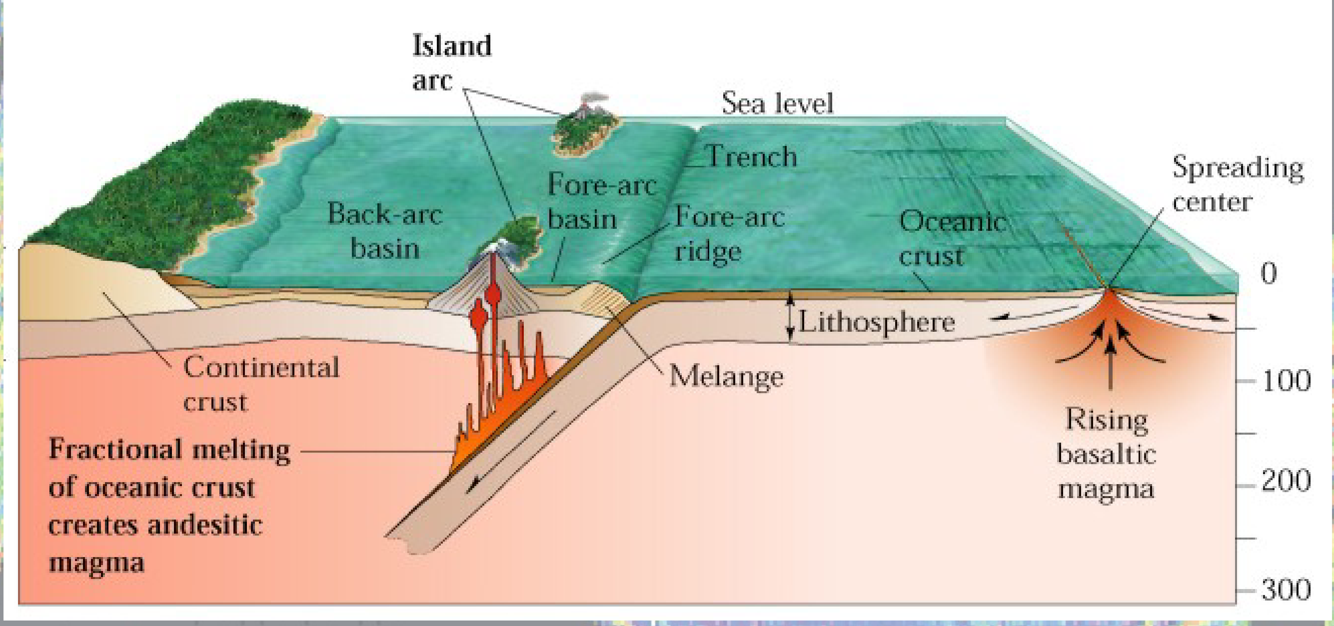
Outline

- The data explosion
- Observational data that we have compiled from the world's subduction zones
- Some results
- End with some examples of how this data has been used in geodynamic modelling

Subduction Factory

- Subduction affects every aspect of the earth system and is the primary driving force of plate tectonics and mantle convection



Subduction Factory

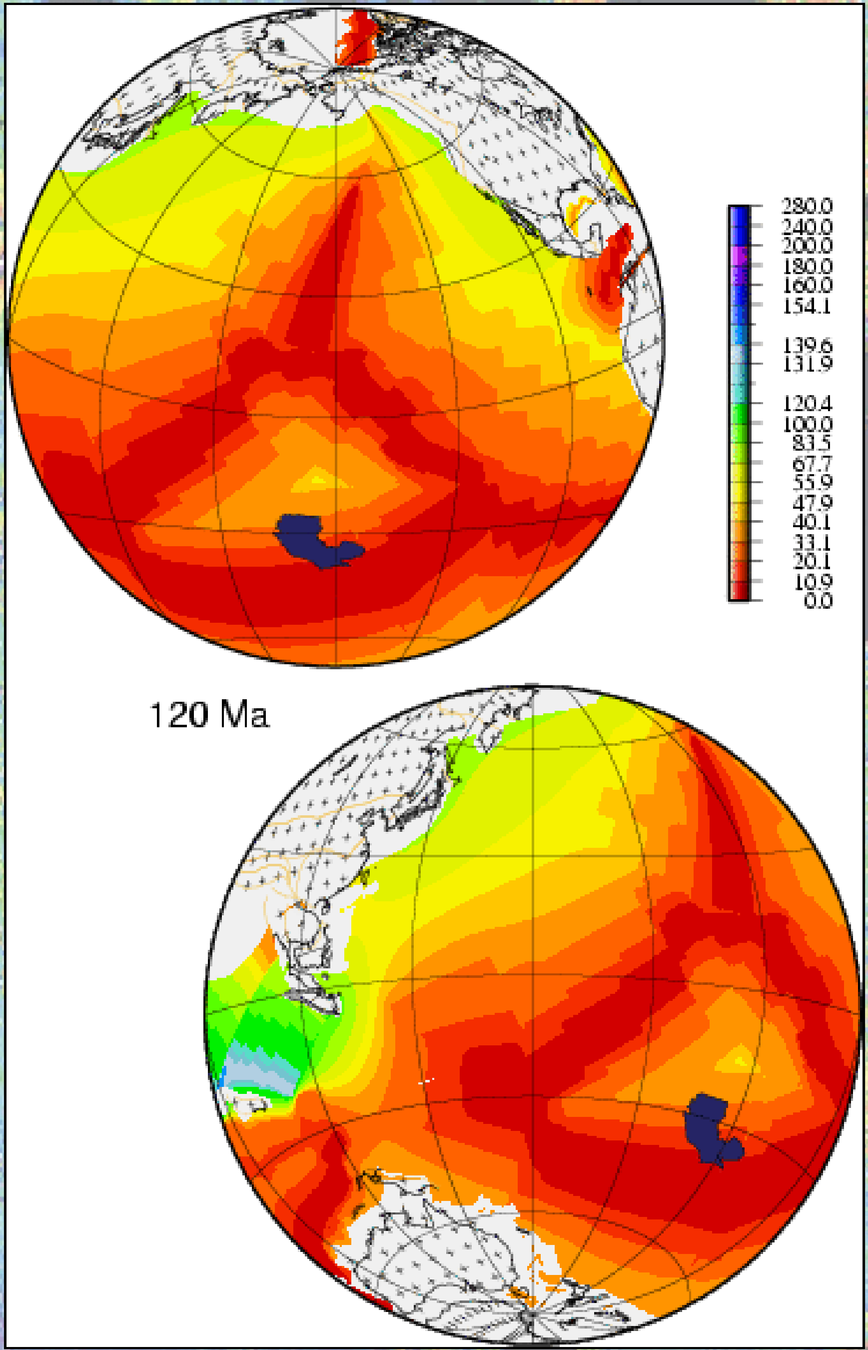
- However, there has been a lack of a detailed, self-consistent observational dataset of global subduction zone parameters through time.

Observational Dataset

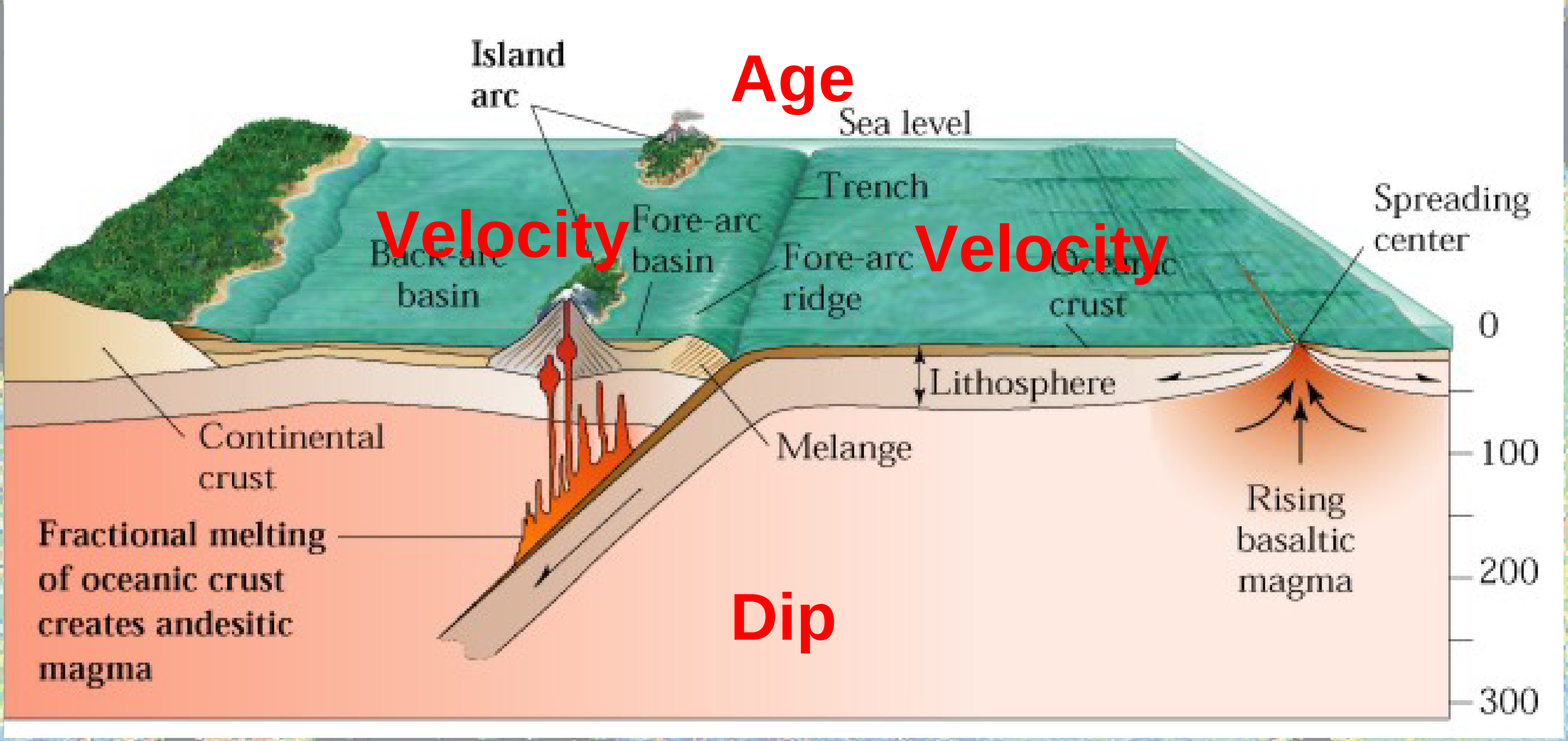
- Our observational dataset is based on a new global plate motion model which includes:
  - New absolute reference frame of *O'Neill et al.*, [2005] based on moving Atlantic-Indian hotspots
  - Tighter constraints on spreading histories of major plates including East-West Antarctic motion
  - Spreading histories in the major back-arc basin plates of the Western Pacific
- We create global palaeo-age grids from late Cretaceous to the present

Palaeo age grids

- Palaeo age grids based on plate motion model
- Extract data along subduction zones



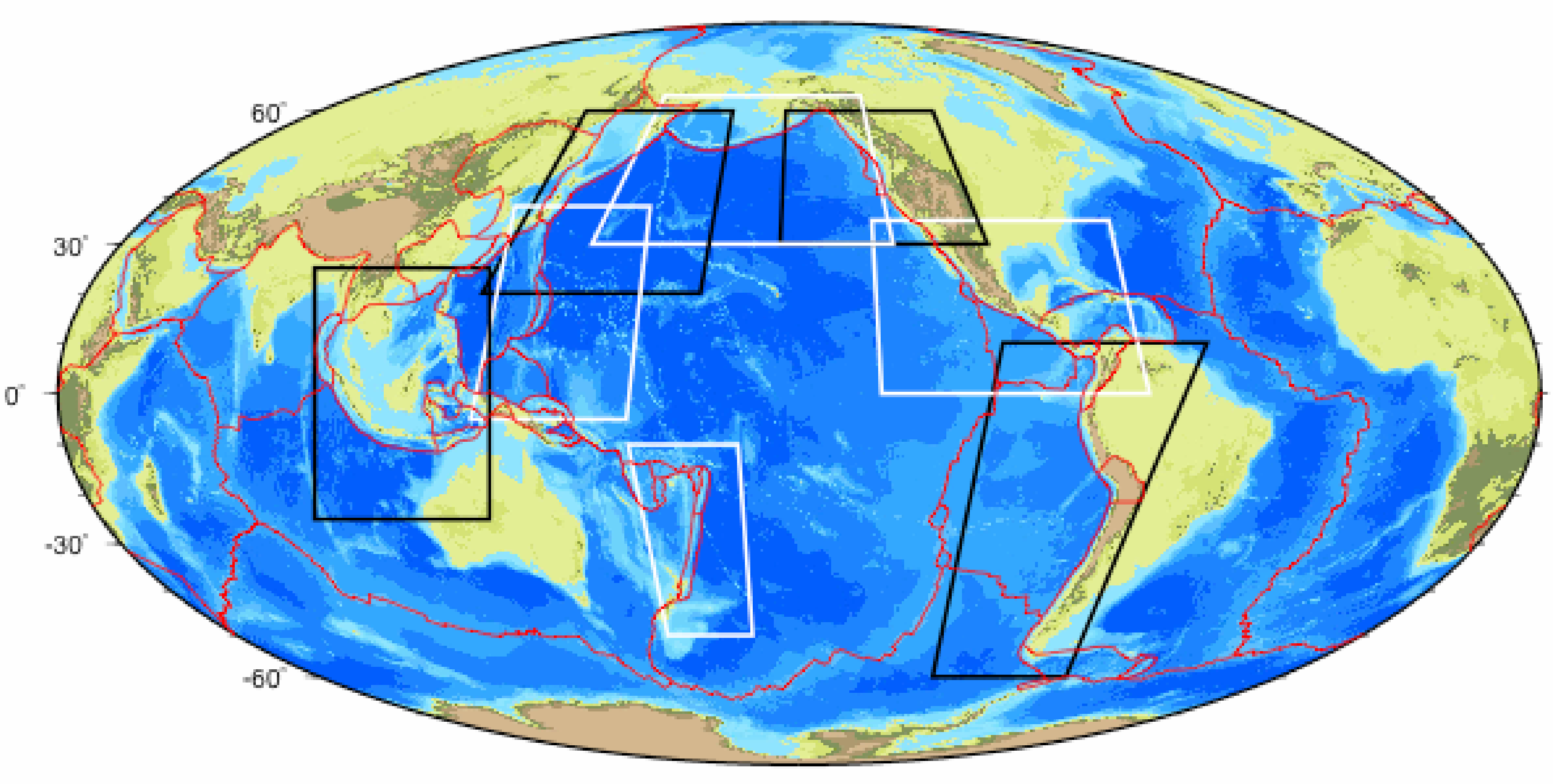
Some Useful Subduction Parameters



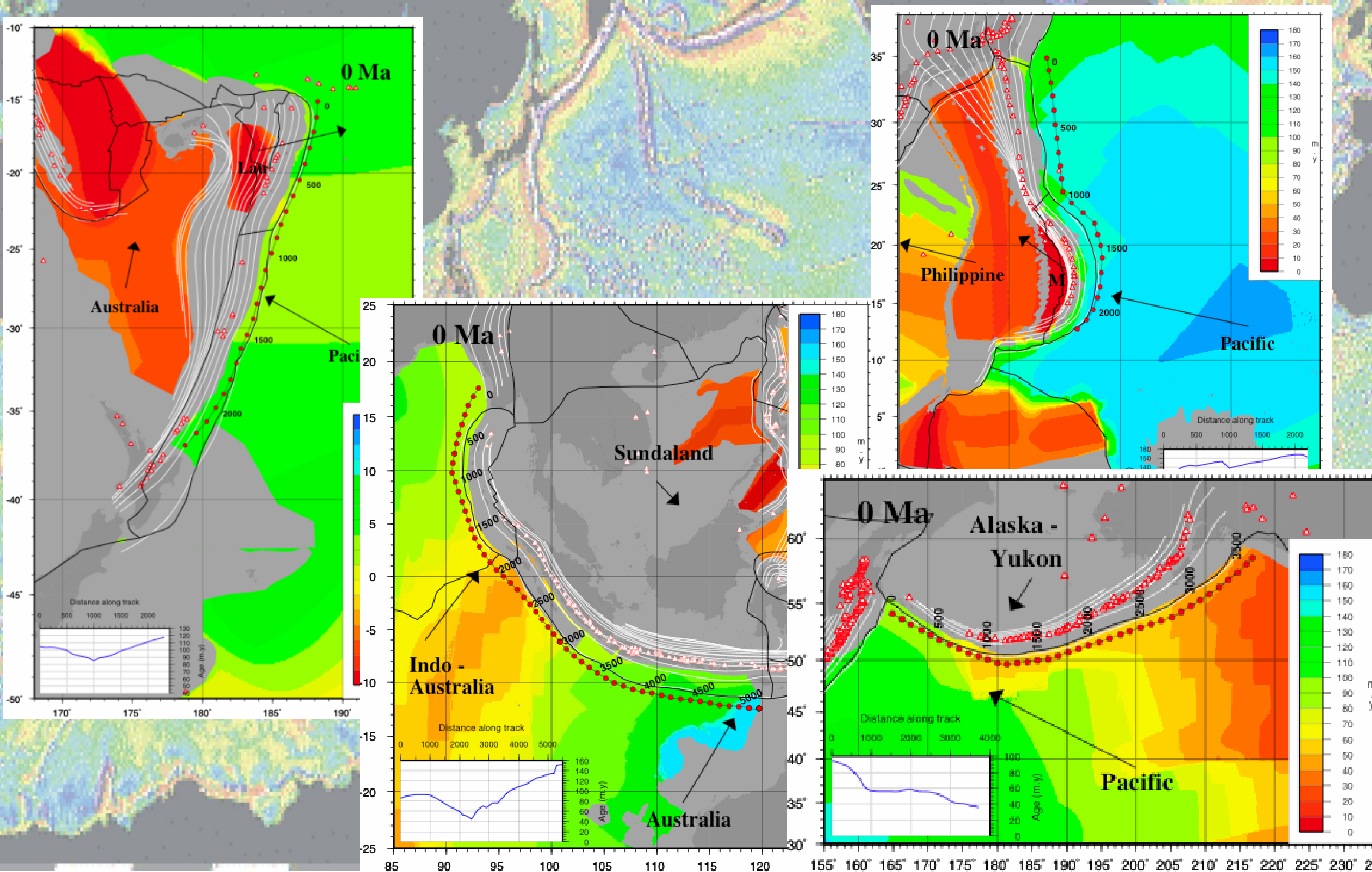
Observational Dataset

- Our new dataset includes densely and evenly spaced sample points along the 8 major subduction zones for:
  - **Age of subducting lithosphere**
  - **Convergence rate and direction**
  - **Absolute motion of the downgoing and overriding plates**
  - **Dip angle of the slab**
- Can also derive global plate velocity grids
- **These observational constraints can be used as boundary layer input into 2D or 3D mantle convection models to achieve more realistic models of subduction initiation and development.**

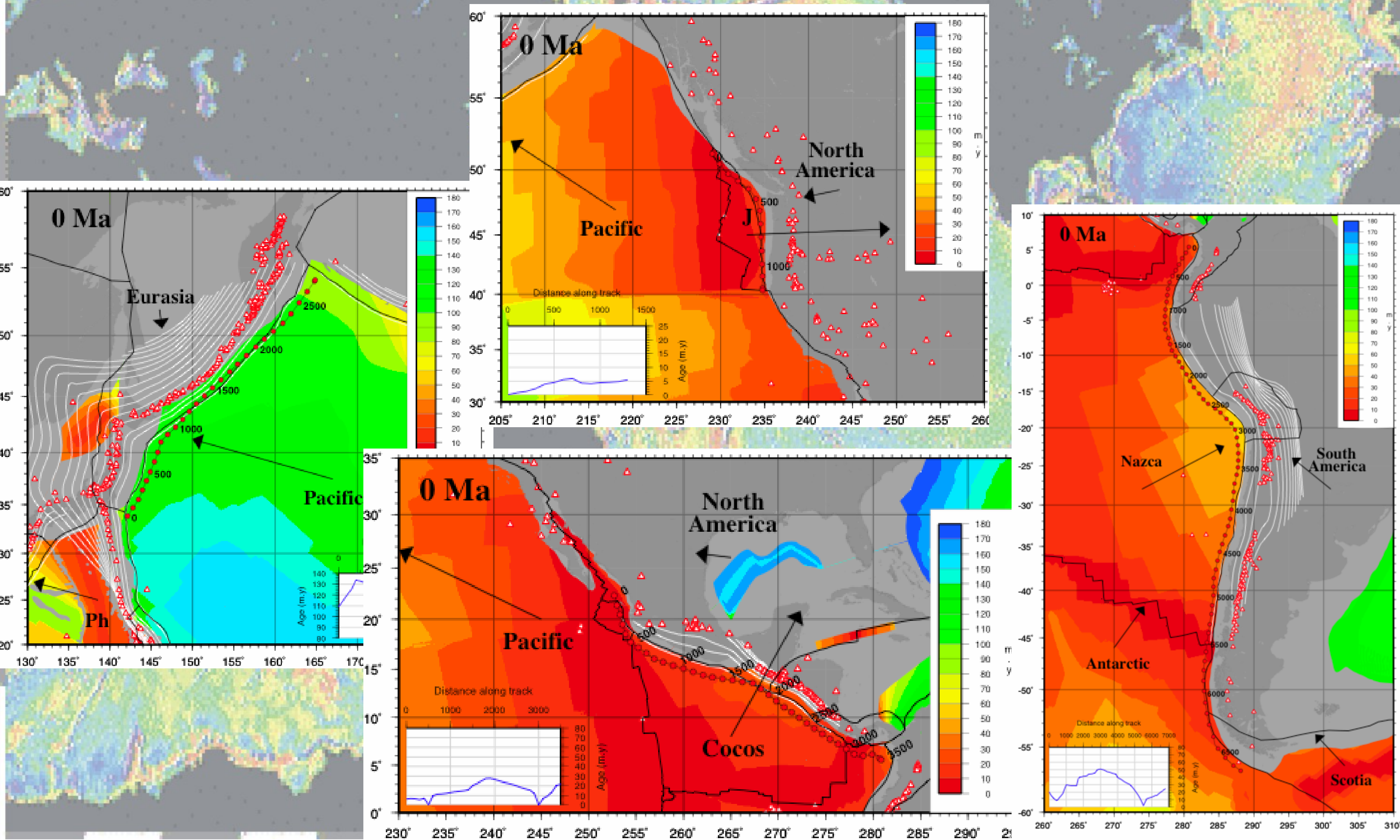
Location of Data



Age of Subducting Lithopshere



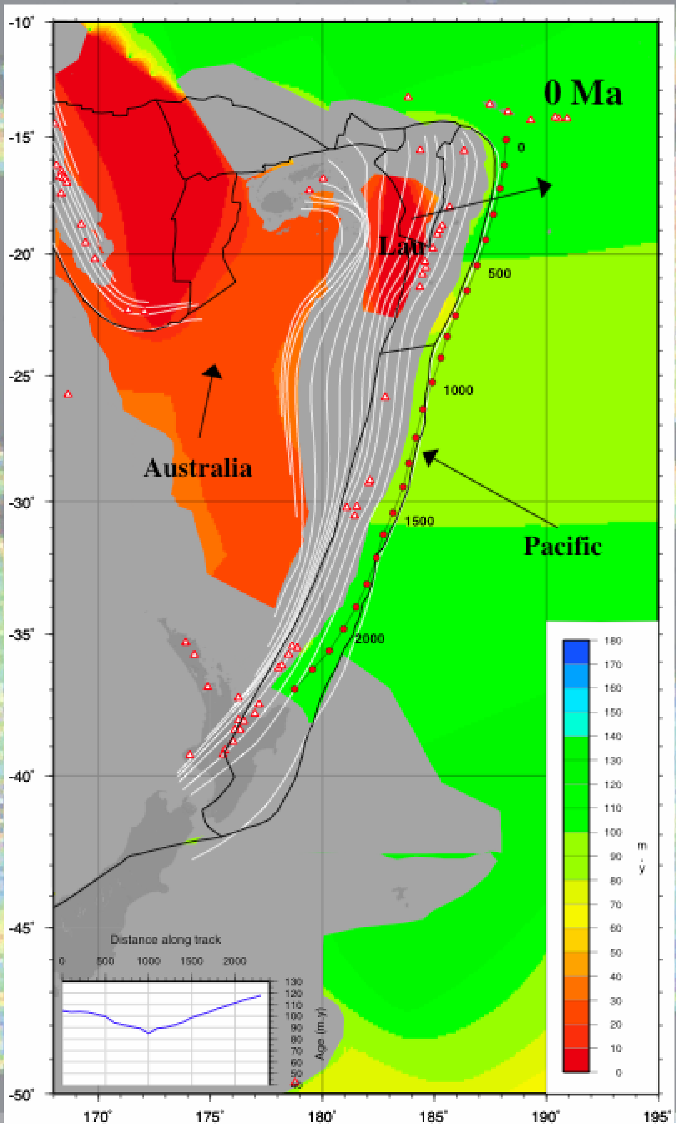
Age of Subducting Lithosphere



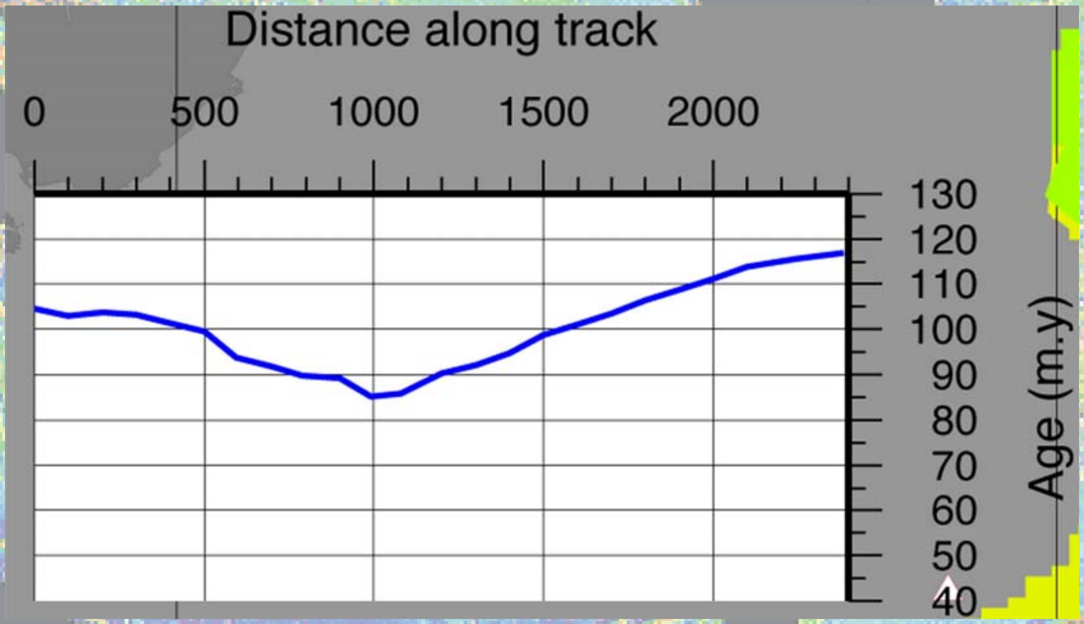
Subduction and Back-arc Basins

- We used our observational data to examine the question of why back-arc basins form associated with some subduction systems but not all subduction systems.

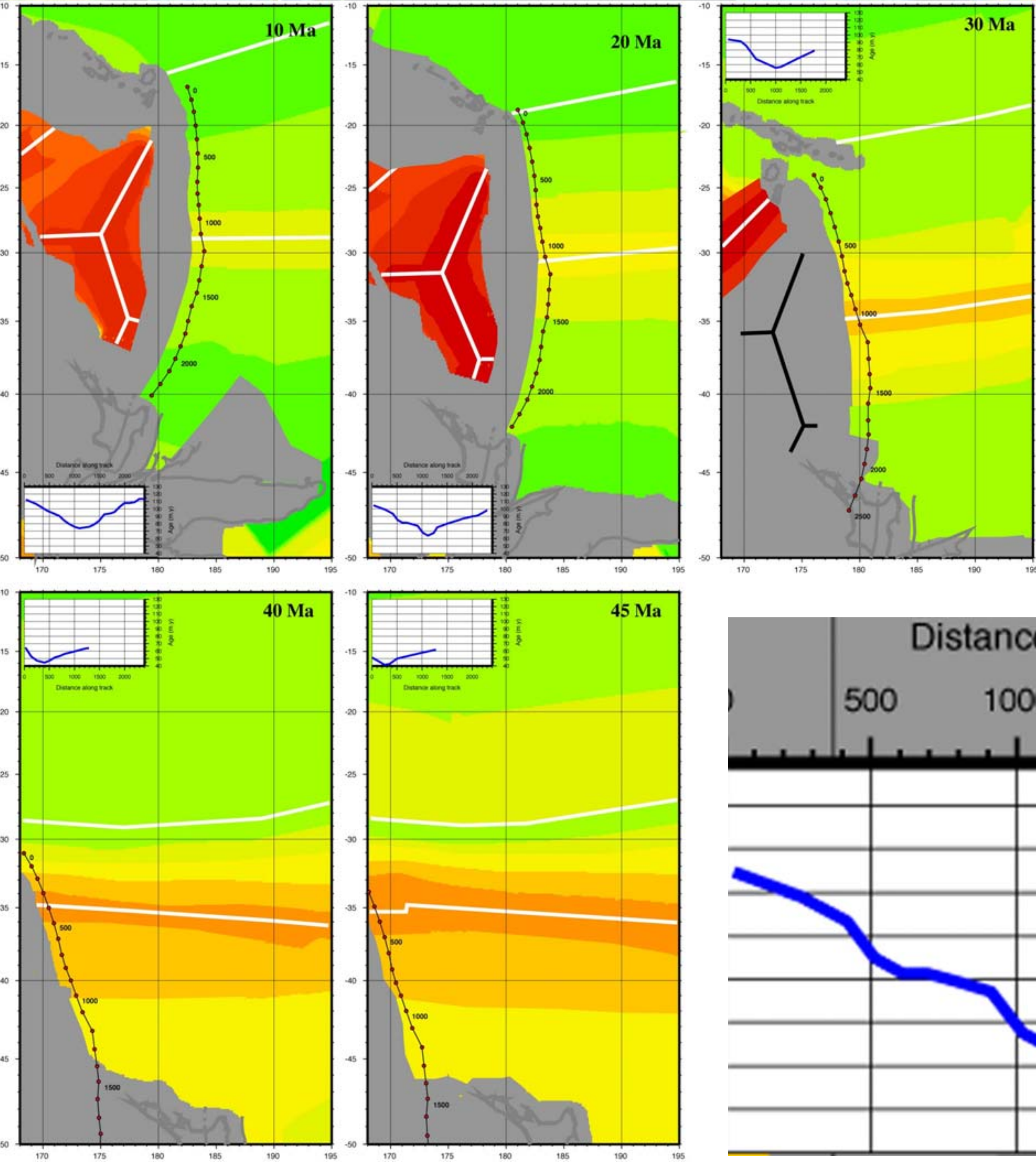
Tonga-Kermadec example

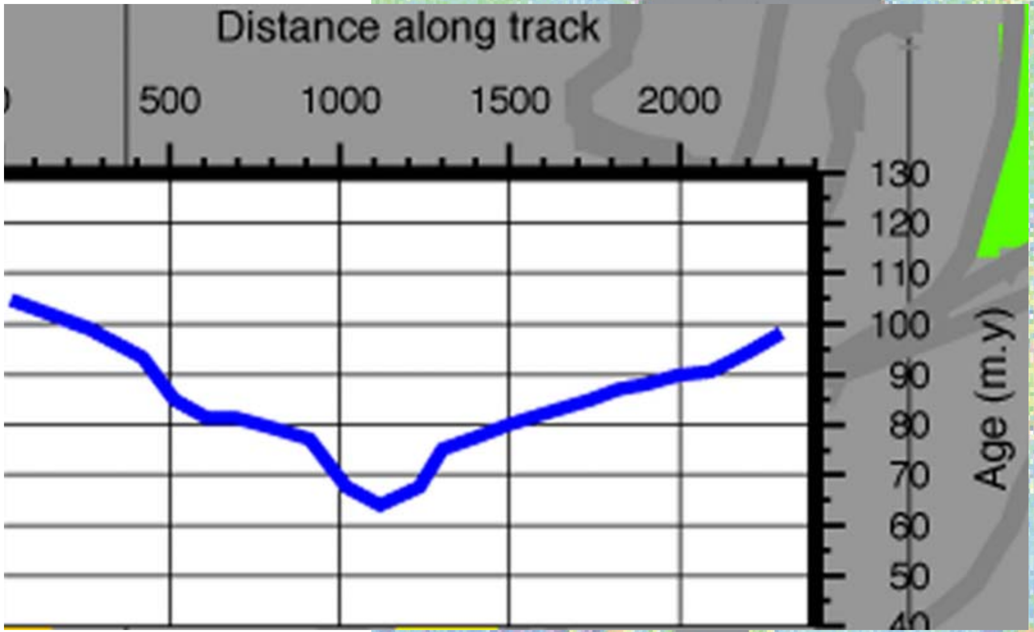


Tonga-Kermadec subduction of old lithosphere - youngest at the location of Osbourn Trough

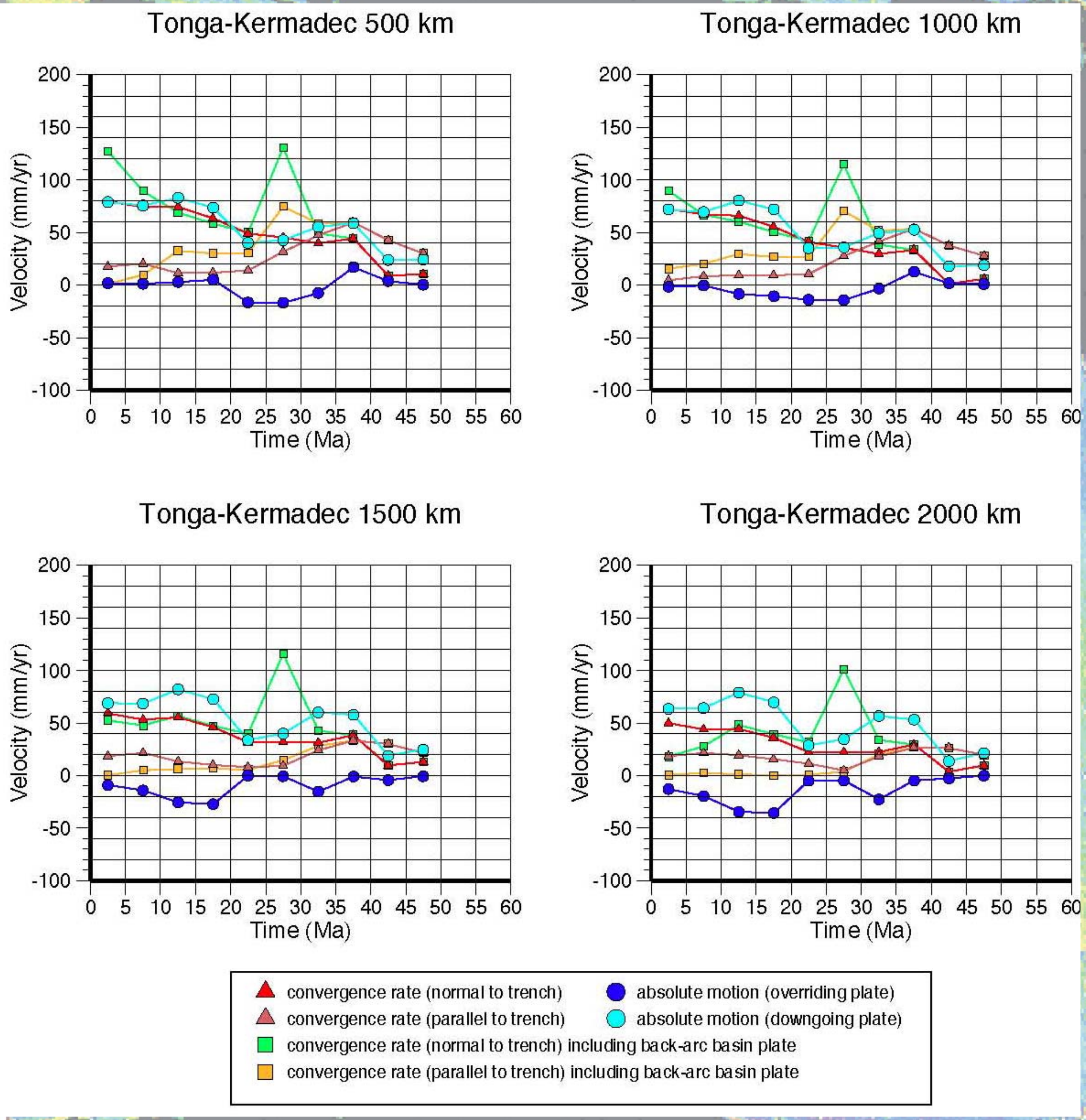


Age of subducting lithosphere increases thorugh time - migration of ridge



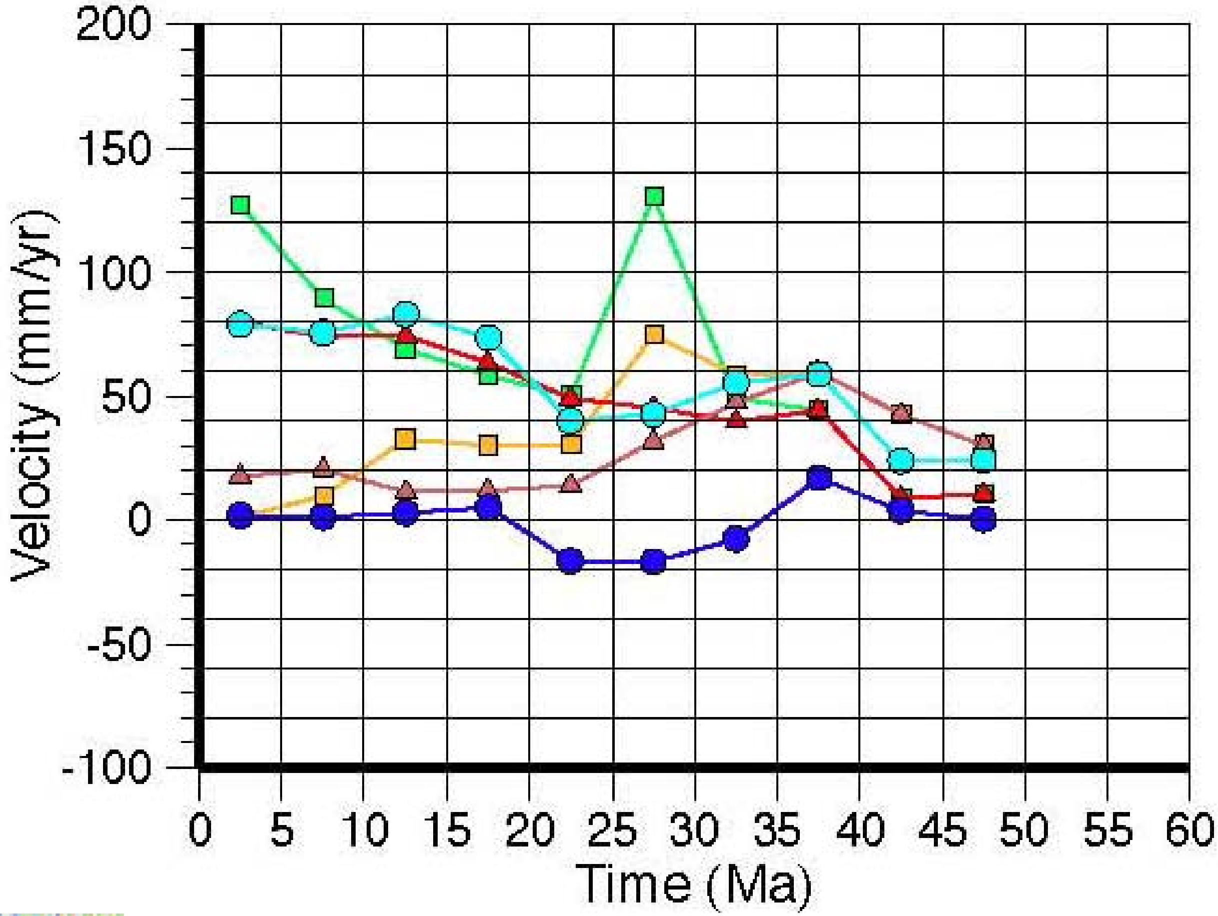


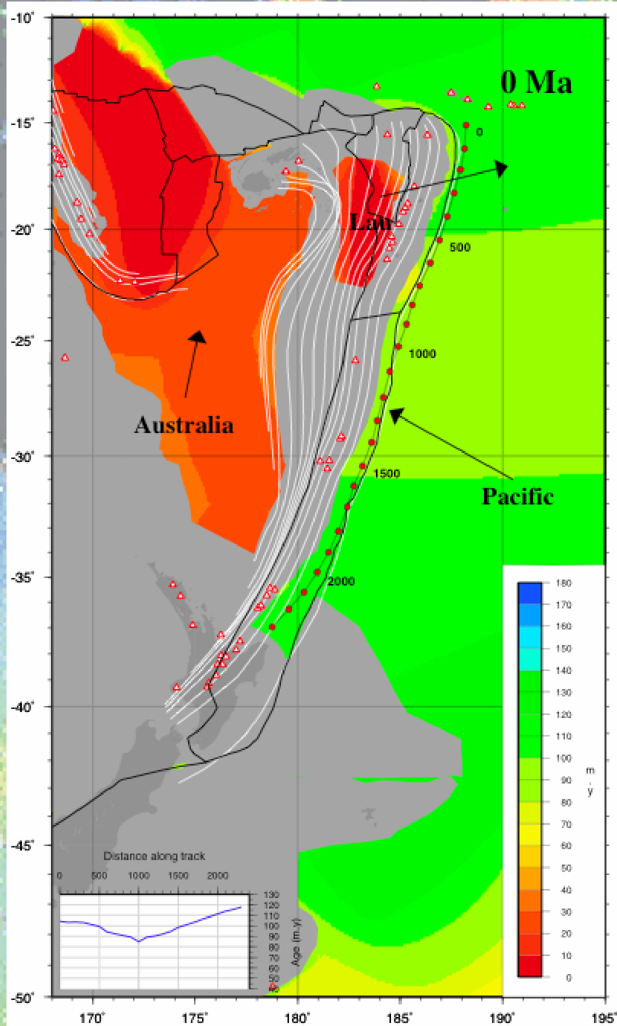
Tonga-Kermadec example



Incorporate back-arc basin spreading

Tonga-Kermadec 500 km

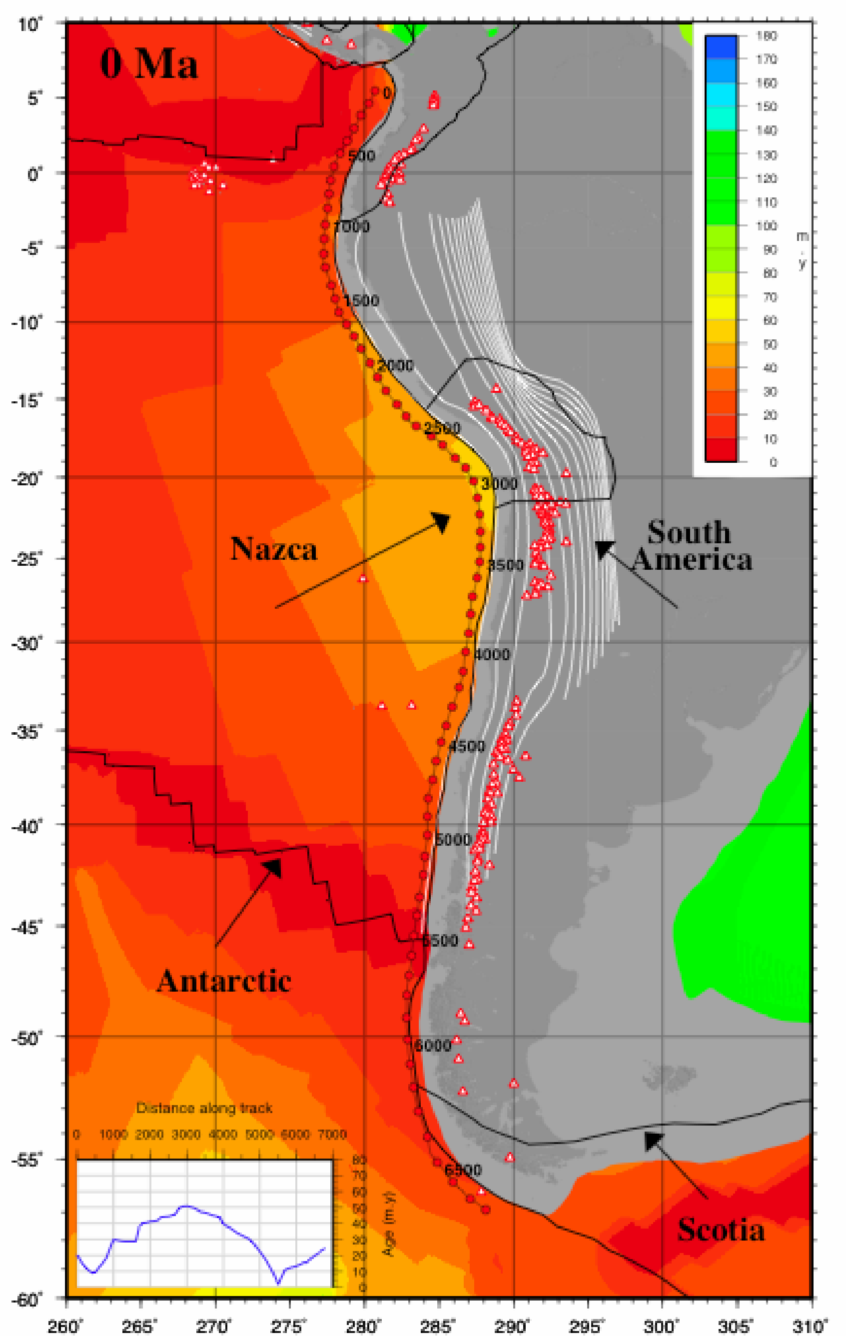


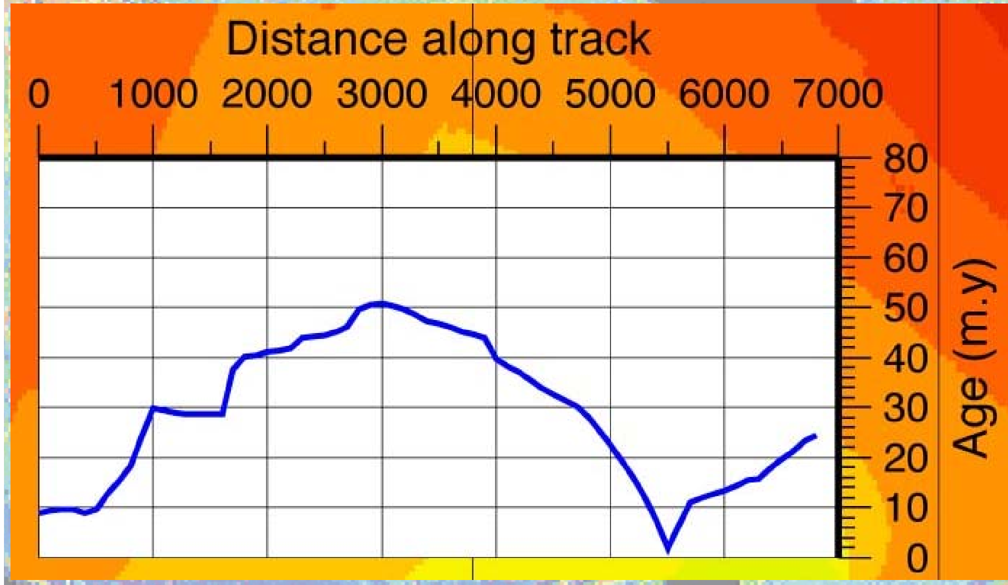


- convergence rate (normal to trench)
- convergence rate (parallel to trench)
- convergence rate (normal to trench) including back-arc basin plate
- convergence rate (parallel to trench) including back-arc basin plate
- absolute motion (overriding plate)
- absolute motion (downgoing plate)

Andes example

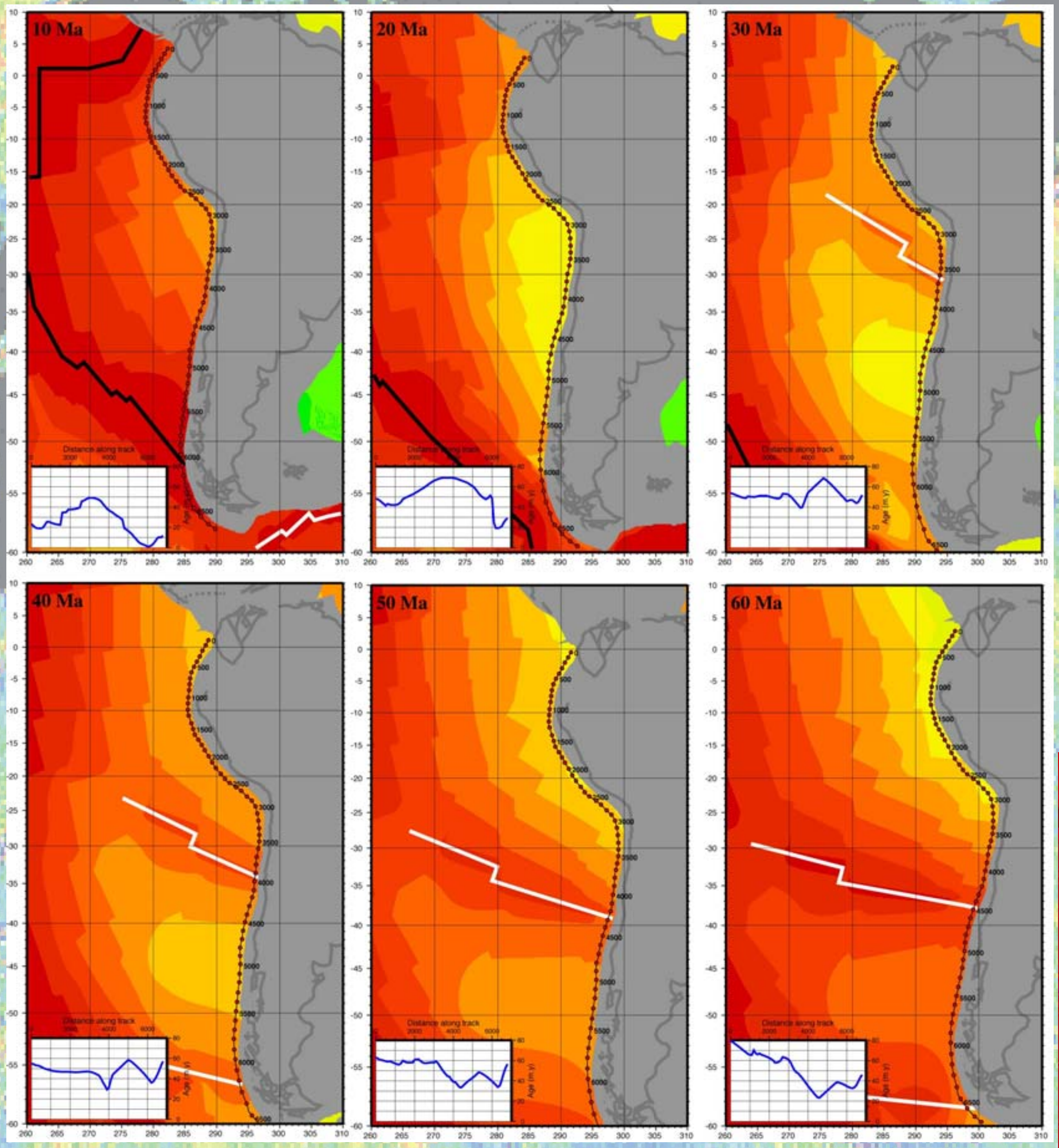
Variable age along the Andes



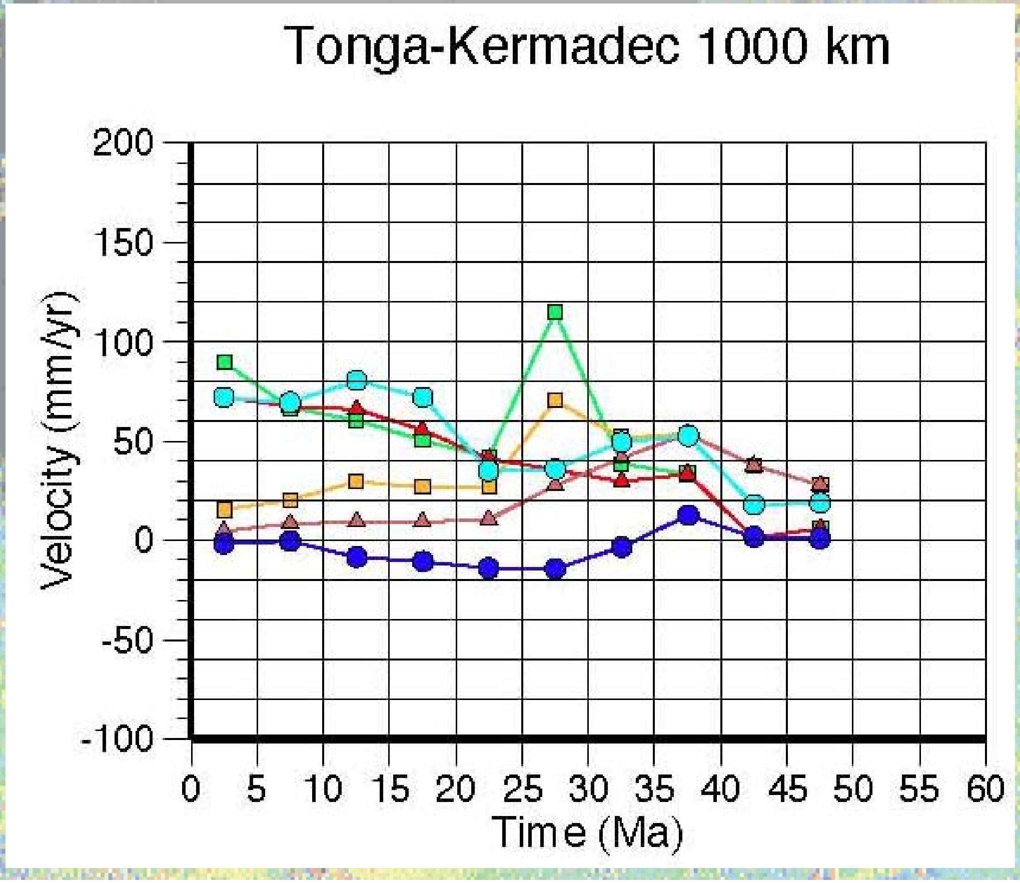


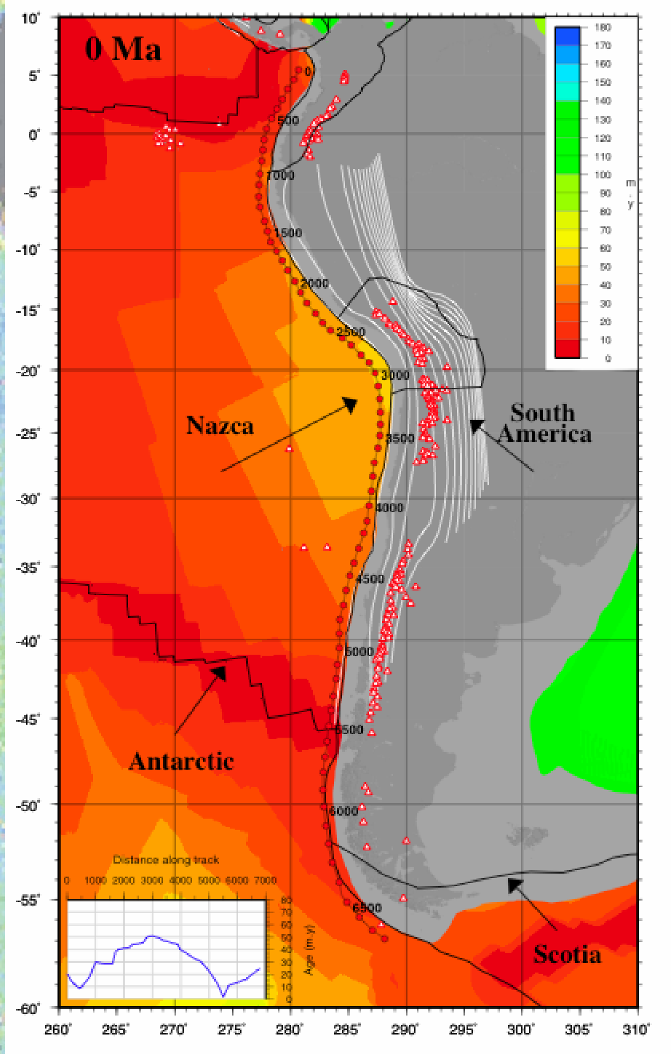
Andes example

Migration of spreading ridges



Andes example





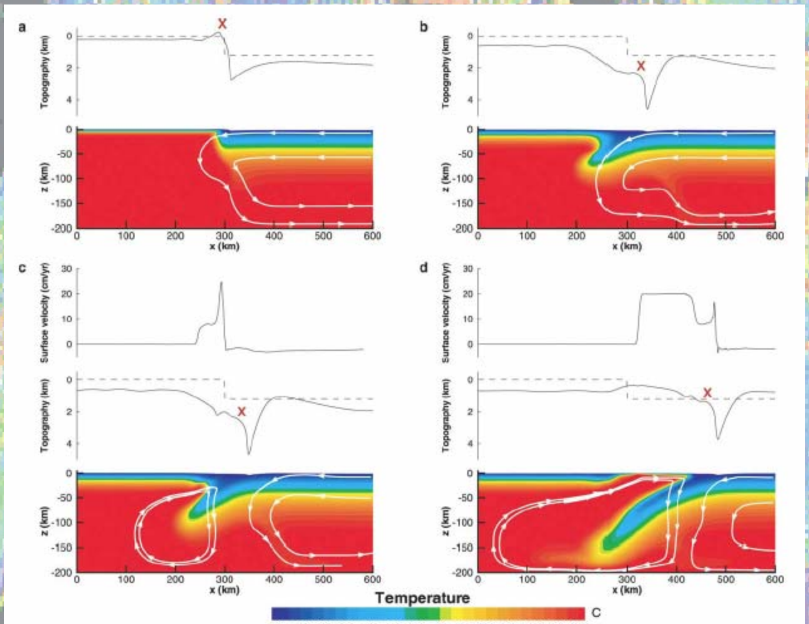
- convergence rate (normal to trench)
- convergence rate (parallel to trench)
- convergence rate (normal to trench) including back-arc basin plate
- convergence rate (parallel to trench) including back-arc basin plate
- absolute motion (overriding plate)
- absolute motion (downgoing plate)

Subduction and Back-arc Basins

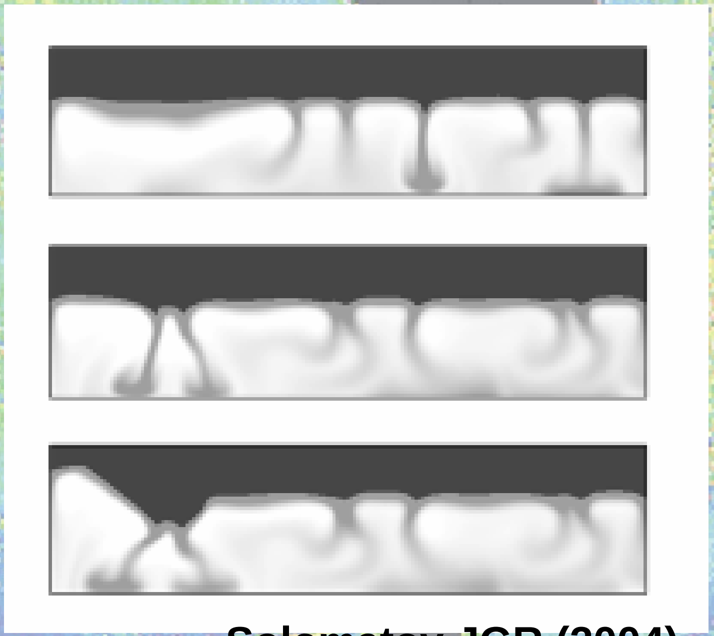
- Back-arc basins occur only when the age of the subducting lithosphere is greater than ~ 55 m.y old
- Back-arc extension initiates when the absolute motion of the over-riding plate is away from the trench
- Once back-arc spreading is established, roll-back becomes the principle driving force for back-arc spreading
- The dip of the subducting slab is greater than 30 degrees when there is active back-arc spreading

Subduction Process Modelling

- Previous models have relied on instantaneous snapshots and/or theoretical boundary conditions not well constrained by geological and geophysical observations.



Hall et al EPSL (2003)



Solomatov JGR (2004)

Subduction Process Modelling

- However, we know that subduction zones are extremely dynamic and have continuously changing shapes, locations, orientations and physical properties through time.

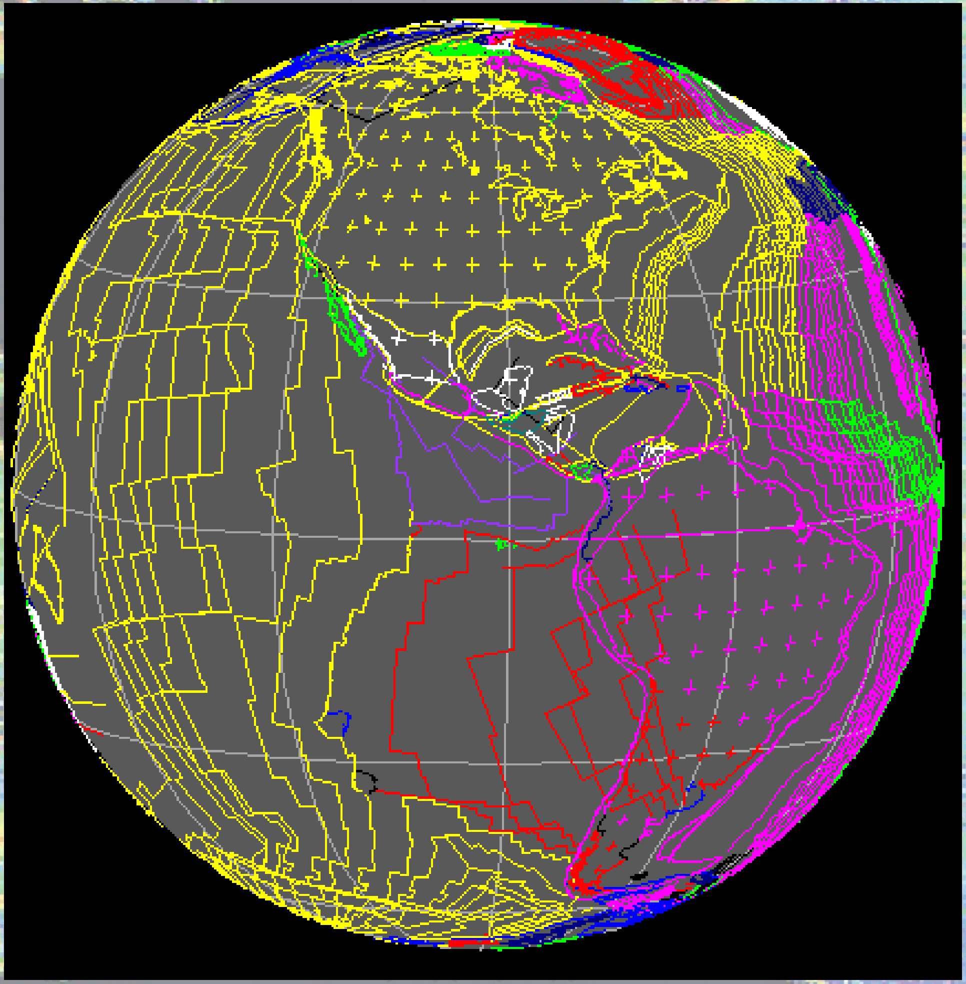
- There is real benefit in incorporating observational data into subduction modelling

Subduction Modelling - CitcomS

- Linking observational data with a 3D spherical mantle convection code, CitcomS[*]
- CitComS is a finite element code designed to solve thermal convection problems relevant to earth's mantle.
- Plate velocity vectors as top boundary layer input

*Moresi, L., Gurnis, M., and Zhong, S., 2000. Plate tectonics and convection in the Earth's mantle: Toward a numerical simulation, Comput. Sci. Eng., 2, 22-33.

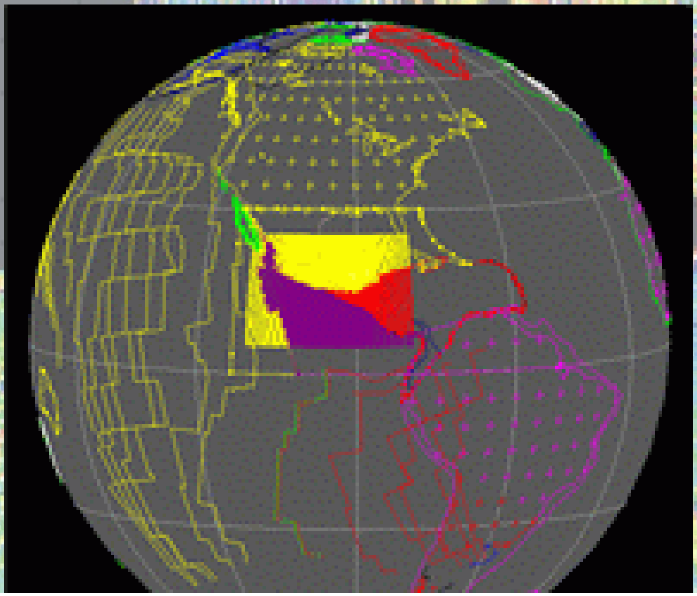
Example - Middle America



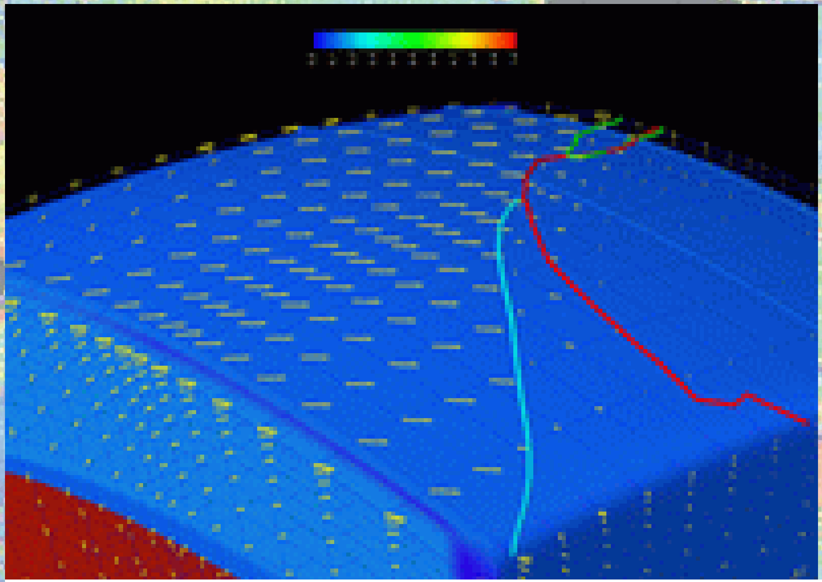
- Present day image of Middle America - plate motion model

Example - Middle America

- Mike Gurnis and Vlad Manea have been working on combining observational data into their geodynamic models.
- Preliminary results



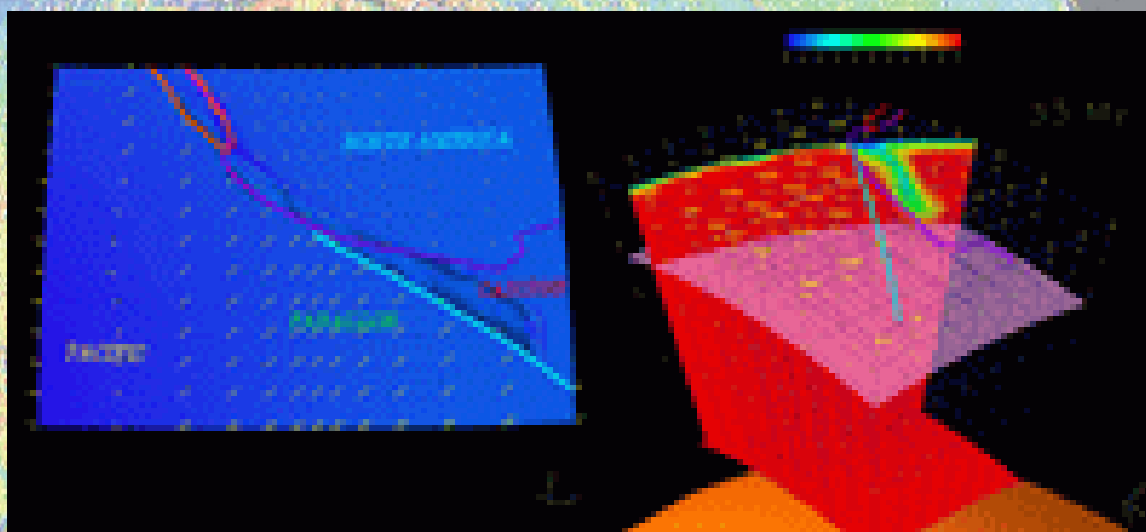
Mesh over Mid-America showing different plates



Top boundary layer velocity

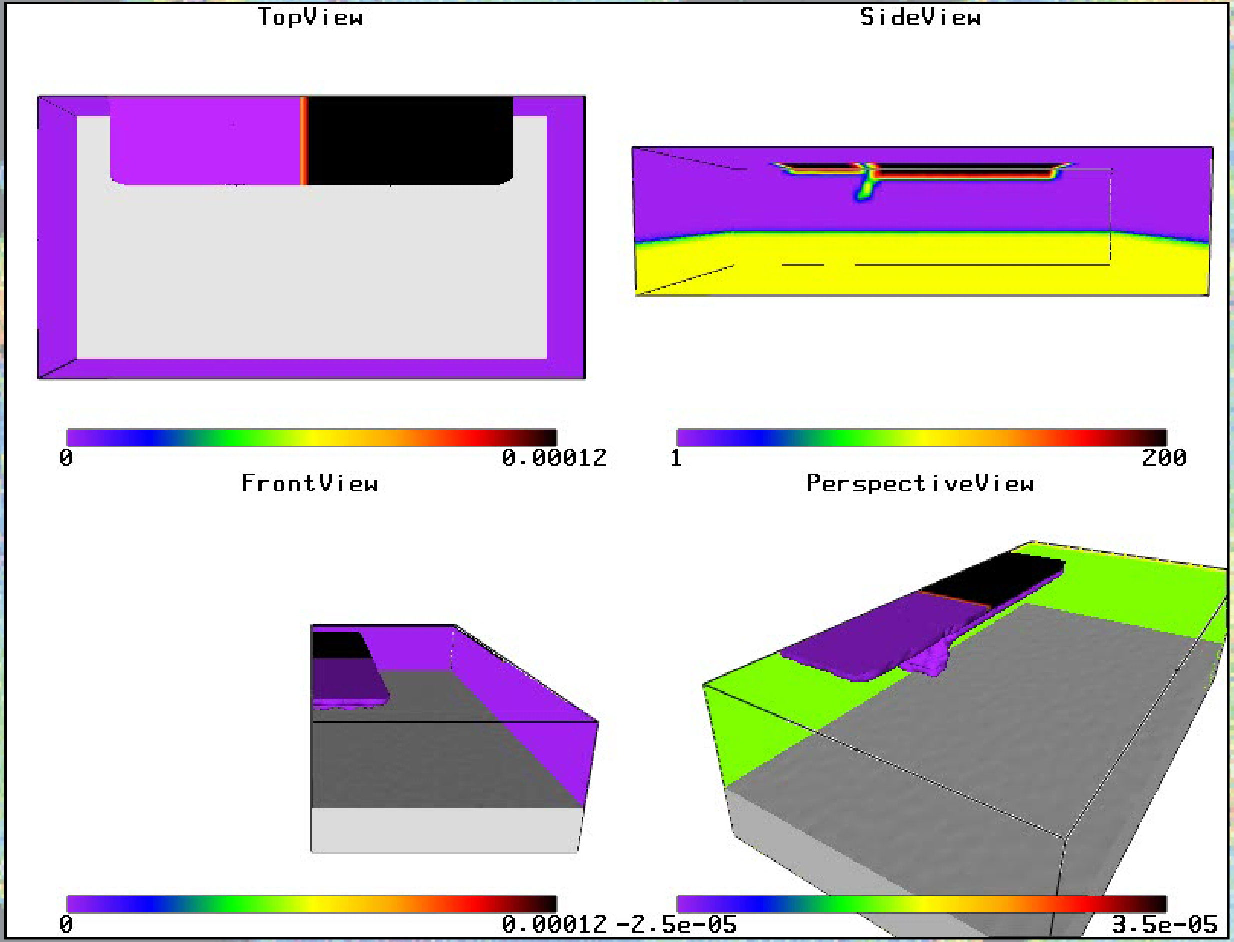
Example - Middle America

- Development of an east-dipping slab under Mexico by imposing overriding and downgoing plate velocities



Subduction Modelling - Underworld

- Courtesy of Stuart Clark
- Preliminary movie of subduction and roll-back processes with overriding plate motion prescibed



Resources

You can download these subduction datasets from the EarthByte webpage:

http://www.earthbyte.org

And follow the links to the subduction pages