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

- Age
- Dip
- Velocity

Fractional melting of oceanic crust creates andesitic magma
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 Lithosphere
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 through time - migration of ridge
Tonga-Kermadec example

Incorporate back-arc basin spreading
Andes example

Variable age along the Andes
Andes example

Migration of spreading ridges
Andes example

Tonga-Kermadec 1000 km

- Red triangle: convergence rate (normal to trench)
- Blue circle: absolute motion (overriding plate)
- Red triangle: convergence rate (parallel to trench)
- Blue circle: absolute motion (downgoing plate)
- Green square: convergence rate (normal to trench) including back-arc basin plate
- Brown square: convergence rate (parallel to trench) including back-arc basin 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
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)
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

Example - Middle America

- Present day image of Middle America - plate motion model
Mike Gurnis and Vlad Manea have been working on combining observational data into their geodynamic models.

Preliminary results

Example - Middle America

- 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 rollback processes with overriding plate motion prescribed
Resources

You can download these subduction datasets from the EarthByte webpage:

http://www.earthbyte.org

And follow the links to the subduction pages