NERC/DTI Ocean Margins Thematic Programme

iSIMM

(integrated Seismic Imaging & Modelling of Margins)

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Co-PIs - **Phil Christie & Alan Roberts** – Schlumberger Cambridge Research, Badley Geoscience

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Industry Partners

A Kinematic Fluid-flow Model of Sea-floor Spreading Initiation and Rifted Continental Margin Formation

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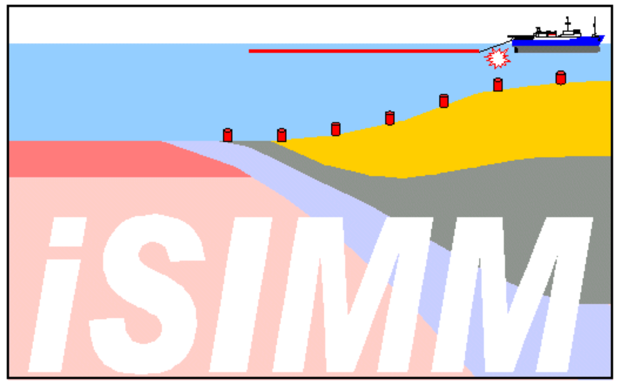

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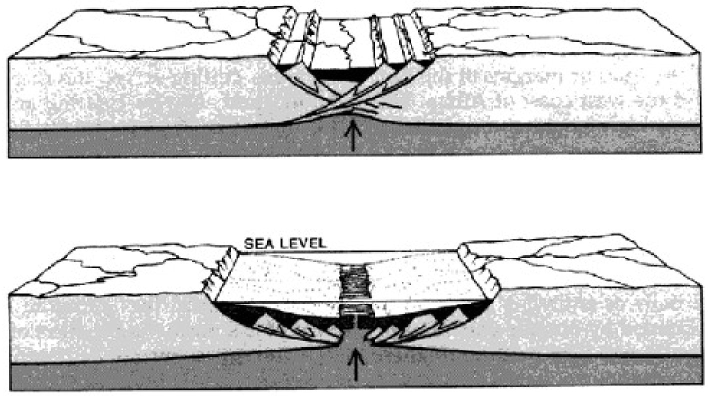
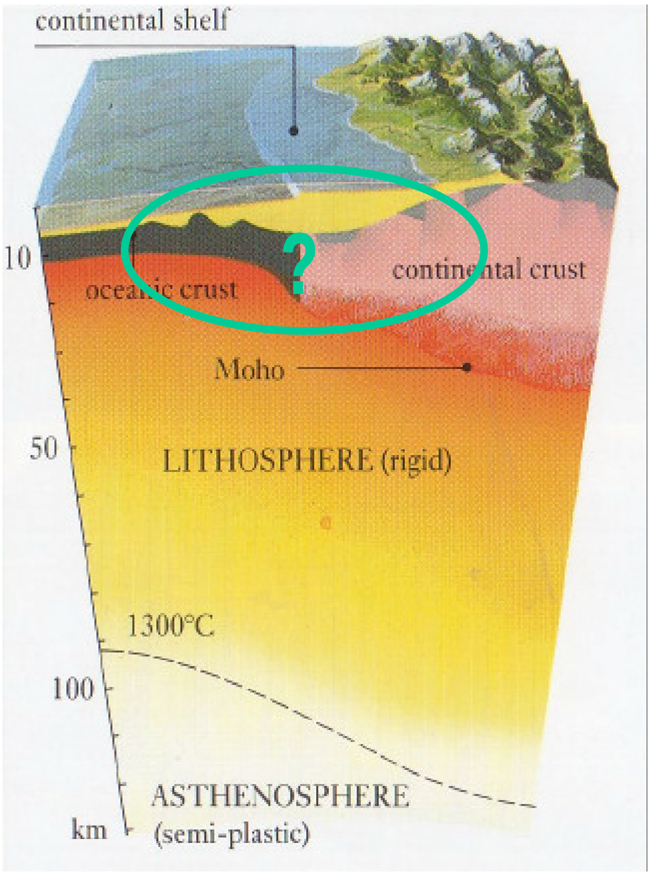
Rifted Continental Margin Formation

Is the process the same as that which forms intra-continental rift basins?





- Do we just stretch the continental lithosphere by infinity to form a rifted margin?

- Recent discoveries at rifted margins
    - *Depth Dependent Stretching*
    - *Mantle Exhumation*

- These cannot be explained by existing rift basin formation models

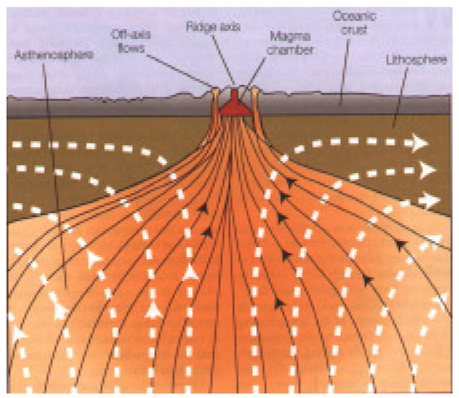
- New rifted margin formation model is needed

New Model of Rifted Margin Formation

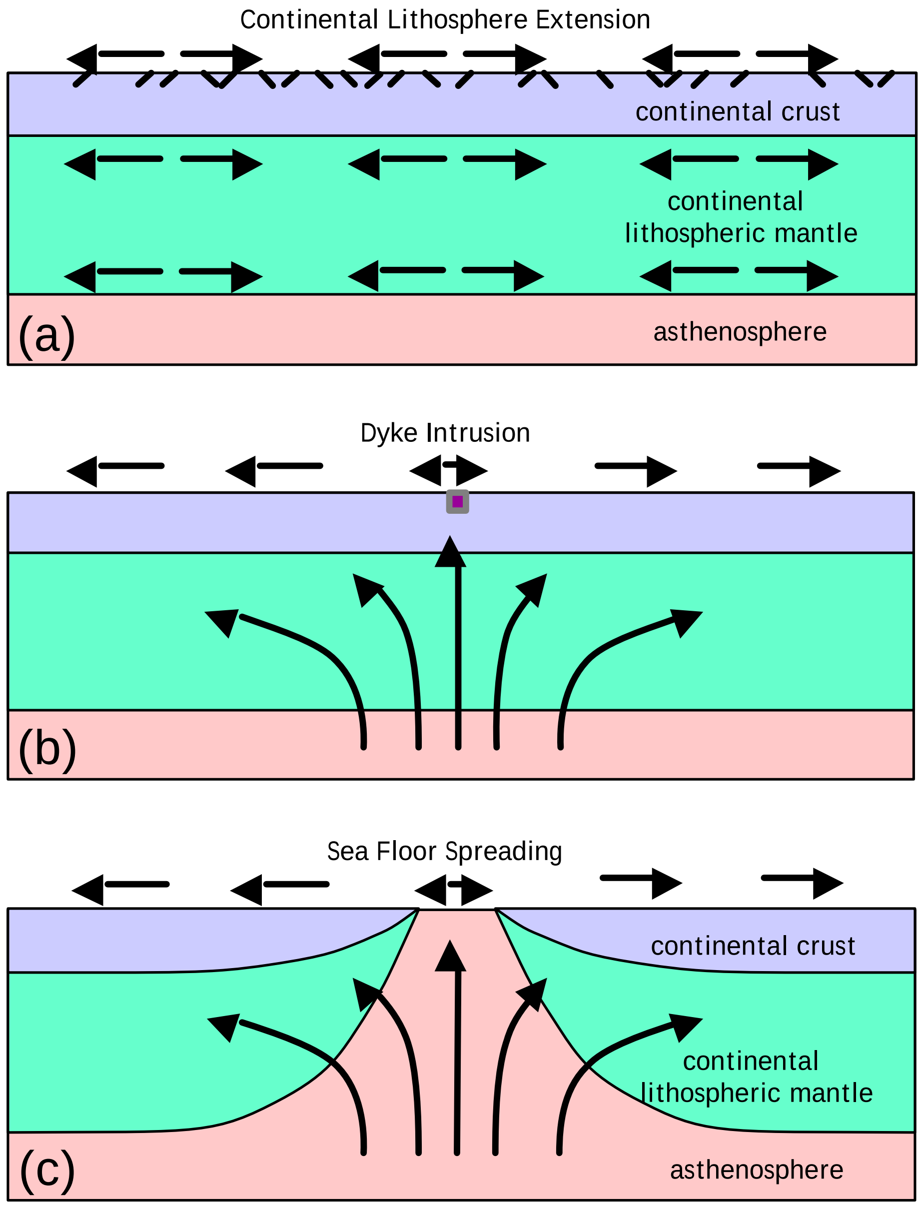
Assume dominant process for thinning continental margin lithosphere leading to breakup is -

•Upwelling & divergent flow within continental lithosphere & asthenosphere

•Not depth-uniform intra-continental extension



•Model sea-floor spreading initiation



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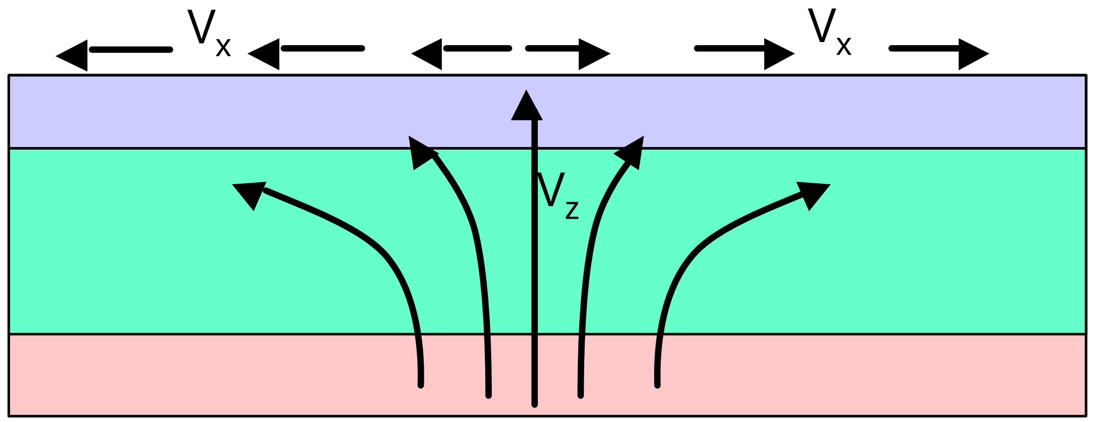
Modelling the establishment of divergent flow-fields leading to breakup

Corner-flow model

- Isoviscous stream-function solution (Batchelor 1967)
- Kinematic - define divergent & upwelling velocities
    - Define V_x (divergent half-rate velocity)
    - Define V_z (upwelling velocity)

Pre-breakup Divergent Stretching



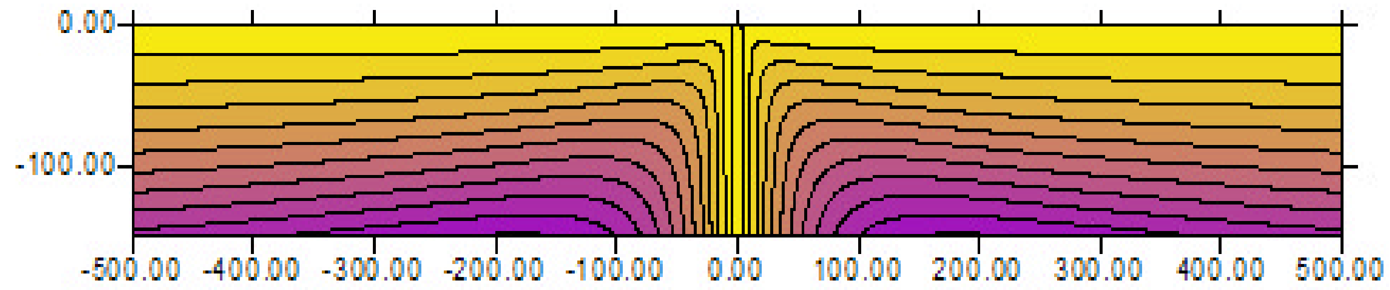
$$\Psi = (Ax + Bz) + (Cx + Dz)\tan^{-1}\left(\frac{z}{x}\right)$$

$$U_x = -B - D\tan^{-1}\left(\frac{z}{x}\right) + (Cx + Dz)\left(\frac{-x}{x^2 + z^2}\right)$$

$$U_z = A + C\tan^{-1}\left(\frac{z}{x}\right) + (Cx + Dy)\left(\frac{-y}{x^2 + z^2}\right)$$

where A, B, C & D depend on U_x & U_z

Flow streamlines



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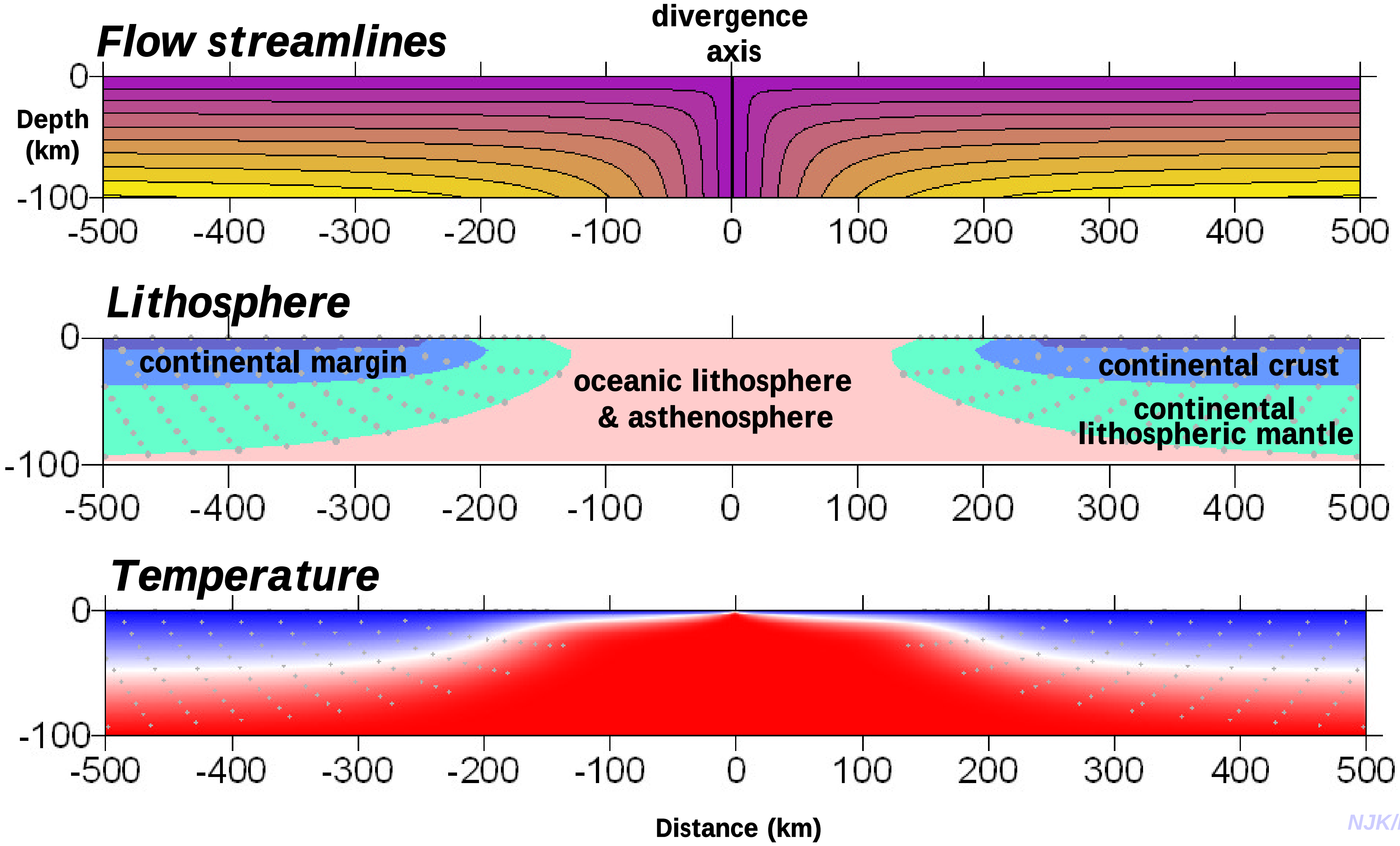
Modelling the establishment of divergent flow-fields leading to breakup

- Derive flow-field
- Advect continental lithosphere material
- Use coupled thermal diffusion & advection solution

$$\frac{\partial T}{\partial t} = k\nabla^2 T - \bar{u}.\nabla T$$



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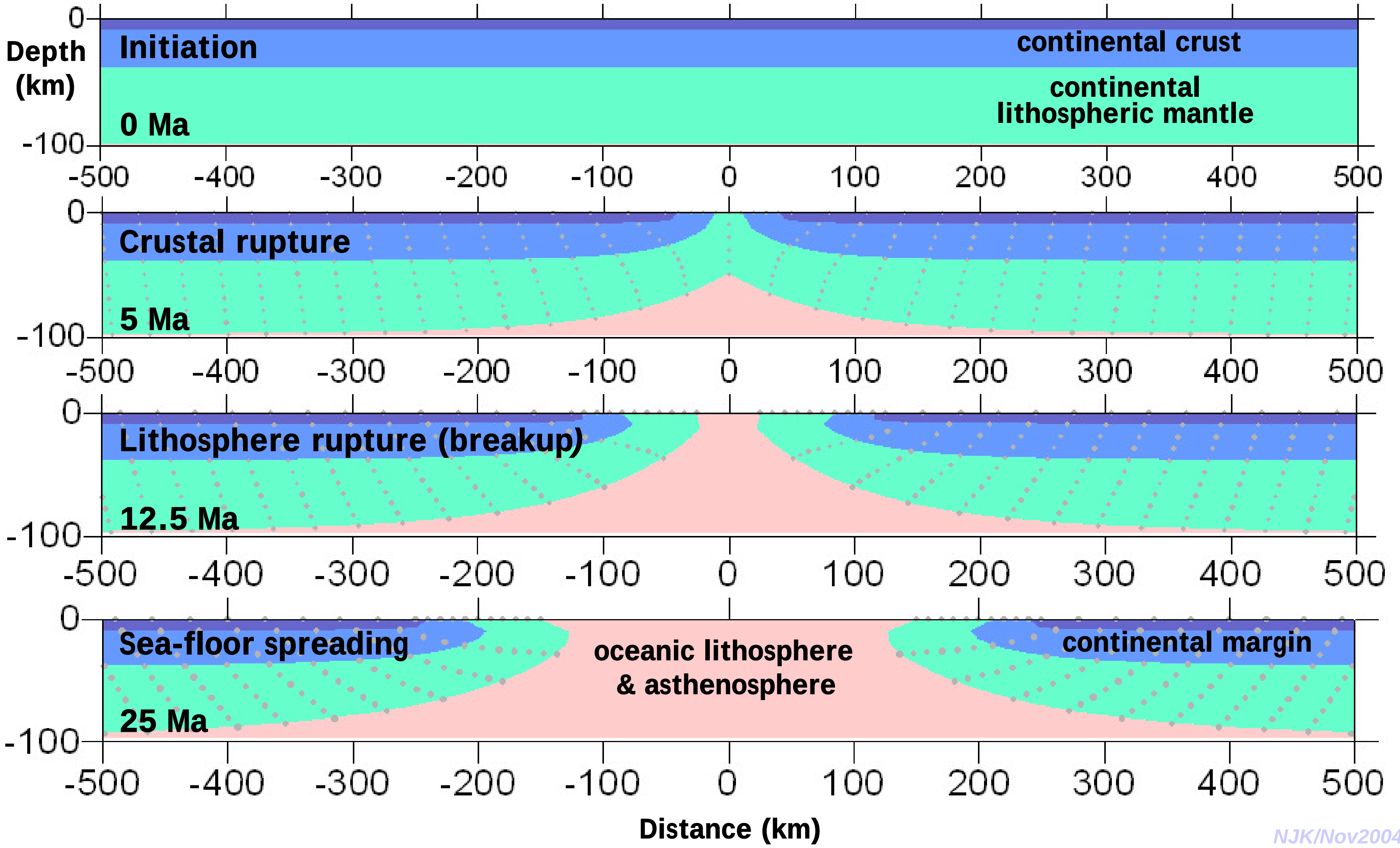
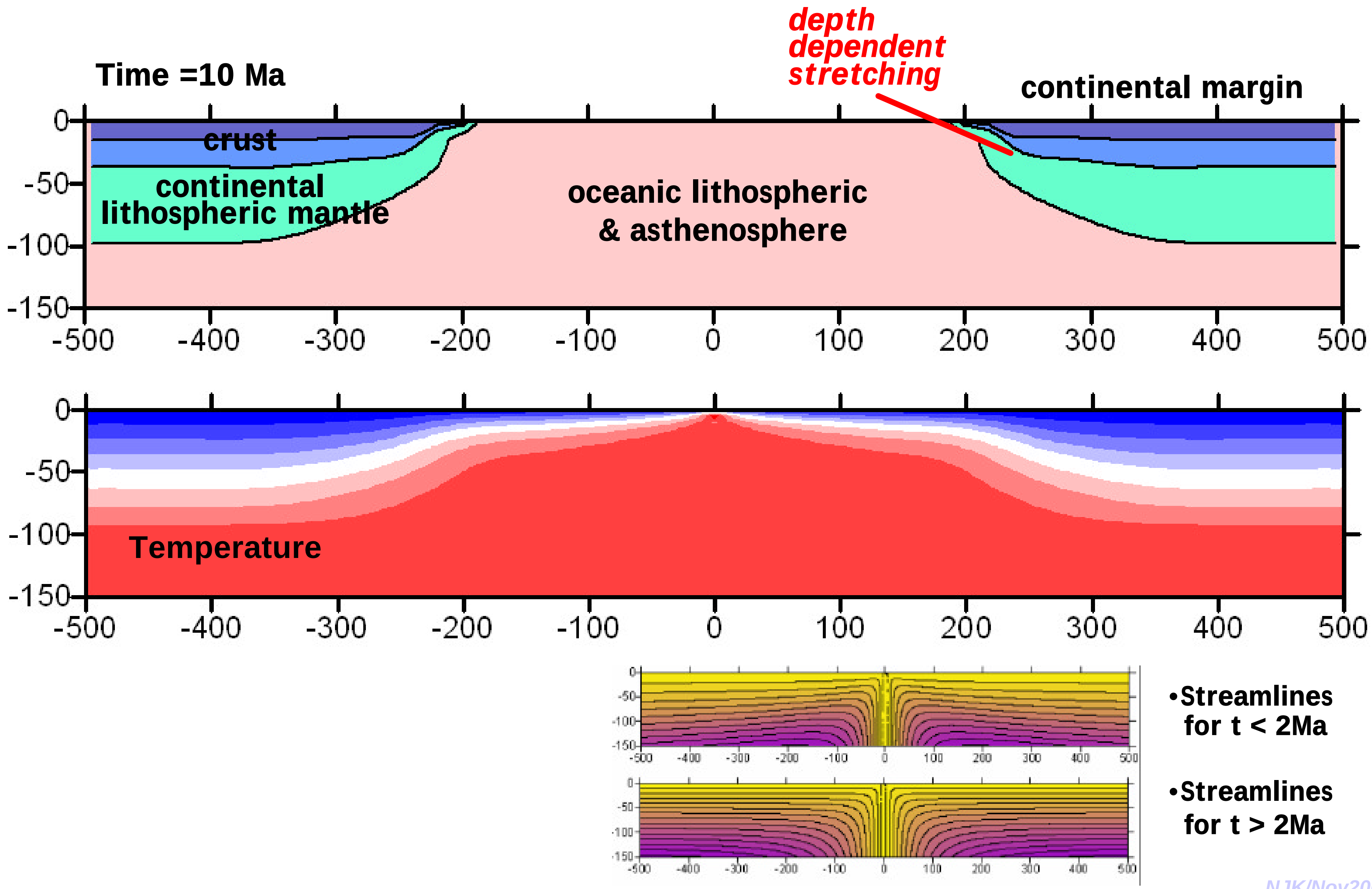
Modelling Rifted Margin Formation

Time Evolution

$V_x = 1$ cm/yr, $V_z/V_x = 1$



Modelling Volcanic Margin Formation



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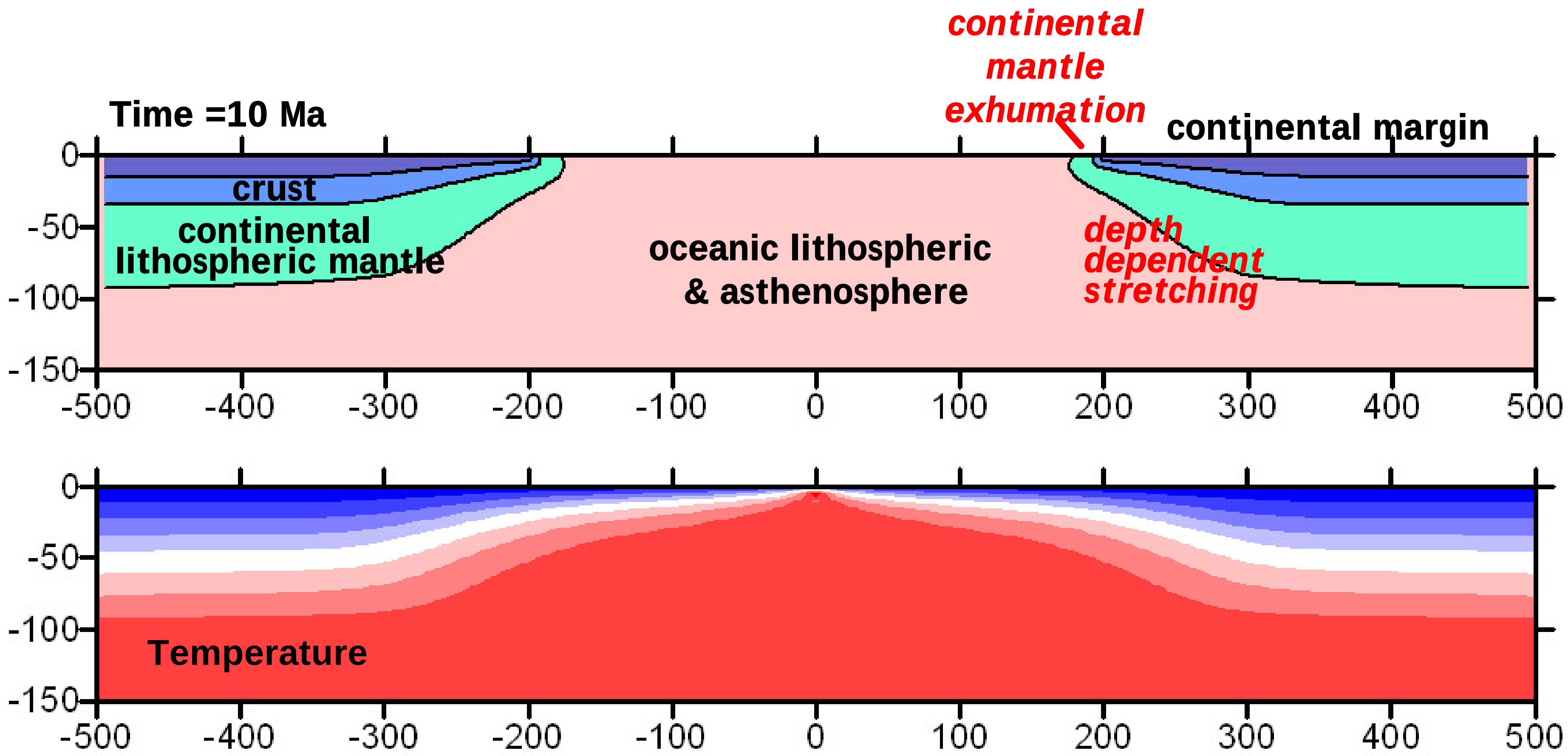
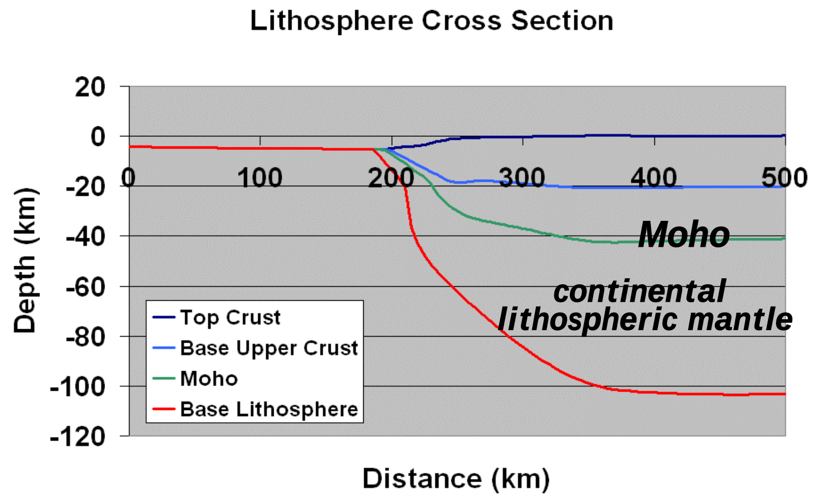
Modelling Non-volcanic Margin Formation

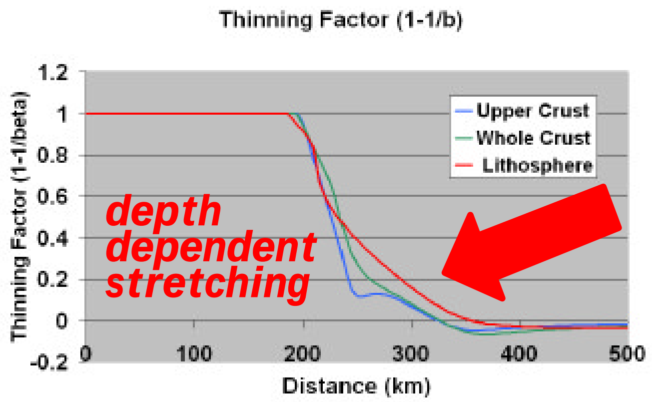


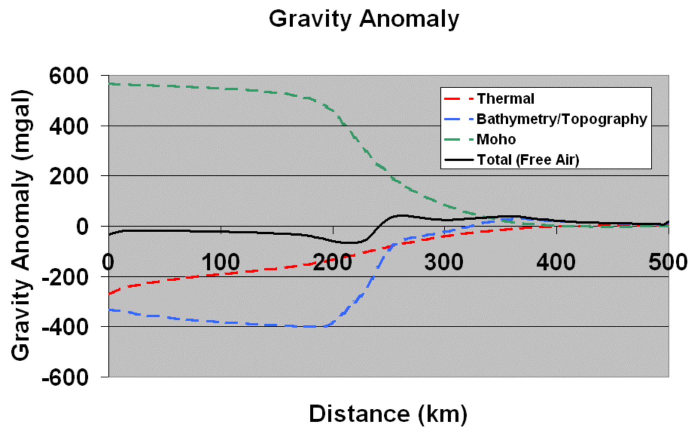
Modelling Margin Formation

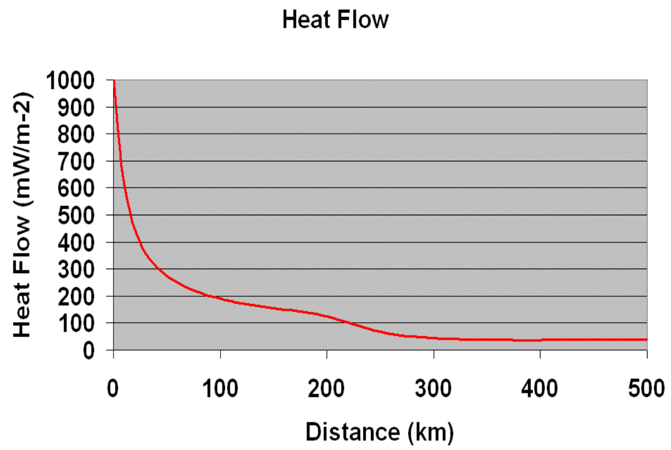
New model predicts

- Depth dependent stretching
- Mantle exhumation
- Bathymetry and subsidence history
- Heat flow history
- Gravity Anomalies

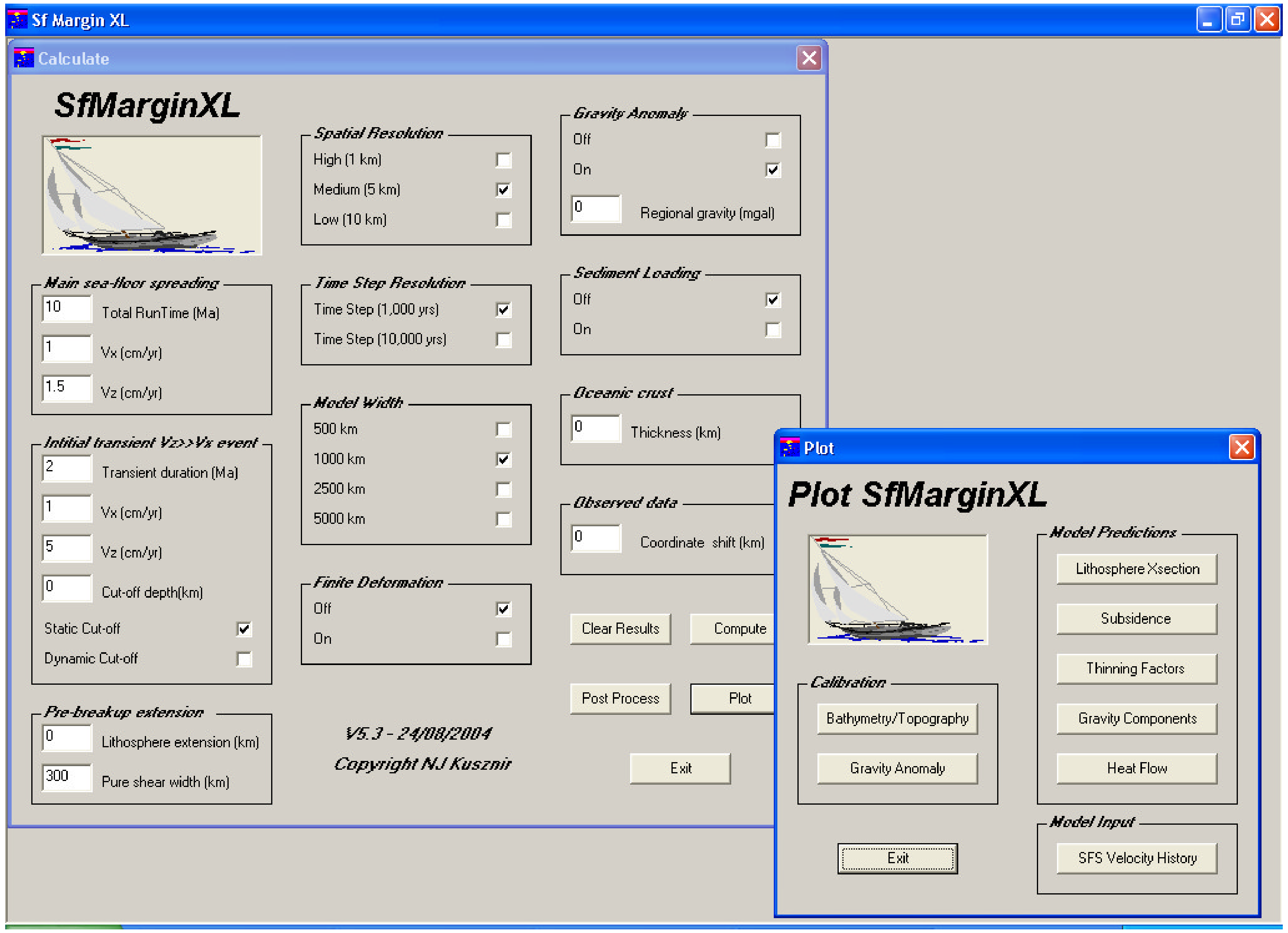


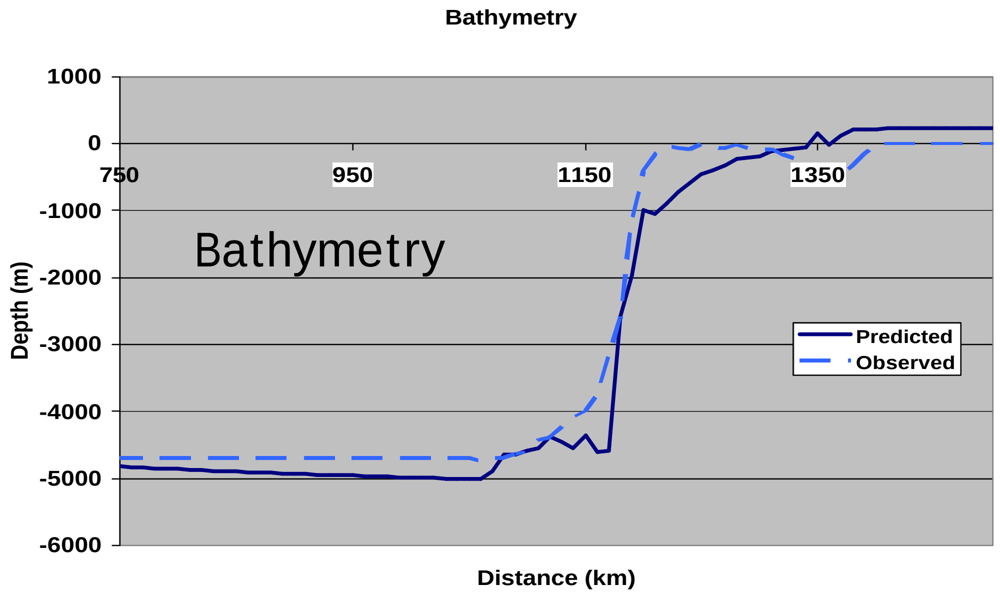






SfMargin - Modelling Margin Formation



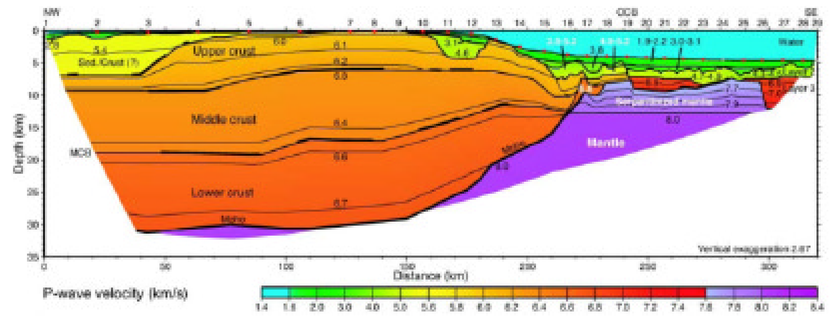


SfMargin Applications

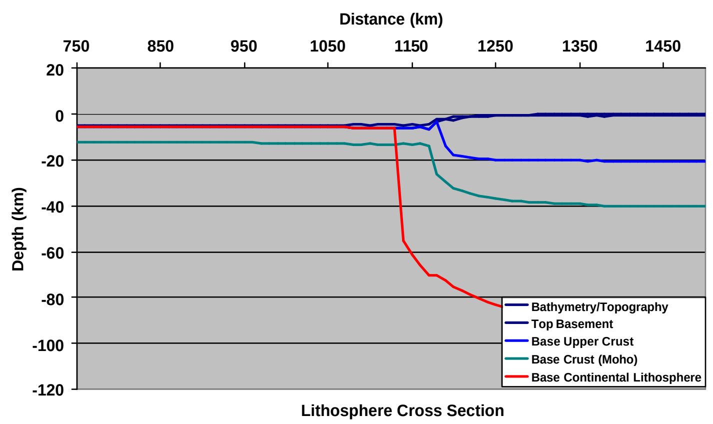
NSF/Intermargins/ESF Margin Modelling Workshop Pontresina July 2004

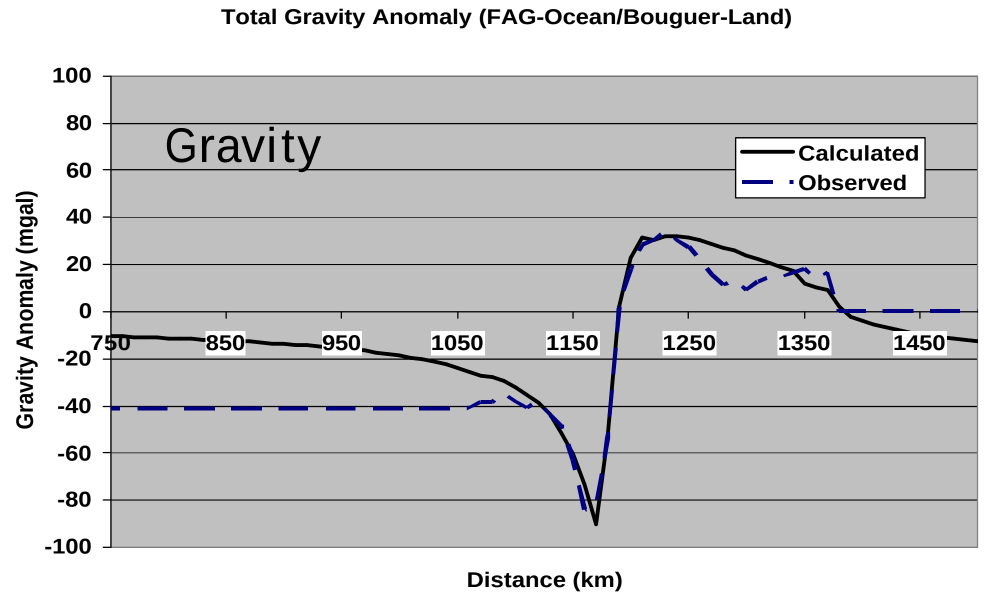
Newfoundland Margin

Screech 1



Vz/Vx =1.5, b = 1 (with sediments)





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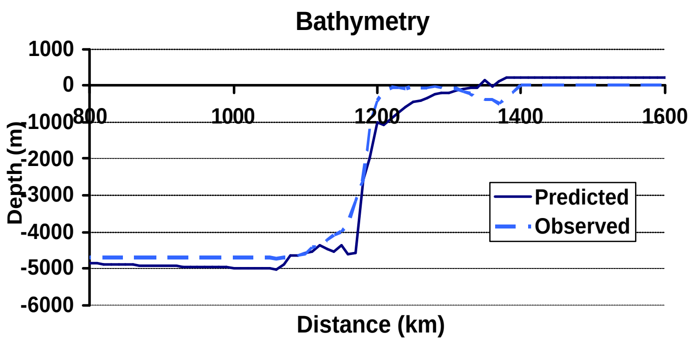
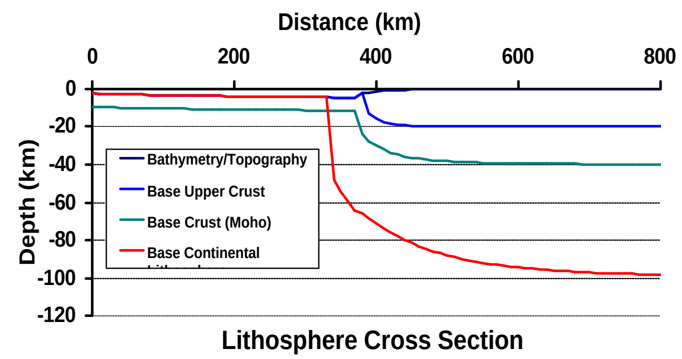
SfMargin - Modelling Margin Formation

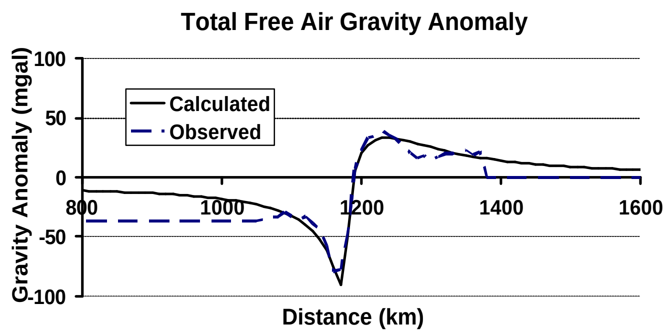
Workflow for Industry Applications

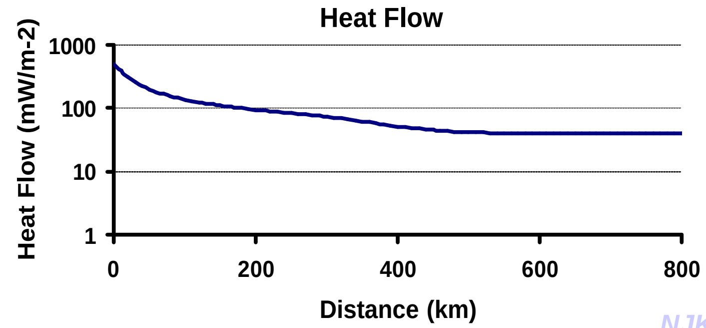
•Invert observed bathymetry & gravity data to give margin deformation kinematics

•Use model to predict –
- •margin crustal structure
- •lithosphere temperature
- •heat flow
- •subsidence history









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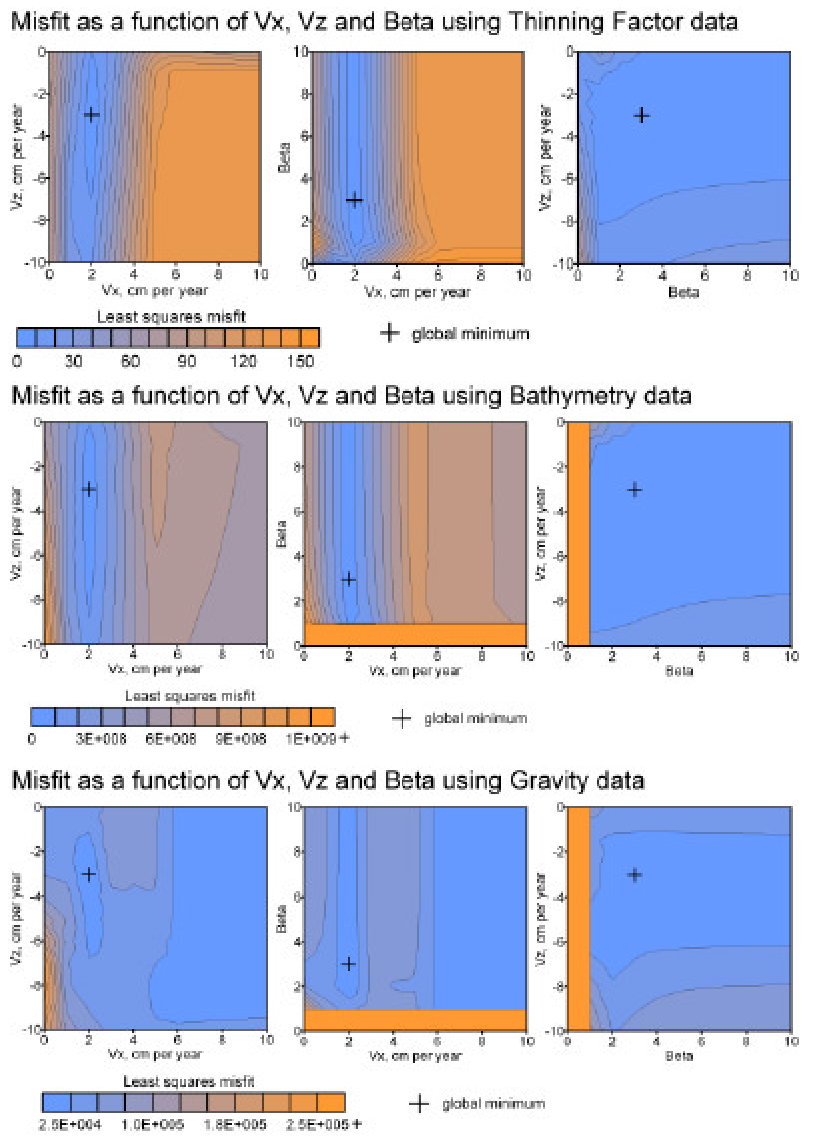
Inverse Methods
Synthetic Data

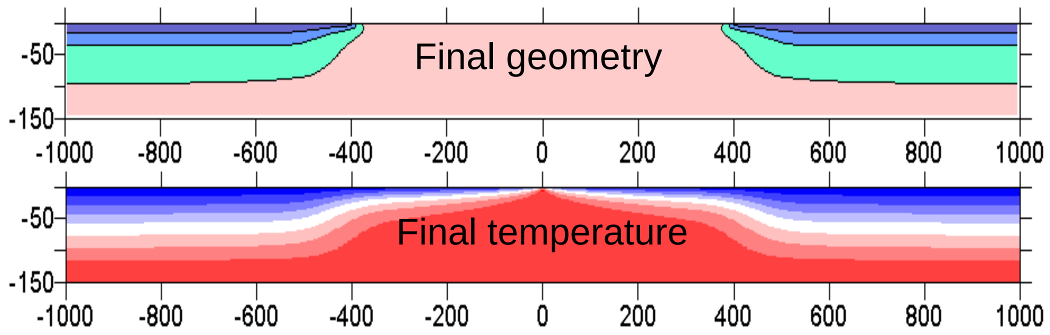


Forward model input parameters

- Vx = 2cm -1
- Vz = 3 cm/yr
- $\beta = 3$

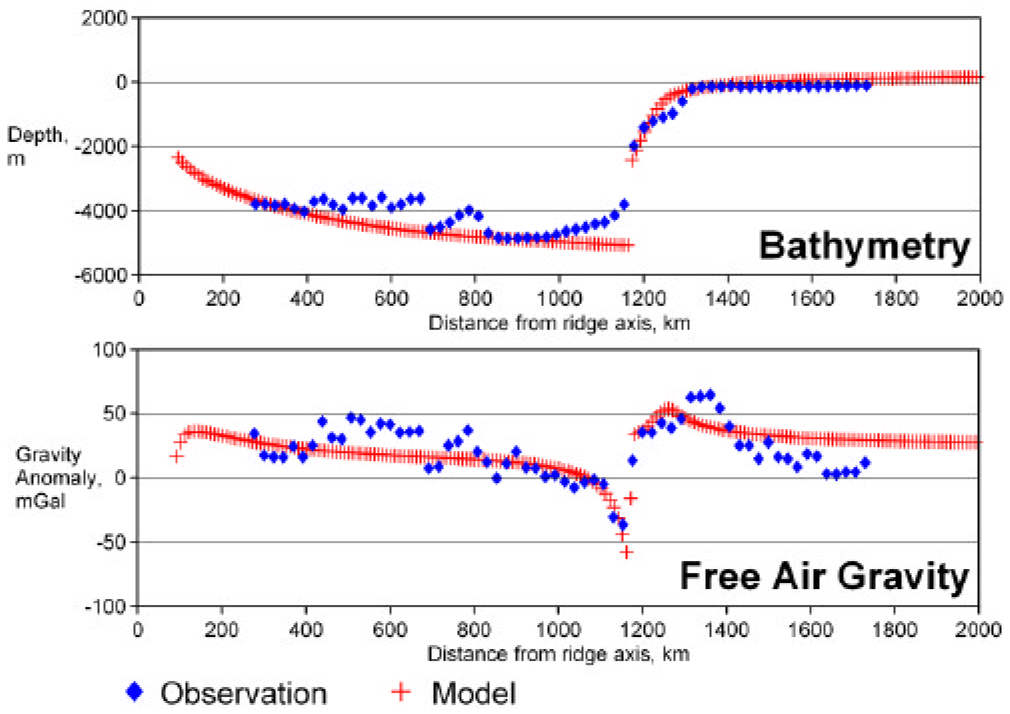
Grid search inversion using predicted thinning factor, bathymetry and gravity

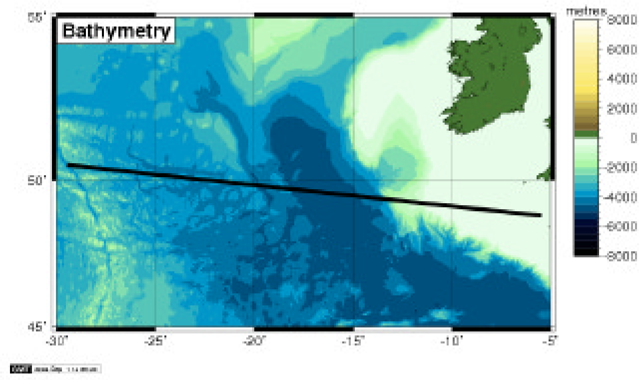
Successful recovery of input parameters with zero least squares misfit (L2 Norm)

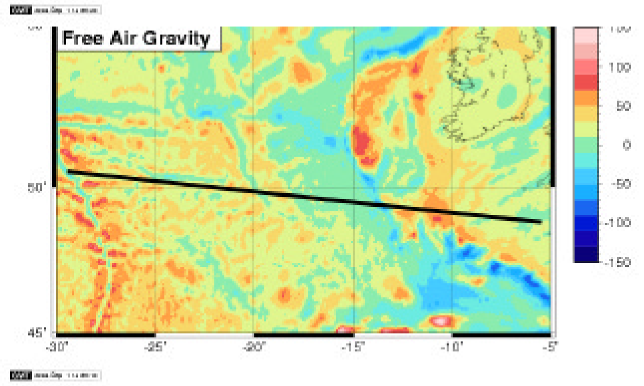


Inverse Methods
Goban Spur

Grid search inversion – minimum misfit
- $V_z / V_x = 1.25$
- $\beta = 1.5$





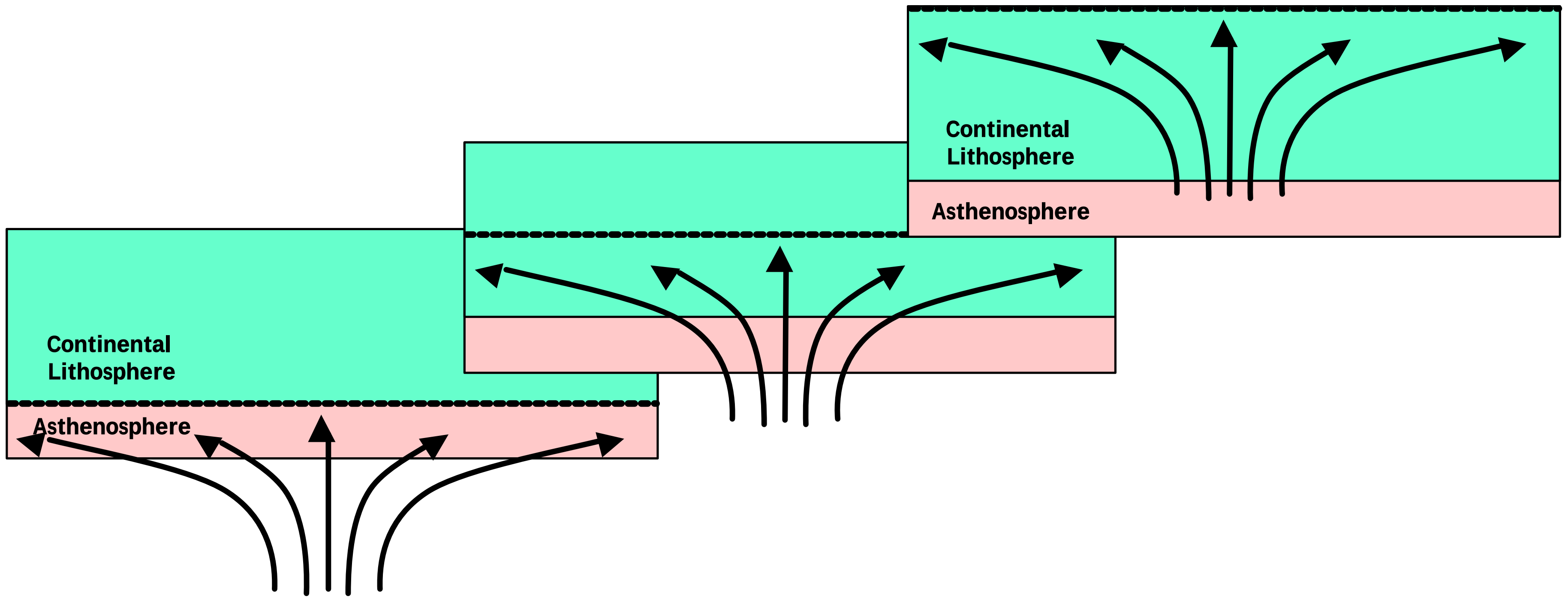


Comparison of best fit model prediction with observations

Breakup Initiation & Pre-Breakup Basin Formation

- Application to basins formed during sea-floor spreading initiation or failed breakup

- Model upward propagation of upwelling divergent flow field within continental lithosphere & asthenosphere



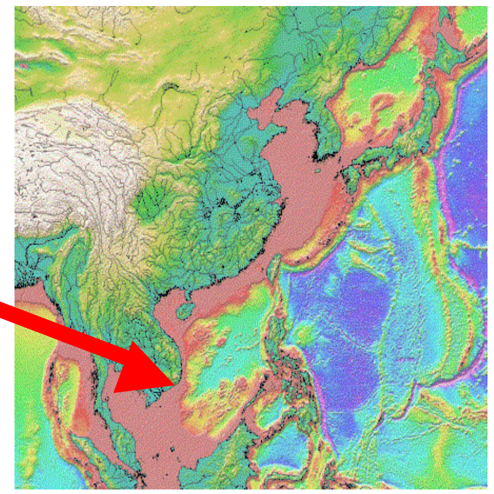
Examples

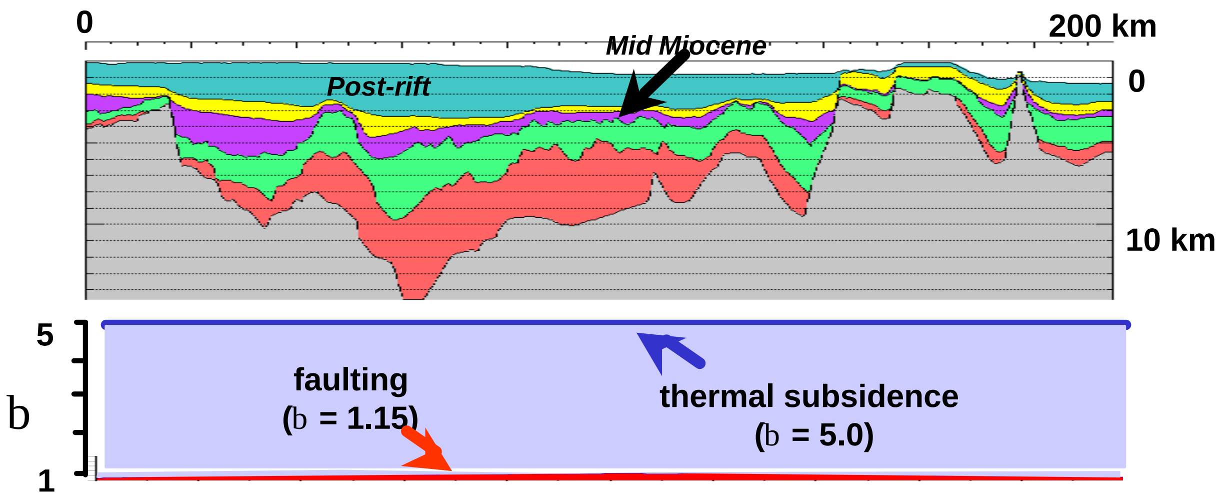
- Woodlark Basin, Nam Con Son Basin, Faroes-Shetland Basin

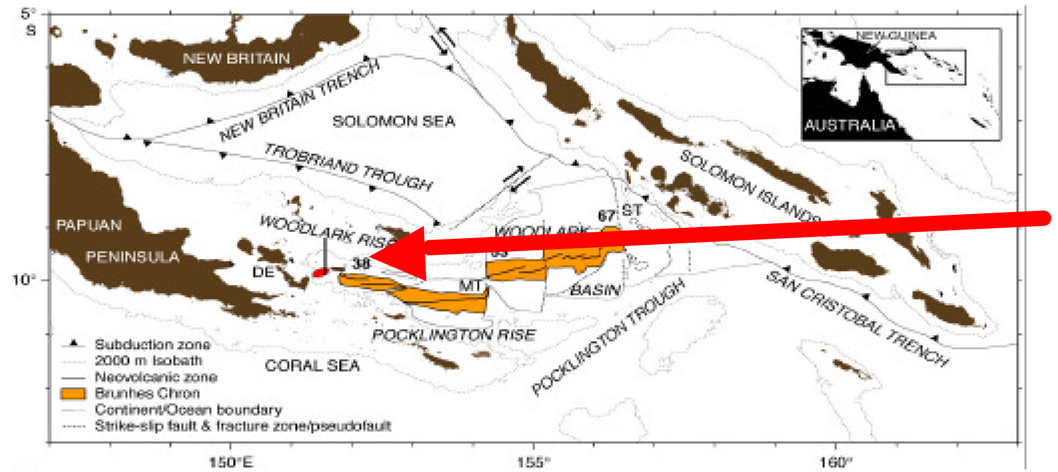
Nam Con Son Basin

Located at propagating SW tip of mid-Miocene sea-floor spreading in South China Sea

- Large post-rift subsidence
- Little continental upper crustal extension







Woodlark Basin

- Young ocean basin - initiated ~ 8 Ma
- 3000 m subsidence in continent ahead of propagating tip
- Little continental upper-crustal extension

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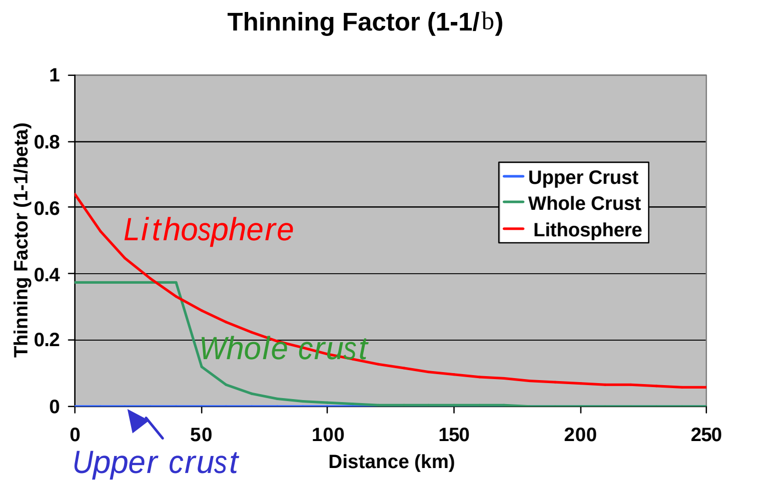
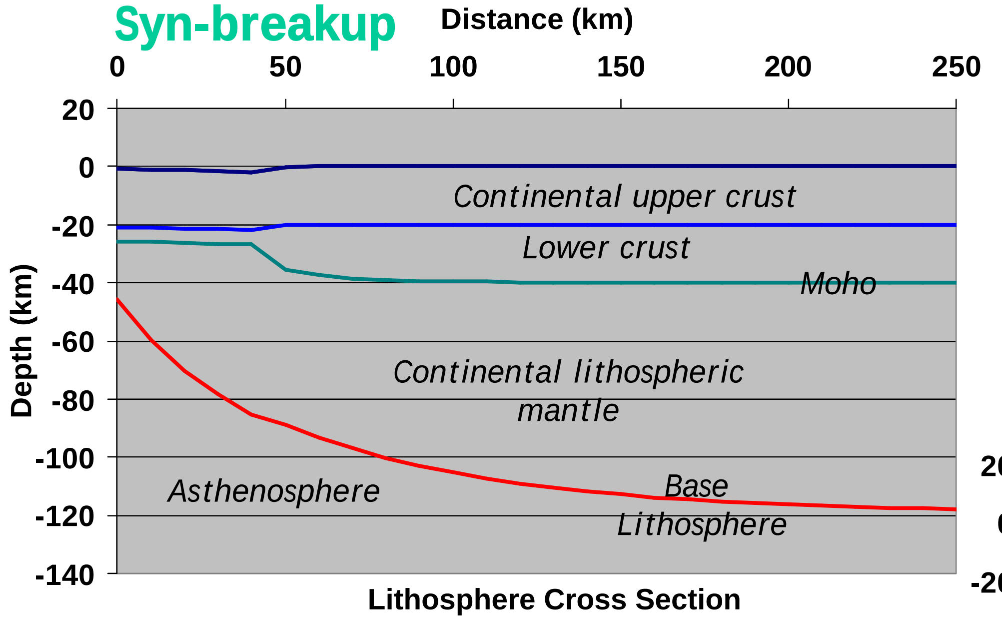
SfMargin Applied to Pre-breakup Basin Formation

- No stretching of the upper crust
- Large thinning of lithospheric mantle and lower crust



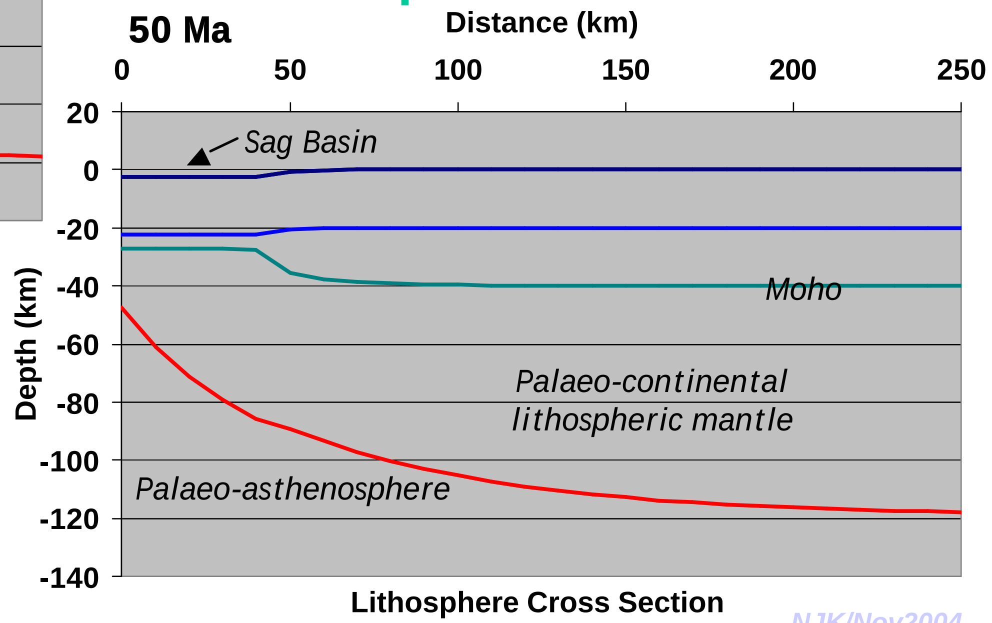
Syn-breakup



- Broad syn-breakup sag basin
- Large post-breakup subsidence

Post-breakup

50 Ma



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the department of earth & ocean sciences
THE UNIVERSITY of LIVERPOOL

iSIMM Posters -Geodynamic Modelling

David Healy - Breakup Kinematics from Inversion of Bathymetry & Gravity Data

Vijay Tymms – Effects of Temperature Dependent Rheology on Continental Breakup & Margin Formation

Neil Hurst – Thinning, Subsidence and Plume Uplift on the Faroes Margin from Flexural Backstripping & Gravity Inversion


Hatton Bank /July 2002