Heat release freezing melt -dike

\[ T = \frac{1}{2\sqrt{\pi \kappa t}} \int_{-\infty}^{\infty} T'(y') e^{-\frac{(y-y')^2}{4\kappa t}} dy' \]

where $\kappa$ is the thermal diffusivity (m$^2$/s)
y' is a dummy variable for integration
t is relaxation time
y is distance from dike or sill center line
Effect on serpentinization

No heat release

Accumulated serpentinization 20.01 Ma

Area of melt production 20.01 Ma

Magmatic crustal thickness 20.01 Ma

Heat release

% Serp

% Melt

Time [Ma]

Crustal thickness [km]
Thermal and rheological model at start of rifting.

1. Water into mantle
2. Serpentinization
3. Weakening

\[
Z_c = Z_{c0} / Z_c
\]

TIME DURING EXTENSION

1. Water into mantle
2. Serpentinization
3. Weakening

\[ \beta = \frac{Z_{c0}}{Z_c} \]

Start of Margin Stage

Most active Faults

Less active Faults

Faults rotate from 65° to 45°, crust thins from 30 to 23.4 km

Faults fb and fc further rotate from 45° to 30°. Crust thins from 23.4 to 21.3 km.

Fault fc further rotates from 40° to 30°. Crust thins from 21.3 to 16.6 km.

New fault f1 starts where the crust is ~16.6 km thick.

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Kinematic model: Basin Stage

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Margin stage

CRUST BREAKS
MANTLE EXHUMED - F7 ROTATES BACK
Old Fault fn1 rotates from 35° to 27°

What are fault and crustal thinning kinematics leading to break-up?

Reconstruction of Iberia-Newfoundland Margins at Anomaly M0
1- Image Pre-Syn rift sediment -> synrift younger basinward
2- Faults start at 65°-55° and rotate to 42°-28°.
3- Fault block dimensions decrease basinward.
4- Faults cut progressively thinner brittle layer.

Faulting sequential in time.
Faults cut through progressively thinner crust
1- Image Pre-Syn rift sediment -> synrift younger basinward
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Faulting sequential in time.
Faults cut through progressively thinner crust
1. Upper crust brittle & lower crust ductile
2. Upper and lower crust extend by the same amount. Lower crust deforms compliant to upper crust.
3. Area conservation: $X+Y+Z=T$
4. A wide brittle-ductile transition.
Model rules

Margin stage:

- Lower crust progressively brittle!!
- Upper and lower crust extend by the same amount. Lower crust deforms compliant to upper crust.
- Area conservation: \( X + Y + Z = T \)
- Area conservation leads to back-rotation of previous planar faults.

Implications

• No active faulting at low angles, just normal Andersonian faulting (normal faults at 60°–30°).
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Implications (cont.)

Occurrence of shallow pre-rift and syn-rift over the whole basin, even on top of extremely thinned crust. No need for anomalous subsidence.

Peak heat-flow moves oceanward. Post-rift sediments on continental platform may pre-date continental break-up.
Implications (Illustrated)

- Younger and deeper synrift basin margin

1. Fault f7 starts at 60°
2. New fault f6 starts at 60°
3. New fault f1 starts working at 60° and stops at 40°. Crust thins from 16.6 to 12.3 km.
4. New fault f1 starts where the crust is ~16.6 km thick.
5. Faults rotate from 65° to 45°, crust thins from 30 to 23.4 km.
Implications (Illustrated)

- Younger and deeper synrift Basin Margin
- CRUST BREAKS
  - MANTLE EXHUMED - F7 ROTATES BACK
  - Old Fault fn1 rotates from 35° to 27°
- Fault f7 starts at 60°
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Faults rotate from 65° to 45°, crust thins from 30 to 23.4 km.
Margin architecture
Melting & Serpentinitisation

Influence lower crustal rheology:
1- lower crustal composition
Initial configuration – vel. 5 mm/yr – mafic granulite/wet quartz

Boundary conditions: constant velocity 5mm/yr at box edges
Brittle and viscous strain softening
Initial weak seed: temperature higher by 100°C close to Moho.
Effect of lower crustal composition on margin width/symmetry.

- Mafic granulite
- Wet quartzite
- Dry peridotite solidus melting (parametrization Phipps Morgan, G-cubed, 2001).
- Solidus increases with increasing depletion.
- Serpentinization rate dependence on temperature (Emmanuel and Berkowitz, 2006)
- Serpentinization only occurs when the whole crust is brittle.
Melting dependency on velocity of extension

How does lower crustal rheology affect onset and melting dependency on velocity of extension?
Effect of lower crustal composition on serpentinization/melting.

- Weak wet quartz
- Strong mafic granulite

Little serpentinisation, less melting

More serpentinisation & melting

Sequential faulting, @14 ma, distributed faulting ~150 km

Narrow margin ~70 km

Wide margin ~300 km

Narrow margin ~180 km

Accumulated serpentinisation, Wet quartz 28.01 ma

Accumulated serpentinisation, wet quartz, 23.01 ma

Area of melt production, Wet quartz, 28.01 ma

Area of melt production, wet quartz, 23.01 ma

Crust thickness 28.01 ma

Crust thickness 23.01 ma

Wet quartzite

Mafic granulite

Same velocity = 5 mm/yr
Margin architecture
Melting & Serpentinisation

Influence lower crustal rheology:
2- crustal thickness
Questions

• Formation of asymmetry.

• Degree of asymmetry and margin width.

• Fault geometry with extension and along margin length.

• Oceanization style (abrupt transition vs exhumed mantle).

Lower crustal rheology: composition, crustal thickness, velocity.
Questions

• Formation of asymmetric conjugate margins.
• Degree of asymmetry.
• Margin width.
• Controls on faulting patterns.
• Oceanization style (abrupt transition vs exhumed mantle).