Mineral-scale constraints on the geodynamics of extension

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Motivation & Outline

1. How is strain vertically distributed during rifting?

2. What are typical rates of mantle cooling/upwelling during extension?

Approach: use high-T thermochronology and diffusion speedometry to harness thermal signature of geodynamics
1. Strain distribution and thermal history

→ *Uniform thinning (pure shear)*

McKenzie 1978
1. Strain distribution and thermal history

→ Depth-dependent thinning

Royden & Keen 1980
1. Strain distribution and thermal history

- Uniform thinning drives cooling at all structural levels
- Partitioning of strain into mantle lithosphere drives conductive heating of lower/middle crust
- *Is this signal recorded in attenuated lower crust?*
1. Strain distribution and thermal history

→ Application: attenuated lower crust; Ivrea Zone, Italy

- ~ 6 kbar, Mu+Qtz
- ~ 8 kbar, Gt+Kfs+Sill+melt
1. Strain distribution and thermal history

- Zircon texturally younger than rutile, yet >90 Ma older
- U-Pb rutile system reset ~180-190 Ma

"Rutile U-Pb thermochronology, Ivrea Zone"
1. Strain distribution and thermal history

→ Rutile U-Pb thermochronology, Ivrea Zone

Smye & Stockli 2014, EPSL
1. Strain distribution and thermal history

- Rutile U-Pb thermochronology, Ivrea Zone

- 4 km depth interval of granulites (at 20° C/km ΔT is 80° C)
- 5° C/Ma cooling, 40 Ma age spread is expected
- Elevated dT/dz at onset of rift-related exhumation, ~180 Ma
1. Strain distribution and thermal history

Revised thermal history, Ivrea Zone
1. Strain distribution and thermal history

Revised thermal history, Ivrea Zone
1. Strain distribution and thermal history

→ High-magnitude thinning of the lithospheric mantle

Thermal history consistent with preferential thinning of lithospheric mantle ($\delta:\beta > 1:4$)
2. Rates of mantle cooling/upwelling

→ Duration of rifting critical for melt generation (Bown & White 1995)
2. Rates of mantle cooling/upwelling

- Duration of rifting critical for melt generation (Bown & White 1995)

Cooling rate of lithospheric mantle is a good indicator of melt generation during extension
2. Rates of mantle cooling/upwelling

→ *Lanzo peridotite massif, Italy*
2. Rates of mantle cooling/upwelling

→ *Porphyroclastic peridotites of exhumed lithospheric mantle*
2. Rates of mantle cooling/upwelling

- Diffusional equilibration of opx during mantle upwelling
2. Rates of mantle cooling/upwelling

→ *Diffusional equilibration of opx during mantle upwelling*

Cherniak & Liang 2007
2. Rates of mantle cooling/upwelling

→ Diffusional equilibration of opx during mantle upwelling

Cherniak & Liang 2007
2. Rates of mantle cooling/upwelling

→ *Cooling rate determination by opx speedometry*
2. Rates of mantle cooling/upwelling

→ Implications of slow cooling, Lanzo peridotite body
→ 10 °C/Ma cooling of lithospheric mantle achieved when $\beta=5$; slow enough to suppress melt generation

$\beta = 5$

$T_m = 1330^\circ C$
1. U-Pb thermochronology and diffusion speedometry afford opportunity to recover thermal history information relevant to extension.

2. Lower crust of Adriatic margin underwent reheating ~180 Ma, contemporaneous with the onset of mantle exhumation.

3. Adriatic lithospheric mantle cooled at ~10 °C/Myr, slow enough to suppress significant melt generation.