

Thermochemical evolution of the mantle wedge

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Collaborators

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Outline

Does the physical state of the sub-arc mantle vary with time?

1. Long-term thermal evolution of the mantle wedge beneath arcs
2. Thermochemical evolution of sub-arc mantle due to melting at a back-arc spreading center (“pre-conditioning”)

GeoPRISMS Relevance



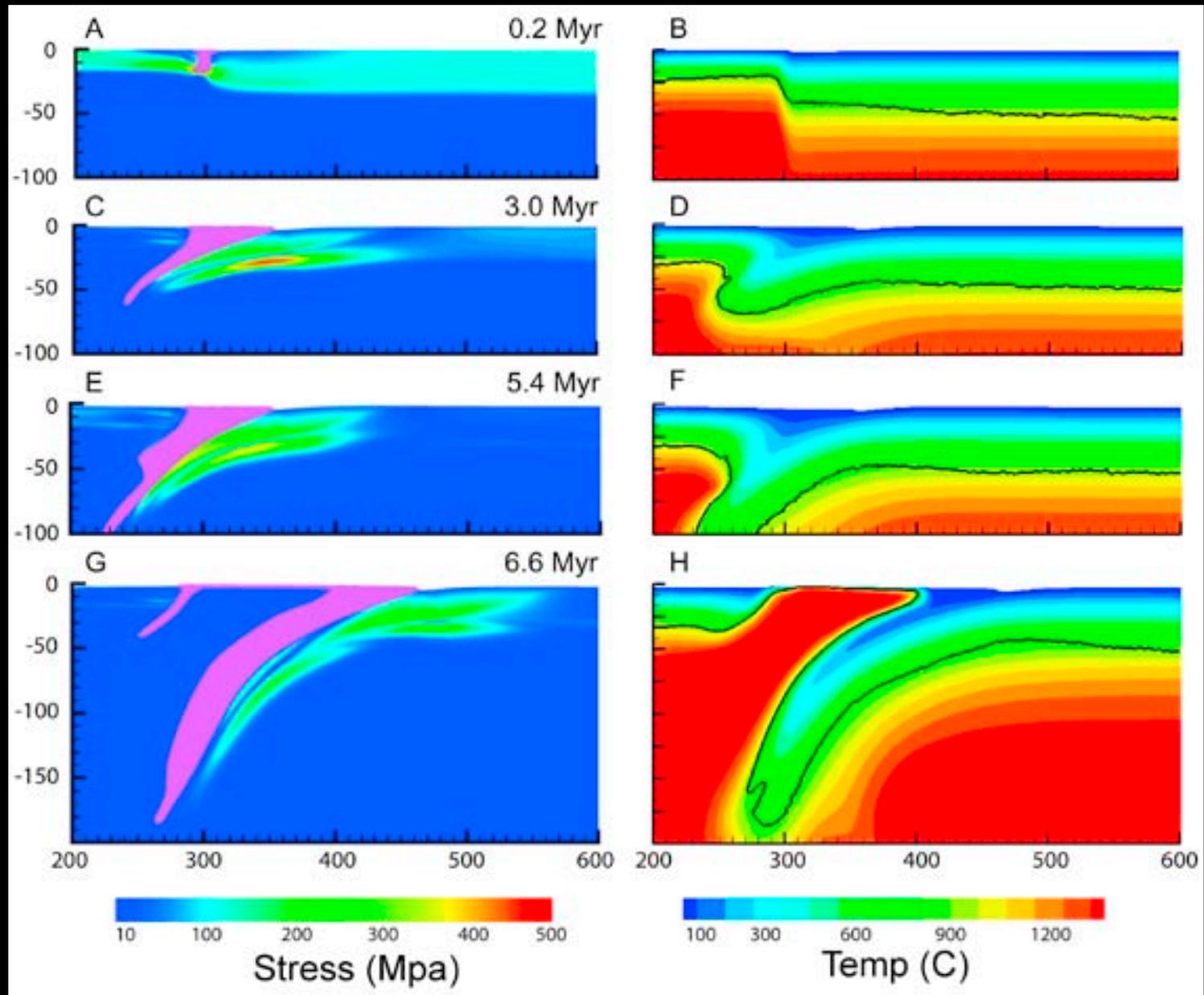
How are volatiles, fluids and melts stored, transferred and released through the subduction system?

- *What are the melting reactions and loci, and melt pathways from the mantle wedge to the surface?*
- *... how are fluids and melts focused to the volcanic front?*

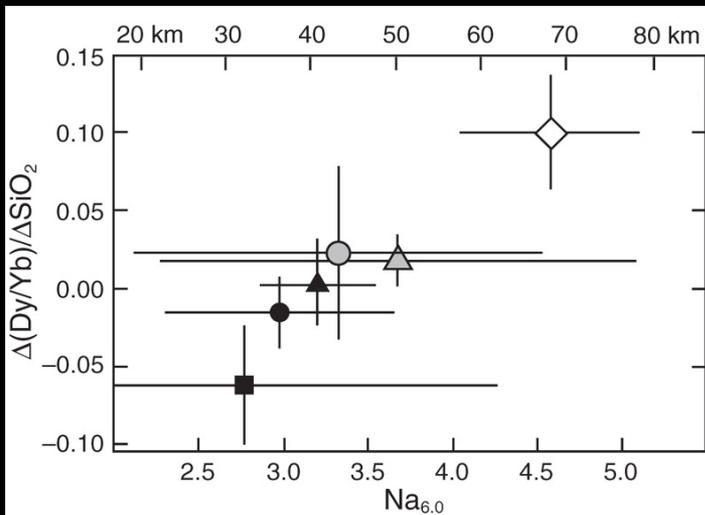
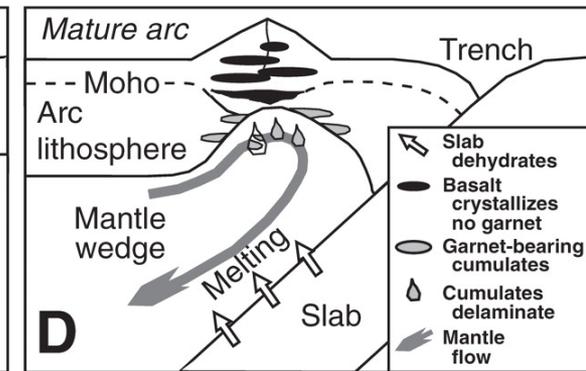
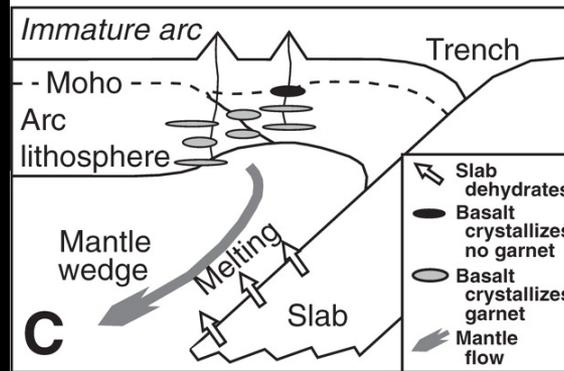
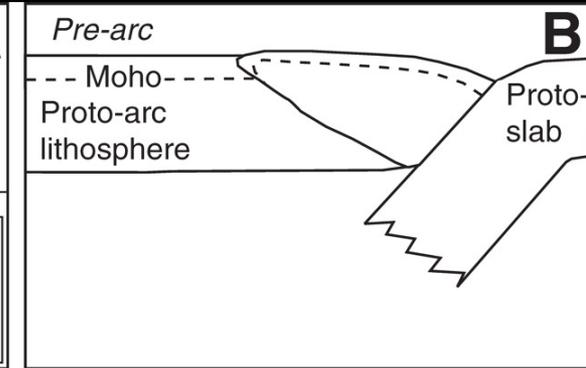
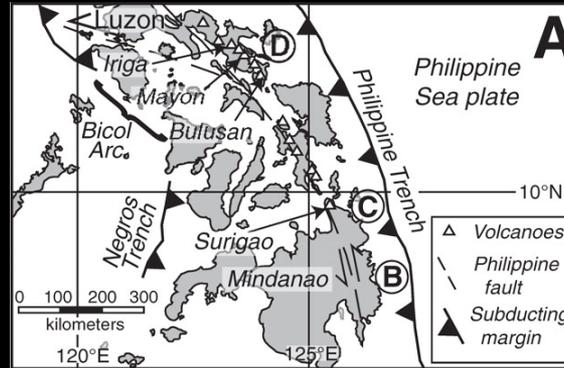
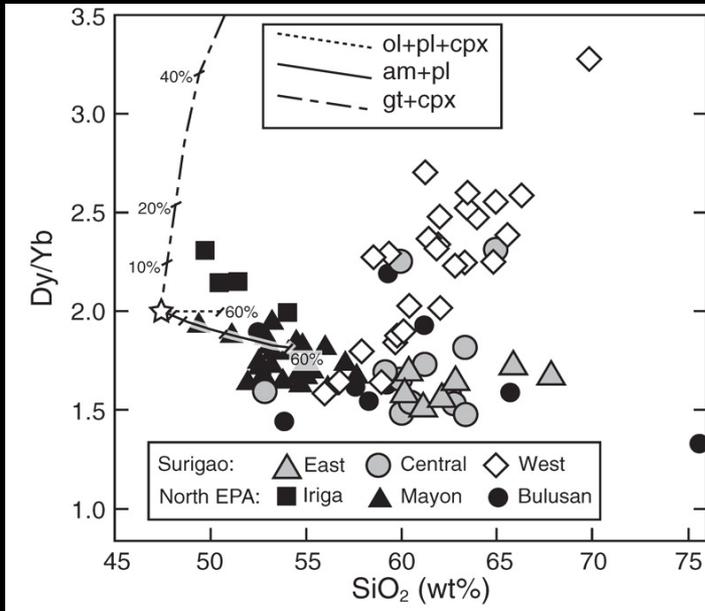
What are the physical and chemical conditions that control subduction zone initiation and the development of mature arc systems?

- *What controls the distribution of volcanoes in space and time?*

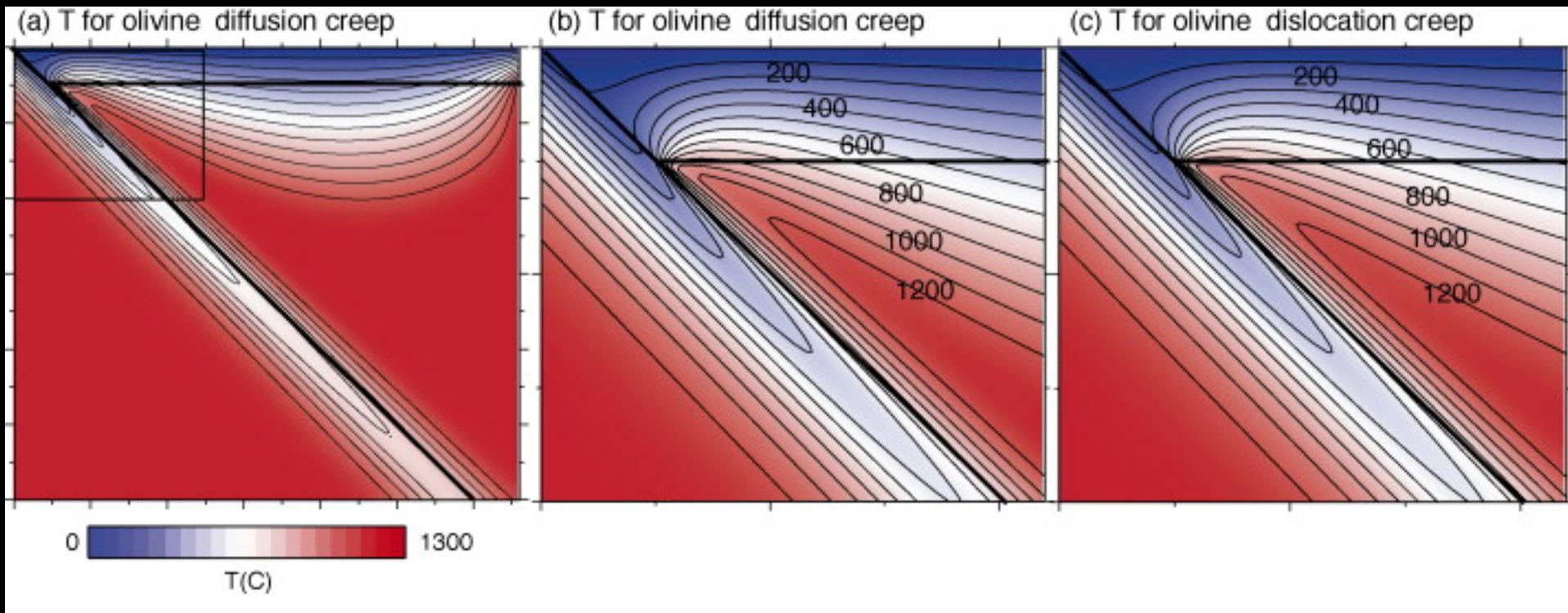
Subduction Initiation



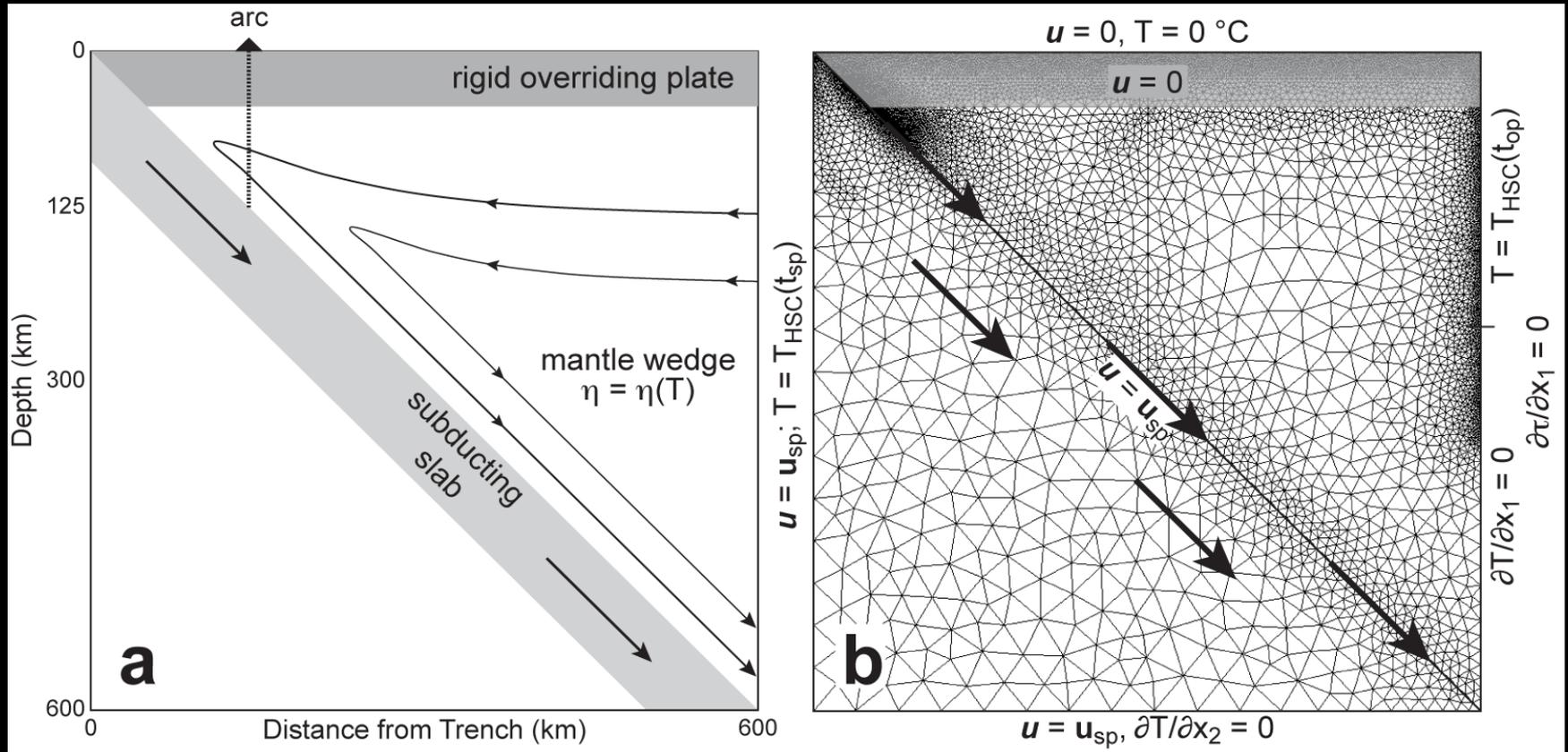
Thermal Evolution During Subduction Initiation



Steady-State Thermal Models of Subduction



Model Geometry and Boundary Conditions



$$\nabla \cdot u = 0$$

Mass

$$\nabla \cdot \tau - \nabla p = 0$$

Momentum

$$\frac{\partial T}{\partial t} = -(u \cdot \nabla)T + \frac{k}{\rho C_p} \nabla^2 T$$

Heat

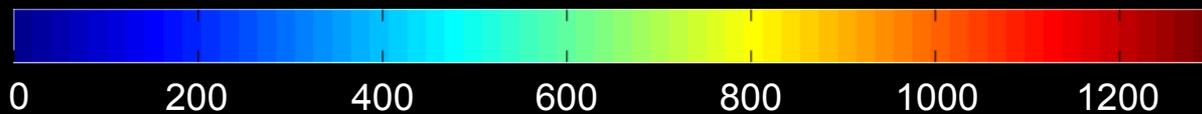
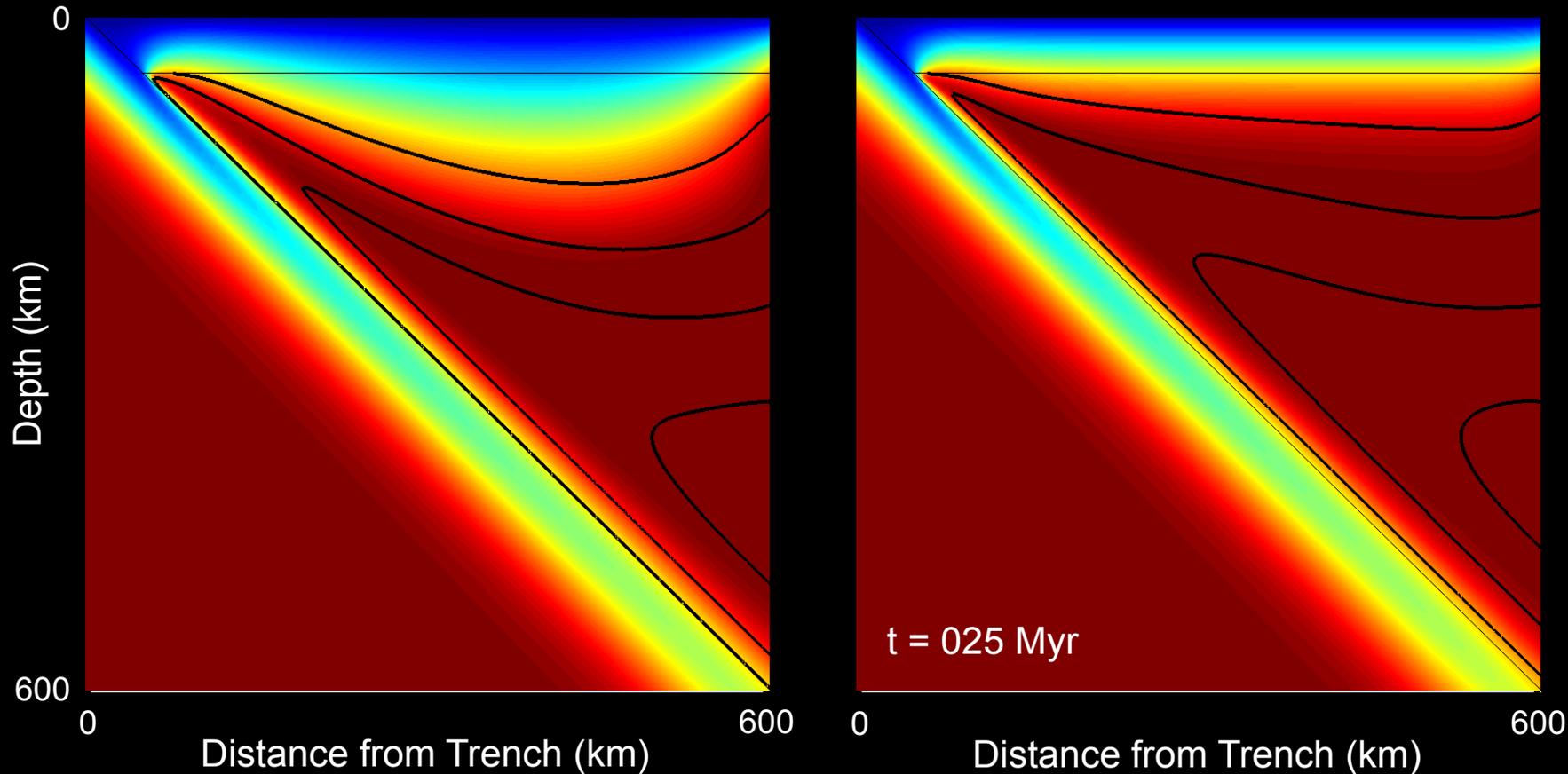
$$\eta = A \exp\left(\frac{E}{RT}\right)$$

Diffusion creep

Temperature

Steady State

Transient

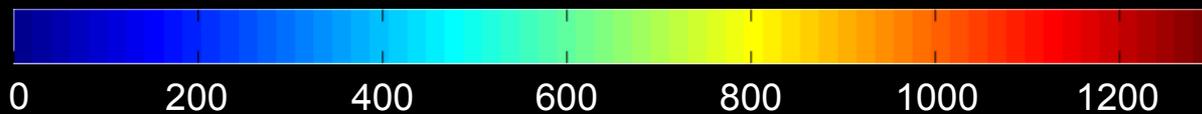
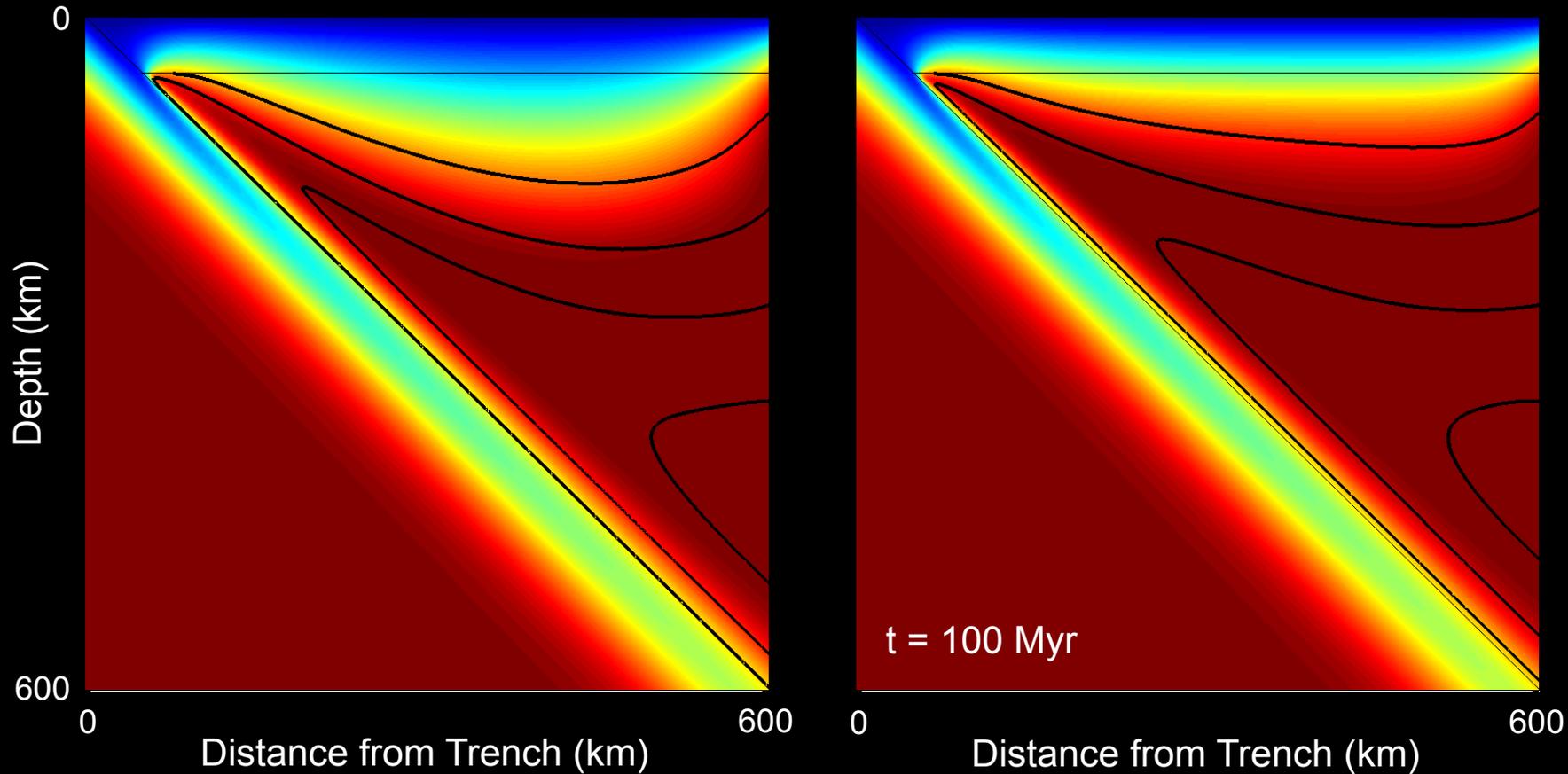


Potential Temperature ($^{\circ}\text{C}$)

Temperature

Steady State

Transient

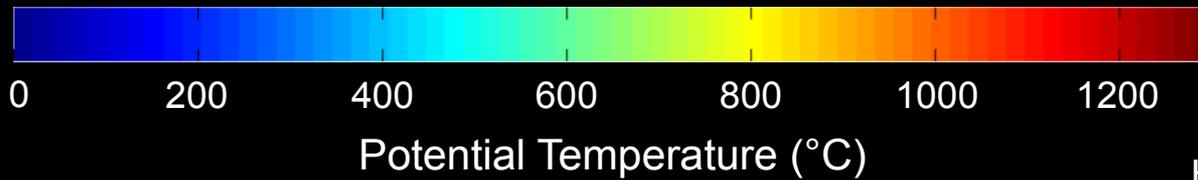
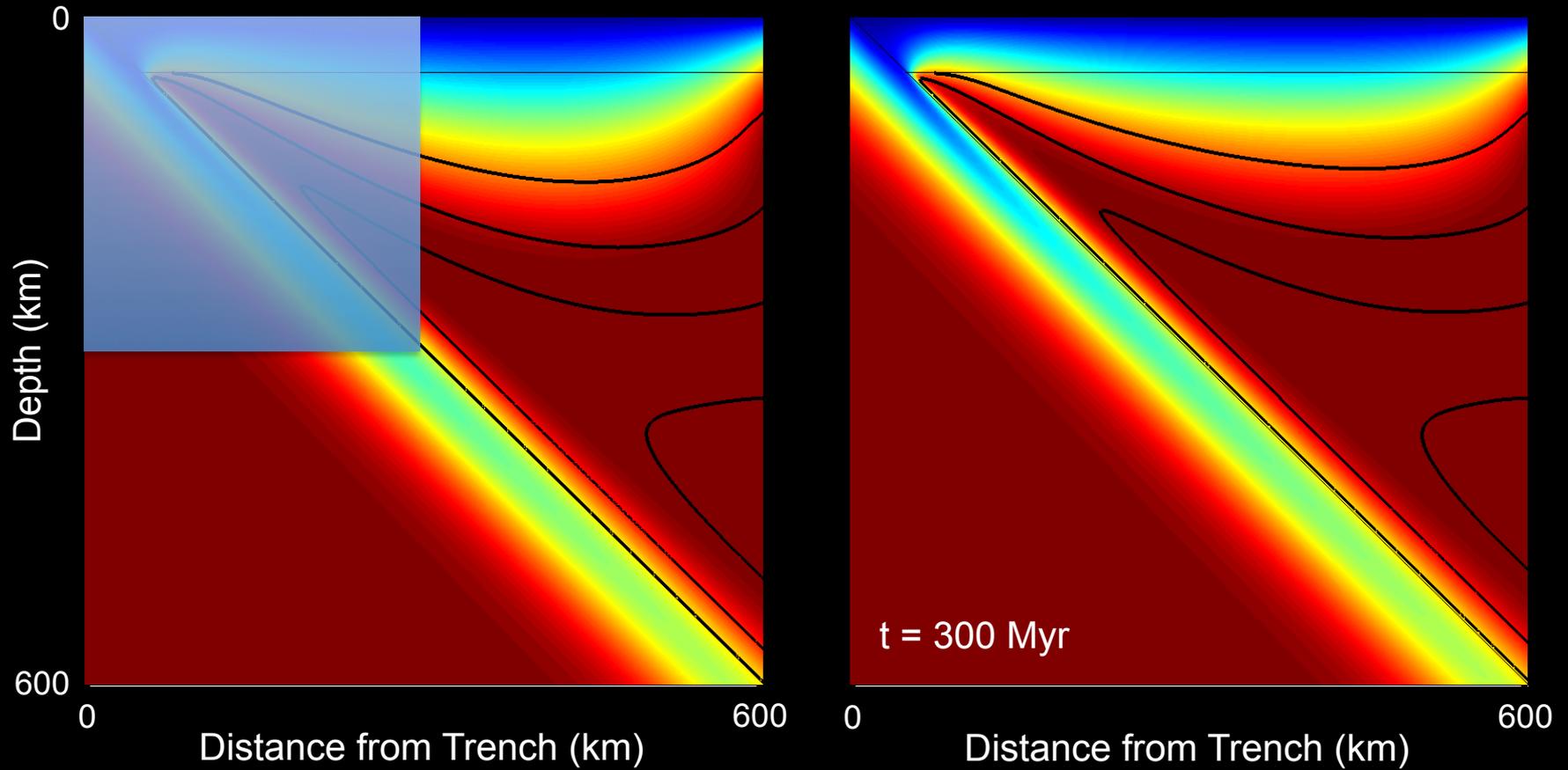


Potential Temperature ($^{\circ}\text{C}$)

Temperature

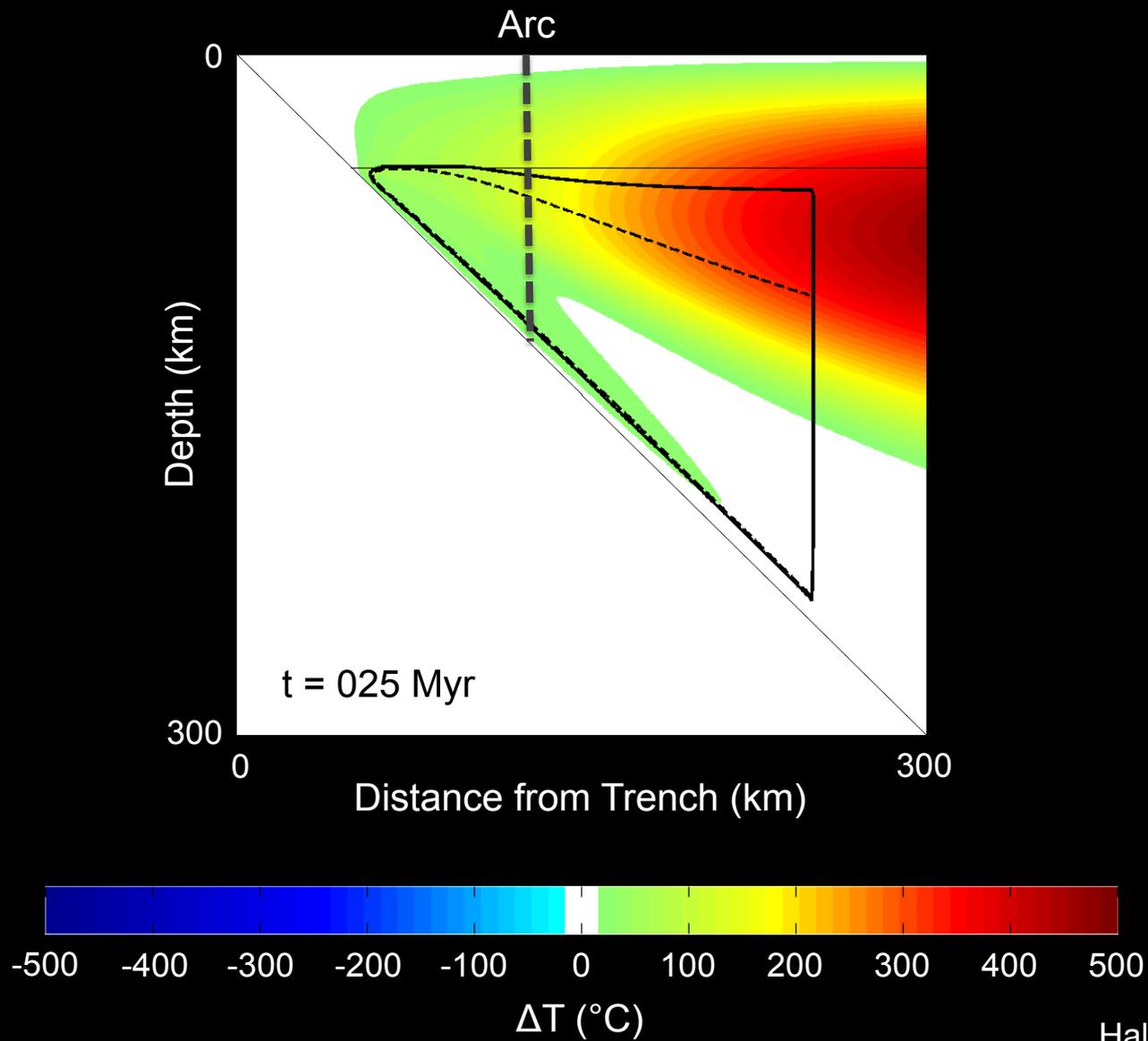
Steady State

Transient



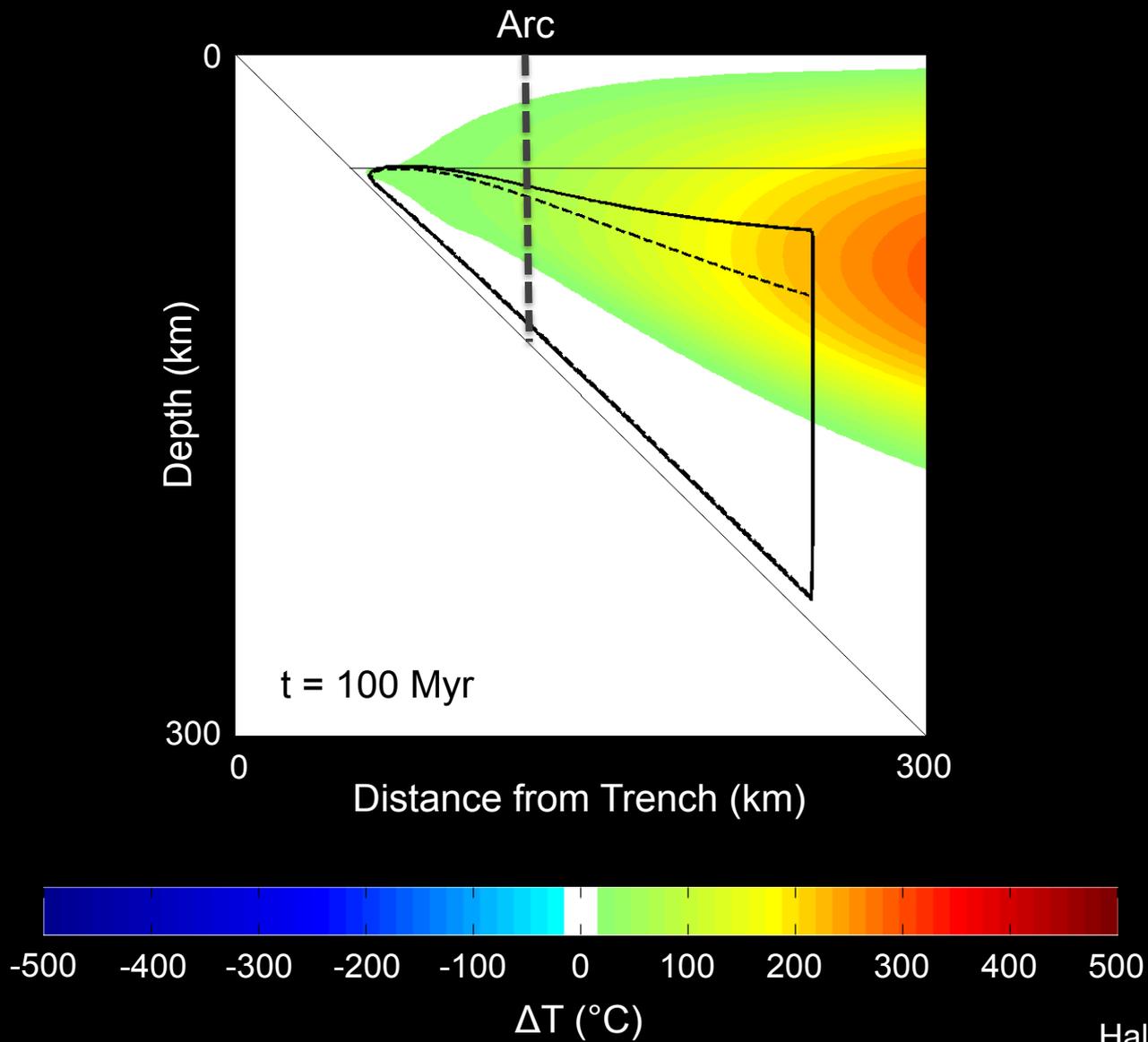
Temperature

Transient - Steady State



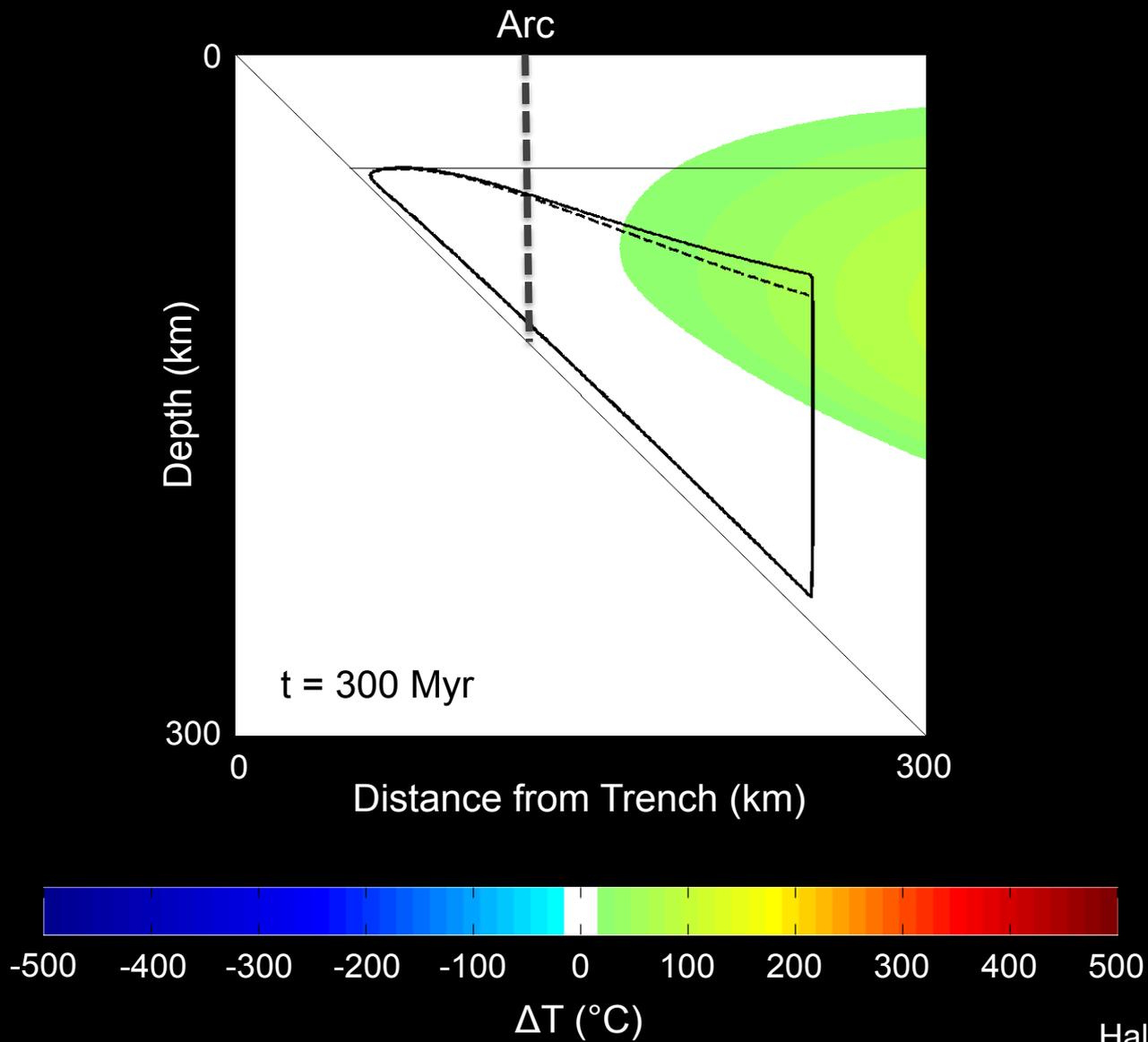
Temperature

Transient - Steady State

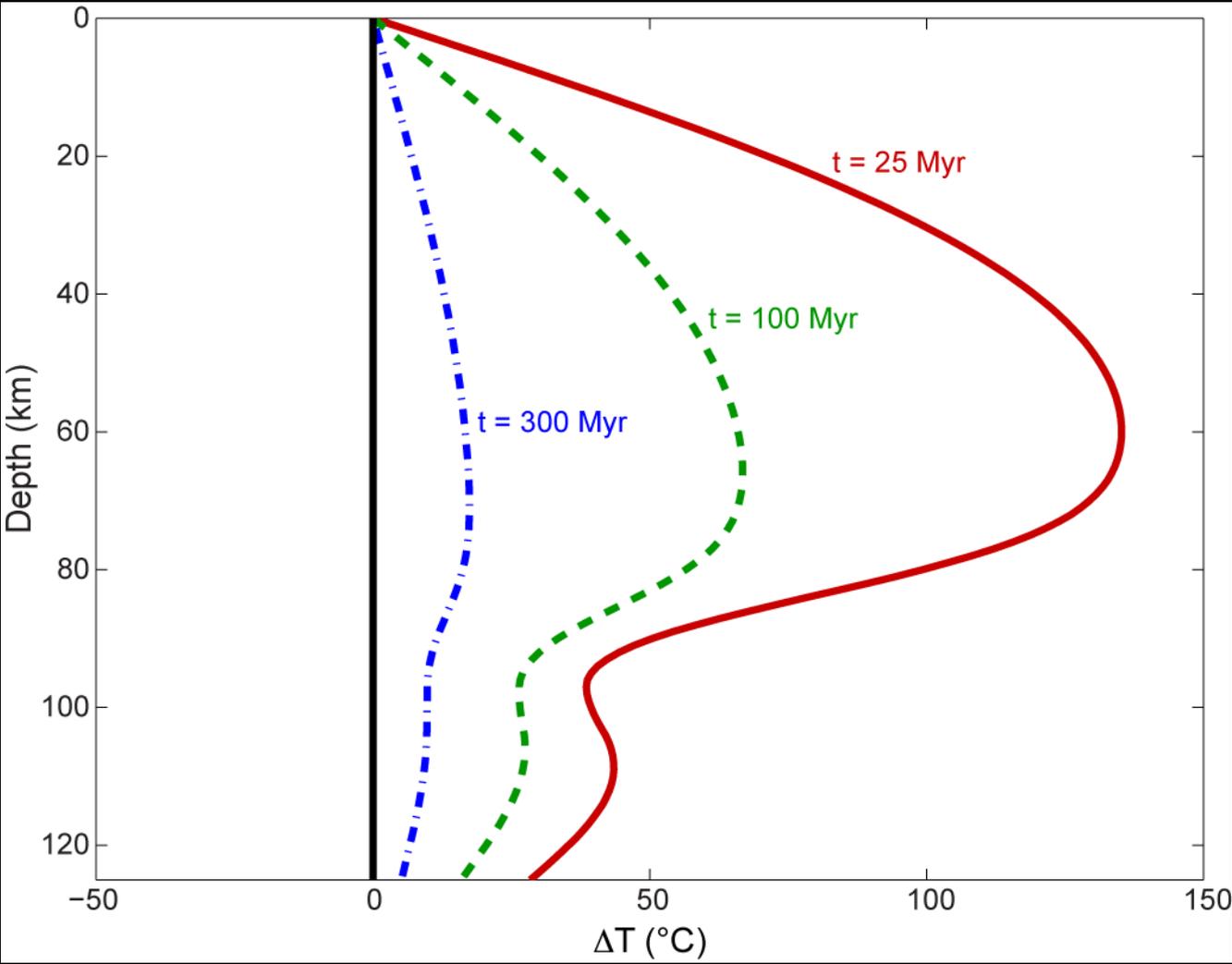


Temperature

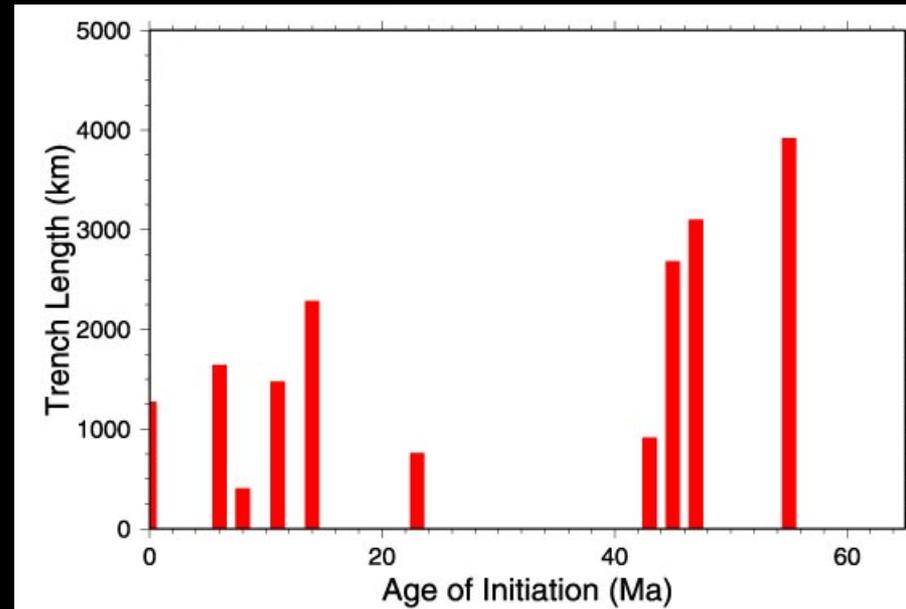
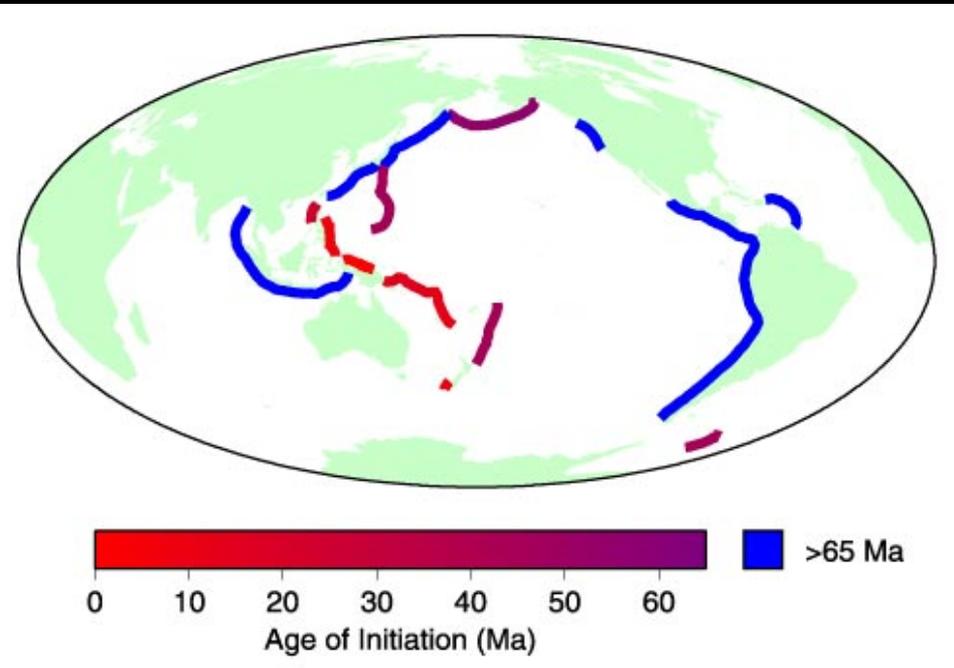
Transient - Steady State



Difference in Sub-Arc Temperature (Transient – Steady State)

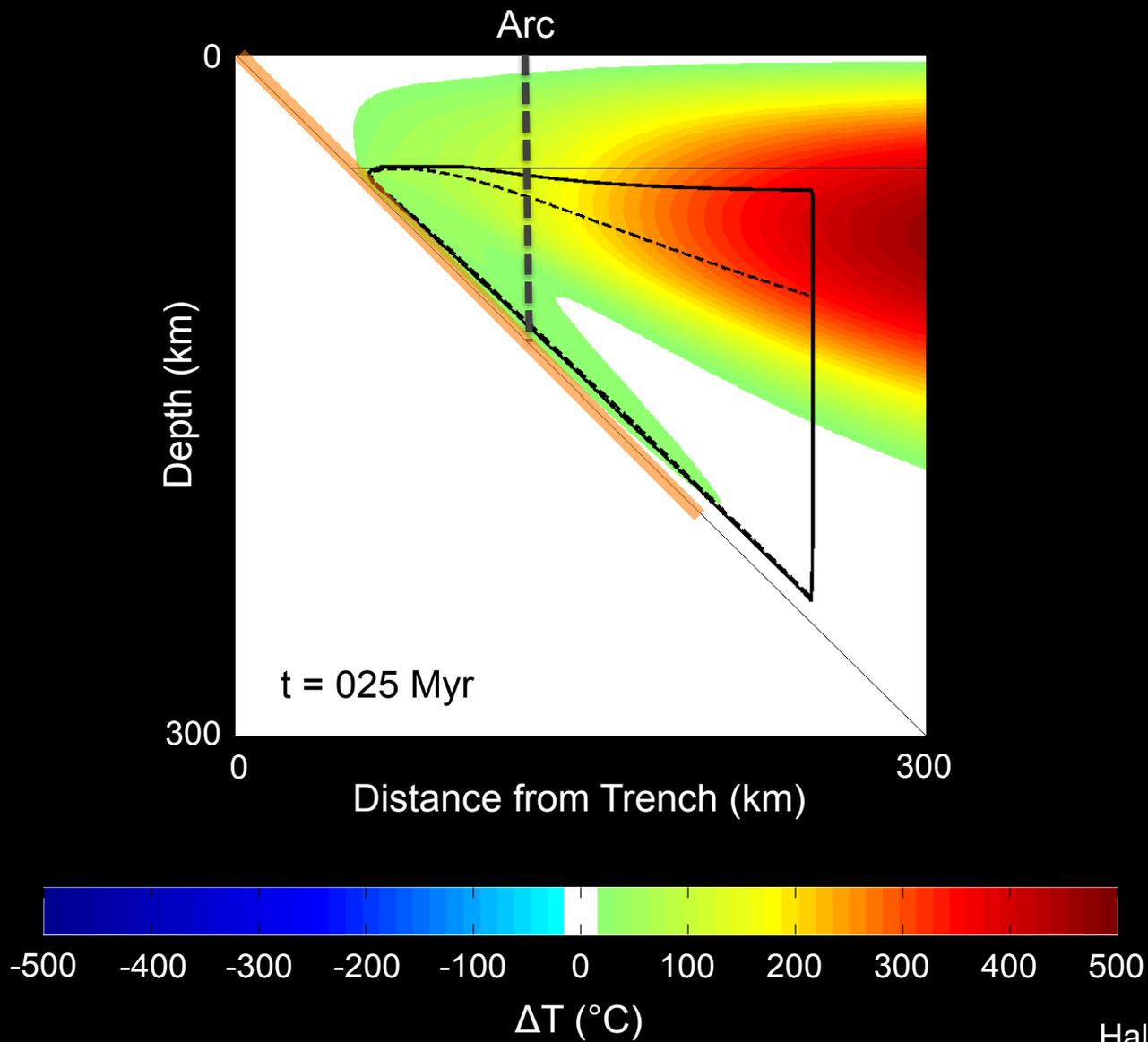


Age of Subduction Zones

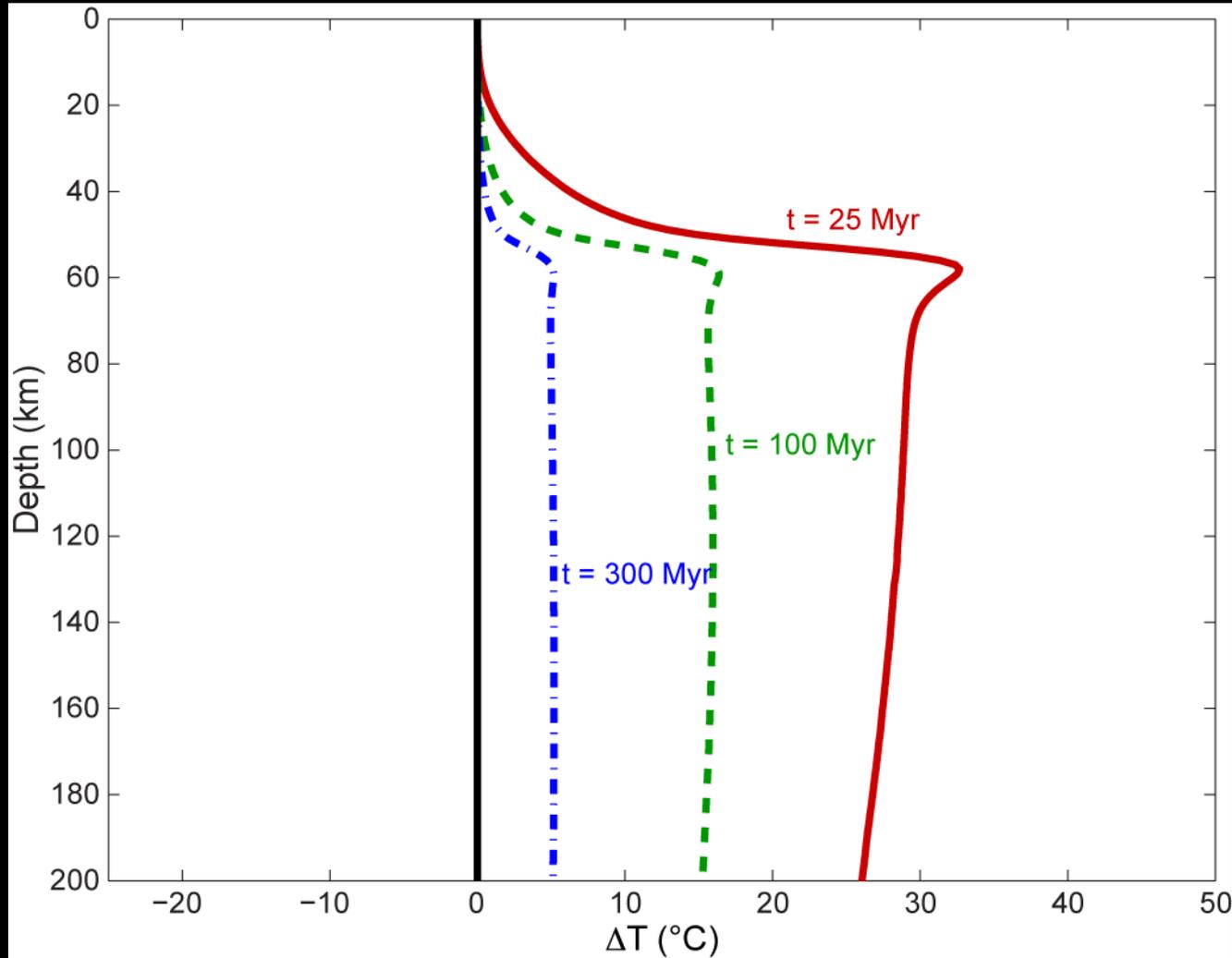


Temperature

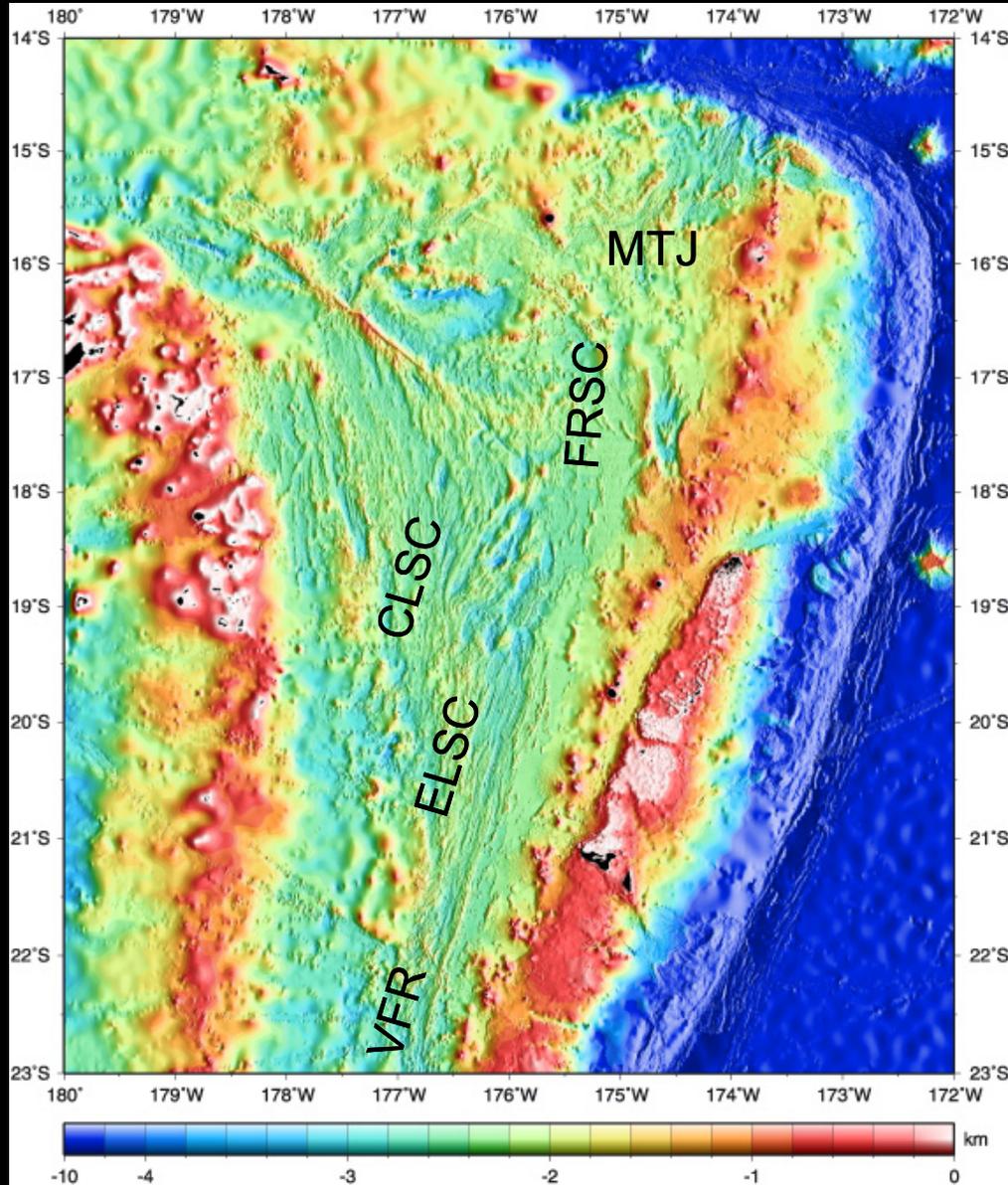
Transient - Steady State



Difference in Slab Surface Temperature (Transient – Steady State)



Tonga Arc and the Lau Basin



Convergence
Rate

~240 mm/yr



~75 mm/yr

Spreading
Rate

~90 mm/yr



~40 mm/yr

Arc –BASC
Distance

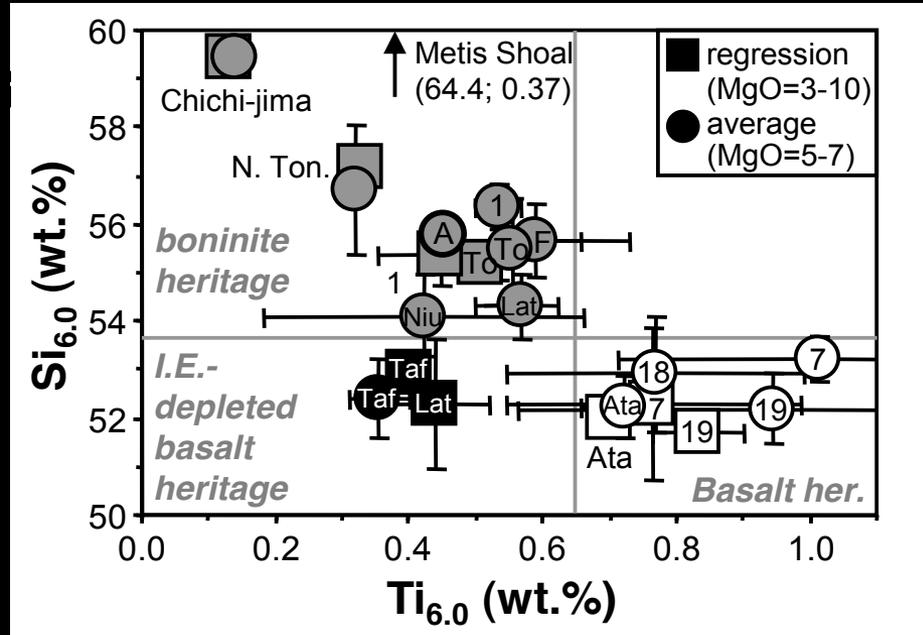
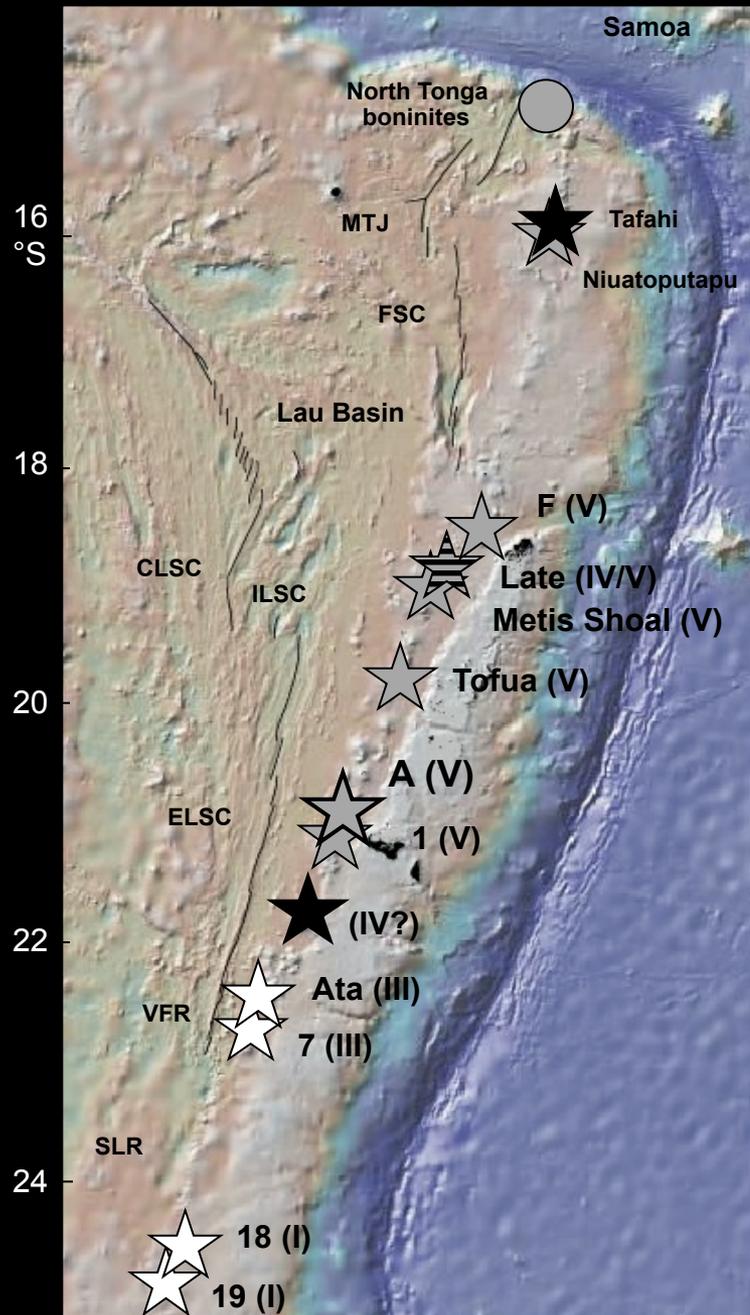
~200 km



~40 km

after Zellmer and Taylor (2001)

Along-Strike Trends in Parental Magma

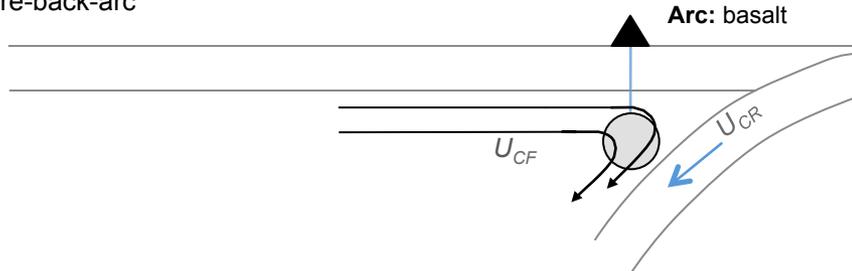


Magmatic Heritage

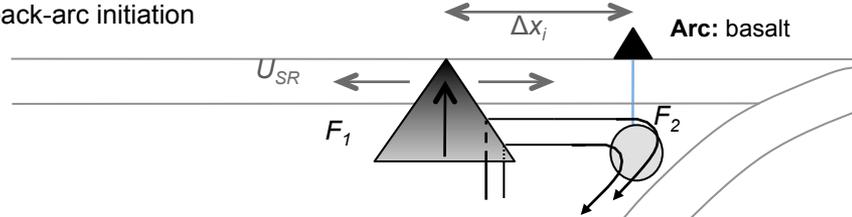
-  **basalt**
-  **I.E.-depleted basalt**
-  **boninite**
-  **I.E.-depleted basalt / boninite**

Evolution of the Mantle Beneath the Arc

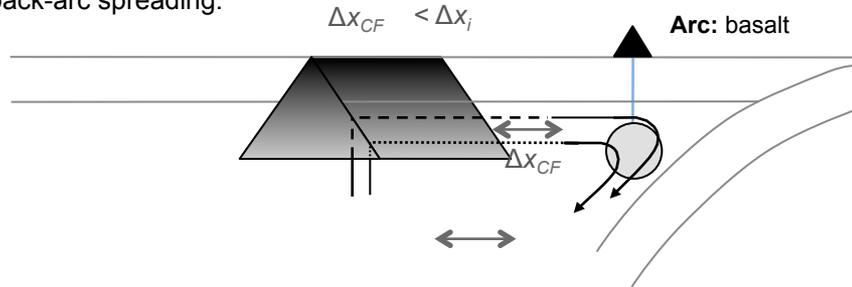
Stage I:
pre-back-arc



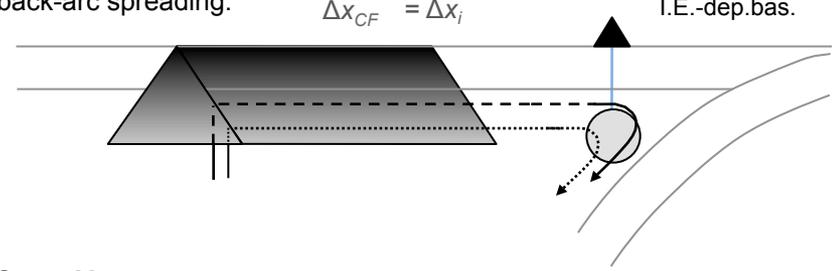
Stage II:
back-arc initiation



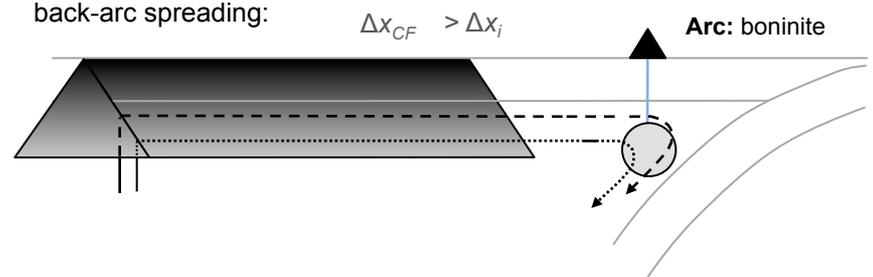
Stage III:
back-arc spreading:



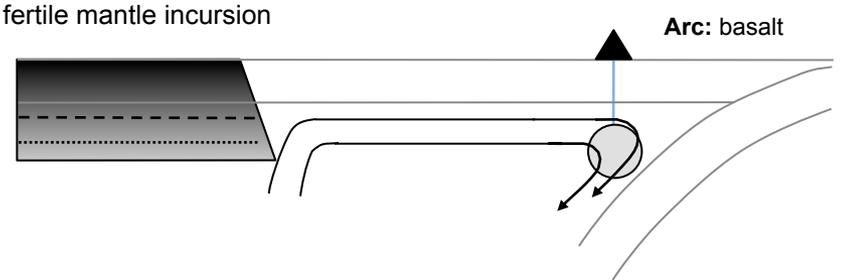
Stage IV:
back-arc spreading:



Stage V:
back-arc spreading:

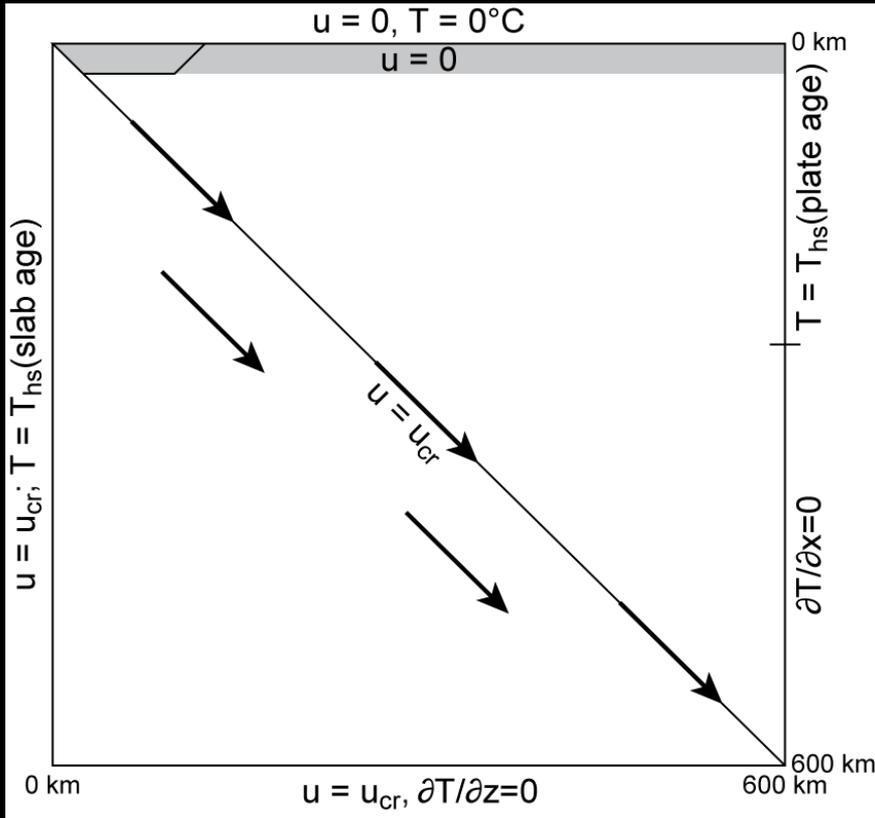


Stage VI:
fertile mantle incursion

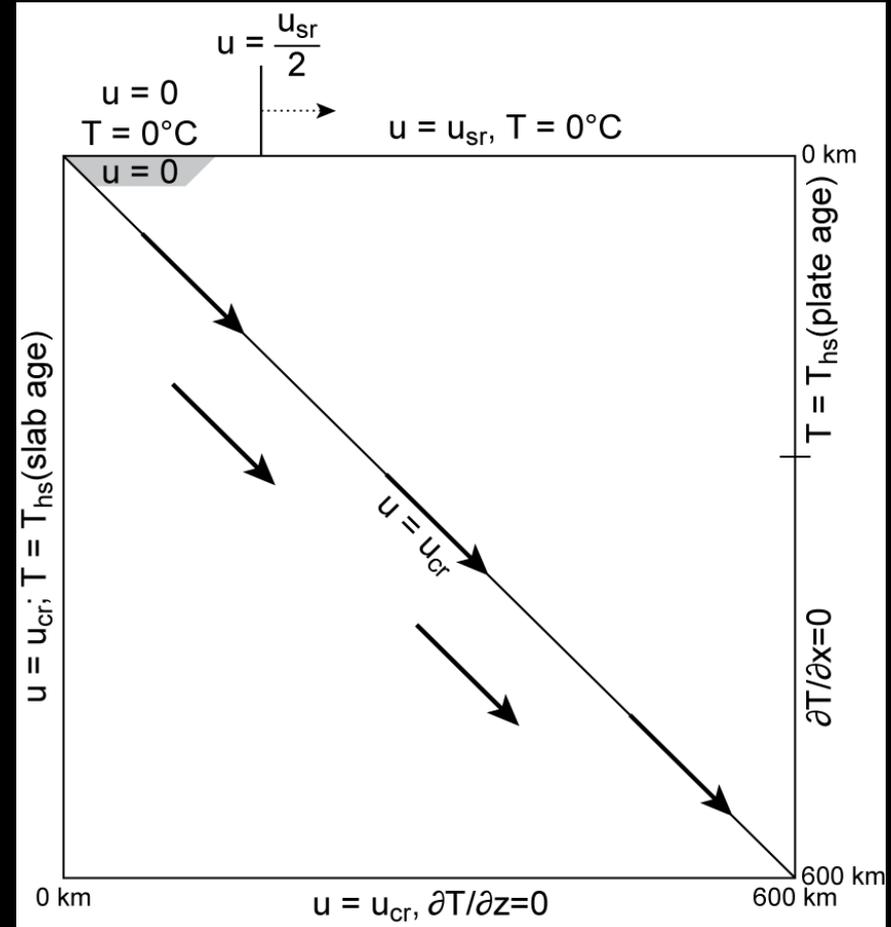


- fertile mantle ($F_1 = 0$)
- refractory mantle (low F_1)
- - - refractory mantle (high F_1)

Model Geometry: BASC

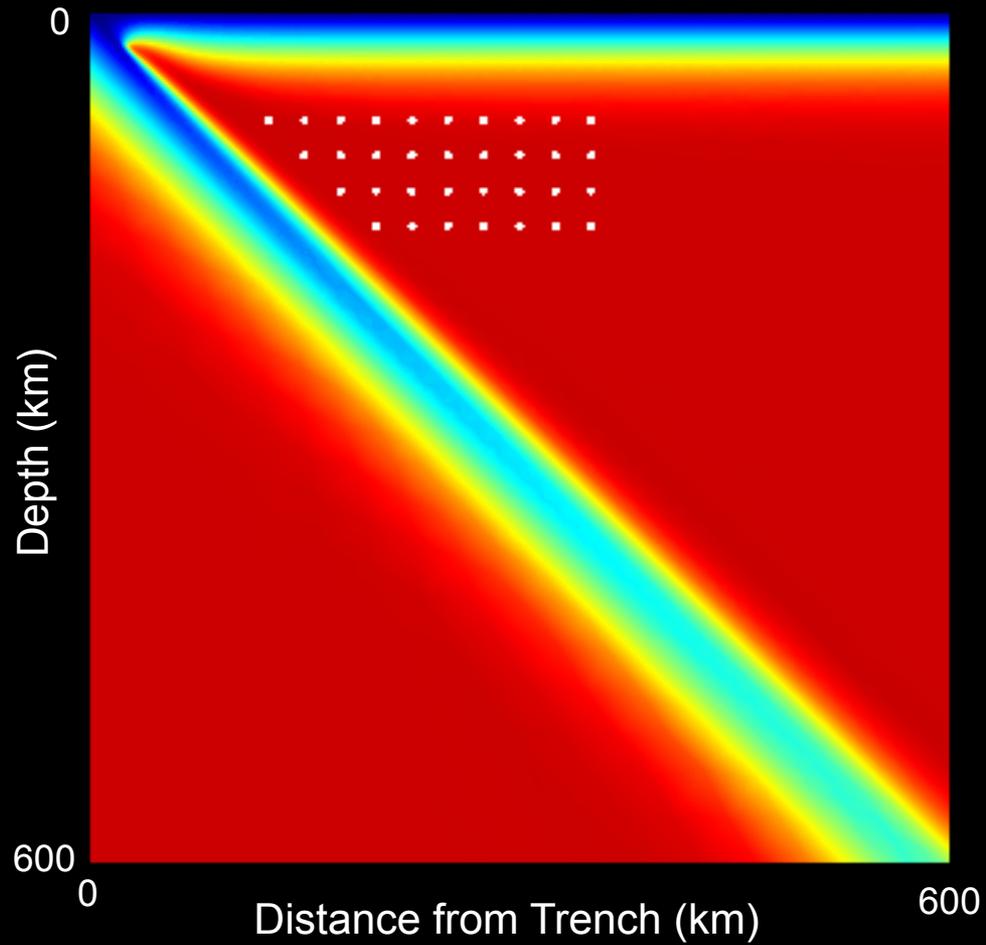


Prior to spreading at BASC
(establishes initial conditions)

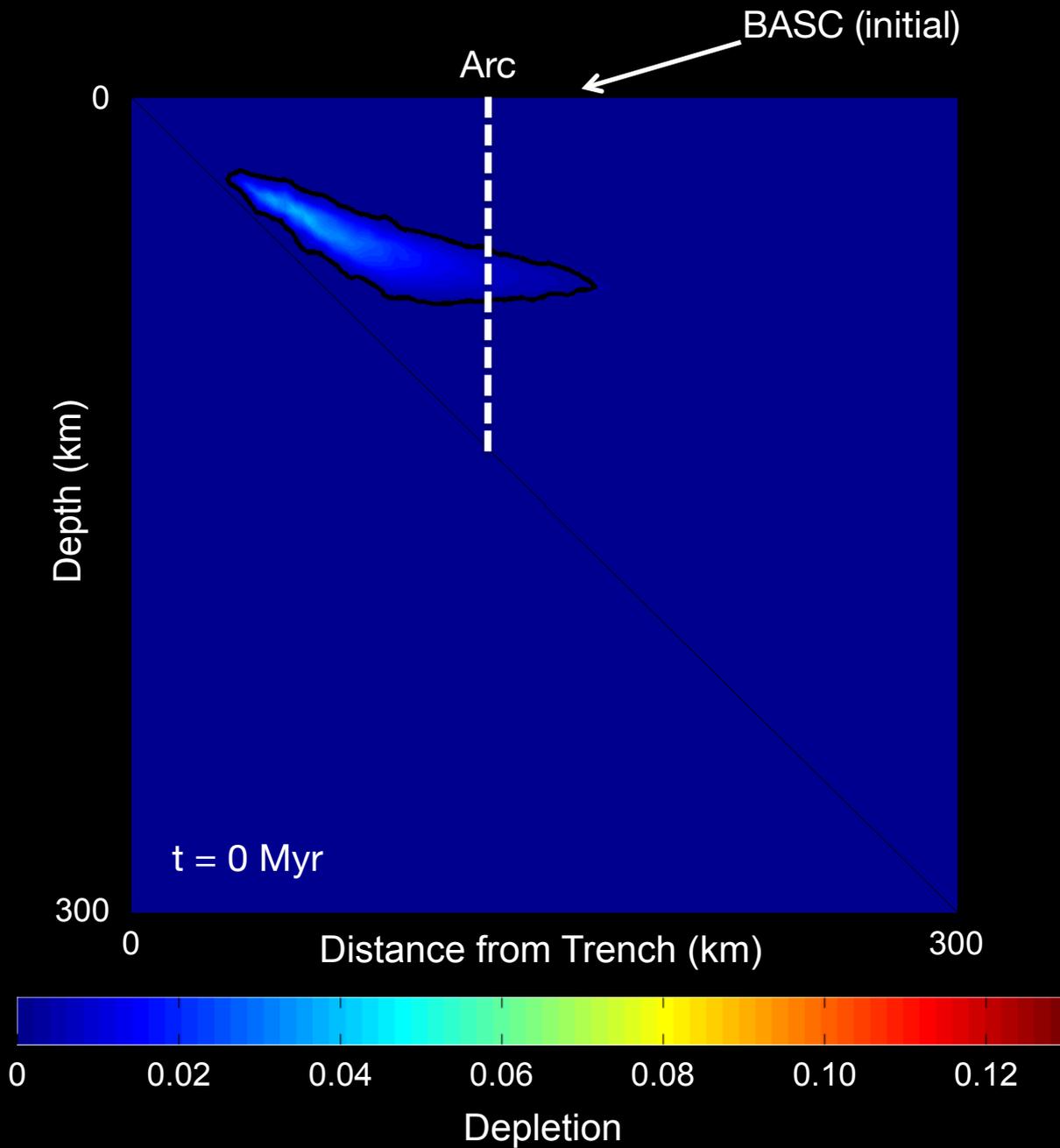


After onset of spreading

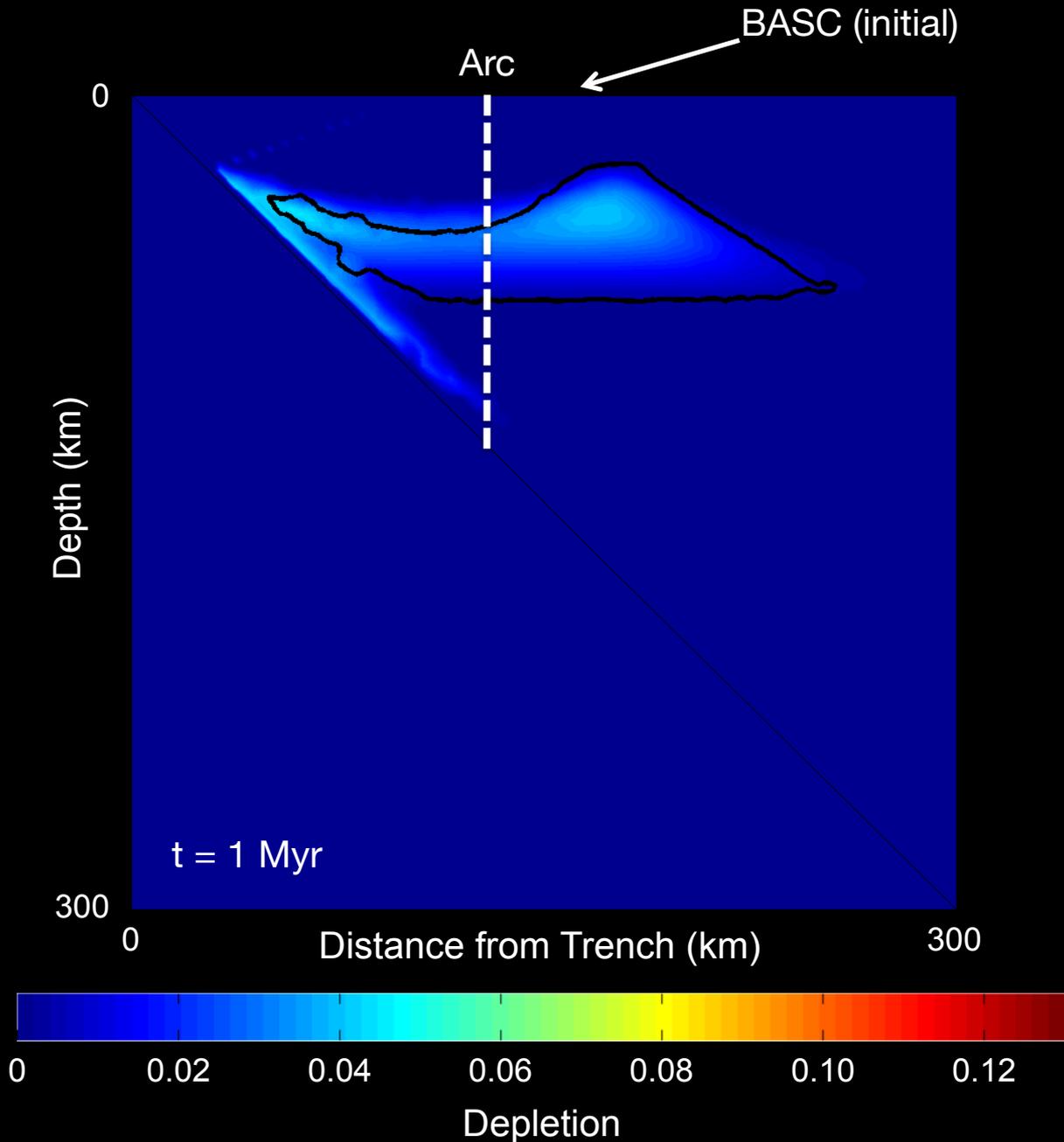
Evolution of Mantle Flow in Arc-BASC Systems



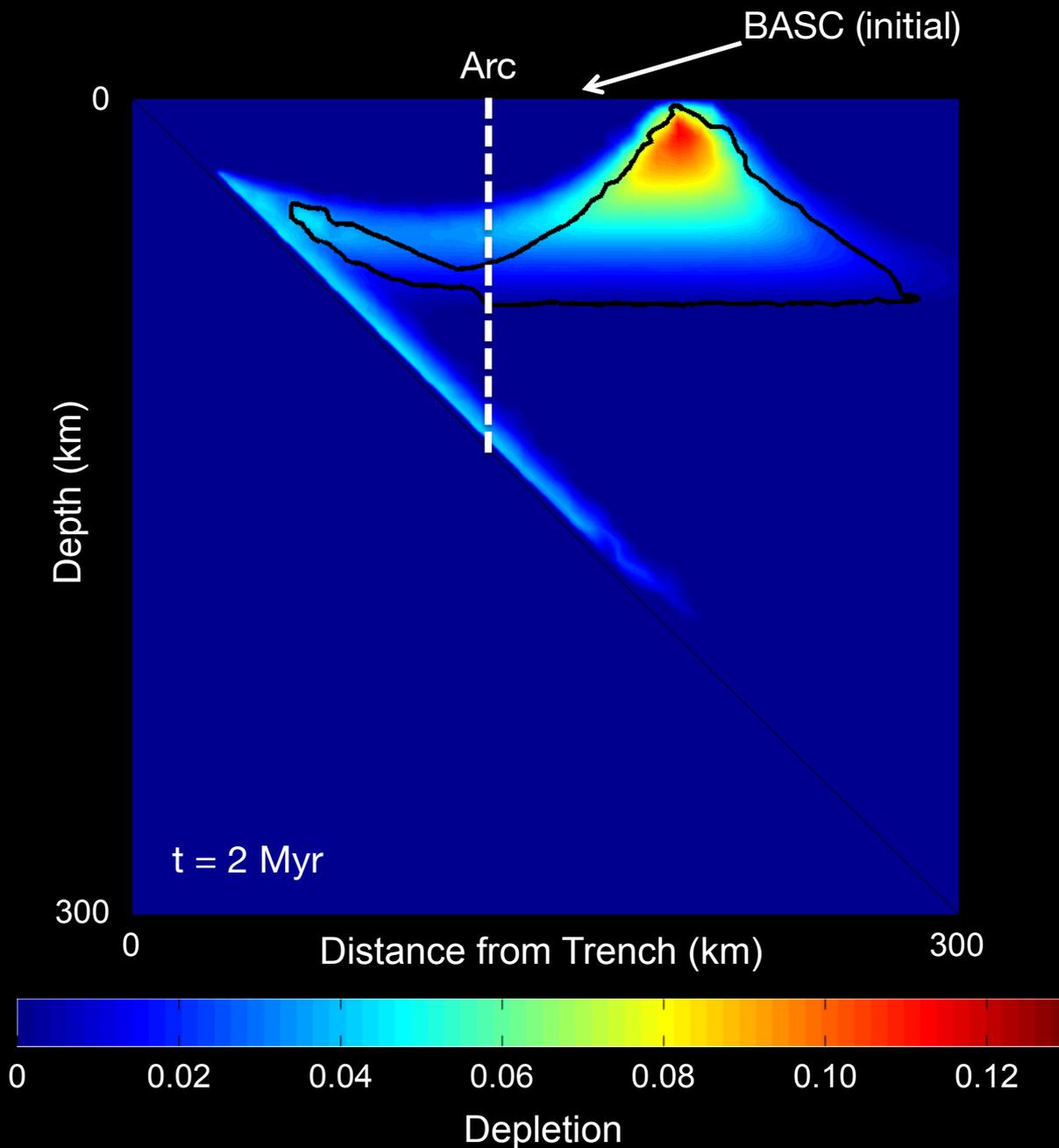
Mantle Depletion



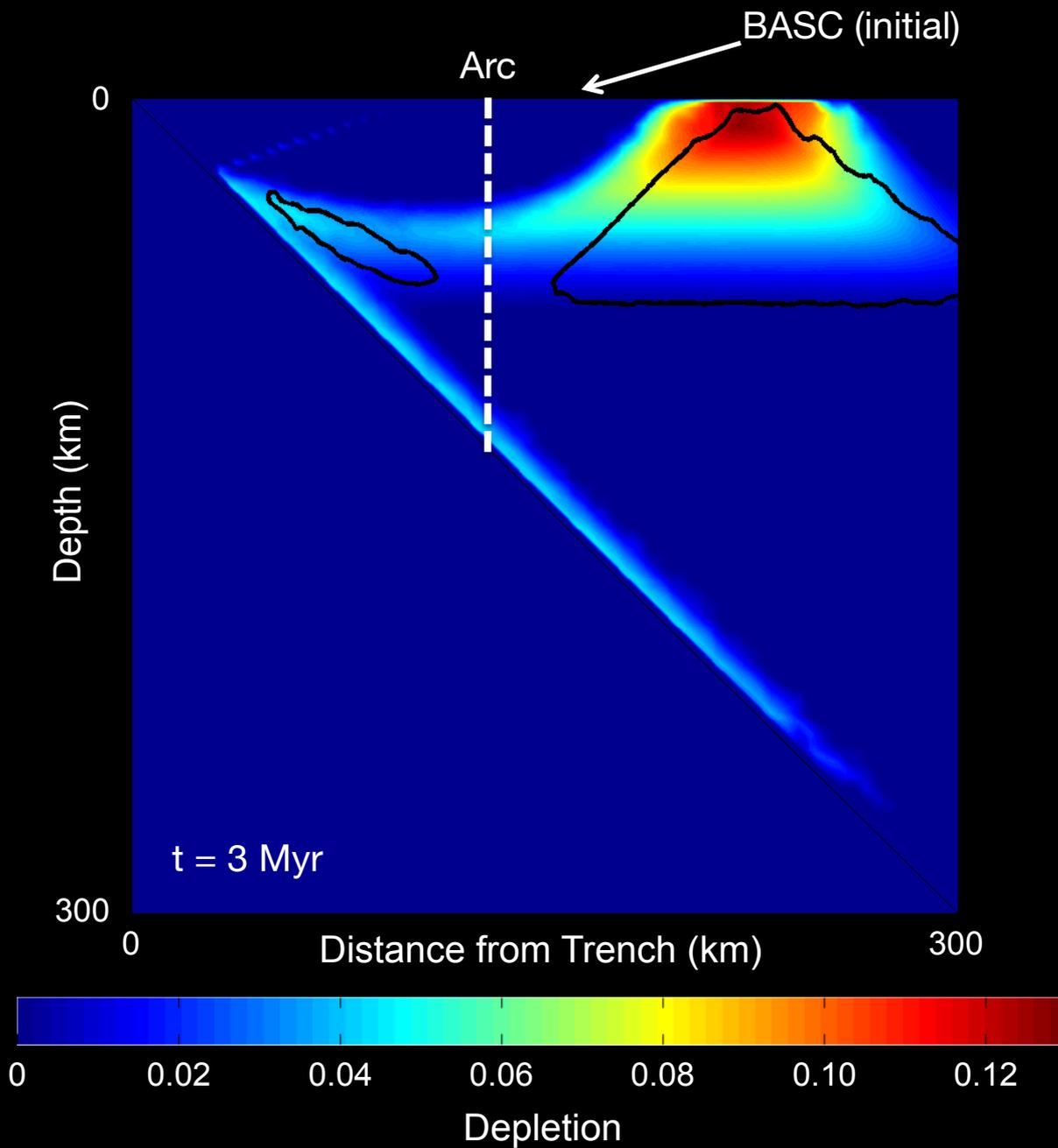
Mantle Depletion



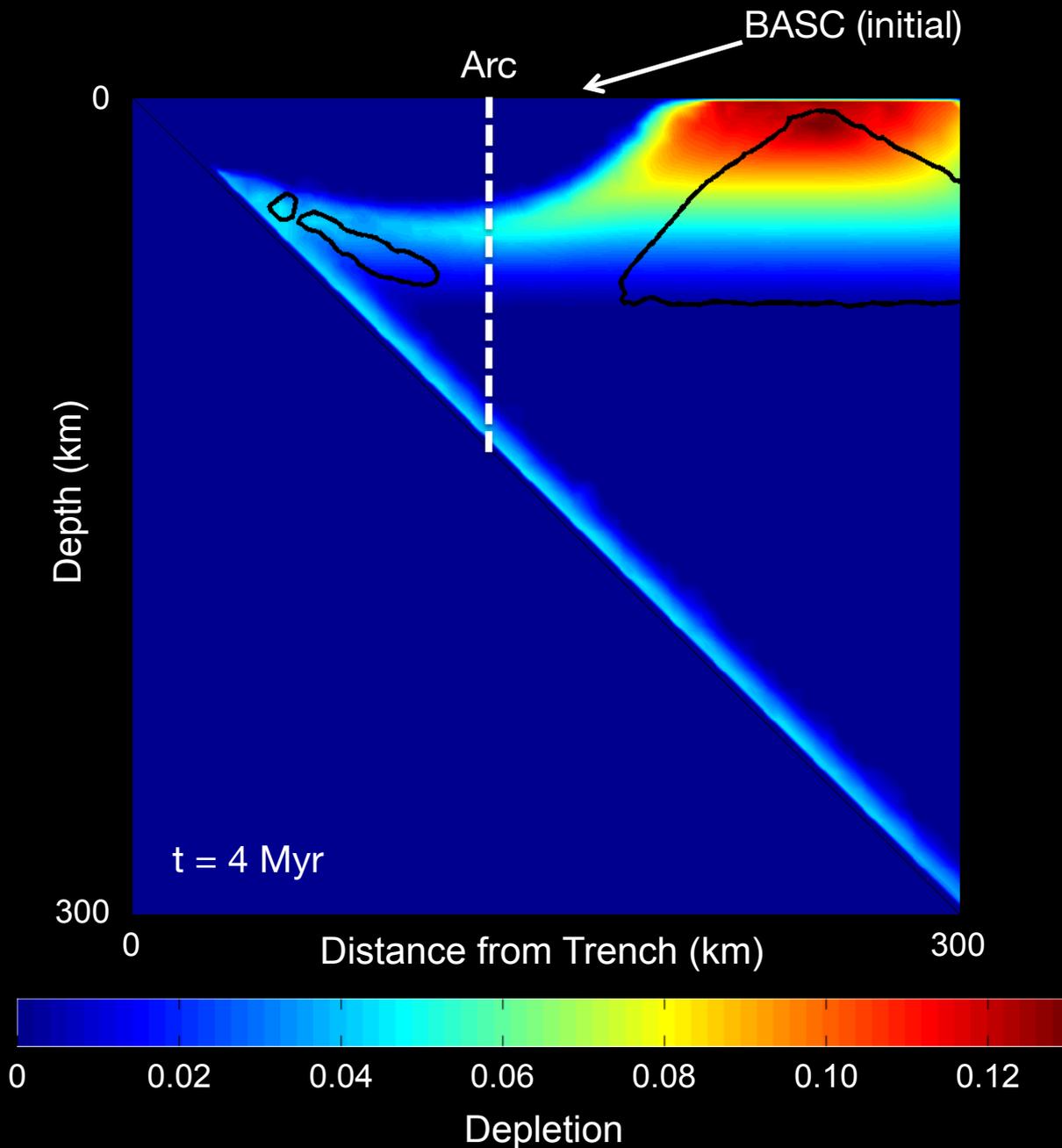
Mantle Depletion



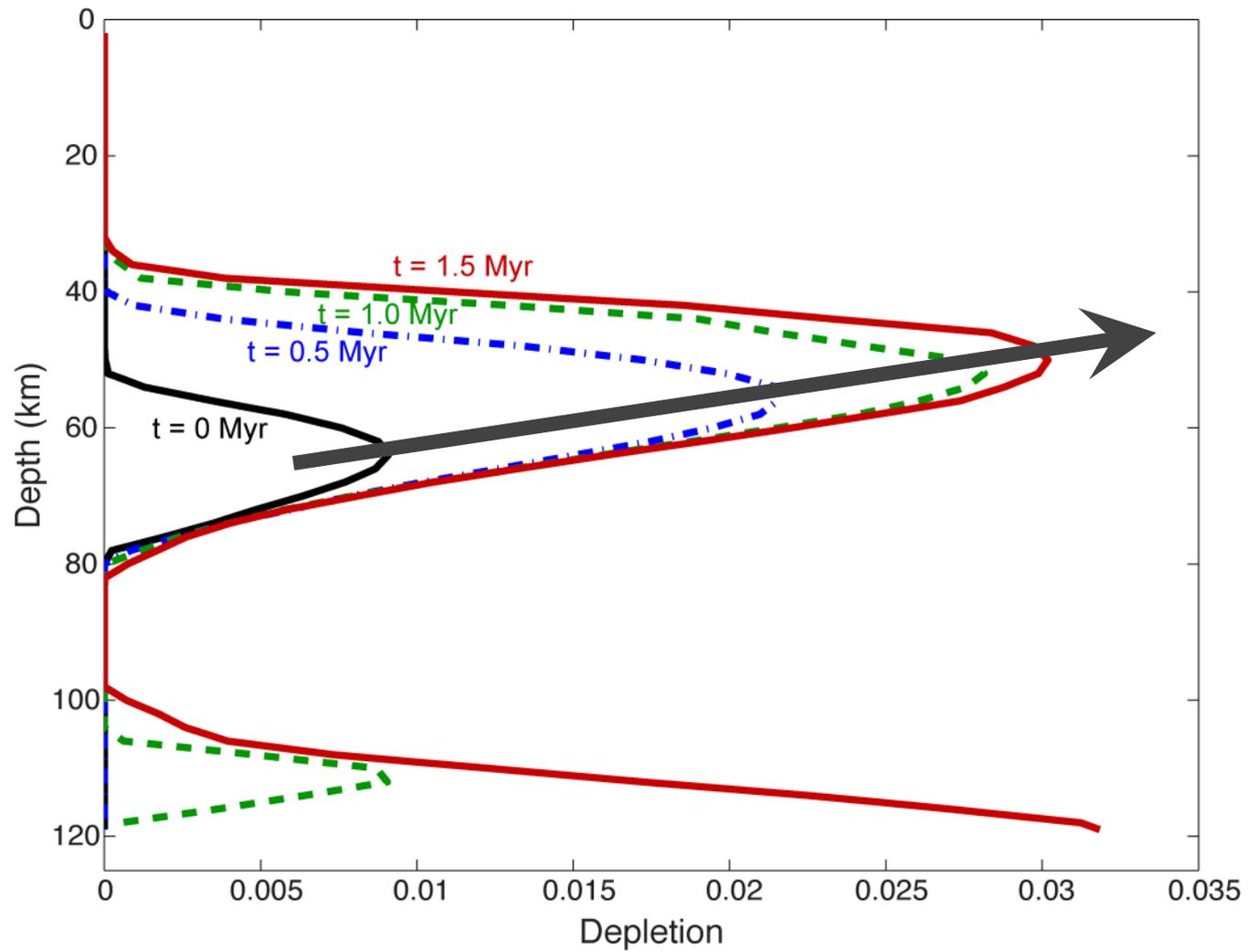
Mantle Depletion



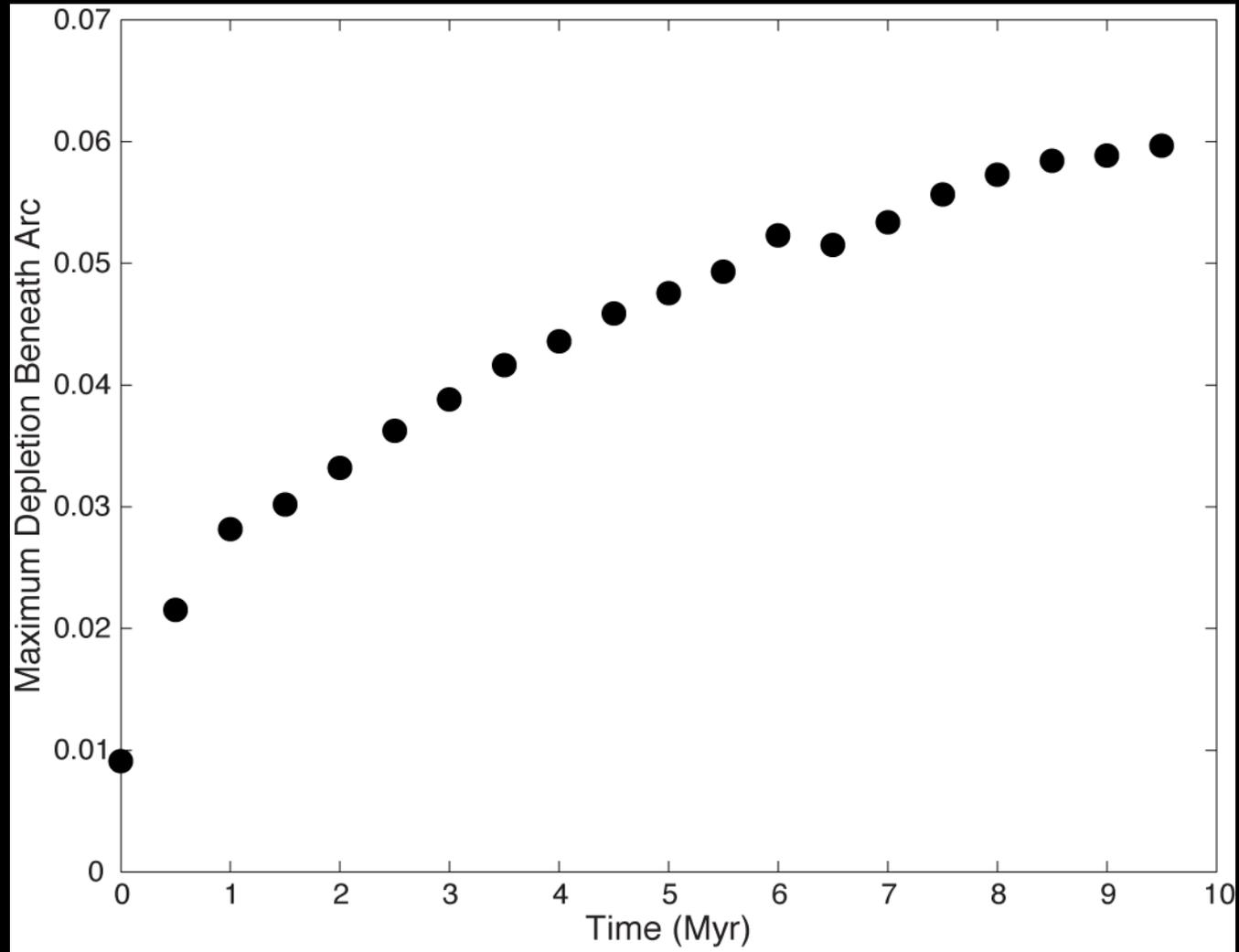
Mantle Depletion



Depletion of Sub-Arc Mantle



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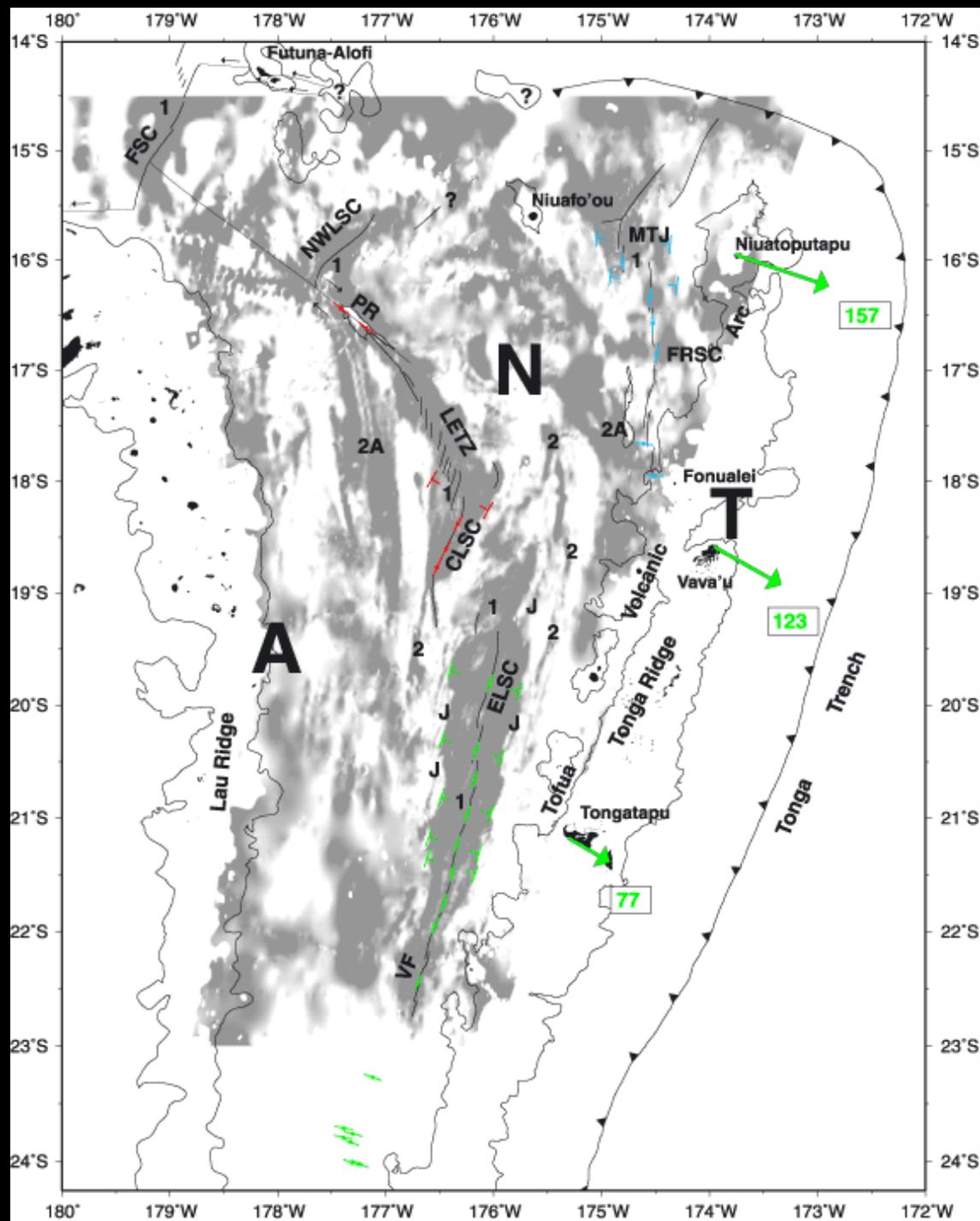
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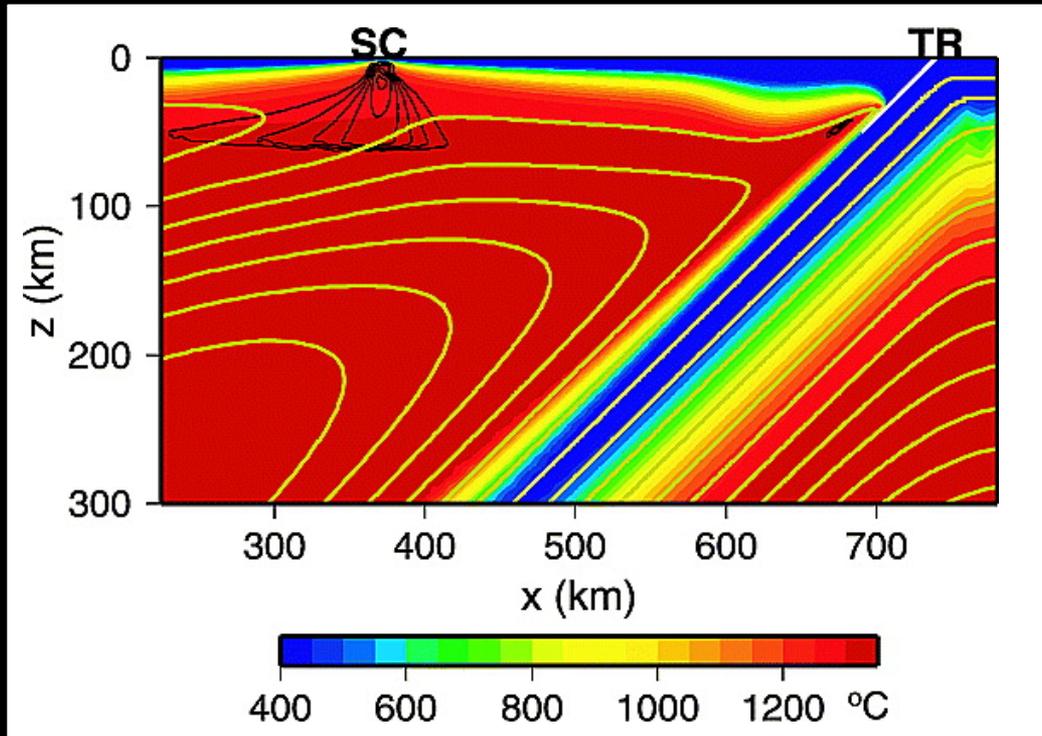
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Questions?



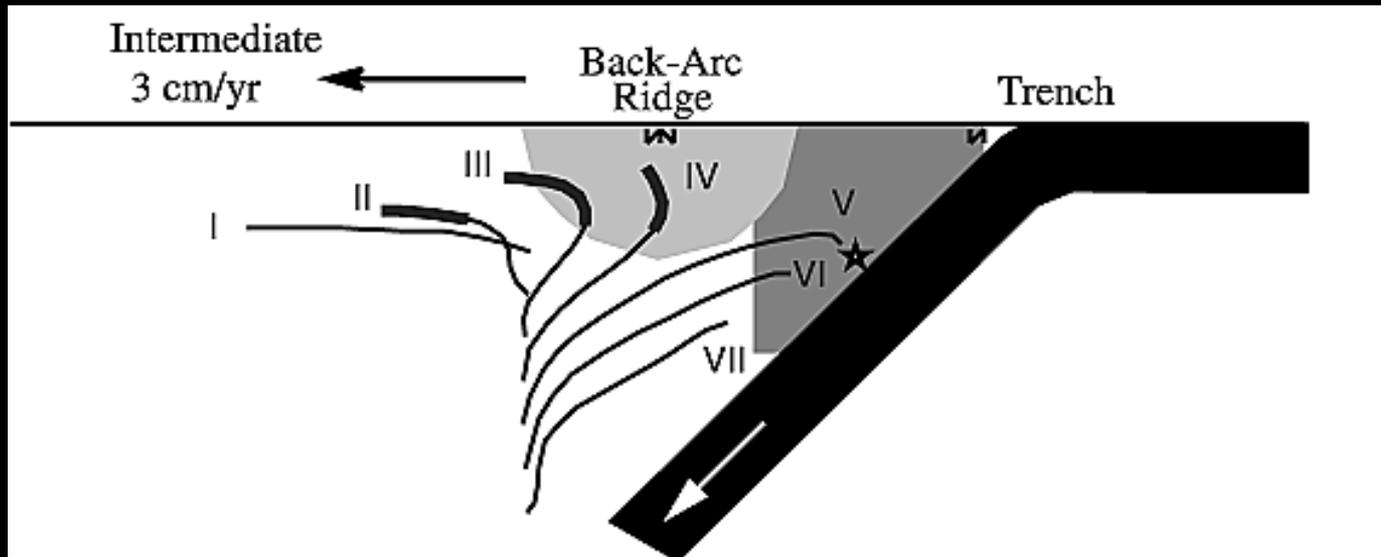
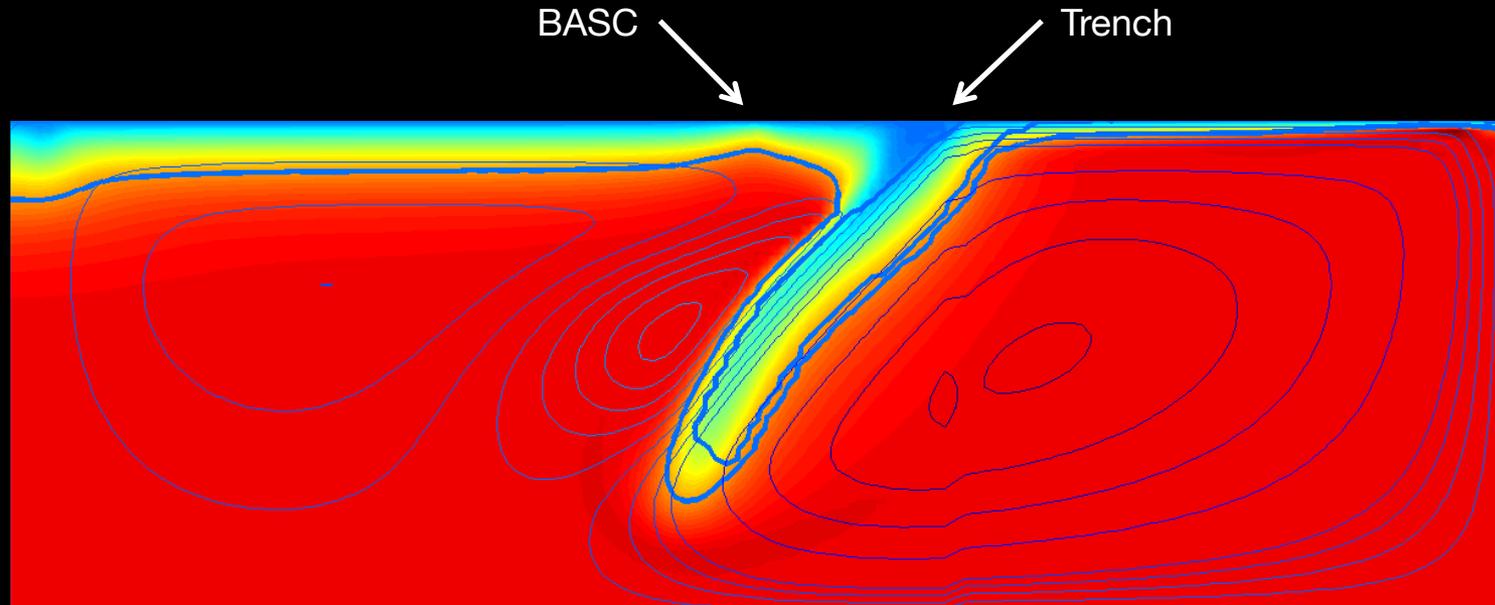
after Zellmer and Taylor (2001)

Previous Modeling of Arc – BASC systems

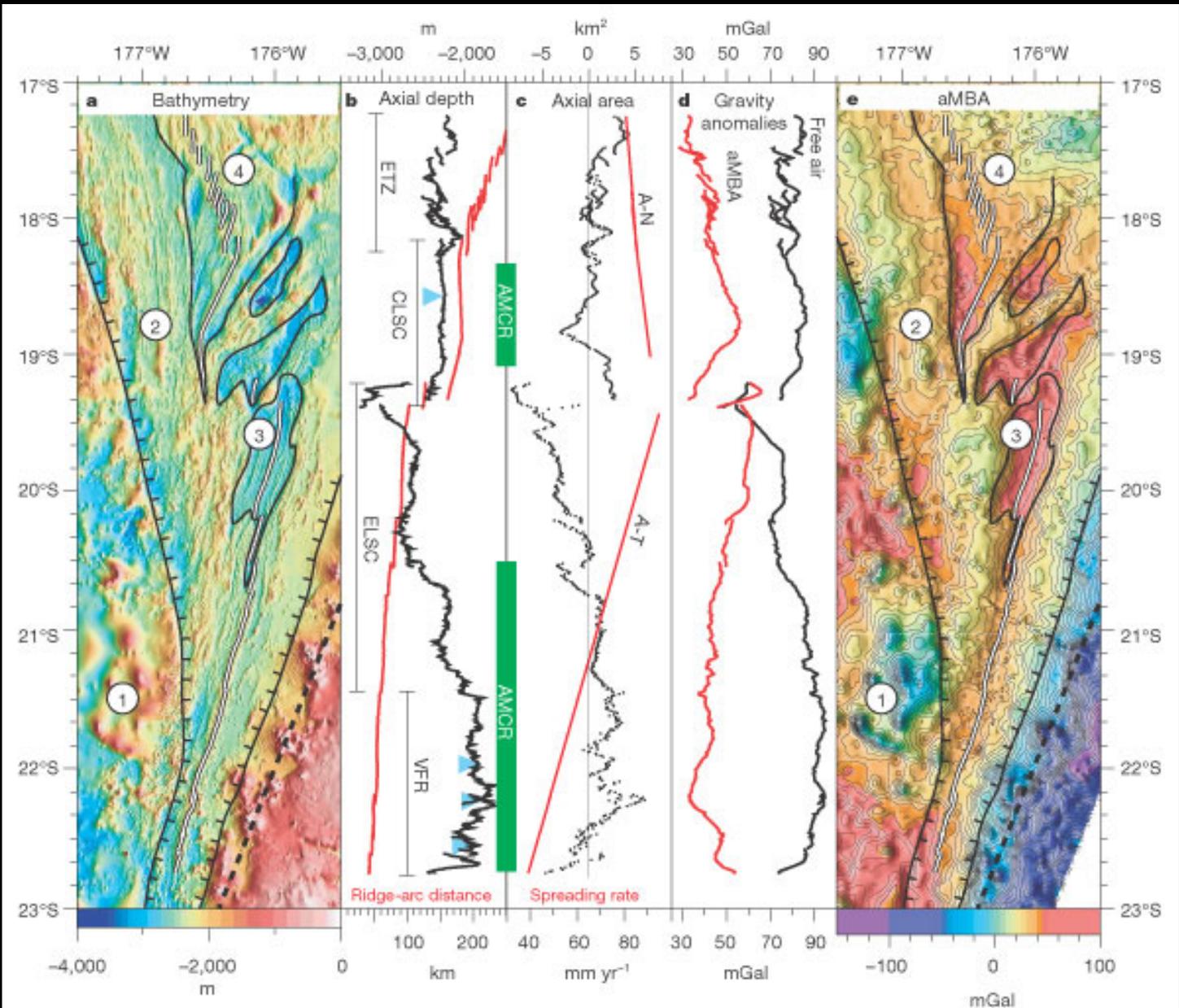


Conder et al. (2002)

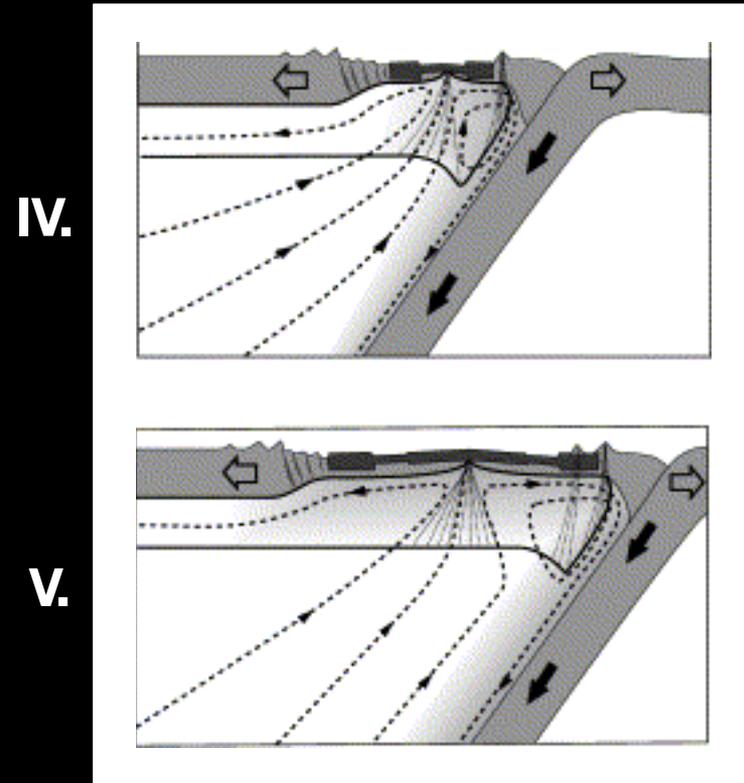
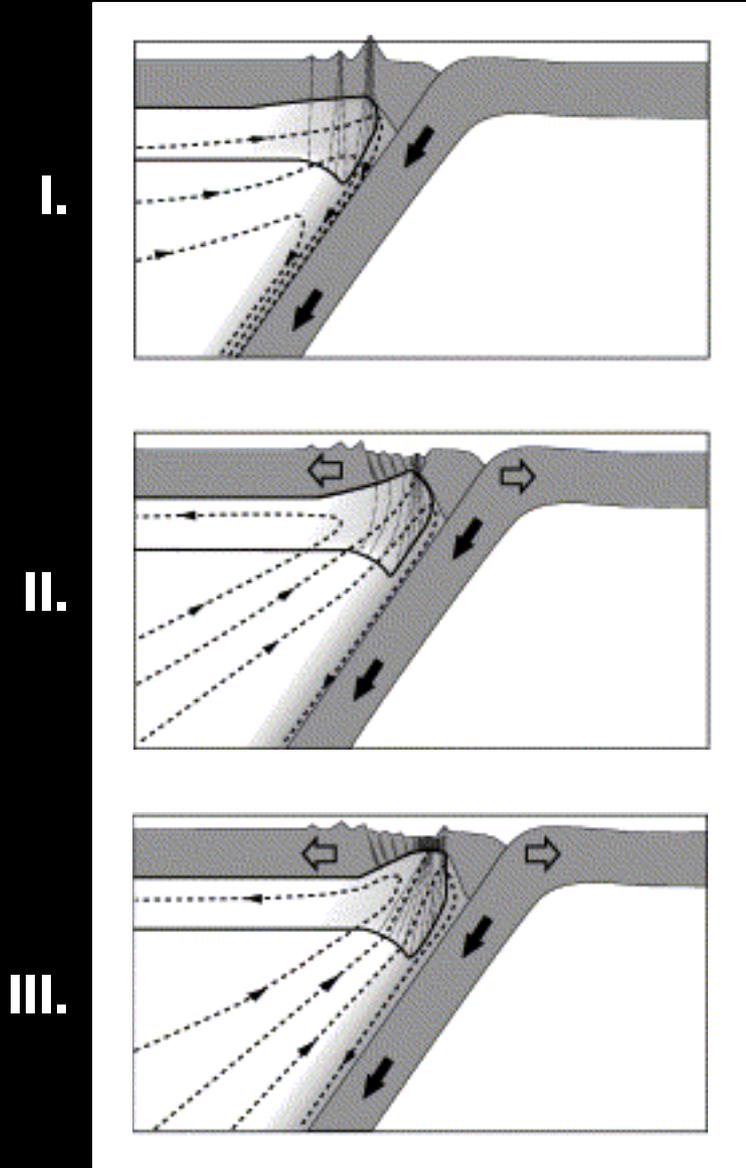
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Along-Strike Trends in BASC Magmatism in the Lau Basin



Evolution of the Mantle Beneath a BASC



Taylor and Martinez (2003)