# The effect of heterogeneous conductivity on the long-term thermo-chemical evolution of the lower mantle : implications for primordial reservoirs

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# Stability of thermochemical piles

- **The total buoyancy of piles directly influences its stability**
  - piles' density contrast controls chemical buoyancy ratio (B)
  - enrichment in heat-producing elements ($dH_{prim}$) augments thermal buoyancy

- **Secondary factors including chemical viscosity contrast or the presence of post-Perovskite phase affect pile topography and entrainment**

- **Mantle thermal conductivity affects thermal buoyancy but its effects on pile stability are not well known**

# Conductivity model

- **Total conductivity**

$$\tilde{k} = \tilde{k}_D(\tilde{d}) \times \tilde{k}_T(\tilde{T}) \times \tilde{k}_C(C)$$

- **Depth- dependence**

$$\tilde{k}_D(\tilde{d}) = 1 + (K_D - 1)\tilde{d}$$

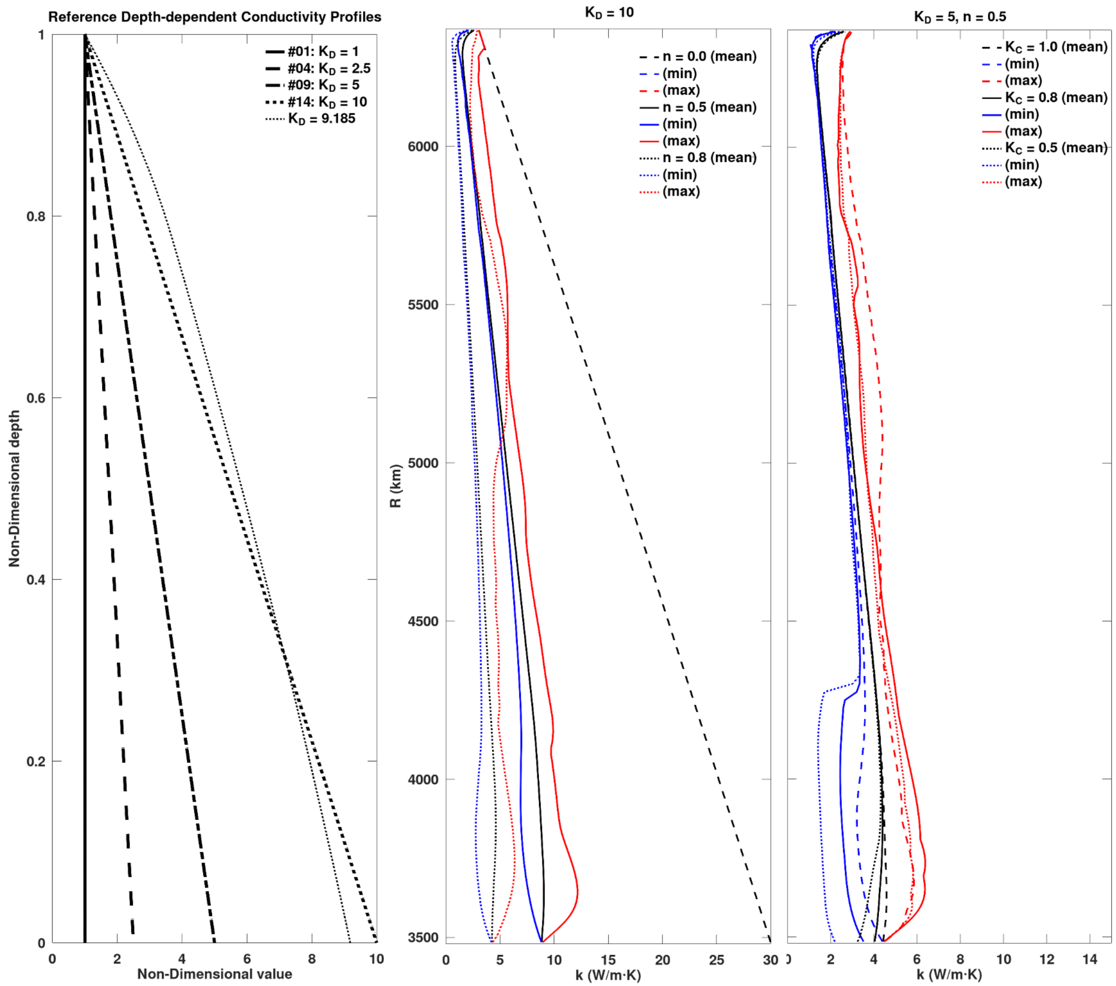
- **Temperature- dependence**

$$\tilde{k}_T(\tilde{T}) = \left( \frac{(T_{surf}/\Delta T_S)}{\tilde{T}} \right)^n$$

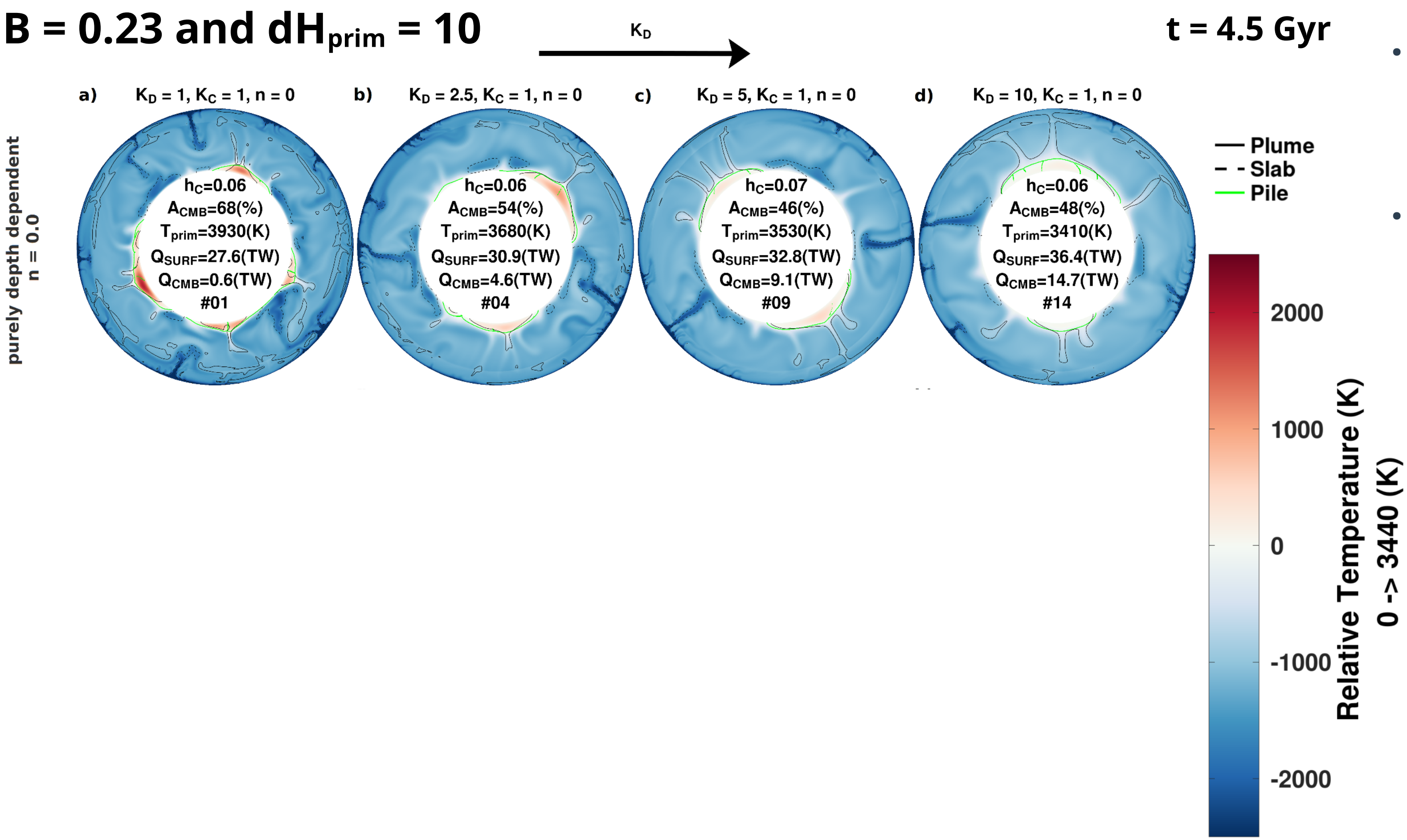
- **Composition- dependence**

$$\tilde{k}_C(C) = 1 + (K_C - 1)C$$

**Sample Conductivity Profiles at 4.5 Gyr:**



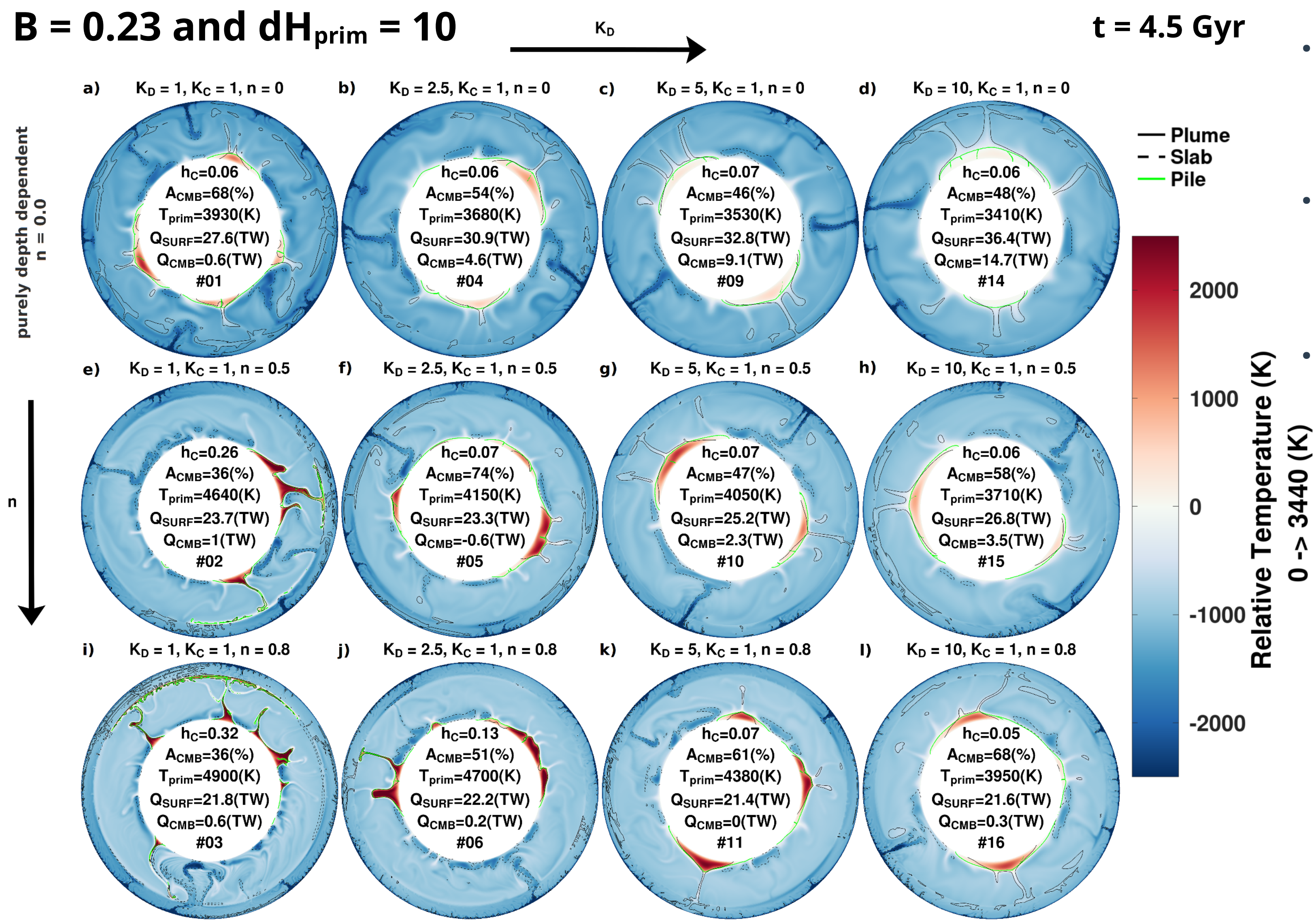
# T-,D- dependent conductivity




- $K_D > 1$ results in 2-pile configuration by 4.5 Gyr
- Increased $K_D$ acts to reduce $T_{prim}$.

Relative temperature field with respect to CMB Temperature

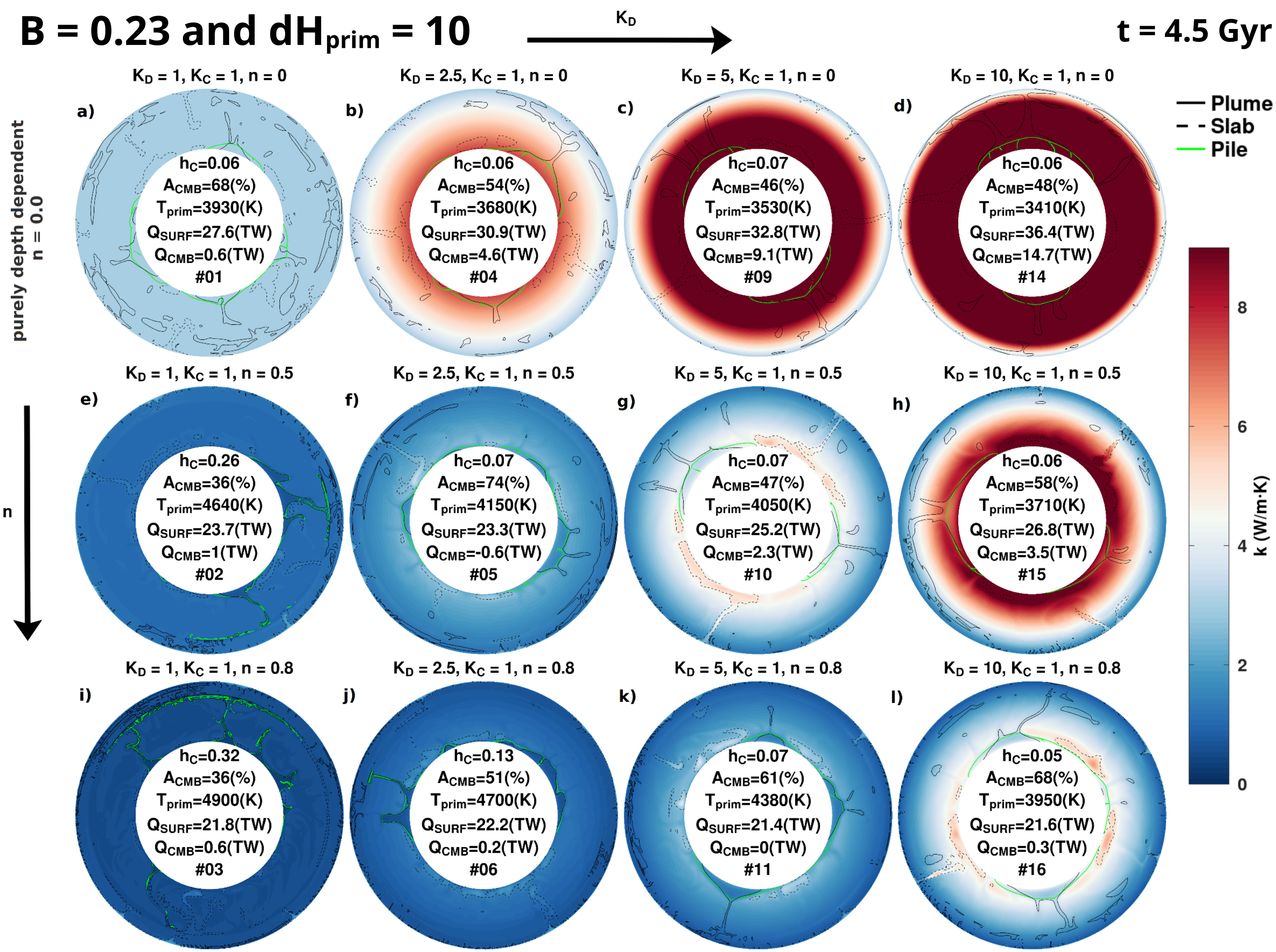
# T-,D- dependent conductivity




Relative temperature field with respect to CMB Temperature

- $K_D > 1$ results in 2-pile configuration by 4.5 Gyr
- Increased $K_D$ acts to reduce $T_{prim}$.
- Temperature- dependence increases $T_{prim}$ and may destabilize piles.

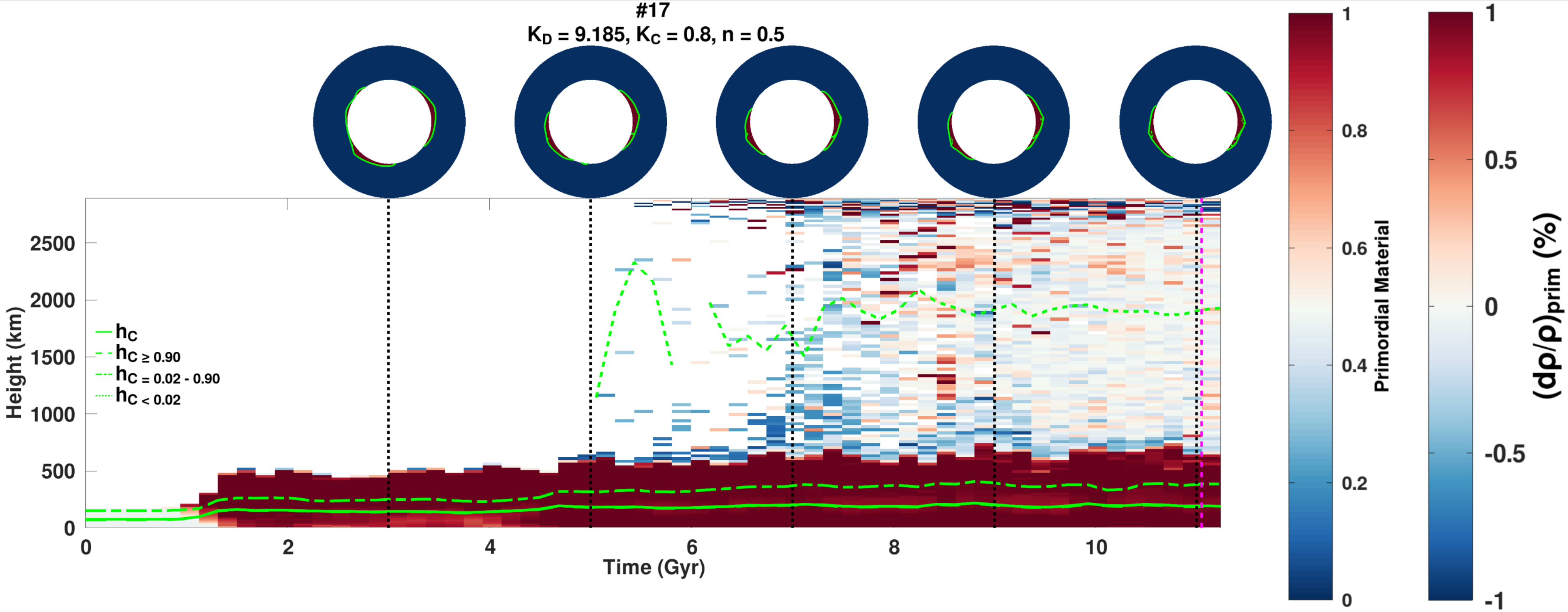
# T-,D- dependent conductivity




Conductivity field

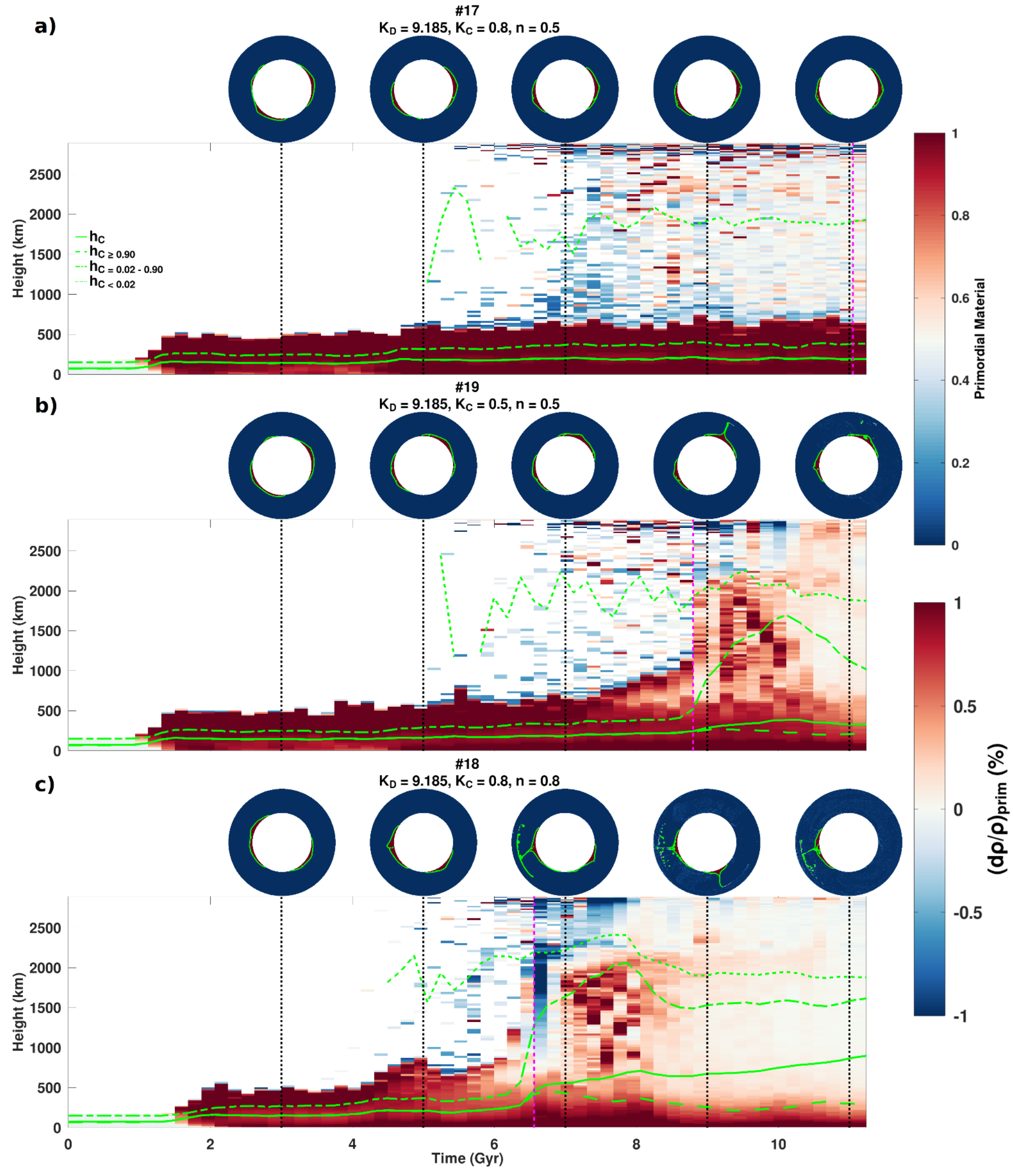
- $K_D > 1$ results in 2-pile configuration by 4.5 Gyr
- Increased $K_D$ acts to reduce $T_{prim}$.
- Temperature- dependence increases $T_{prim}$ and may destabilize piles.
- In general, heat flow is enhanced with increasing depth-dependence.

# D- dependent conductivity emulating mantle materials




- Moderate n and $K_c$ result in a long-lived 2-pile configuration
- Slow erosion occurs after 5 Gyr (for material with C < 0.02)

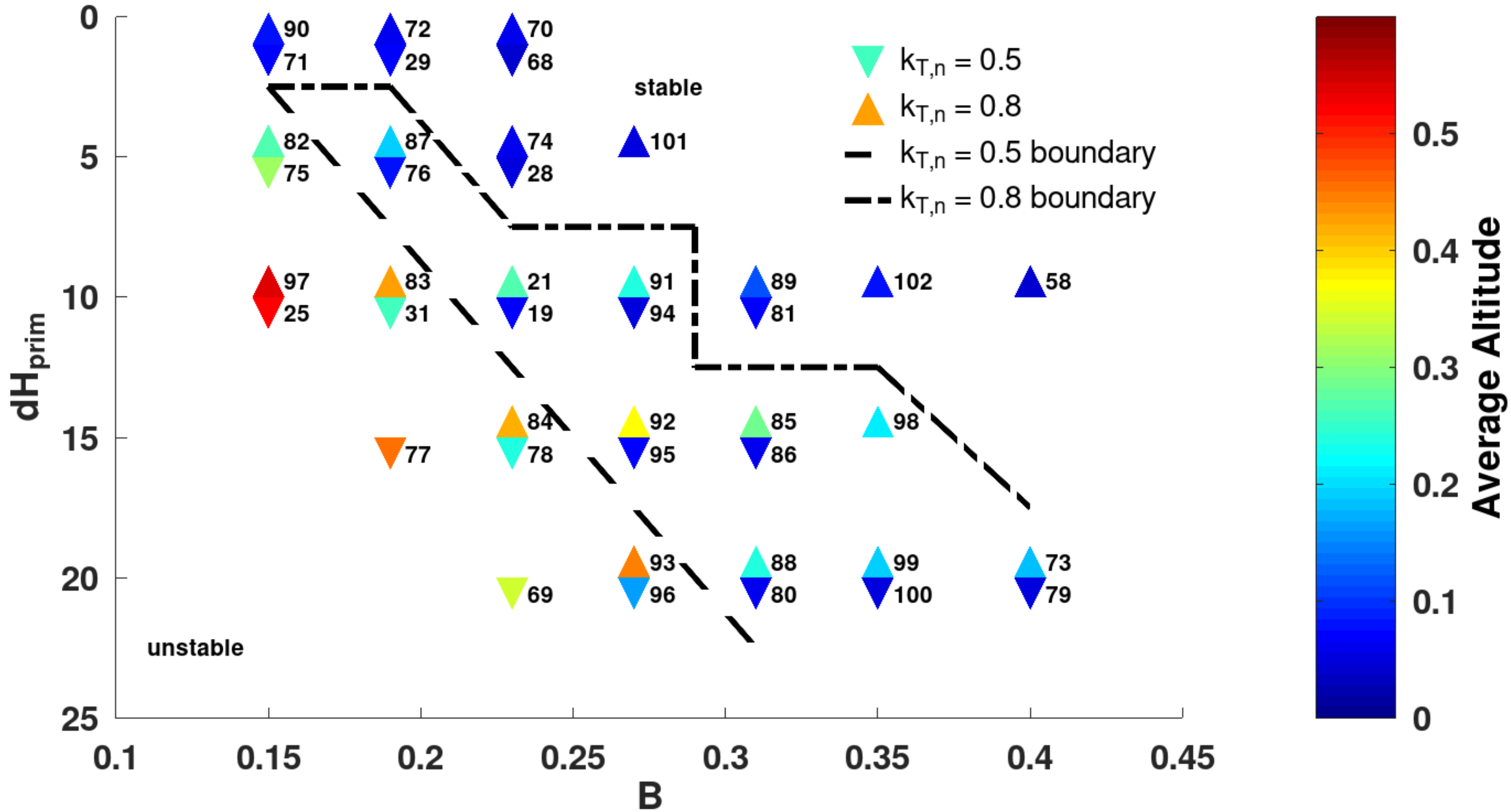
# D- dependent conductivity emulating mantle materials




- **When $K_c$ is reduced, a 2-pile configuration is maintained ( comparing a) to b) )**
  - Bulk erosion occurs by 9 Gyr
- **When n is reduced, the onset of instability occurs sooner ( comparing a) to c) )**
  - Piles coalesce by 11 Gyr
- **Period between light and heavy erosion is reduced when lower mantle conductivity is reduced**

# $h_c$ Regime Plot | B vs. $dH_{prim}$

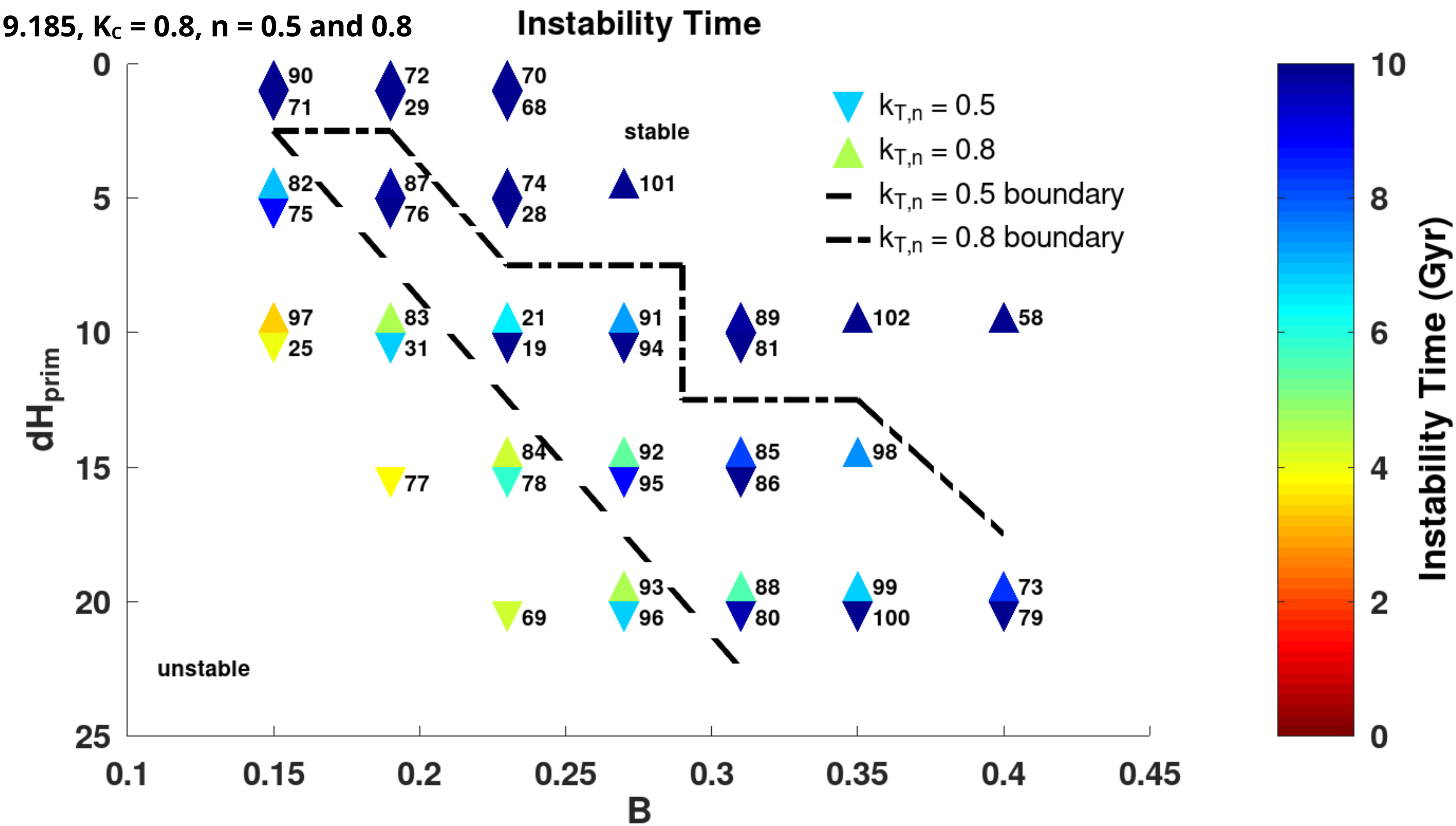
$K_D = 9.185$, $K_C = 0.8$, n = 0.5 and 0.8 t = 10.5 Gyr




Average height is a useful (ad-hoc) parameter for measuring entrainment.
But comparisons and differences between cases will require a later snapshot in time.

# $t_{inst.}$ Regime Plot | B vs. $dH_{prim}$

$K_D$ = 9.185, $K_C$ = 0.8, n = 0.5 and 0.8




Determining a system's instability time from the onset of rapid erosion may be more useful for comparisons between cases.

# Conclusions

- Onset of entrainment is dependent on the lowermost mantle's mean conductivity value and the piles' implied cooling history
- Instability caused by heat-producing element enrichment is enhanced by conductivity's temperature dependence and diminished by greater depth- dependence
- Greater temperature- dependent conductivity instigates earlier pile instability even at greater B and $dH_{prim}$.