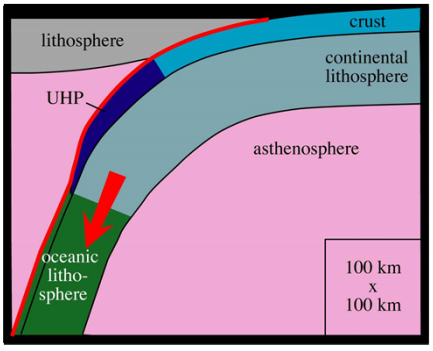
Role of UHP Tectonism in Earth Evolution

geodynamics & geochemistry
Relamination (including secular evolution & multiple events

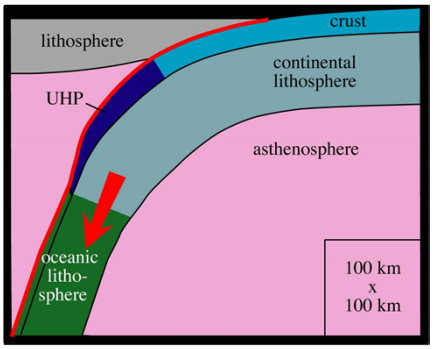
What happens to continental crust when it meets its ultimate fate—subduction?

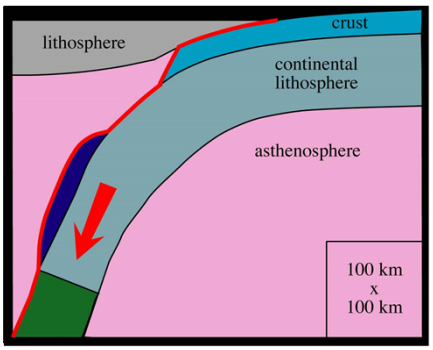
Is it…
…recycled into the mantle?
…exhumed to the surface?
…forced into the lower crust?
…or...?.



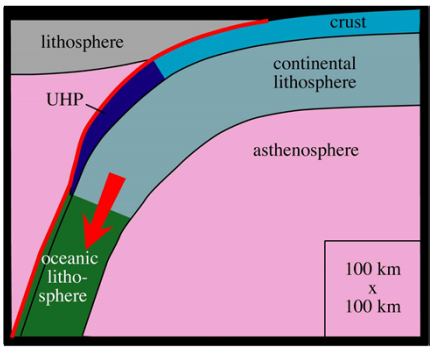
Xenoliths & UHP terranes provide novel answers to these significant geodynamical–geochemical questions

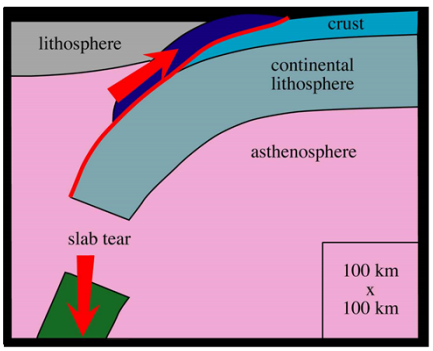
Are subducted continents…
…recycled into the mantle?



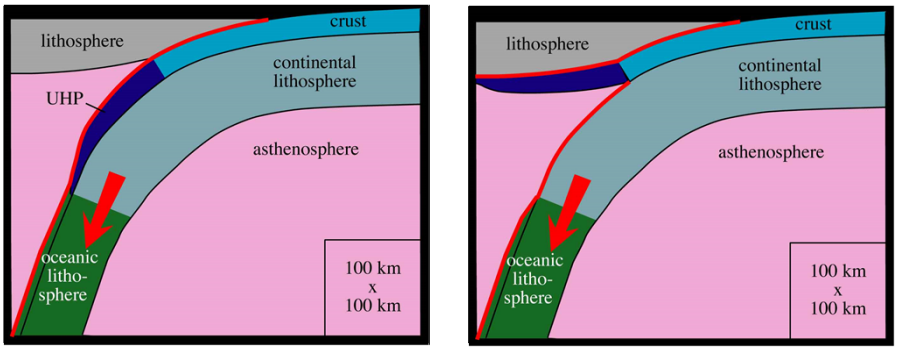


Are subducted continents…
…exhumed to the surface?

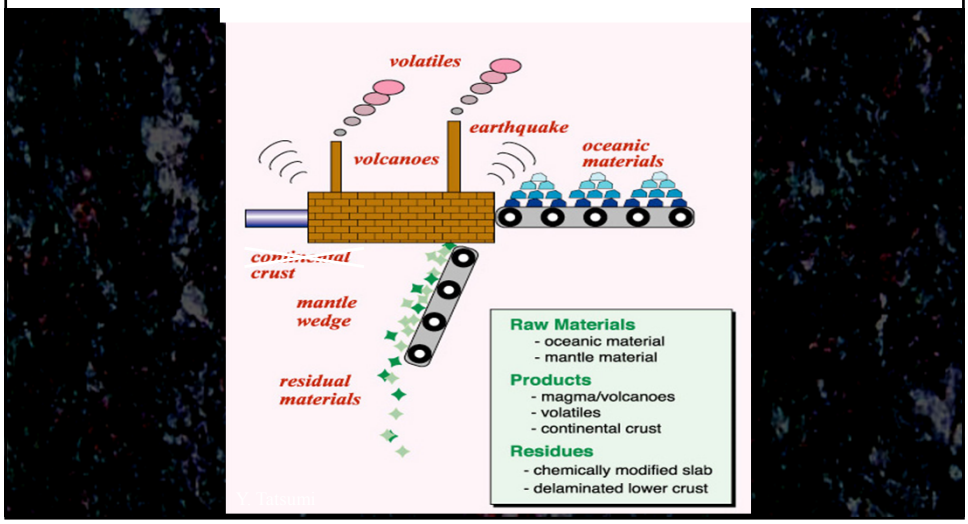




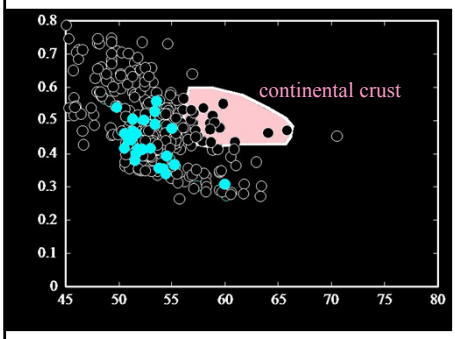
Are subducted continents…
…forced into the lower crust?

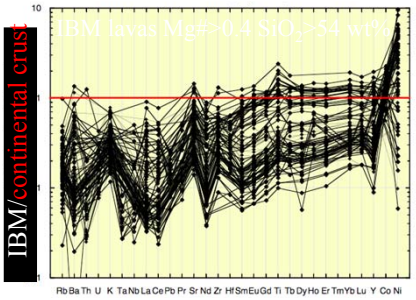


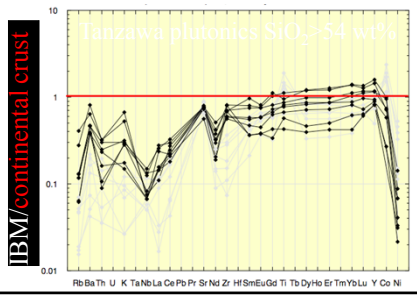
Subduction Factory:
Production of continental crust from oceanic crust & mantle wedge(?)



Continental Crust Not Made in Most Arcs







Continental Refinery: Refining of crust from magmatic arcs

extracted 'volatiles' (upper crust)

magmatic arc crust

buoyant refractory residue (lower crust)

dense refractory residue (mantle)

Case Studies of Continental Refining

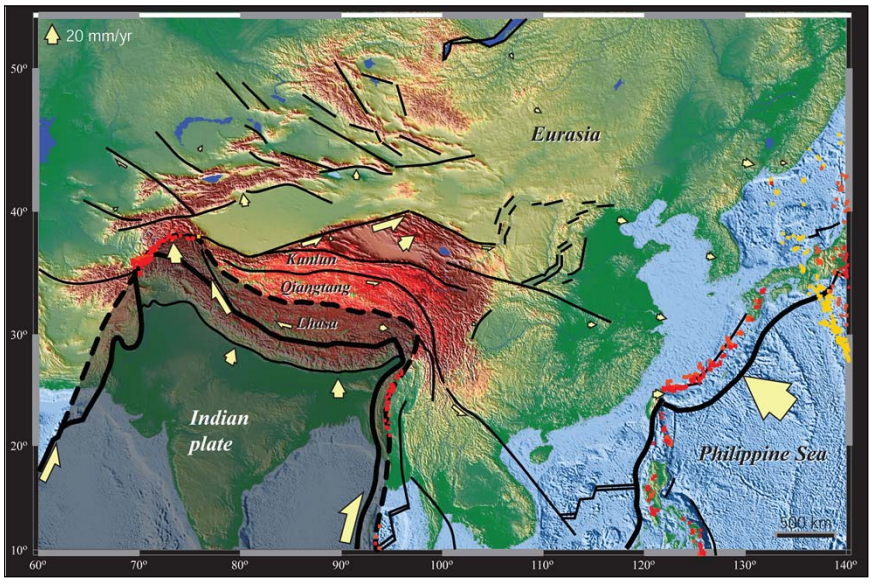
I Crustal thickening of Tibet

II Continental subduction of Norway

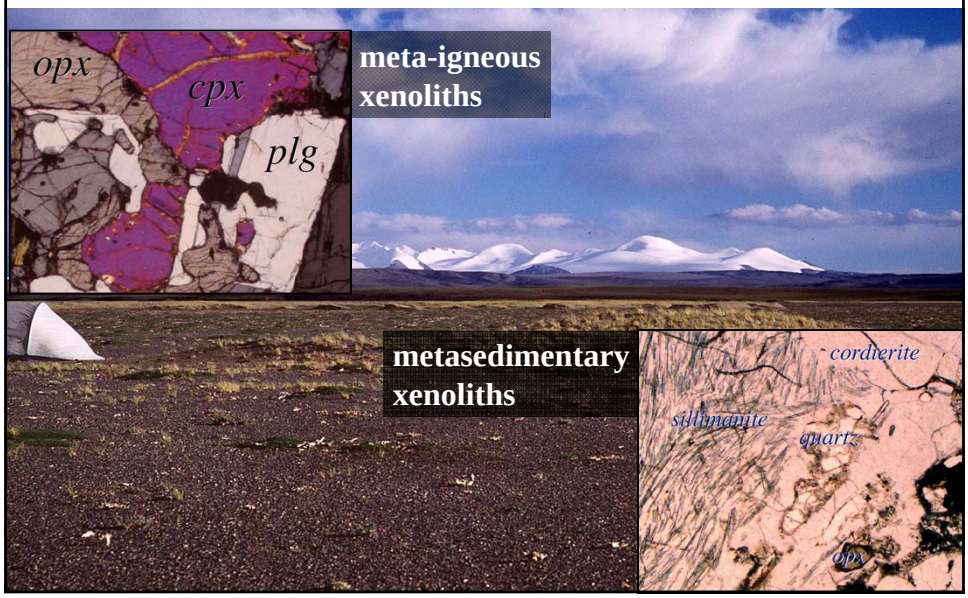
III Subduction erosion of Pamir

magnitude, scale & rate of crustal refining?

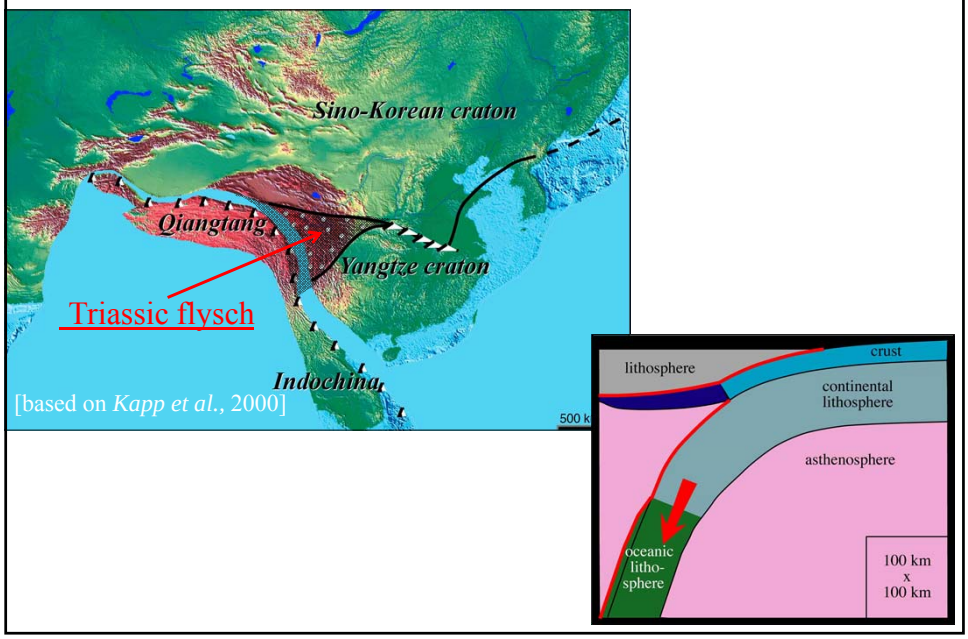
I. Refining During Crustal Thickening: Tibet Archetype



Mid–Lower Crustal Xenoliths of Central Tibet

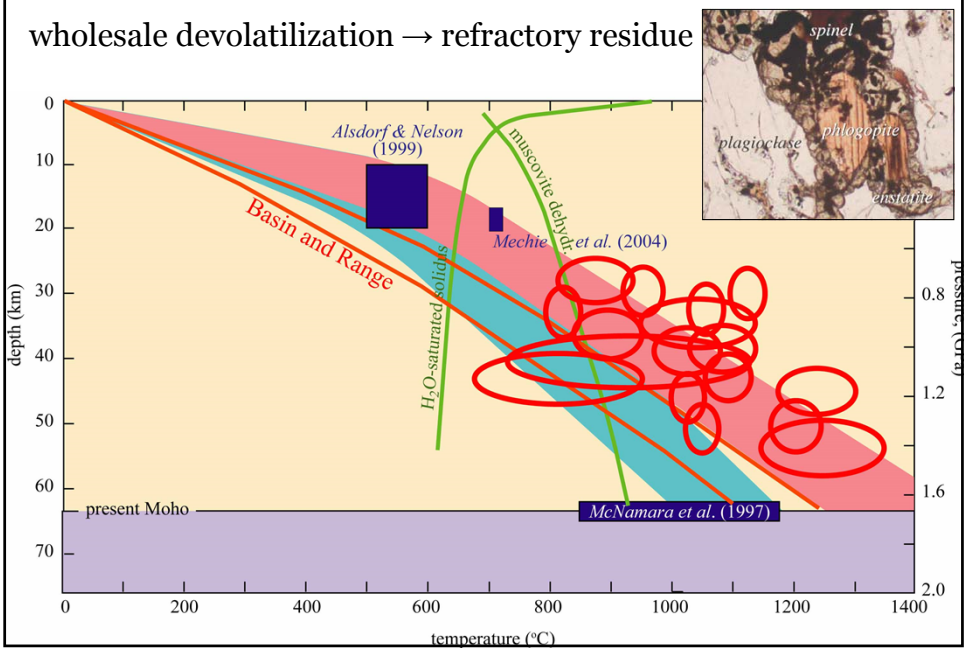


Triassic Flysch Relaminated Beneath Tibet

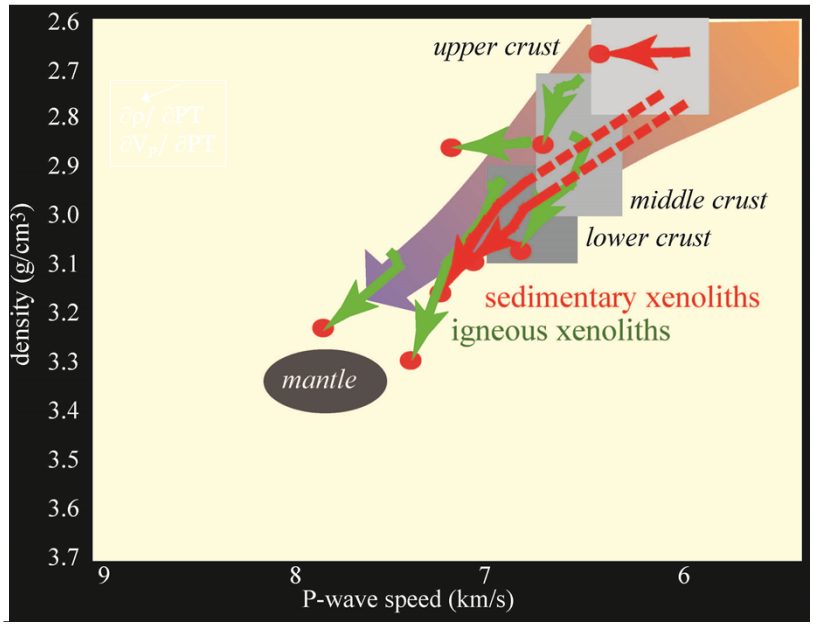


Extreme Refining Conditions

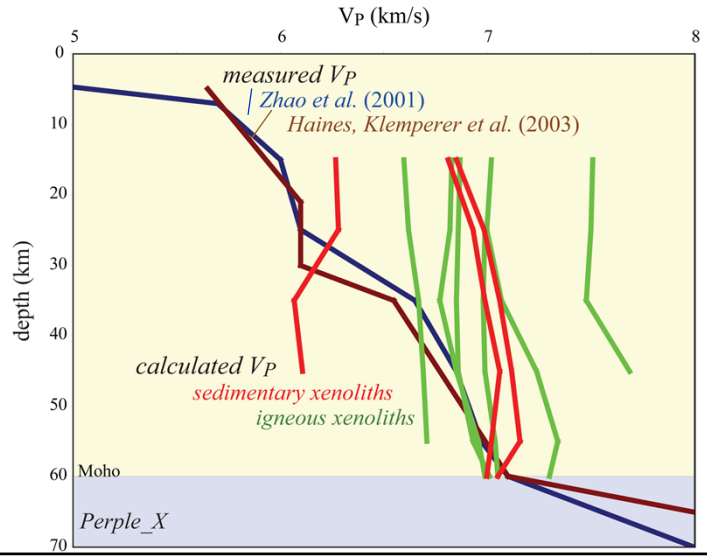
wholesale devolatilization → refractory residue



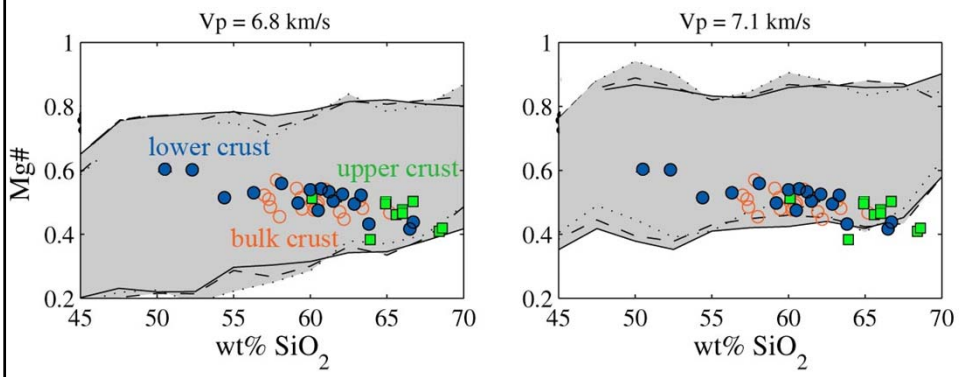
Refining Changed Physical Properties



Xenolith V_P = Measured V_P Even for Metasediments

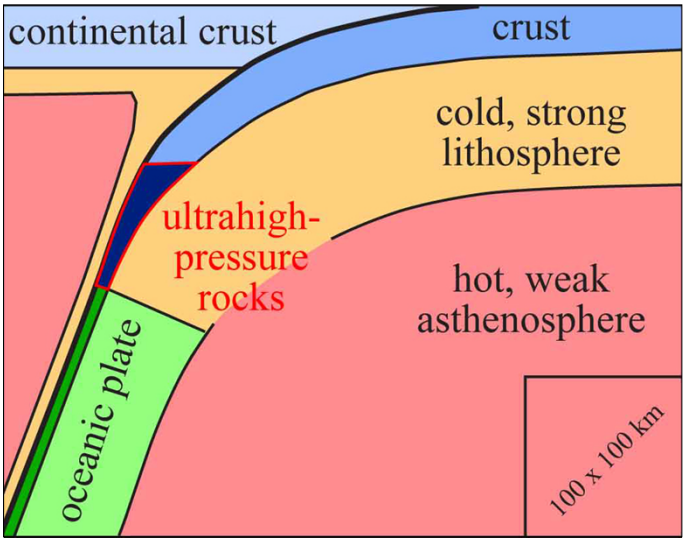


Wave Speeds do not Reveal Composition of Lower Crust

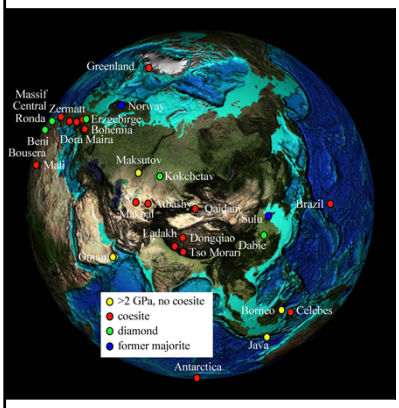


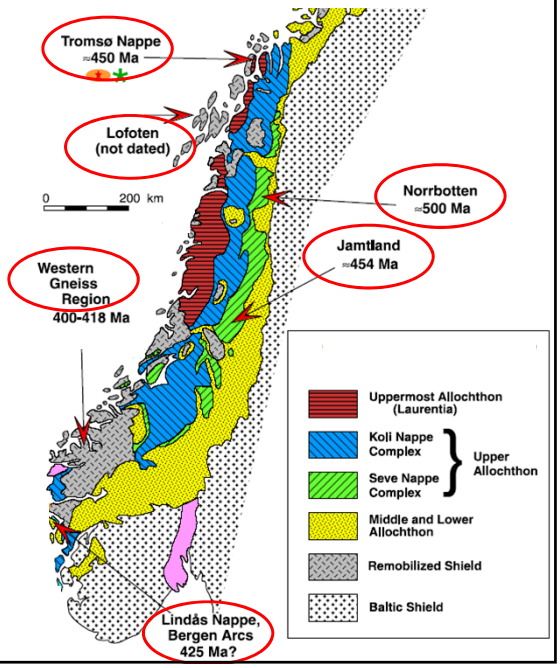
Behn & Kelemen [2003]

II. Crustal Refining During Continent Subduction: Norway UHP Archetype

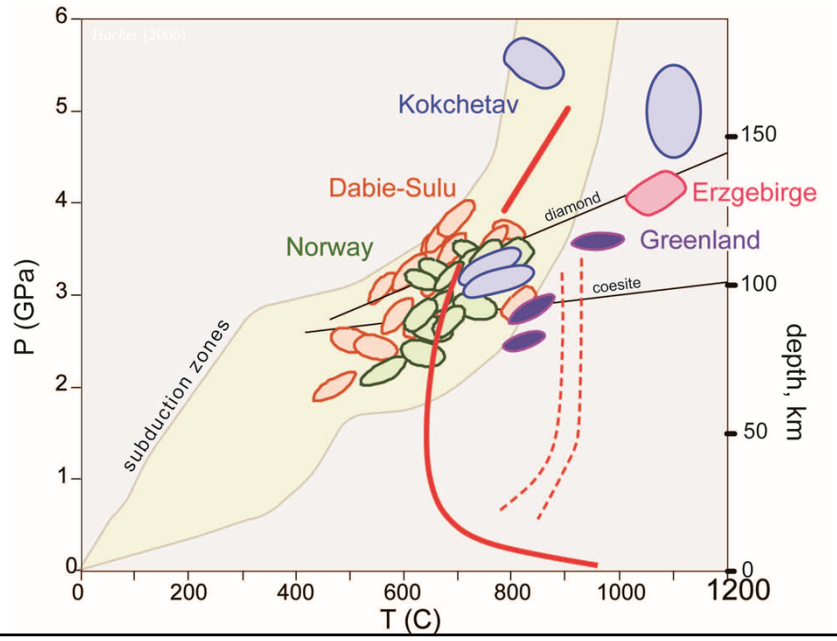


Frequent Continent Subduction



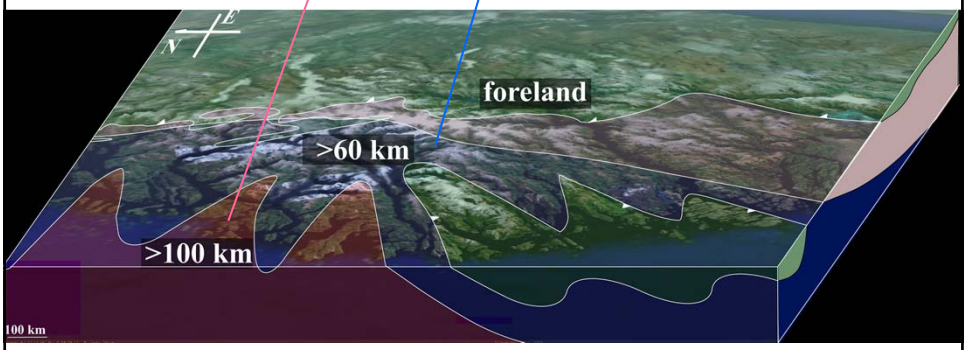


Norway Subduction to 750 °C, 100+ km

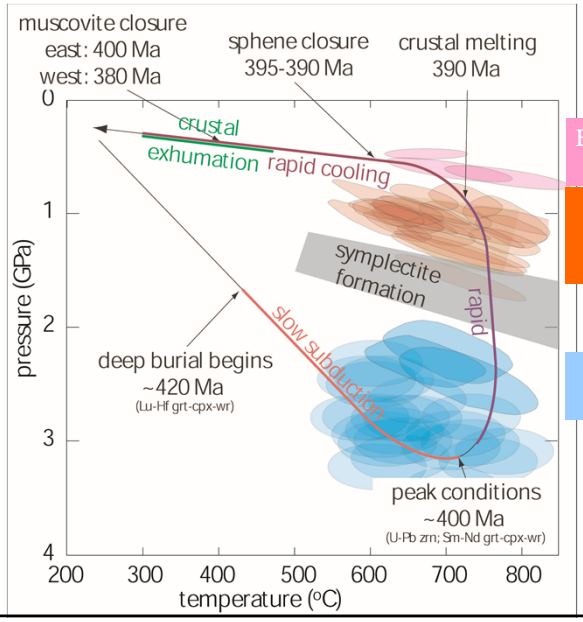


Huge Subducted & Exhumed Margin

- >10,000 km^2 UHP overlain by >60,000 km^2 HP veneer



UHP → Moho → Upper Crust @ 750°C

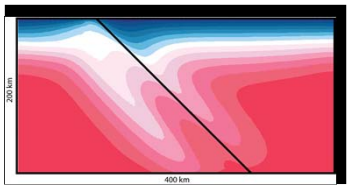


Buchan (low-P/T) metamorphism

supra-Barrovian metamorphism at the Moho

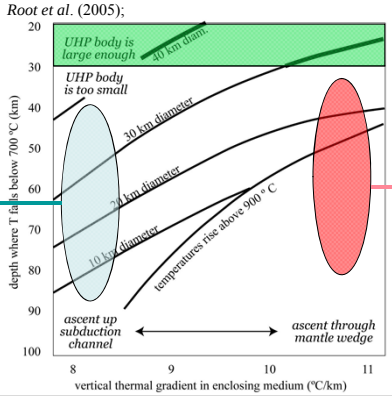
continental subduction

Models Require 15–20 km Dimension



Kylander-Clark et al. (in review)

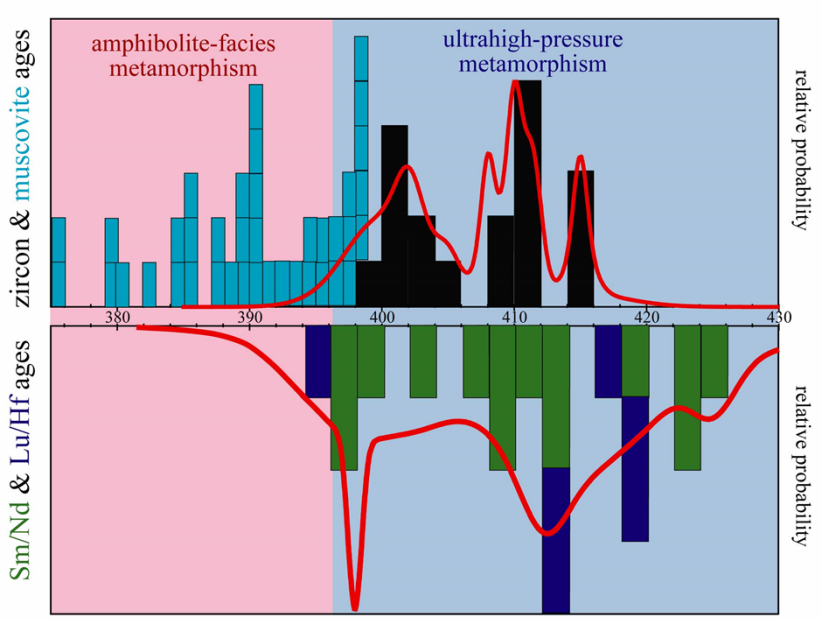
Root et al. (2005);



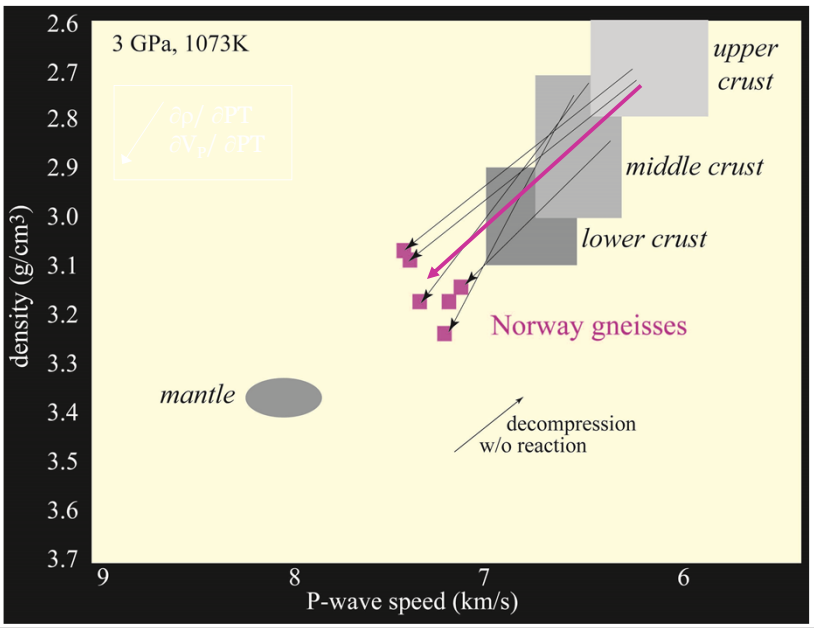
low ∇T:
small body
cools too much

high ∇T:
small body
heats too much

15–20 Myr at (Ultra)High Pressure

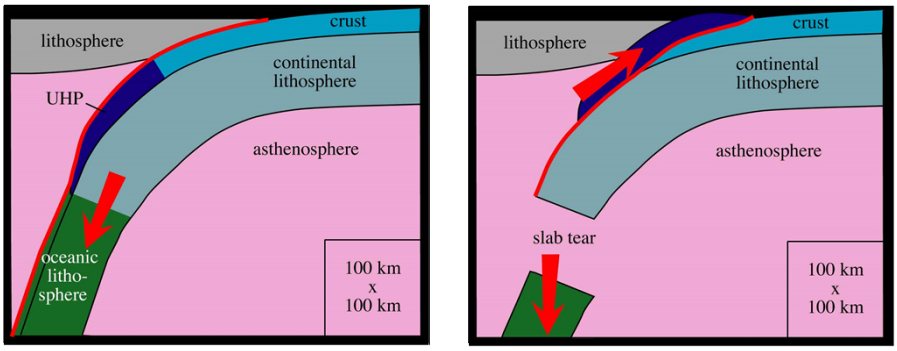


Huge Changes in Physical Properties



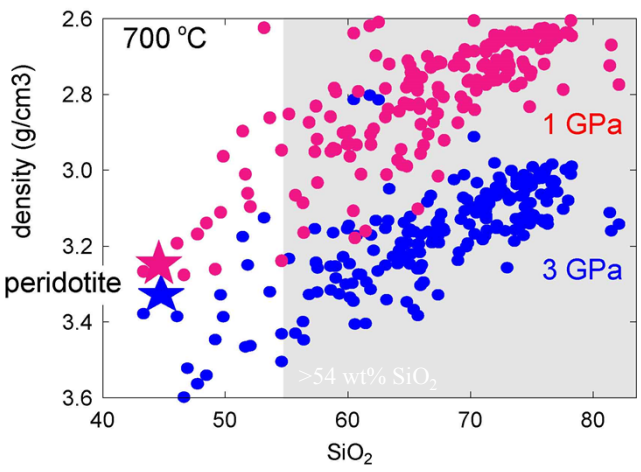
Some UHP Terranes Exhumed to Surface

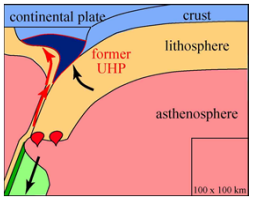
but is this normal?

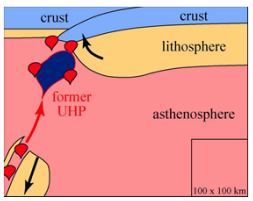


Non-Mafic UHP Rocks Are Buoyant

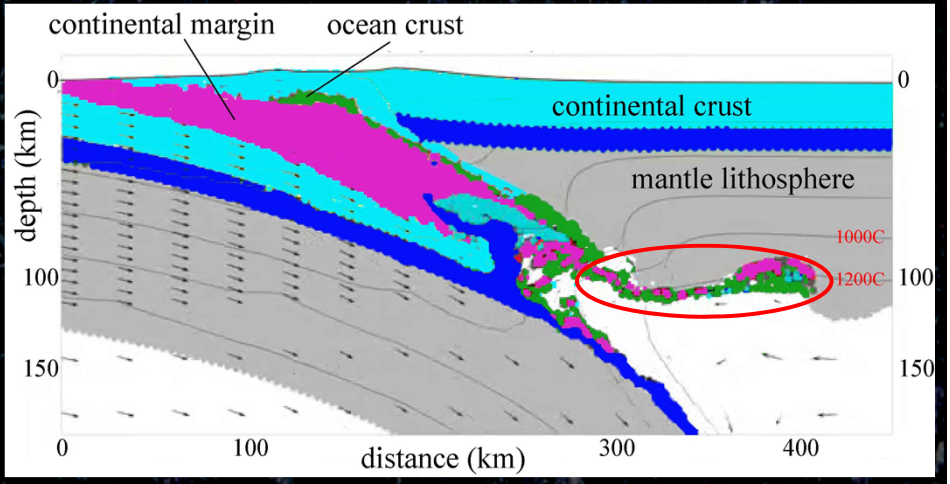
Perple_X densities from global database



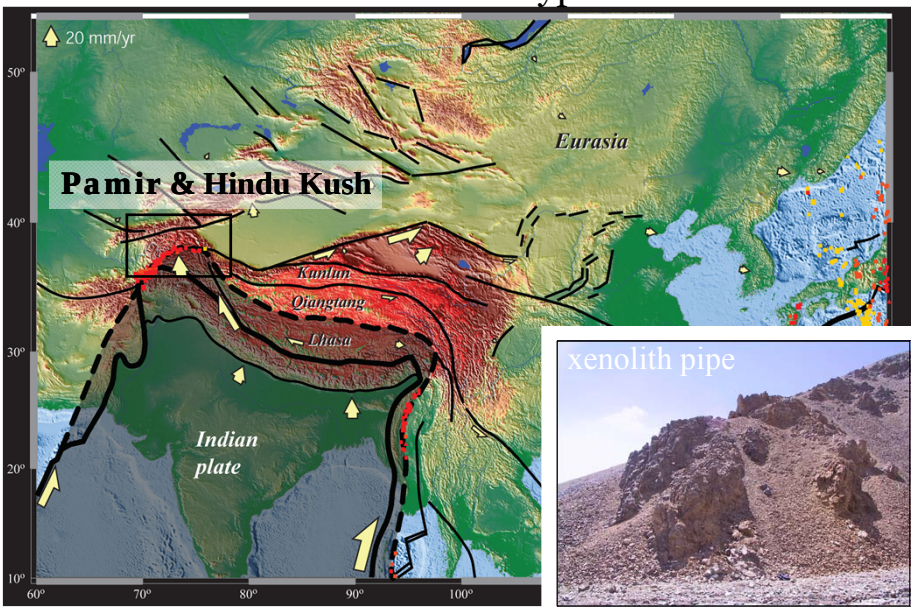




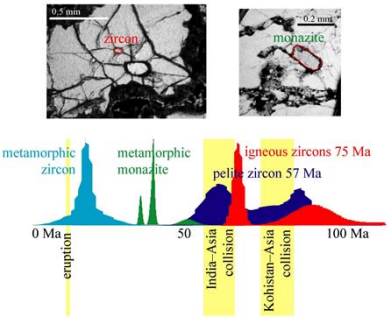
Relamination of Subducted Continental Material



III. Refining During Subduction Erosion: Pamir Archetype

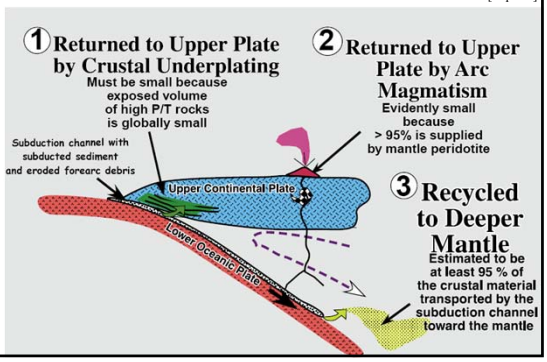


Subduction Erosion of Asian Margin

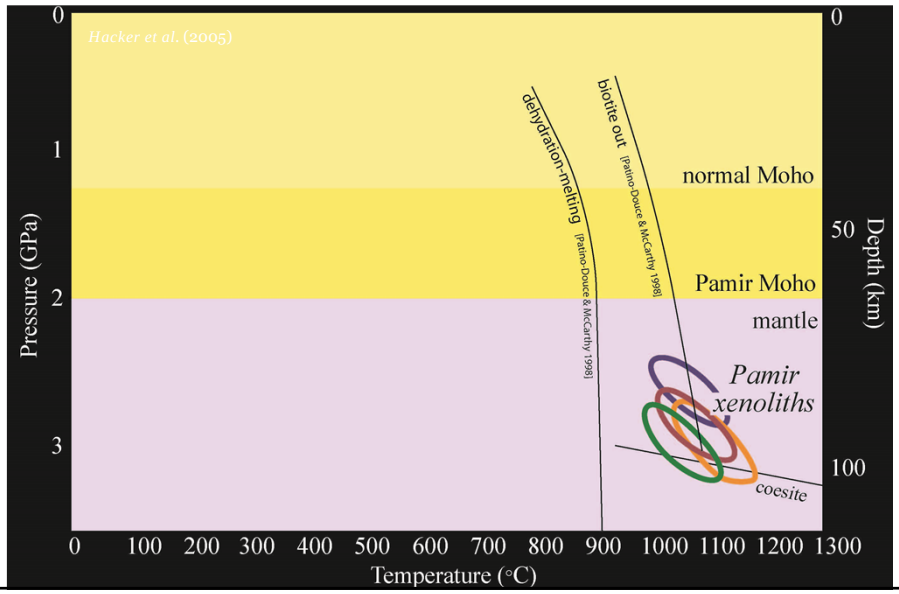


Ducea et al. [2003]

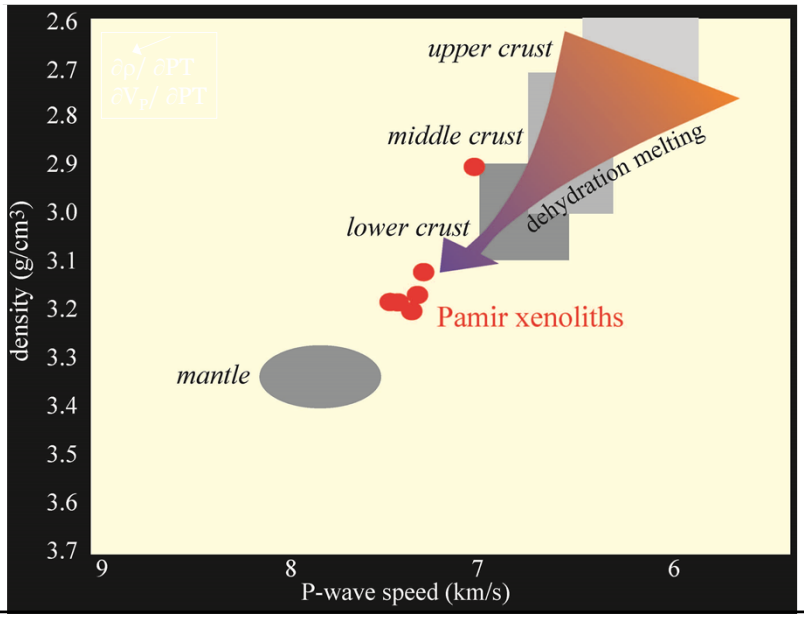
Scholl & von Huene [in press]



Extreme Sub-Moho Refining Conditions



Large Changes in Physical Properties



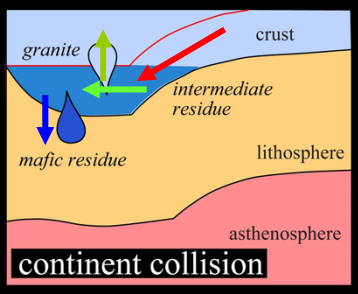
Relamination Summary

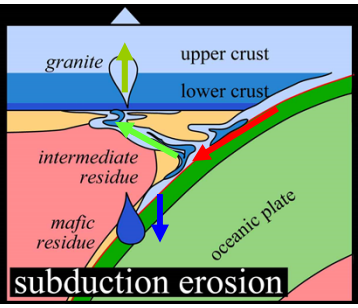
introduction of continental material

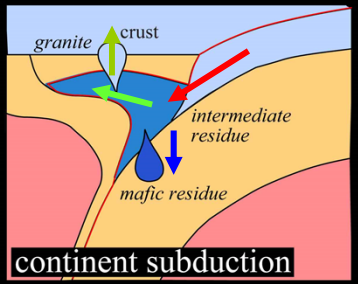
'volatile' injection

foundering of dense material

relamination of buoyant residue

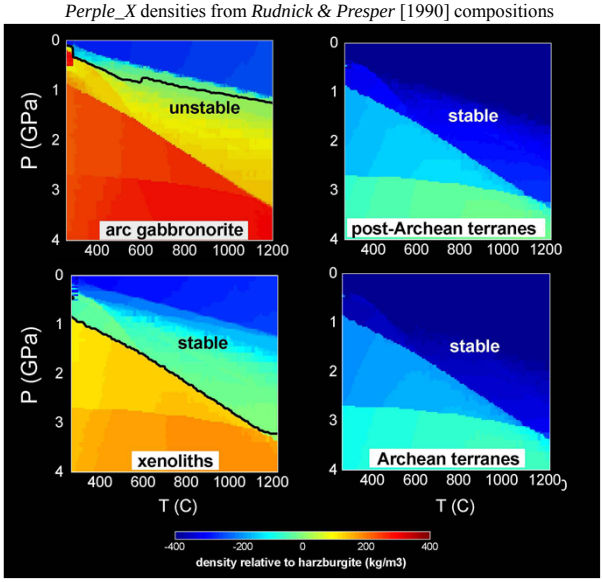




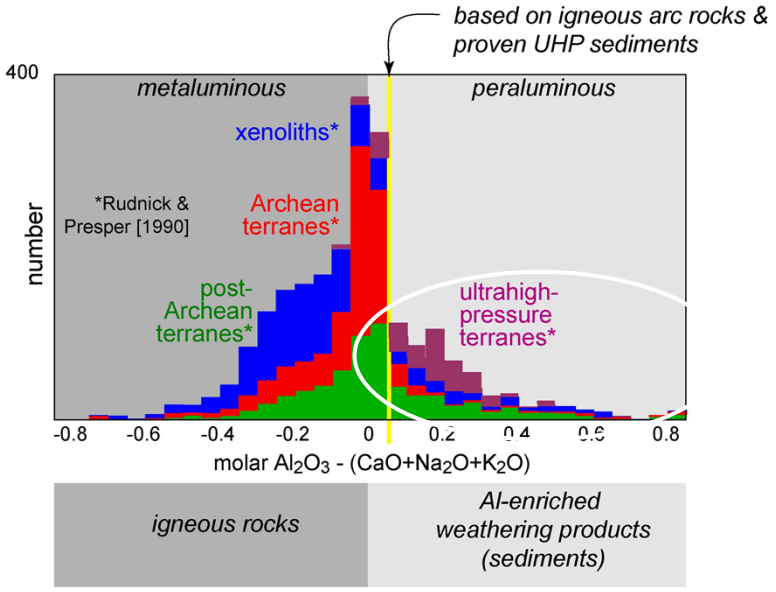


Arc Lower Crust Unstable; Continent Lower Crust Buoyant

Perple_X densities from *Rudnick & Presper* [1990] compositions



Lower Crust, UHP Terranes Include Sediment

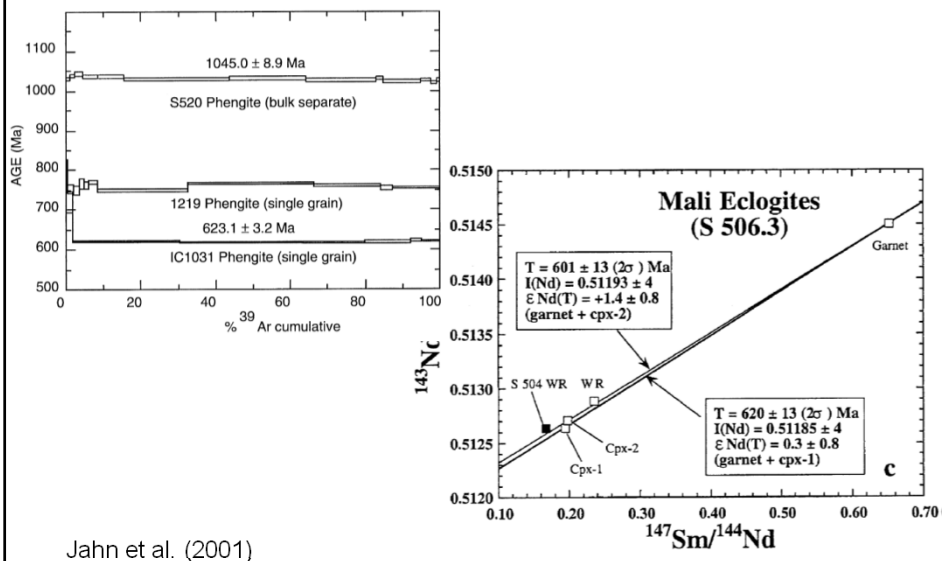


Relamination is Geodynamically & Geochemically Significant

- *subduction erosion (e.g., Pamir)*
  ≈ 1.5 km³/yr (*Clift & Vannucchi*, 2004; *Scholl & von Huene*, 2006)
- *crustal thickening (e.g., Tibet)*
  30 km lower crust x 1.5E6 km² ≈ 4E7 km³ / 50 Myr
  ≈ 1 km³/yr
- *continent subduction (e.g., Norway)*
  10,000 km x 200 km "deep" x 20 km thick / 50 Myr
  ≈ 1 km³/yr

- present volume of crust 7E9 km³
- cycle time for any *one* process:
  (7E9 km³/**1–1.5** km³ /yr) = 4–7 Ga!

Oldest UHP Rock



Jahn et al. (2001)

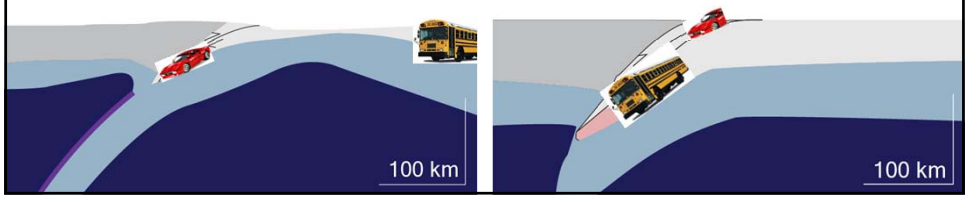
- Dora Maira
- Tso Morari
- Kaghan

Active orogens

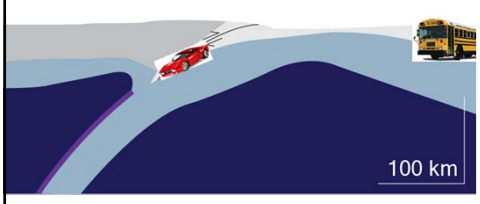
- Norway
- Dabie-Sulu

Ancient orogens

small UHP terrane	large UHP terrane
• weak orogenic influence • little change in plate forcing • strong mantle interaction	• strong, long-lived orogenic influence • large change in plate forcing • weak mantle interaction

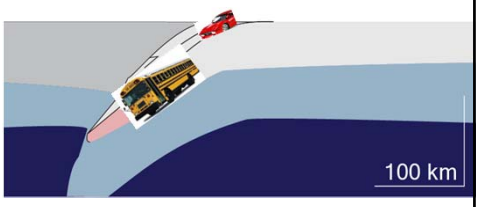


Early vs. late stage orogenesis



ocean-plate dominated

- rapid subduction
- thinner plates
- weak



continental-plate dominated

- slow subduction
- thicker plates
- strong