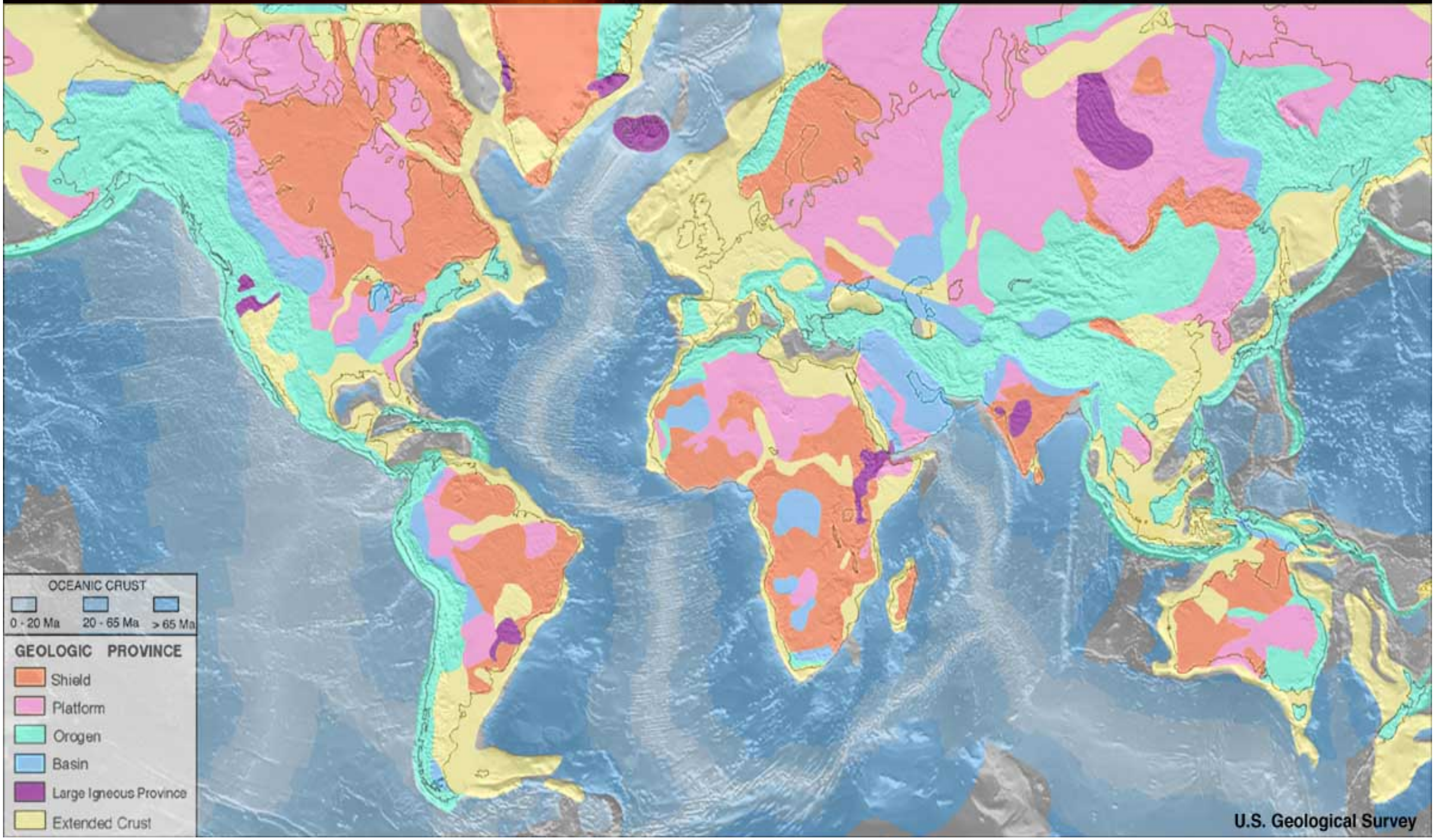
The origins of magmas

What is the **primary** magma?

- Basalt

Origin of Basaltic Magma

Basalt in the world



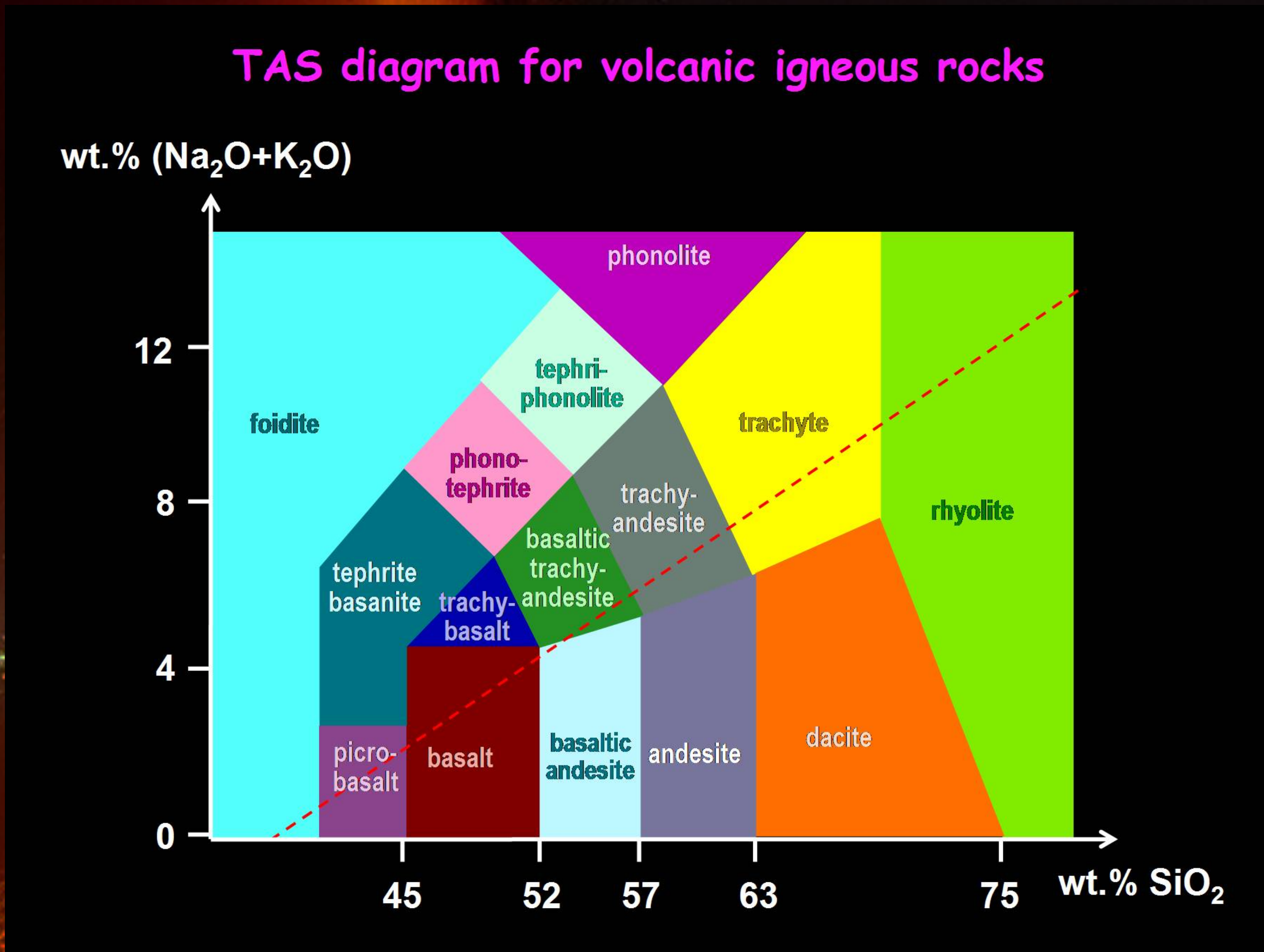
Origin of basalt

- What is basalt?
- Where does it come from?

- How do we know the Earth mantle? What state is it in?

- Why does the mantle melt?

Definition of basalt



Where does it come from?

- Melting in the upper mantle

How do we know the Earth's mantle?

Sources of mantle material

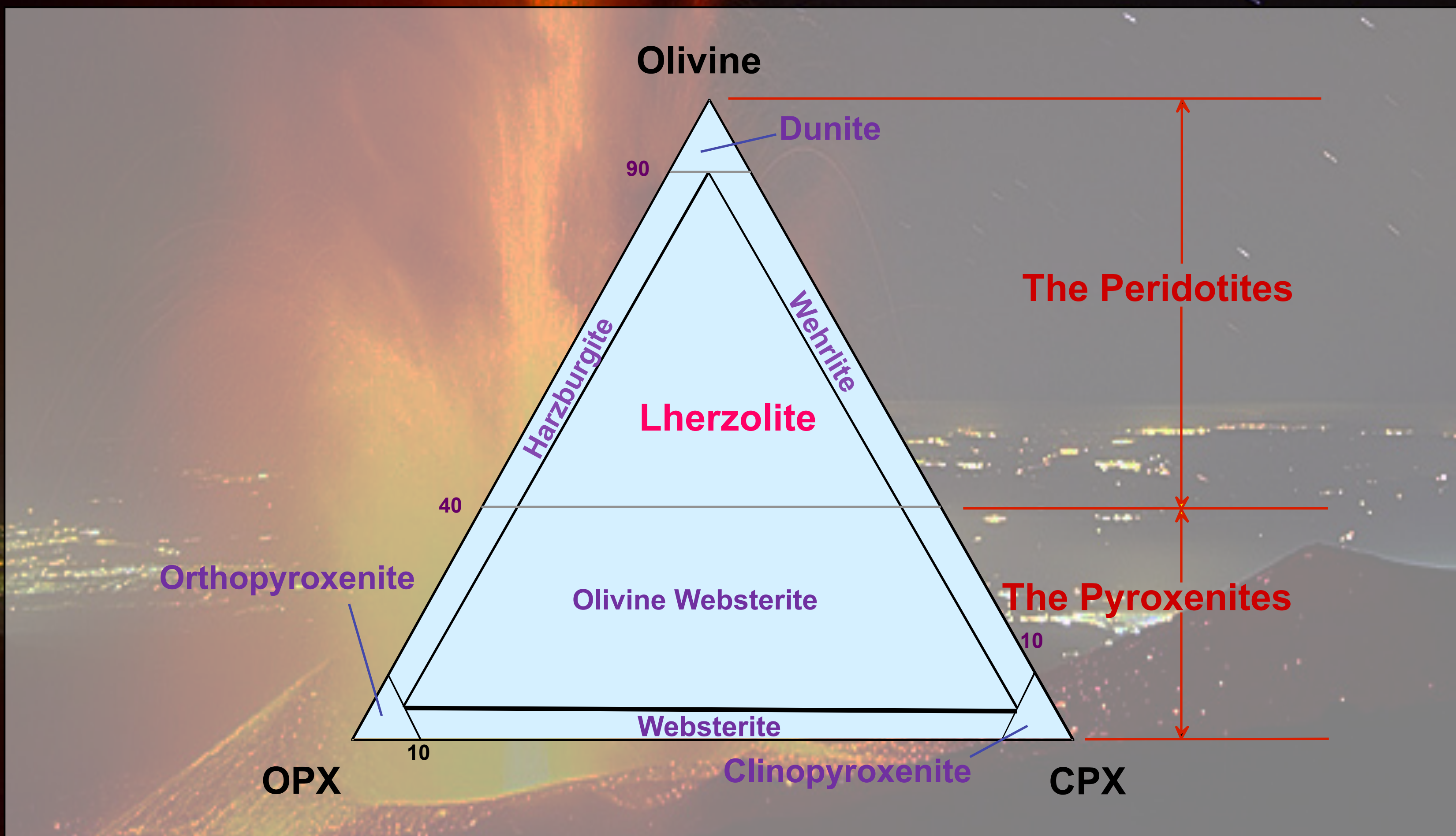
- Fragments of oceanic crust and upper mantle docked onto continents
  - Ophiolites
- Dredge samples from oceanic fracture zones
- Nodules and xenoliths in some basalts
- Kimberlite xenoliths
  - Diamond-bearing pipes blasted up from the mantle carrying numerous xenoliths from depth

Ultramafic Rocks:

> 90% mafic minerals.
Ultramafic rocks have <10% plag.

Plag

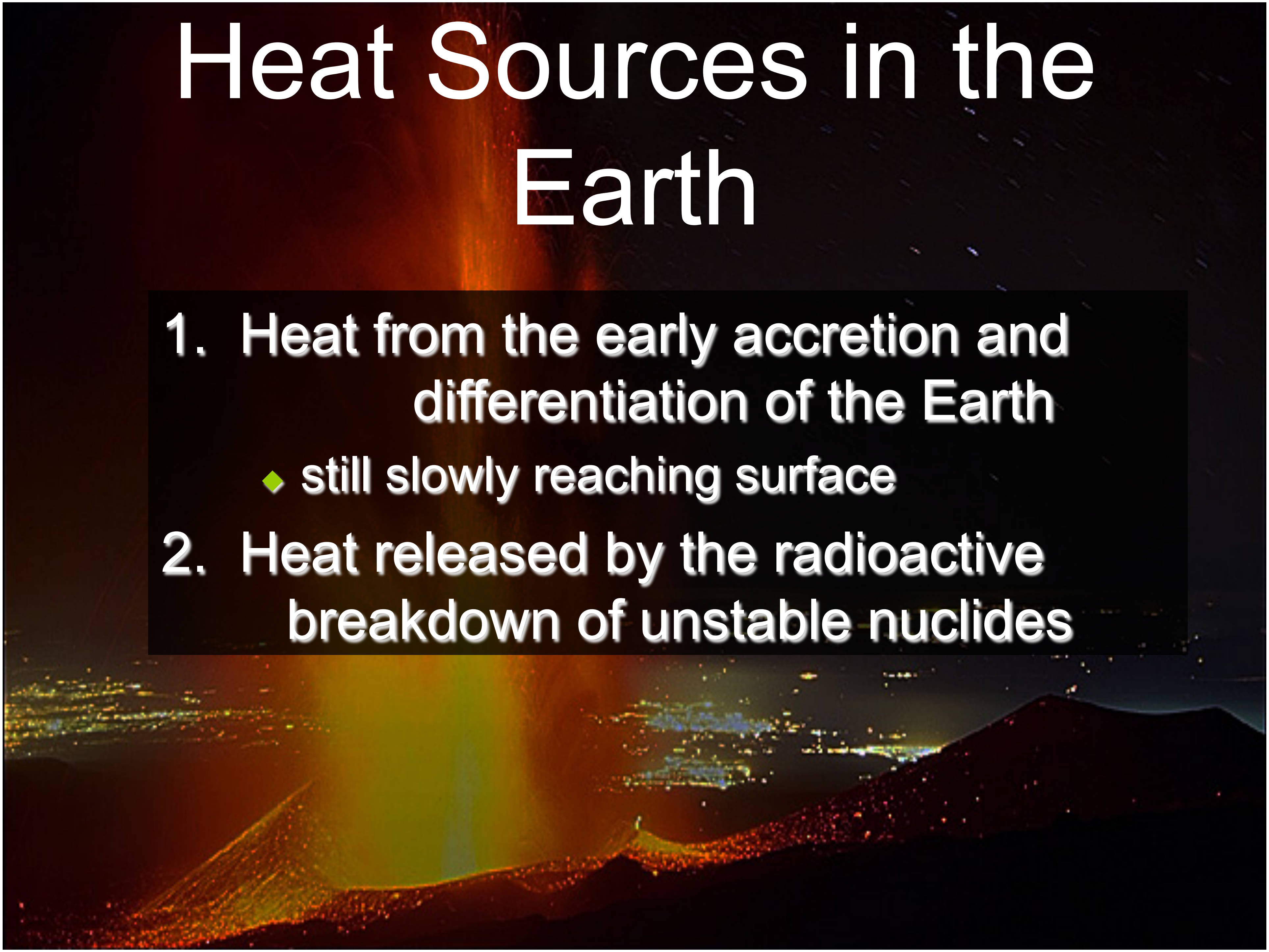
“mafic”



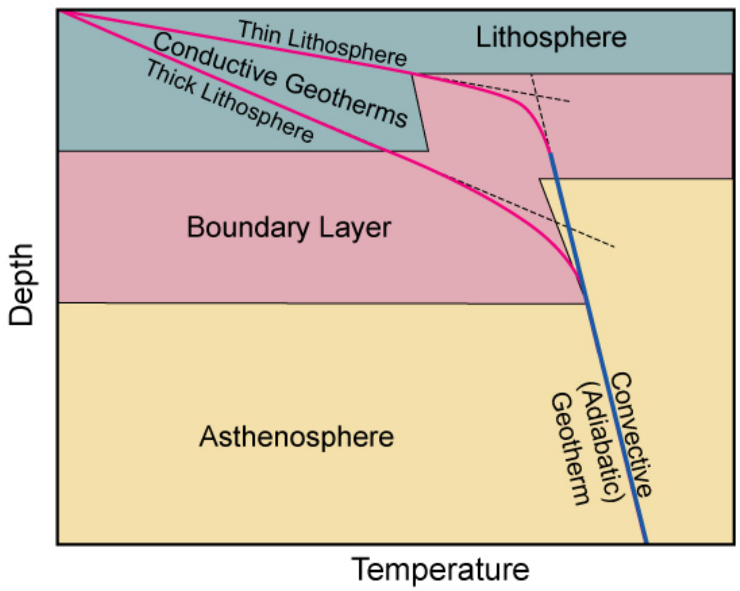
Why does the mantle melt?

Heat Sources in the Earth

1. Heat from the early accretion and differentiation of the Earth
   - still slowly reaching surface
2. Heat released by the radioactive breakdown of unstable nuclides



The Geothermal Gradient



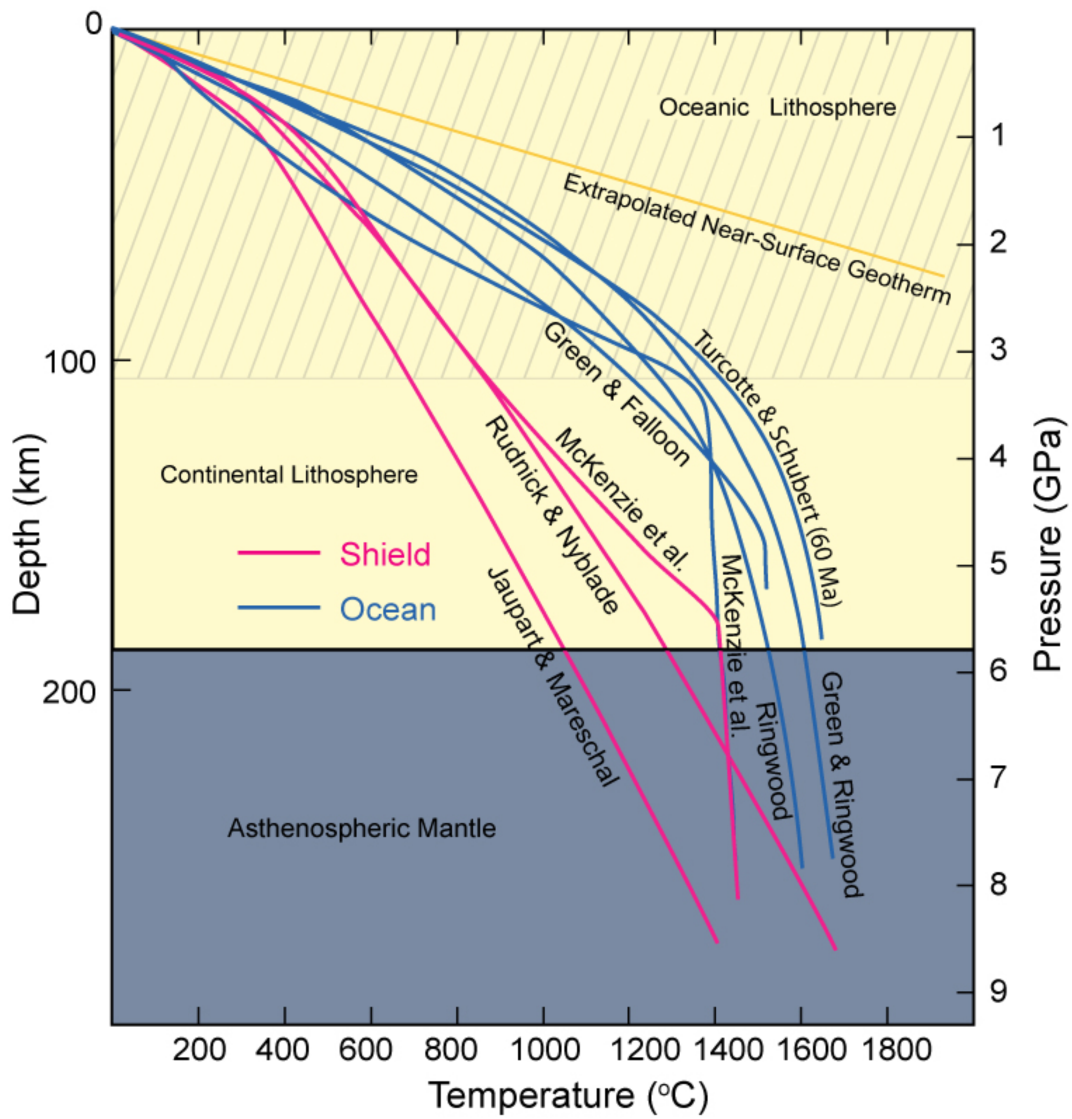


Figure 1-11(new). Estimates of oceanic (blue curves) and continental shield (red curves) geotherms to a depth of 300 km. The thickness of mature (> 100Ma) oceanic lithosphere is hatched and that of continental shield lithosphere is yellow. Data from Green and Falloon ((1998), Green & Ringwood (1963), Jaupart and Mareschal (1999), McKenzie *et al*. (2005 and personal communication), Ringwood (1966), Rudnick and Nyblade (1999), Turcotte and Schubert (2002).

Phase diagram for aluminous 4-phase lherzolite:

Al-phase =

- Plagioclase
  - shallow (< 50 km)
- Spinel
  - 50-80 km
- Garnet
  - 80-400 km
- Si → VI coord.
  - > 400 km

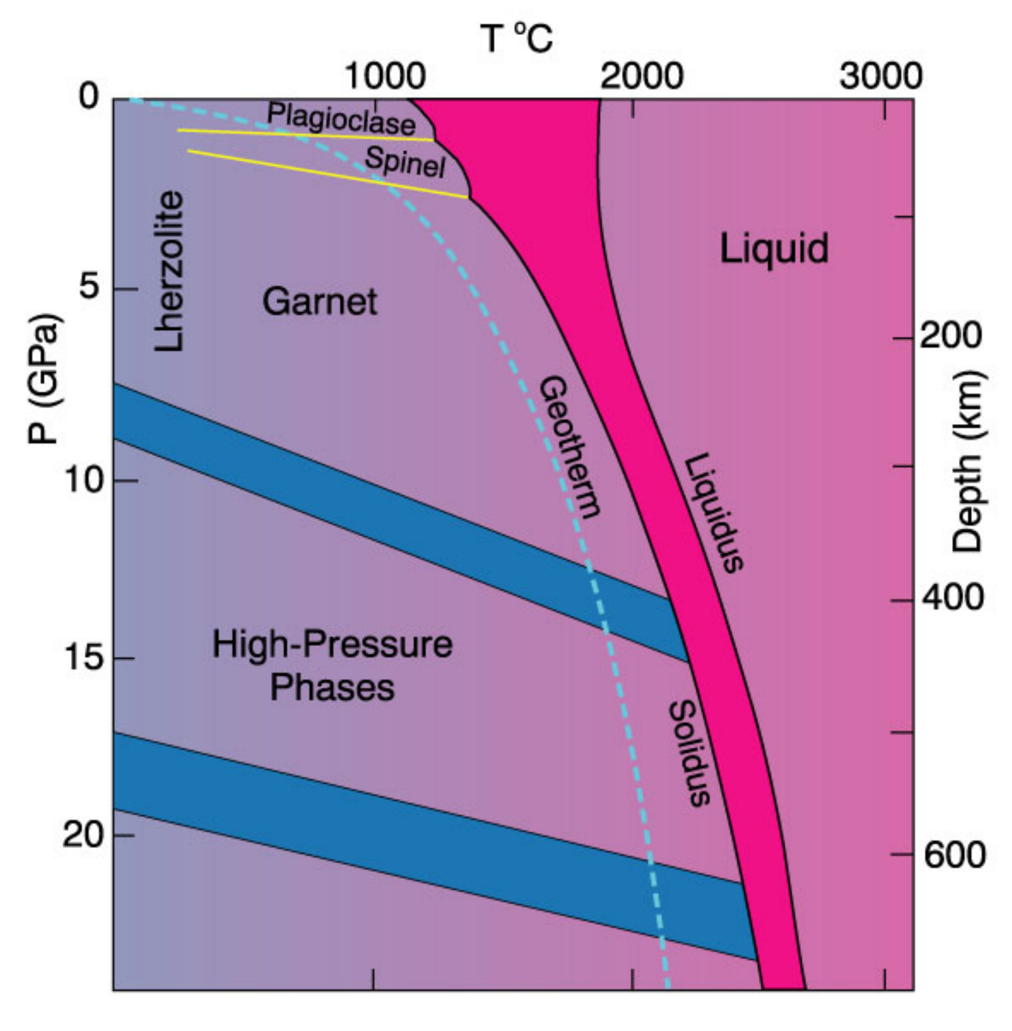
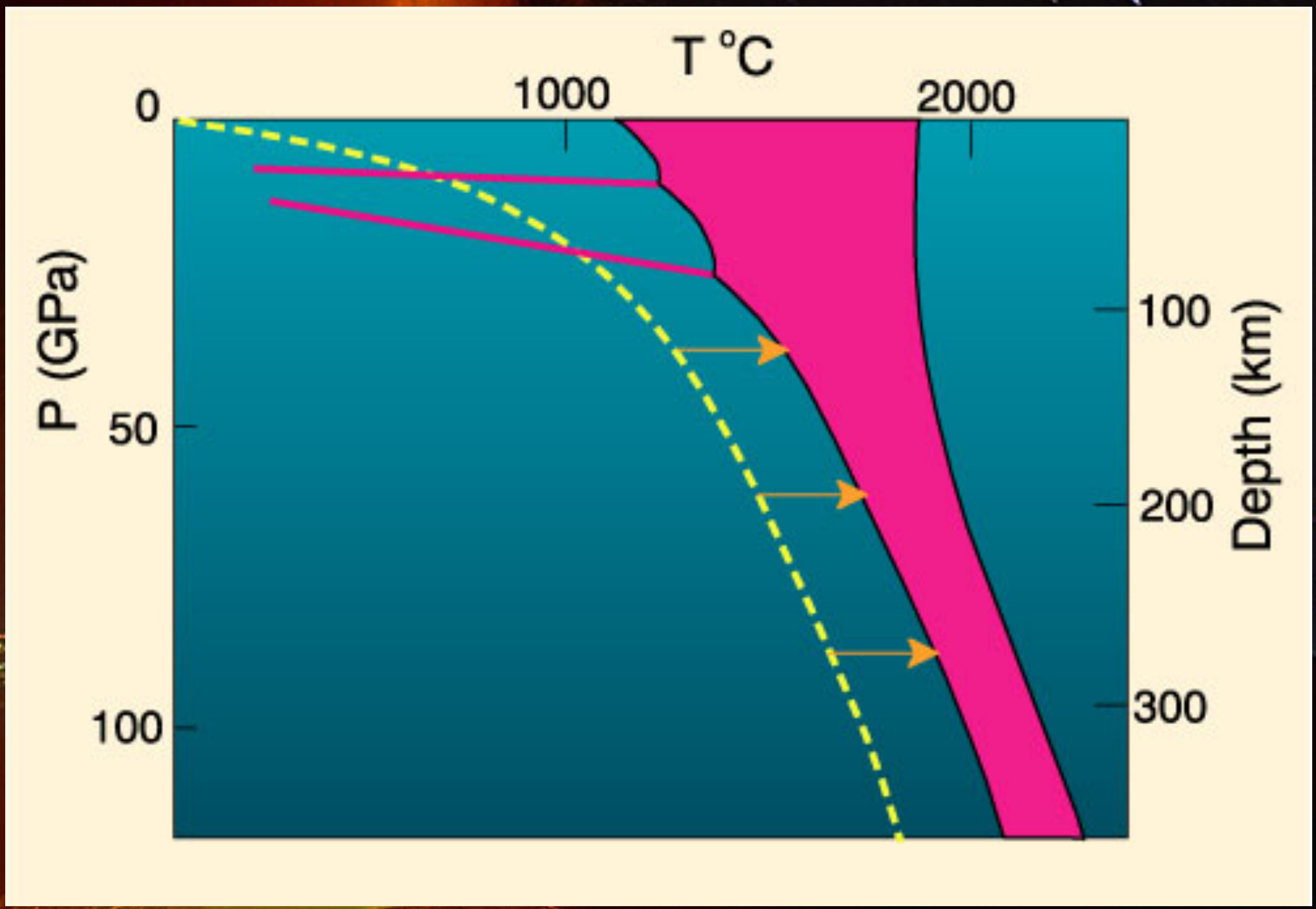


Figure 10-2 Phase diagram of aluminous lherzolite with melting interval (gray), sub-solidus reactions, and geothermal gradient. After Wyllie, P. J. (1981). Geol. Rundsch. 70, 128-153.

How does the mantle melt??

1) Increase the temperature



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2) Lower the pressure

- Adiabatic rise of mantle with little conductive heat loss
- Decompression melting could melt at least 30%

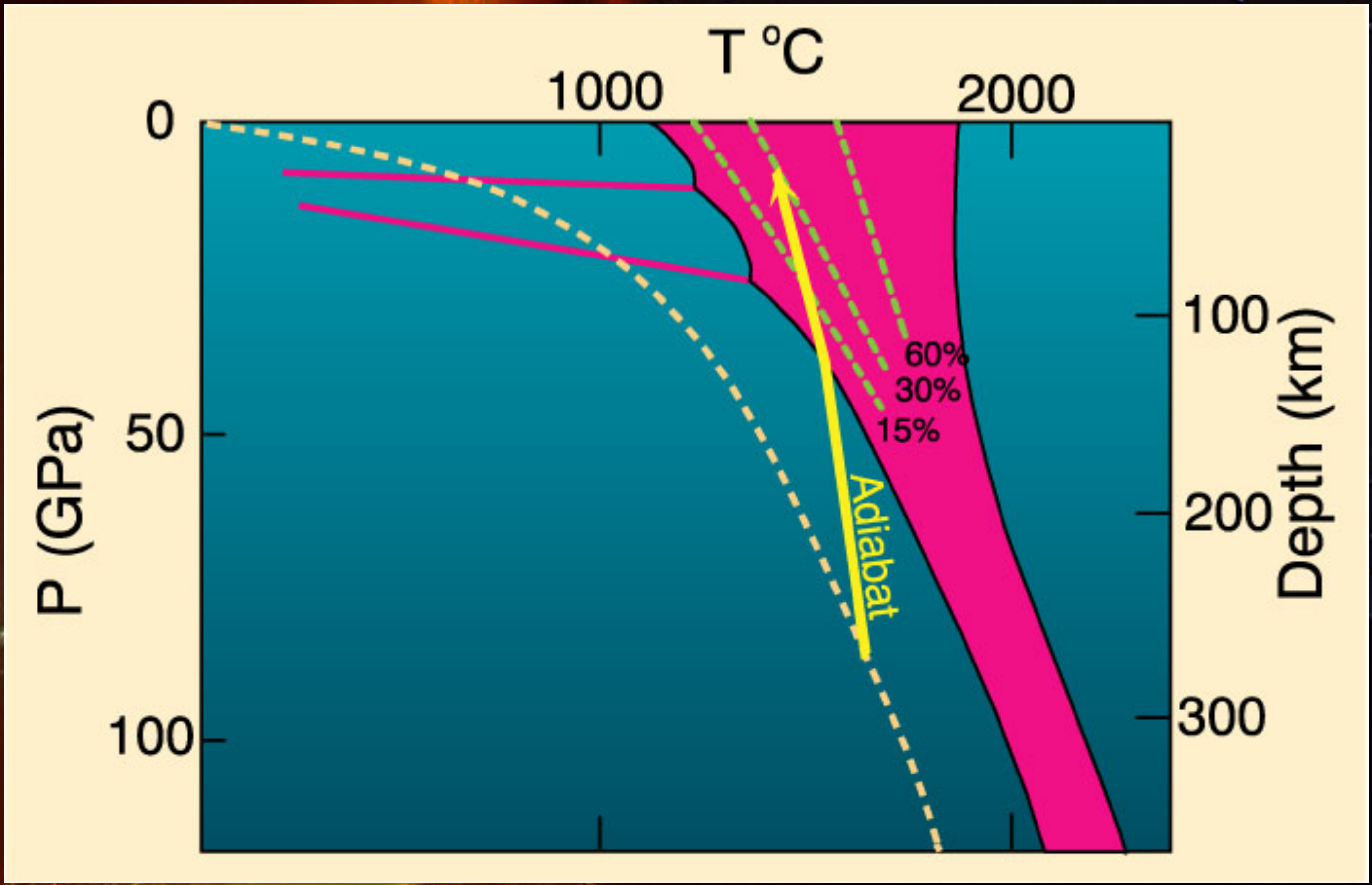
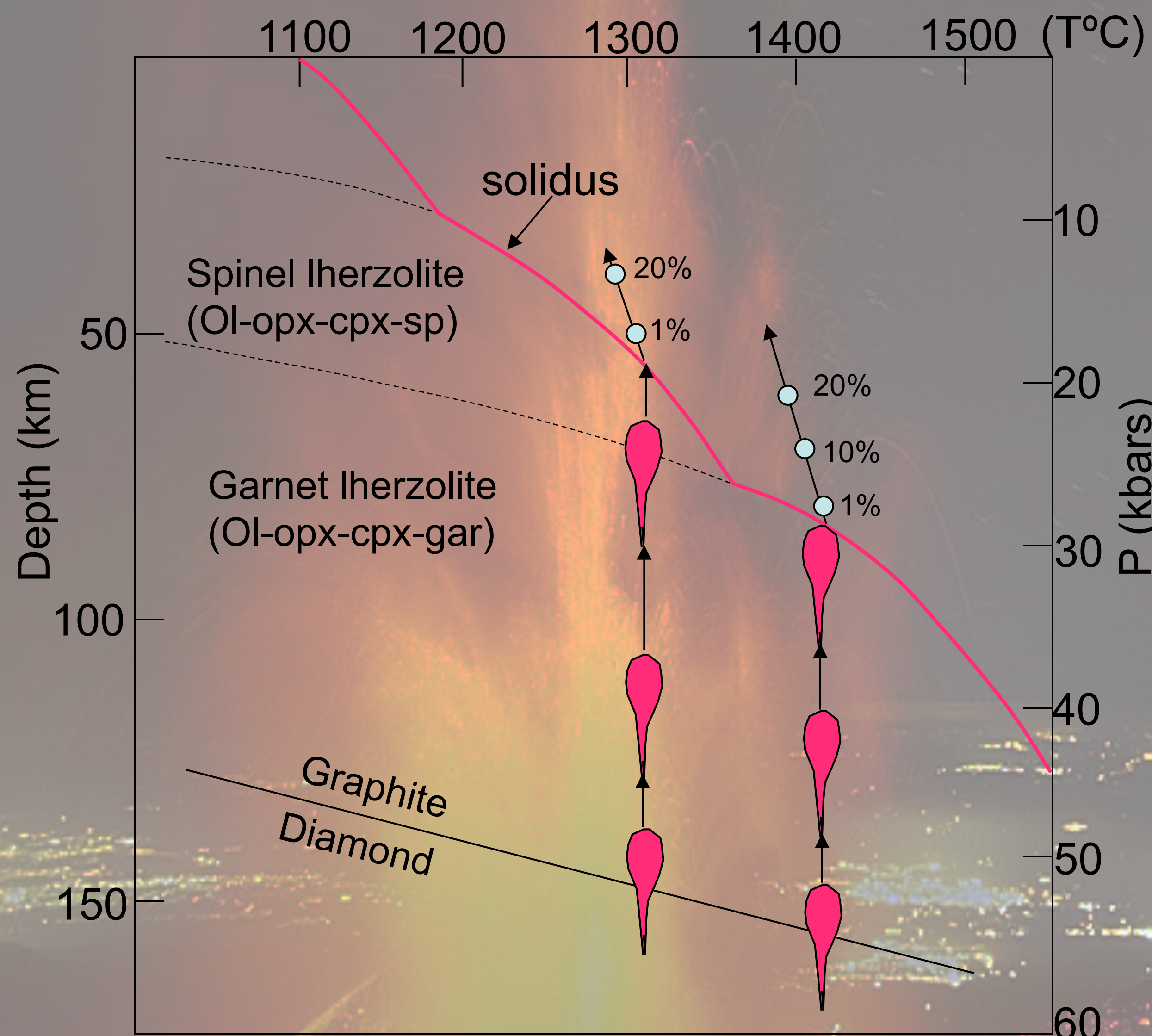


Figure 10-4. Melting by (adiabatic) pressure reduction. Melting begins when the adiabat crosses the solidus and traverses the shaded melting interval. Dashed lines represent approximate % melting.

Partial melting of mantle peridotite



Melting begins when upwelling mantle intersects the peridotite solidus. With decreasing pressure above the solidus, extent of melting increases. The amount of melting is limited by the heat available since the heat of fusion is large. Extent of melting can vary from ~1% to ~20%. The T, P and % melting determine the composition of the basaltic magma produced

3) Add volatiles (especially H_2O)

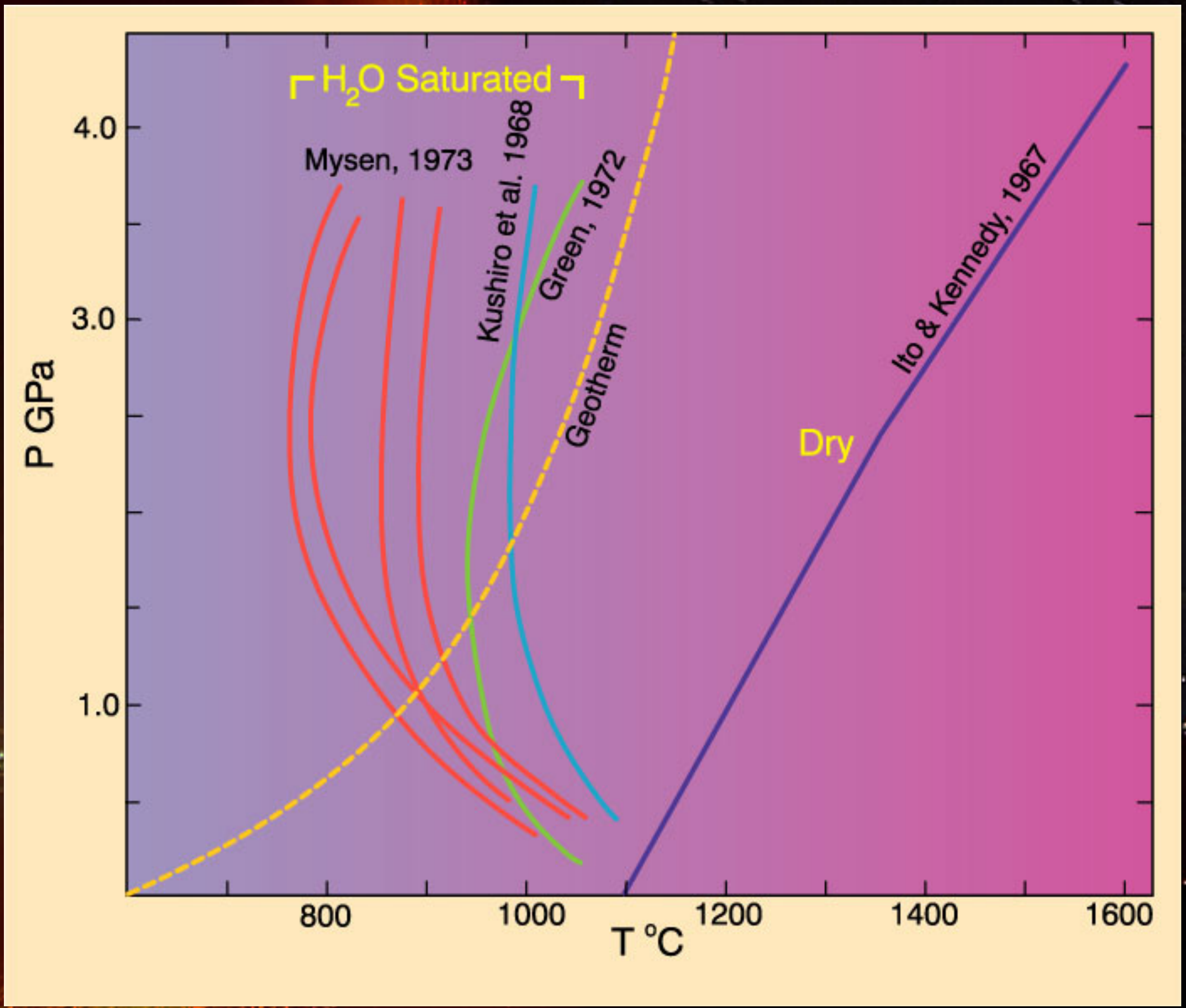


Figure 10-4. Dry peridotite solidus compared to several experiments on H2O-saturated peridotites.

Melts in the mantle can be created under 2 main circumstances

- Decompression melting = Adiabatic rise of the mantle
  - Divergent margins → Large upwelling (convection cells)
  - Hot spots → localized plumes of melt
- Fluid fluxing = Addition of volatiles to the mantle
  - Subduction zones

Two styles of mantle melting

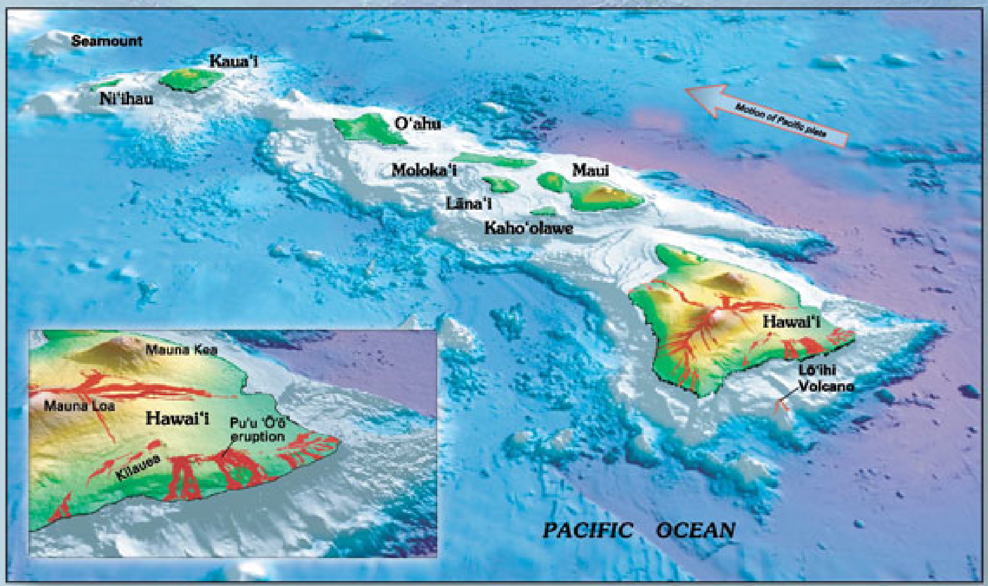
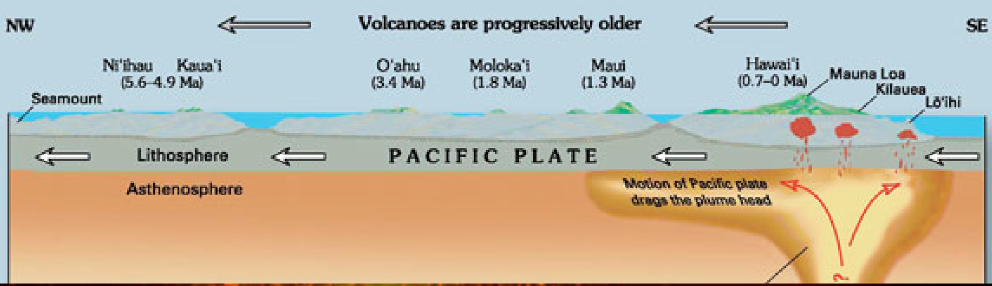
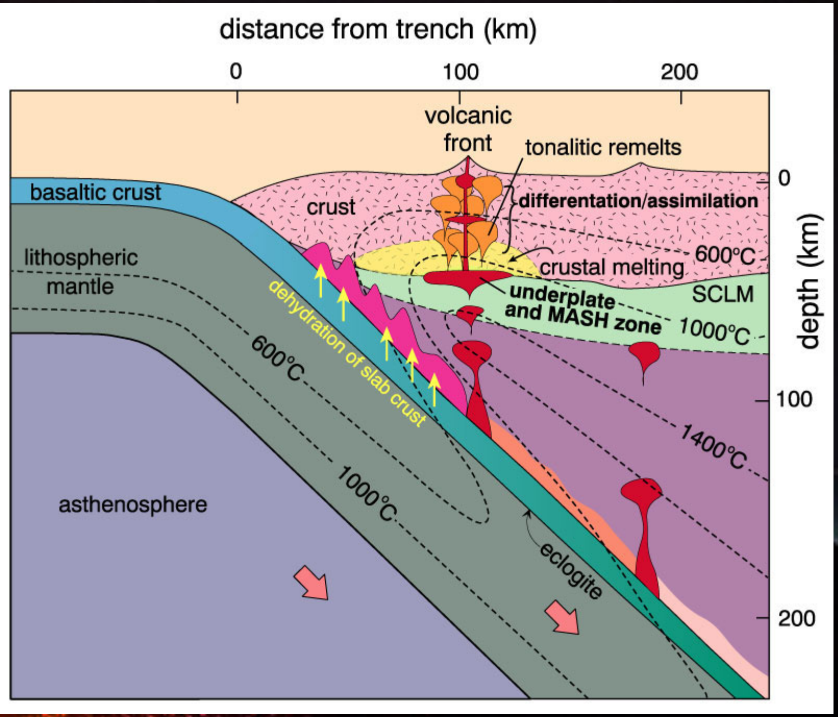
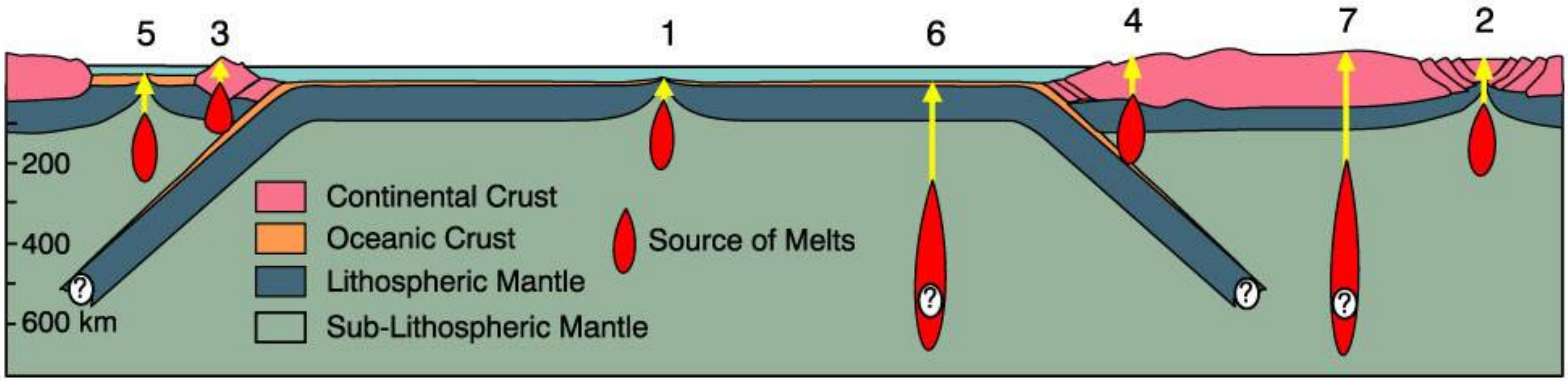


Figure 2.—Oblique view of the principal Hawaiian Islands and (the still submarine) Lō'ihi Volcano. Inset gives a closer view of three of the five volcanoes that form the Island of Hawai'i (historical lava flows are shown in red). The longest duration historical eruption on Kilauea's east-rift zone at Pu'u 'Ō'ō (inset), which began in January 1983, continues unabated (as of spring 2006). View prepared by Joel E. Robinson (USGS).





Schematic cross section through the upper part of the earth showing major magmatic environments



1. Mid-ocean ridge (divergent margin): thin crust, asthenosphere is close to earth's surface, mantle upwelling, abundant basaltic volcanism/plutonism, e.g. Juan de Fuca Ridge, East Pacific Rise, Mid-Atlantic ridge
2. Intraplate volcanic/plutonic rift system, e.g. East African rift, Rio Grande rift
3. Island arc (convergent margin): built largely on oceanic crust—composed largely of island arc basalt and andesite
4. Continental arc (convergent margin): formation of new crust, volcanism/plutonism, mountain building, regional metamorphism
5. Back arc basin: basaltic volcanism—similar to MORB
6. Ocean islands: basaltic volcanism, e.g., Hawaii, Canaries, and many others
7. Scattered intracontinental activity: may be continental hotspots, e.g., Yellowstone