The Wilson Cycle

Dr. Asghar Ali

Department of Geology

University of Peshawar

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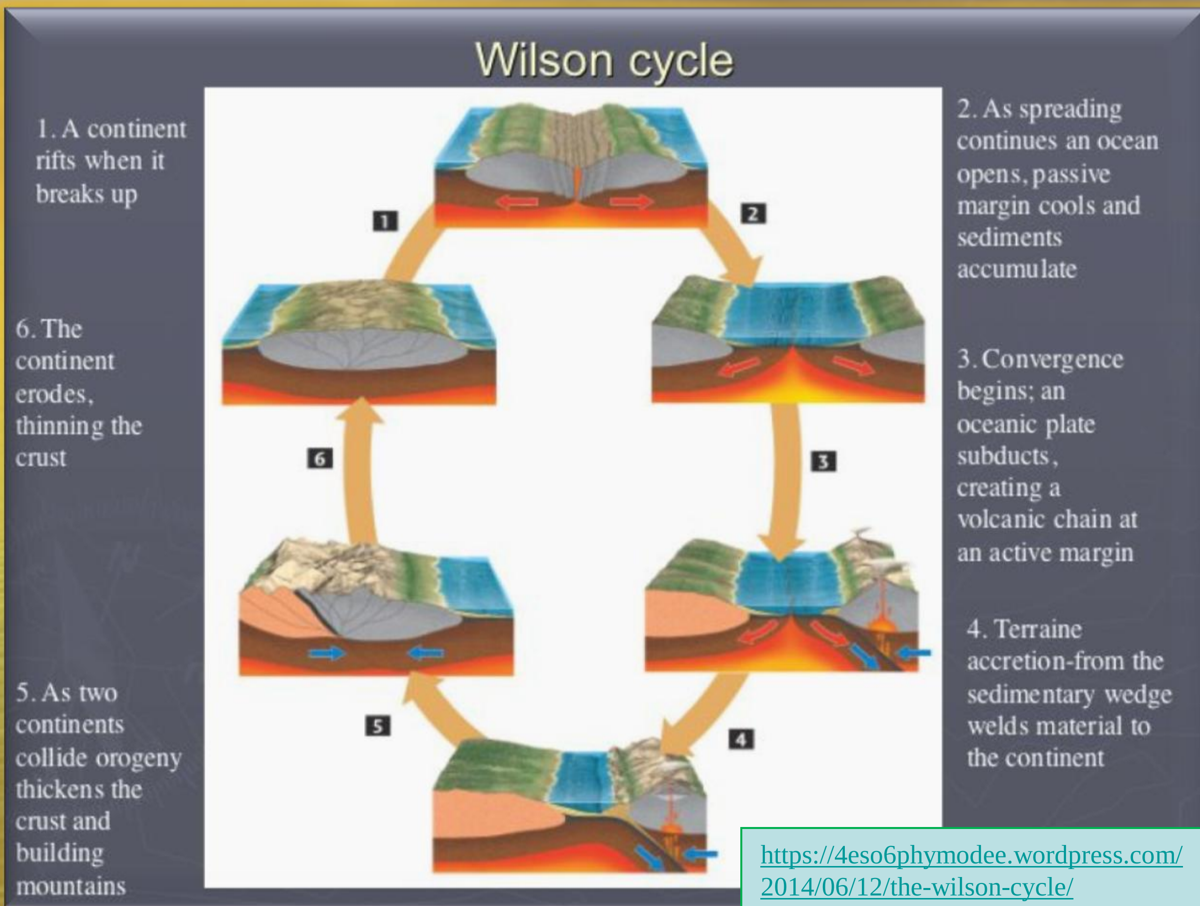


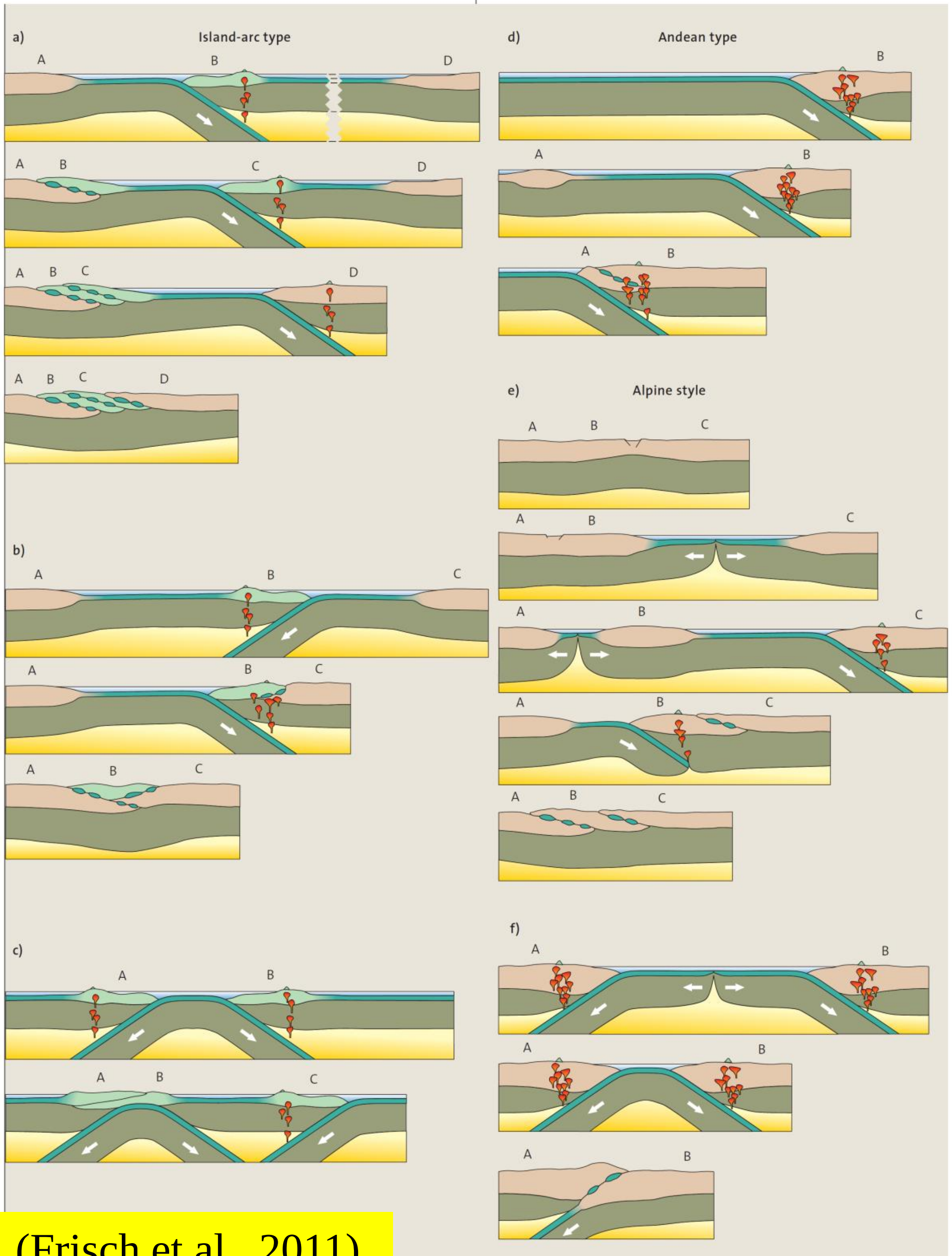
https://4eso6phymodee.wordpress.com/2014/06/12/the-wilson-cycle/

- The biggest achievement of the advanced plate tectonics theory permits to explain the origin of virtually all of the active (Alps and Himalaya) and most ancient mountain (e.g. Appalachian etc) belts on Earth.

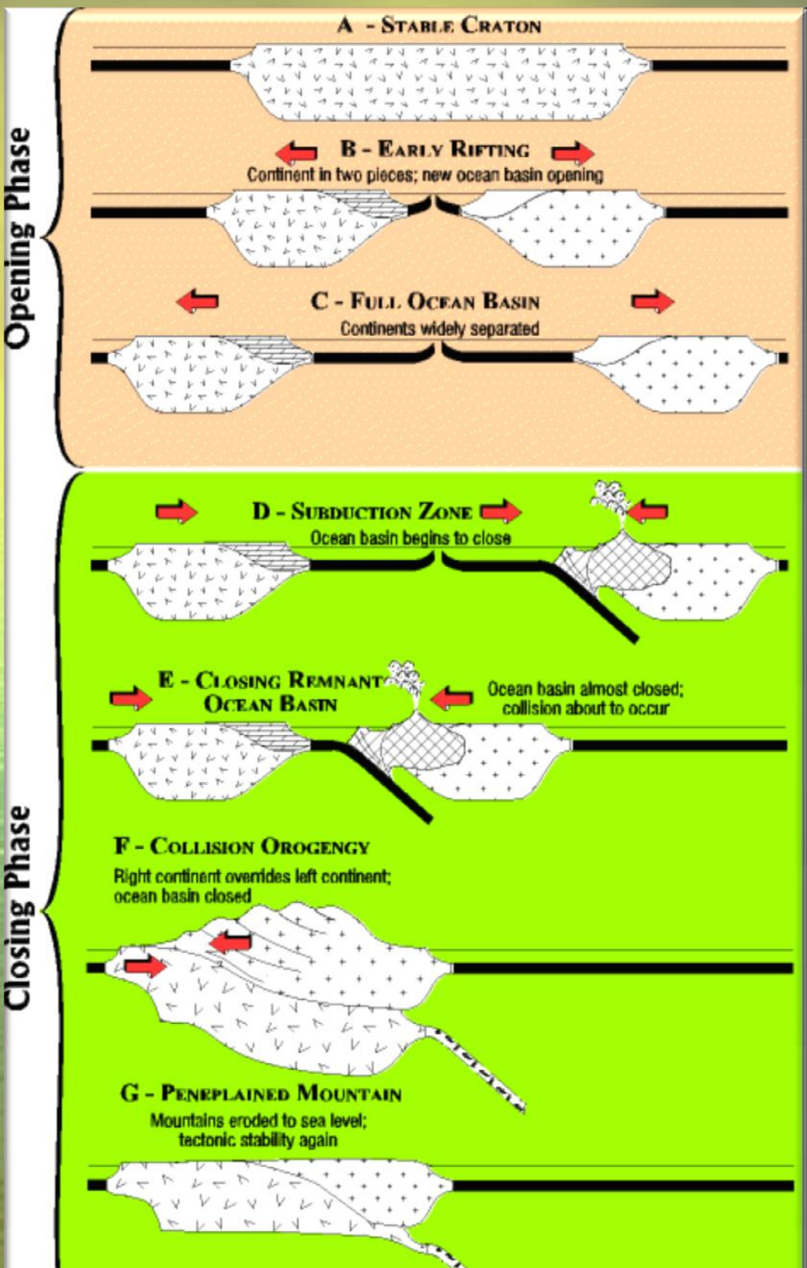
- Orogenesis (Mountain building) occur due to subduction. To render subduction, the closure of an intervening ocean crust is important. Mountain building (orogenesis) keep on going by subduction of an innerving ocean floor, which finds its culmination during the collision of continents and island arcs.

Wilson Cycle is a tectonic cycle that performs at the scale of 10^8 years. During this cycle break-up and ongoing drift of a continent lead to formation of a new ocean crust that subsequently followed by subduction. The cycle end up with the complete consumption of the denser oceanic crust, continent-continent collision and mountain building (Frisch et al., 2011).

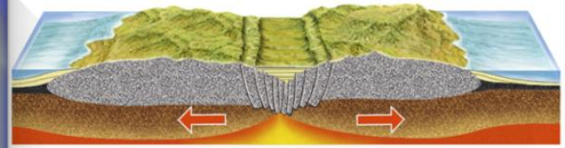
Continent-Continent collision resulting into crustal thickening, gravitational collapse, metamorphism, deformation and exhumation . This type of orogeny leads to Alpine-Himalayan type orogen. Contrary, subduction of an oceanic crust beneath a continental crust result into the Pacific-style or Cordilleran-type mountain Ranges. This Type of Orogeny involves long periods ocean-slab subduction underneath continental margins with repeated episodes of collision that involve active continental magmatic arcs, oceanic plateaus, and micro-continents amalgamation (Frisch et al., 2011).



(Frisch et al., 2011).

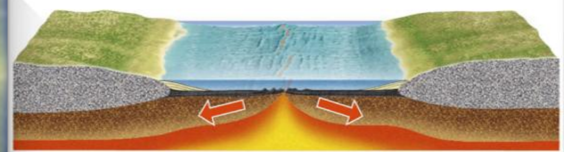


http://www.geologypage.com/wp-content/uploads/2013/01/ASimpleWilsonCycle-1.png



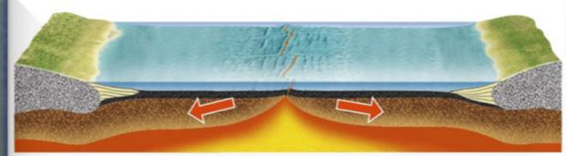
1 Rifting within a continent splits the continent...

Figure 10-18 part 1 *Understanding Earth, Fifth Edition* © 2007 W.H. Freeman and Company



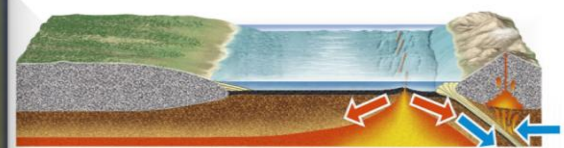
2 ...leading to the opening of a new ocean basin and creation of new oceanic crust, starting the cycle.

Figure 10-18 part 2 *Understanding Earth, Fifth Edition* © 2007 W.H. Freeman and Company



3 As spreading continues and an ocean opens, passive margin cooling occurs and sediment accumulates during seafloor spreading.

Figure 10-18 part 3 *Understanding Earth, Fifth Edition* © 2007 W.H. Freeman and Company

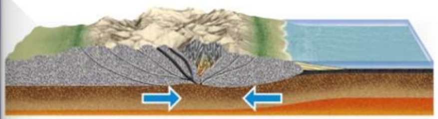


4 Convergence begins; an oceanic plate subducts beneath a continental plate, creating a volcanic chain at the active margin.

Figure 10-18 part 4 *Understanding Earth, Fifth Edition* © 2007 W.H. Freeman and Company

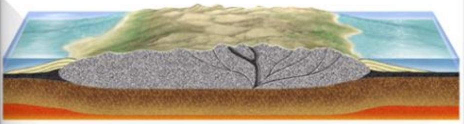
5 Terrane accretion—from the sedimentary accretionary wedge or fragments carried by the subducting plate—welds material to the continent.

Figure 10-18 part 5 *Understanding Earth, Fifth Edition* © 2007 W.H. Freeman and Company



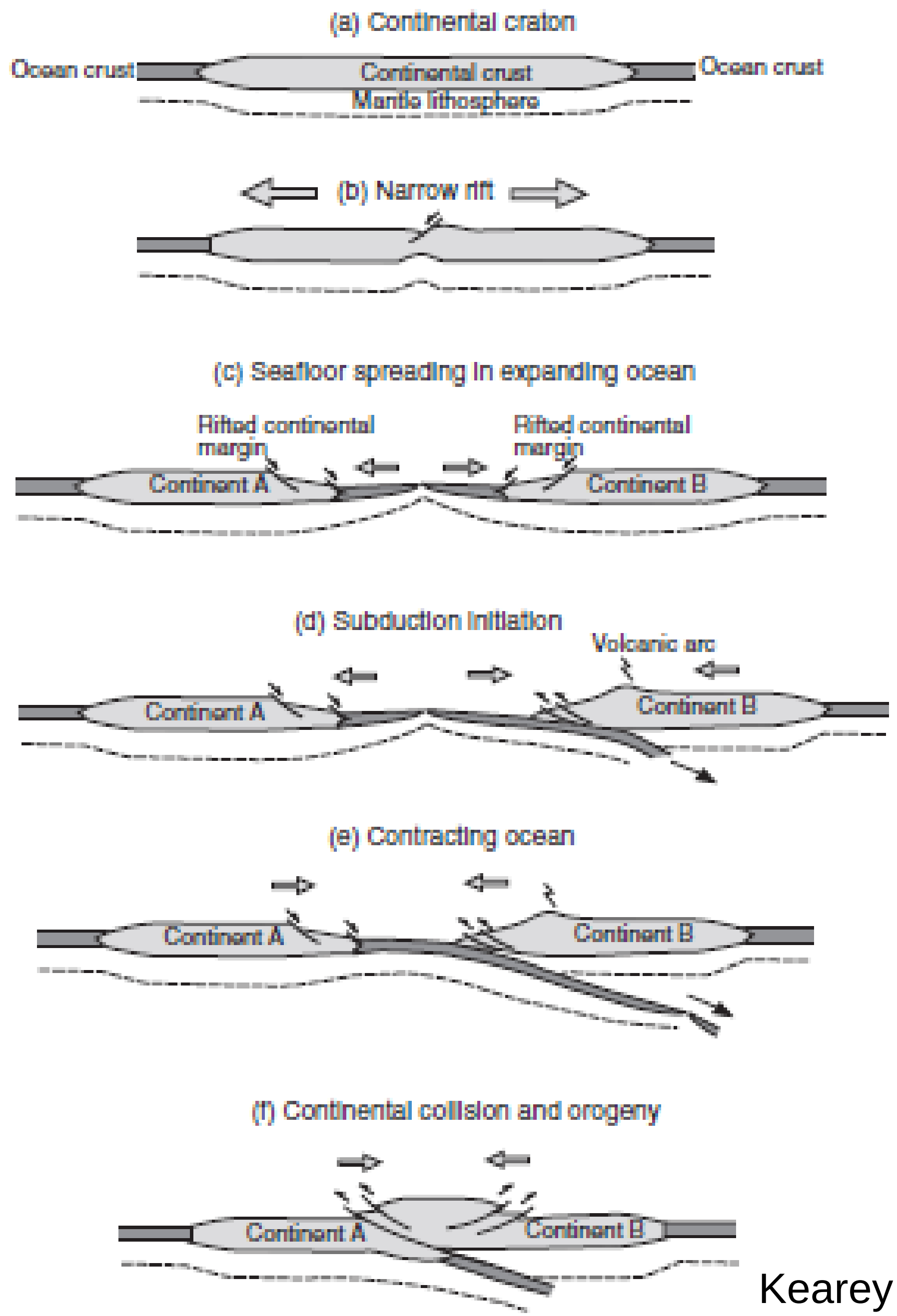
6 As two continents collide, orogeny thickens the crust and builds mountains, forming a new supercontinent.

Figure 10-18 part 6 *Understanding Earth, Fifth Edition* © 2007 W.H. Freeman and Company

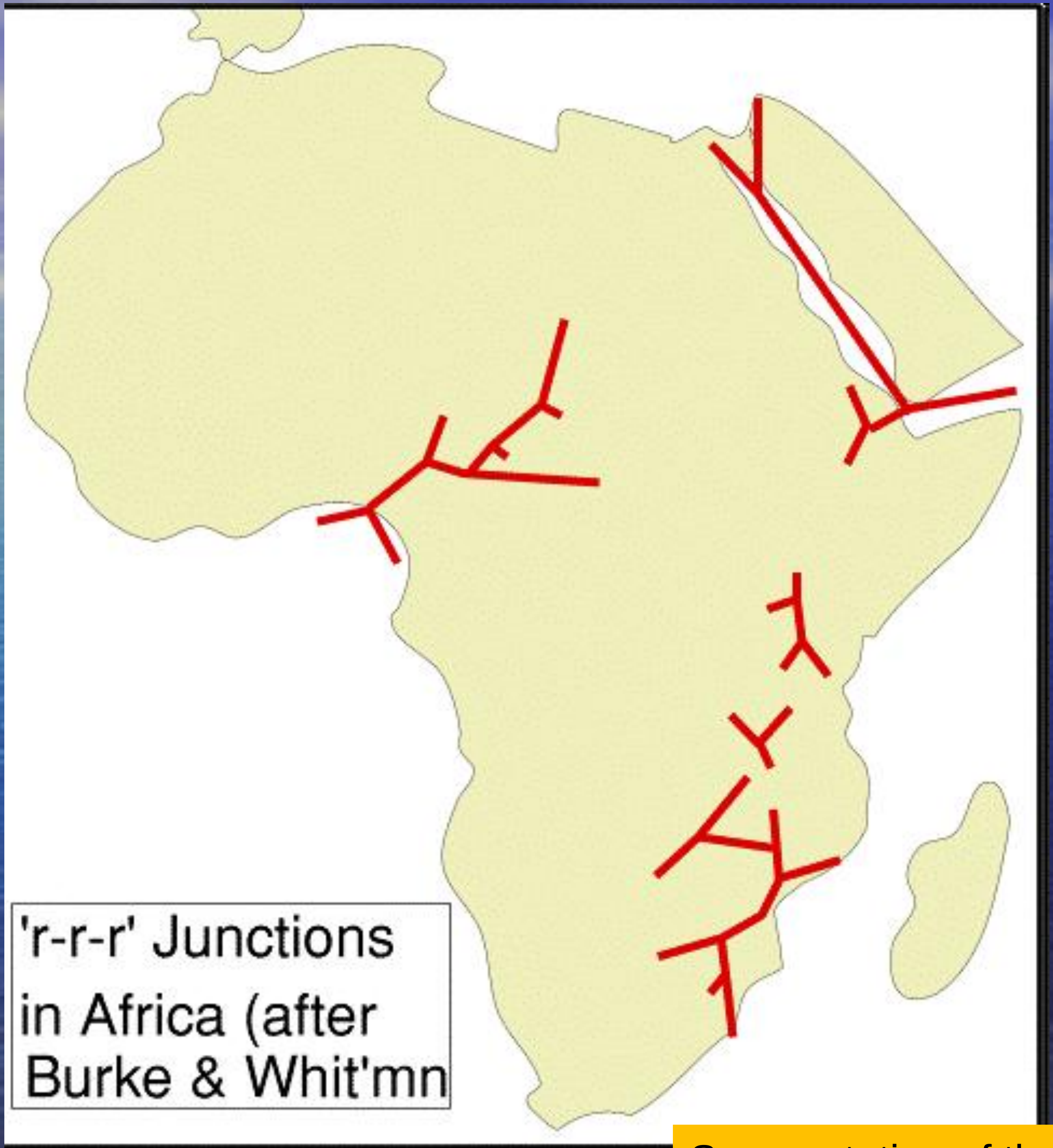


7 The continent erodes, thinning the crust. Eventually the process may begin again.

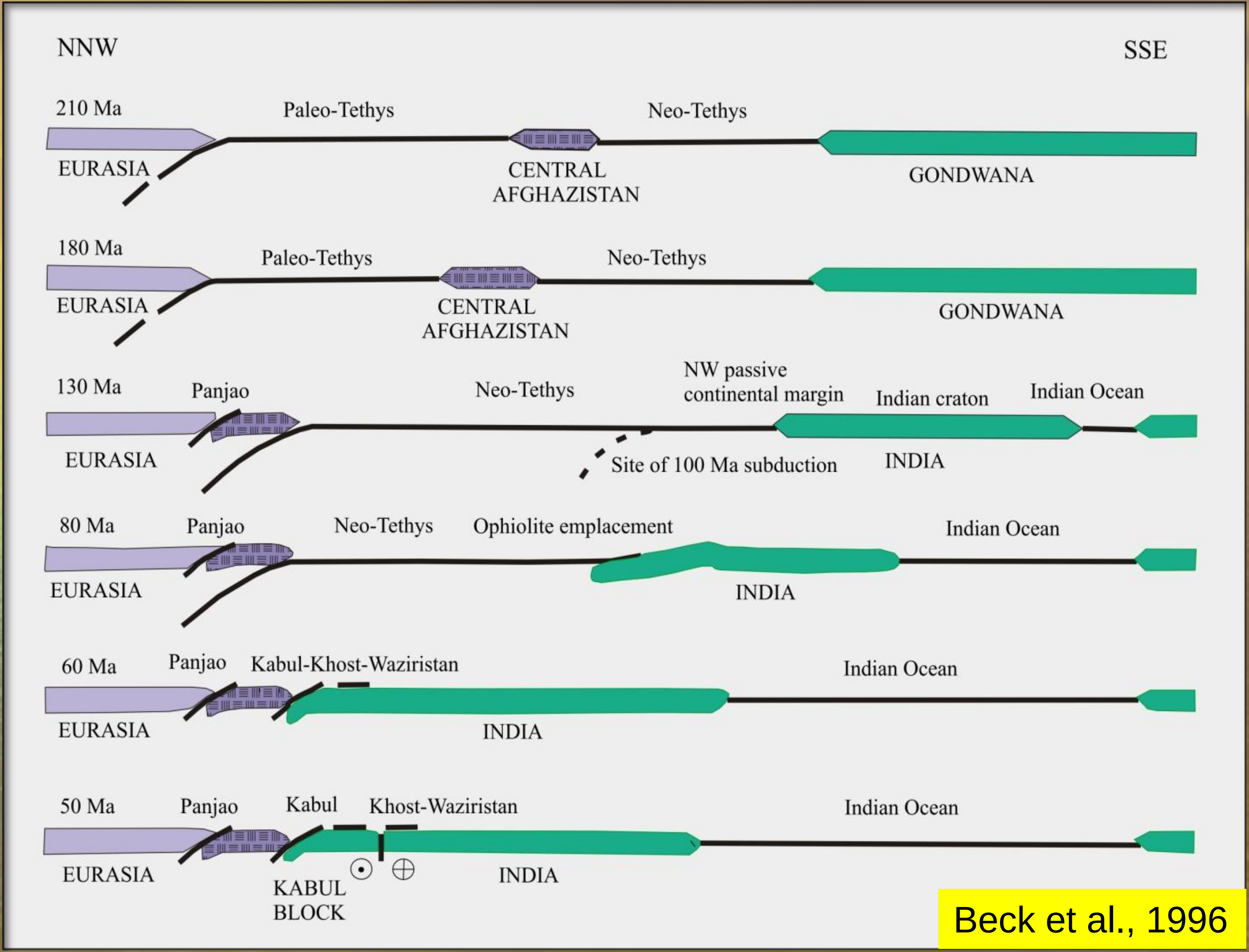
Figure 10-18 part 7 *Understanding Earth, Fifth Edition* © 2007 W.H. Freeman and Company



Kearey et al., 2013

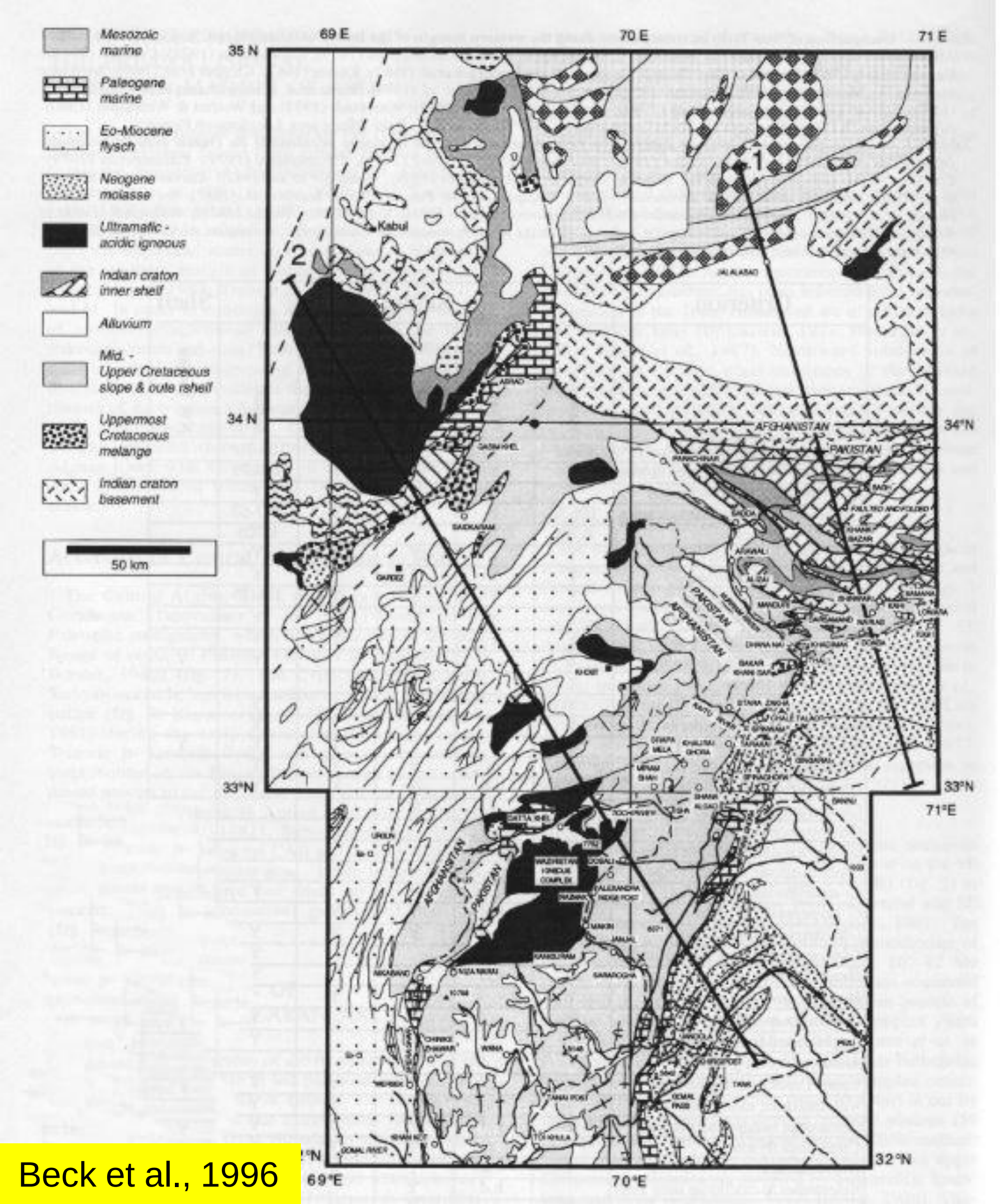


Segmentation of the African Plate



Beck et al., 1996

Closure of the Tethyan Ocean and Opening of the Indian Ocean



Beck et al., 1996

Western Suture of the Indian Plate (Tethyan Remnants)

Stage A or Stage 1 (Embryonic Stage)

- Stage A also termed Stage-1 and Embryonic Stage of the Wilson cycle begins with rifting in a stable craton

- Splitting of a craton is mostly related with hot spots. A hot spot that fed a craton split it into two continents by heating, upward swelling, thinning and stretching
- Hot spots magma originate from mantle rises as diapirs on either the continental or oceanic crusts.

- This process not only splits a continent in two, it also creates a new divergent plate boundary
- Graben/rift related magmatic rocks are usually alkaline in nature –
- These rock contain excessive alkalis (Na_2O, K_2O) compared to (SiO_2) and (Al_2O_3)
- These silica deficient rocks are also called “undersaturated in silica”.
- Alkaline magmas that mainly originate from lithospheric mantle (Frisch et al., 2011).

Example: The East African Rise, the Oslo Graben, the Rhine Graben

Stage A or Stage 1 (Embryonic Stage)

- Highest melt formation along a graben axis favors tholeiitic magmatism

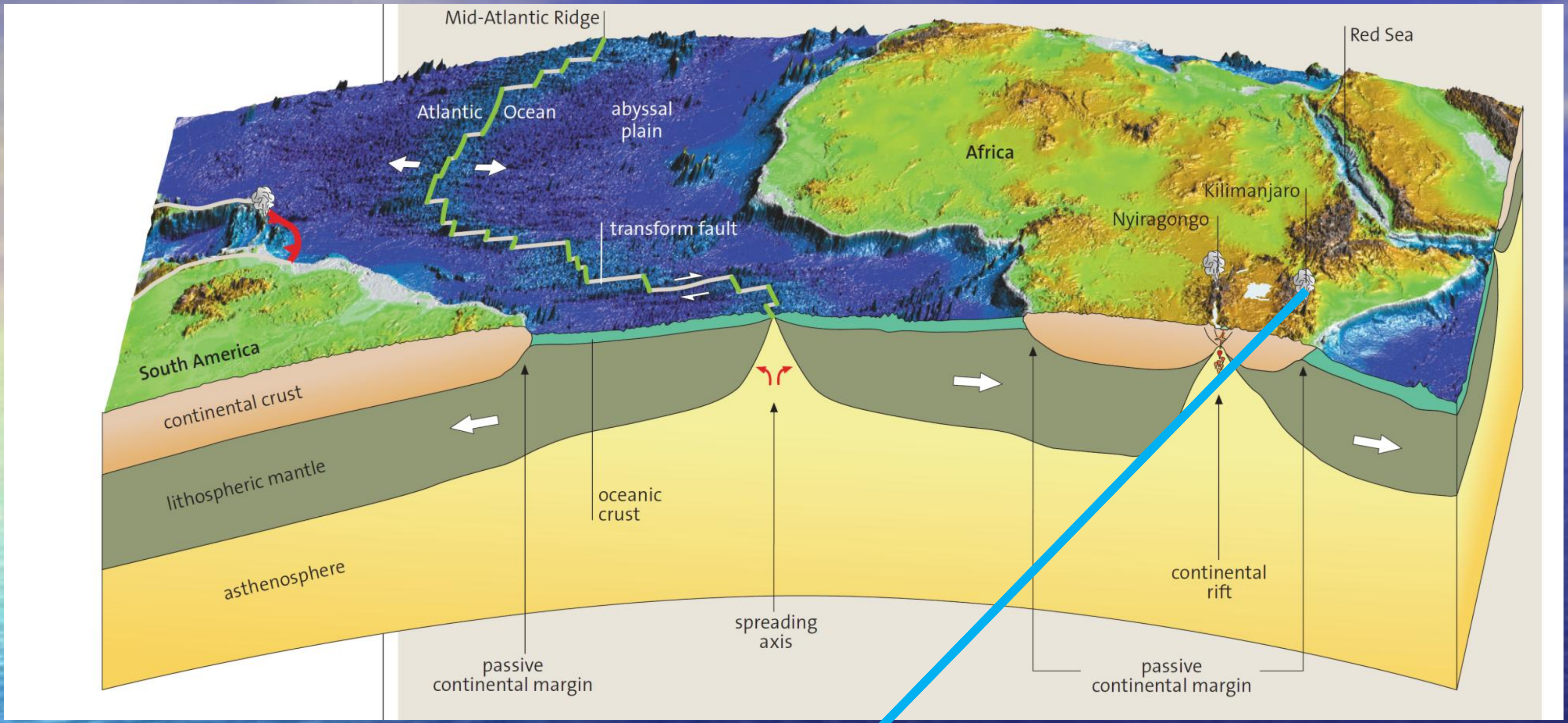
- It also promotes increase in the alkalinity from a graben spreading axis towards rift shoulders. Such system currently reported from the Rio Grande Rift and East African Graben

- High spreading rates initiate decrease of alkalinity and increase of extension plus melt formation. Such graben system is reported as the Permian Oslo Graben and Cenozoic Kenya Graben (Condie, 1997)

- Lithosphere extension provides widow for the asthenosphere to rise to increase melting of the uppermost asthenosphere and overlying lithospheric mantle

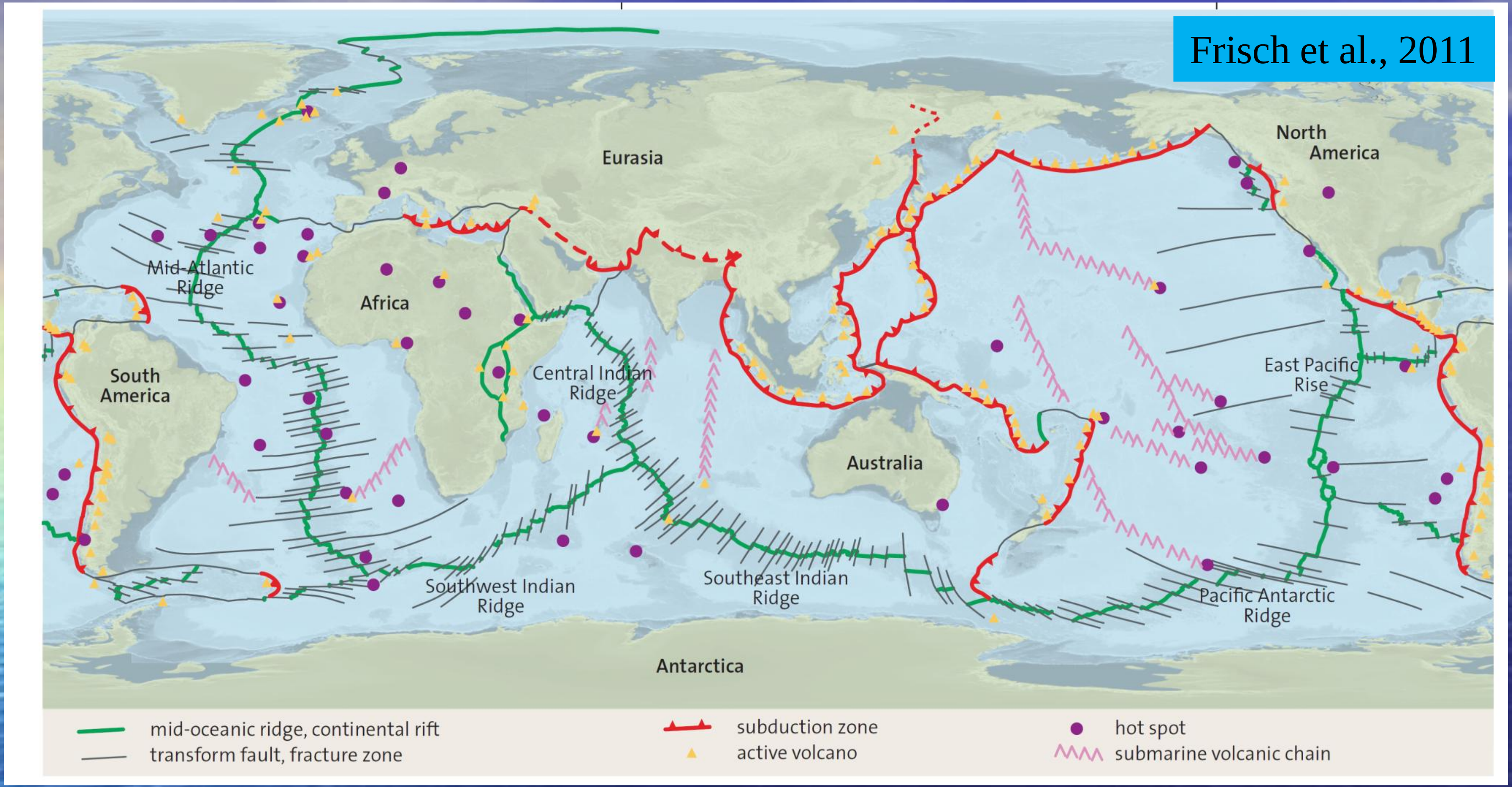
- Extension initiates graben rifting, crustal basaltic volcanoes, magmatism, crustal assimilation and magma differentiation that lead to intermediate and felsic melts

- These diverse tectono-magmatic processes serve to form volcanic and magmatic rocks of different composition

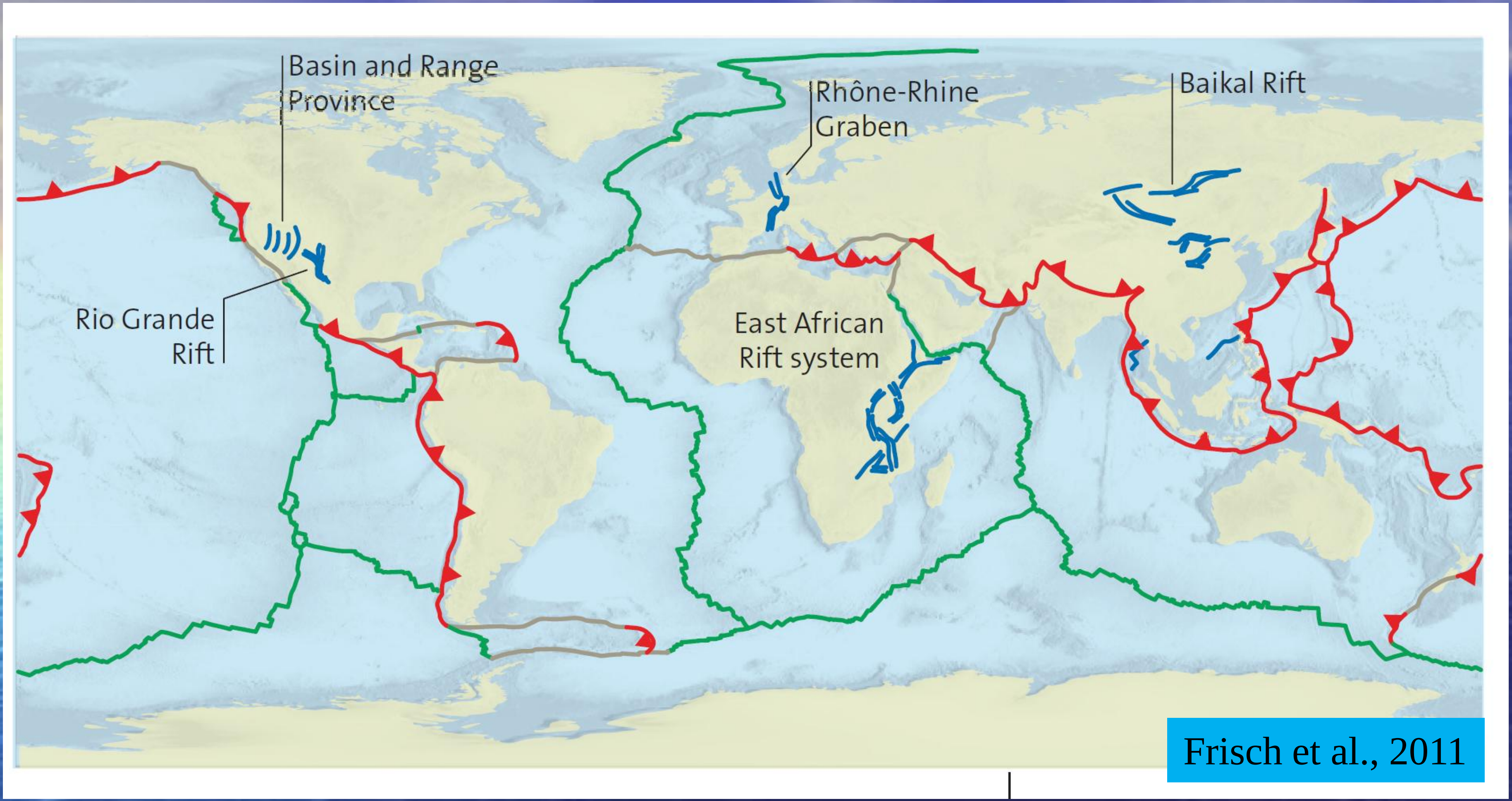


Frisch et al., 2011
Smith and Sandwell (1997)
Amante and Eakins (2009)

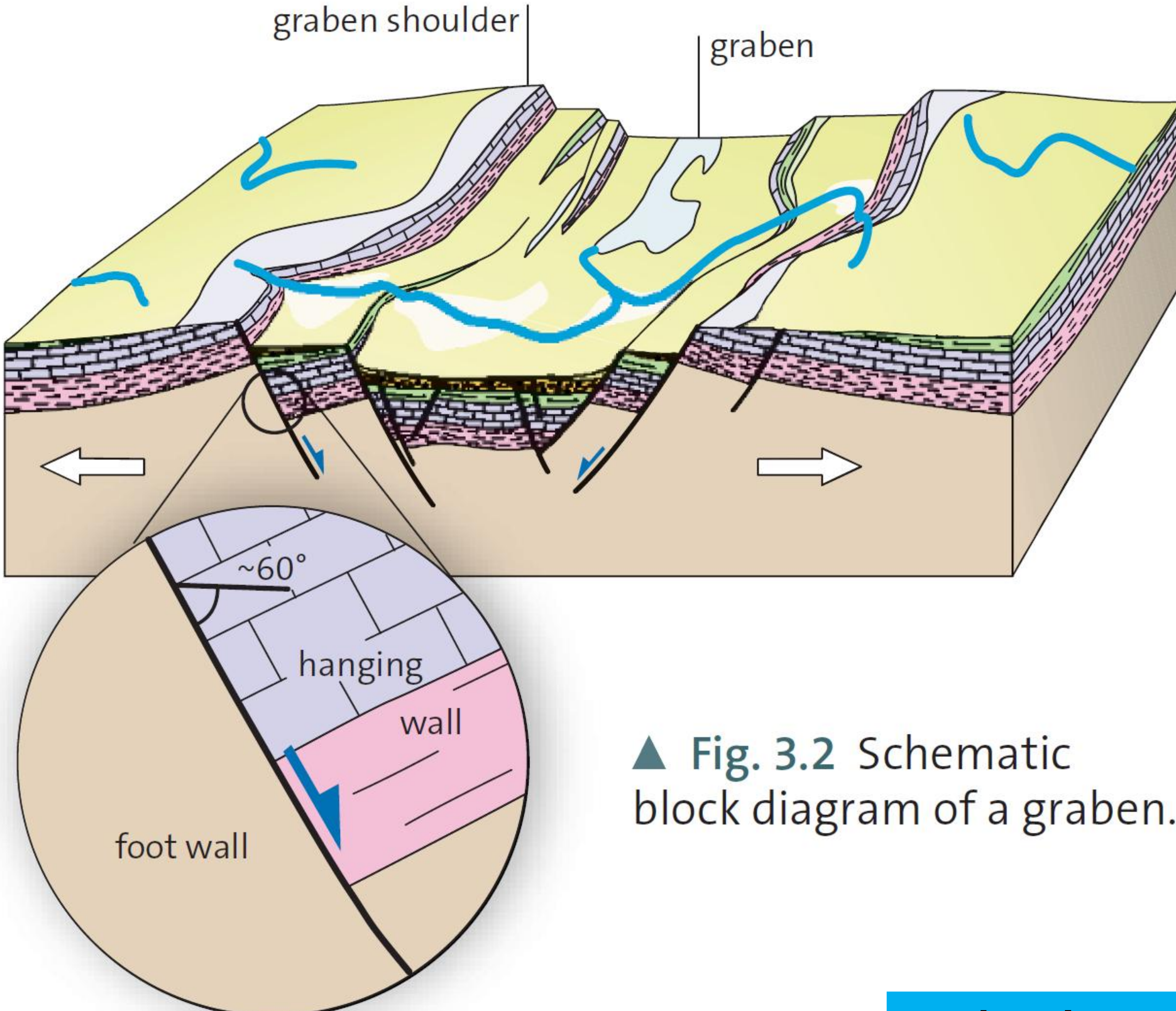
Stage A or Stage 1
(Embryonic Stage)



World tectonic map showing spread of hot spots across Continental and Oceanic Crusts. These hot spots finally lead to splitting a single landmass into two

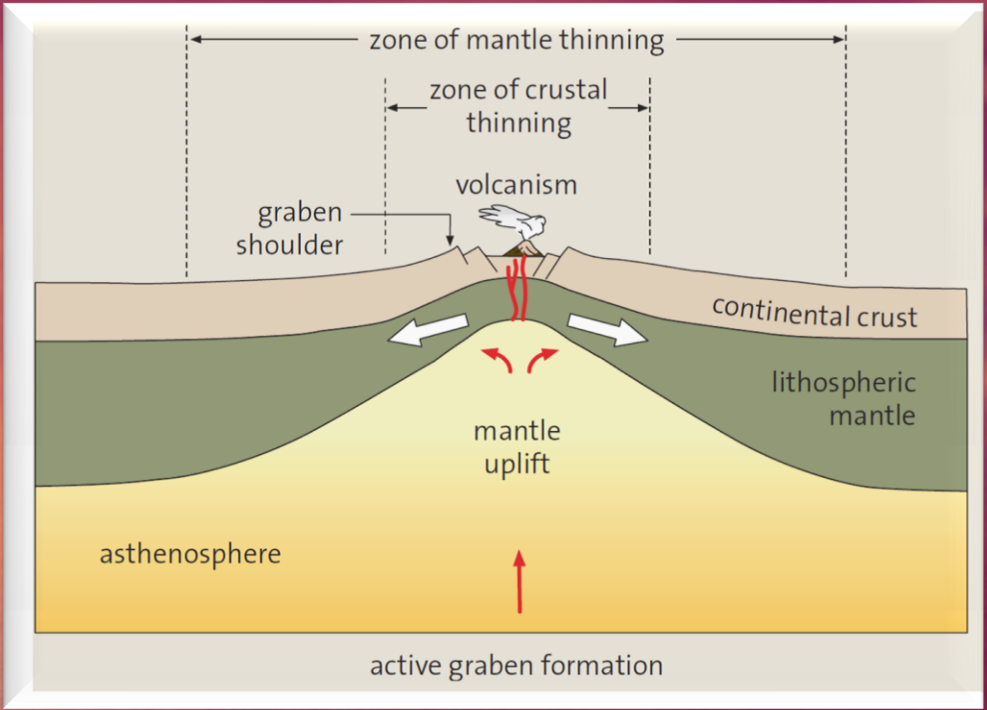


Graben Systems



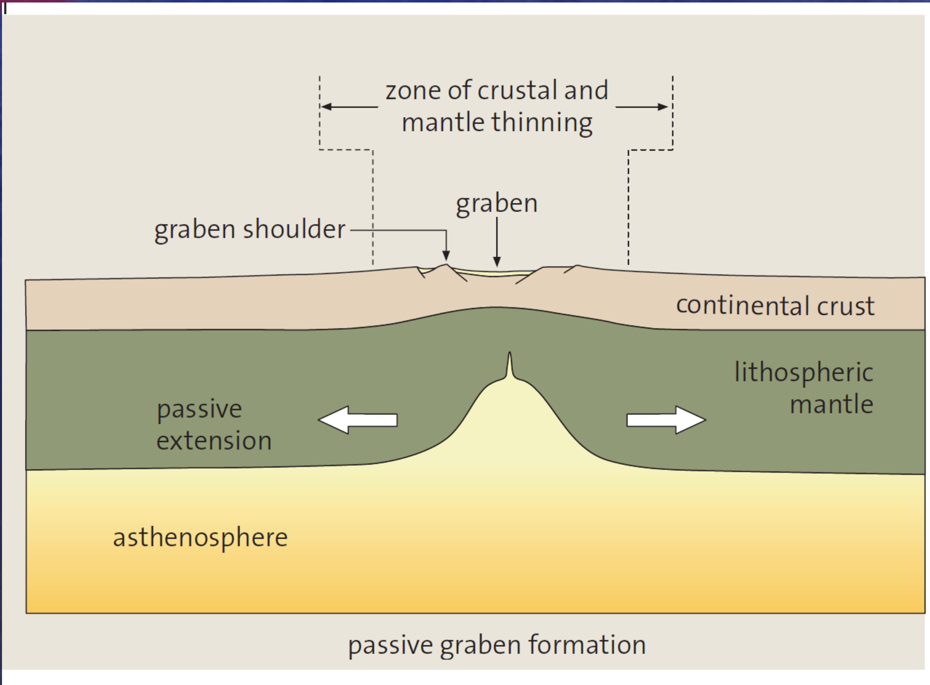
▲ Fig. 3.2 Schematic block diagram of a graben.

Frisch et al., 2011



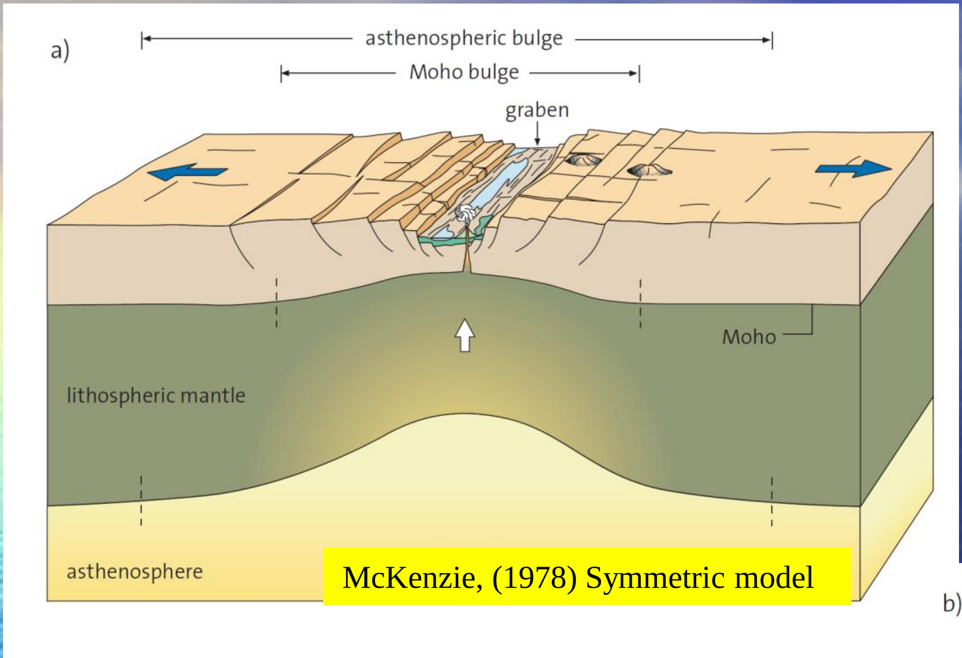
Graben related extension and thinning
(Condie,1997)

Frisch et al., 2011



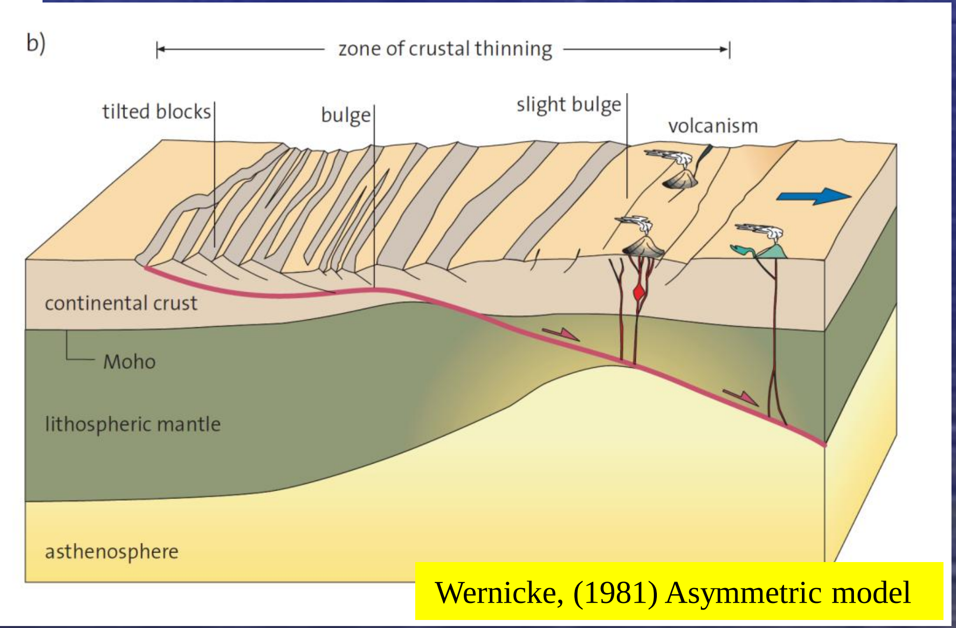
Stage A or Stage 1 (Embryonic Stage)

Symmetric and asymmetric crustal extension



McKenzie, (1978) Symmetric model

Symmetric (McKenzie, 1978) Versus Asymmetric (Wernicke, 1981) models



Wernicke, (1981) Asymmetric model

Crustal Extension associated with:

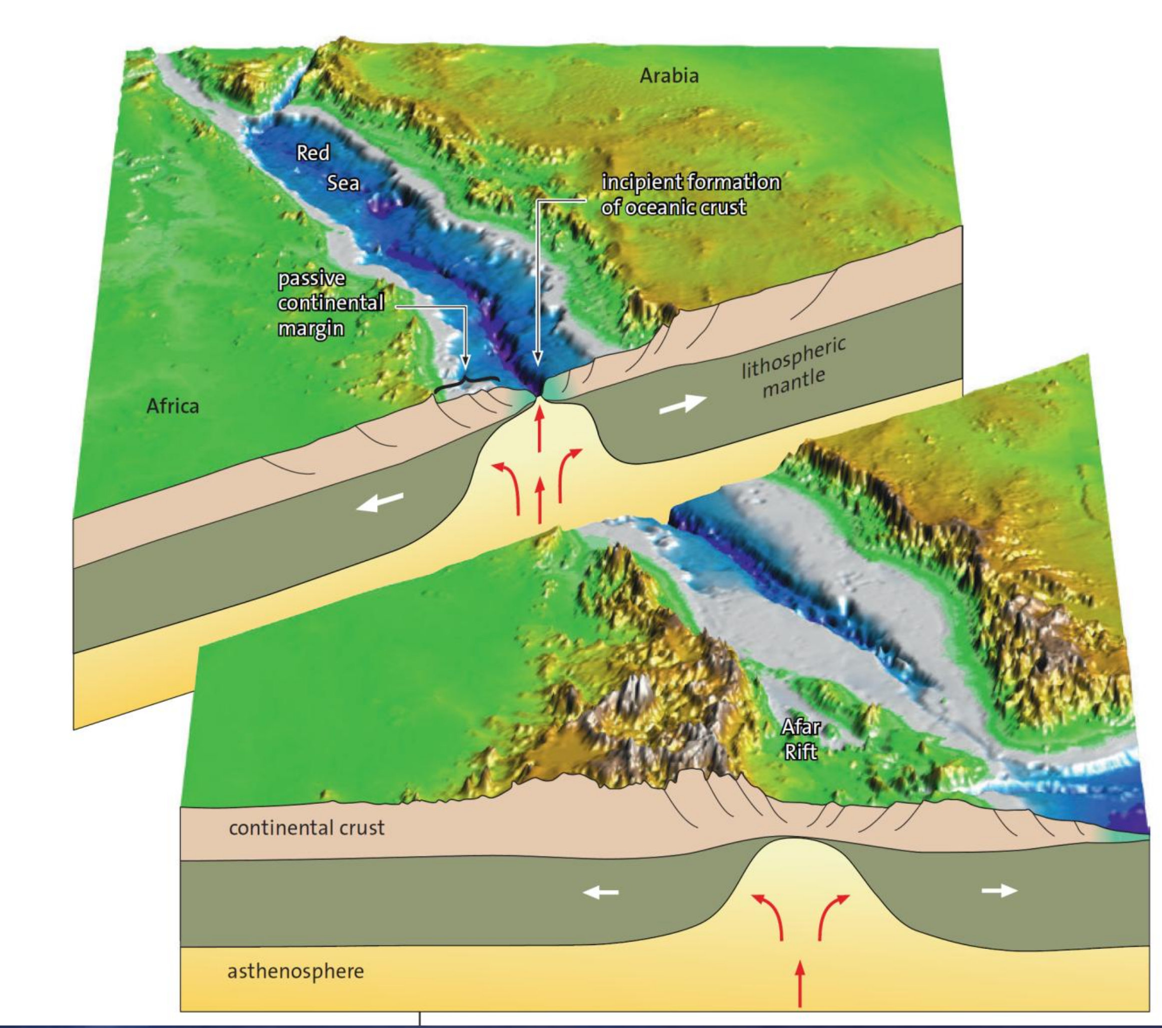
- The upper 10 to 15 km brittle extension of the Crust
- Ductile deformation at depth
- Ascent of hot asthenosphere
- Original bulge of the surface, erosion and thinning
- Thermal subsidence

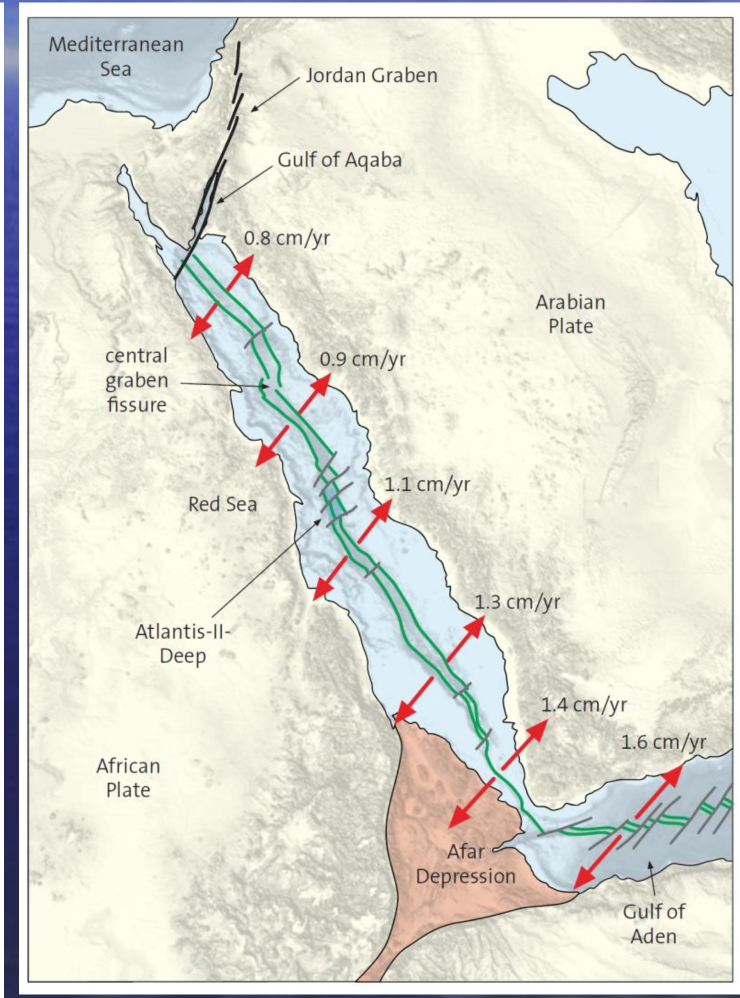
Stage B or Stage 2 (Young Stage)

- A continent separates by an intervening oceanic basin
- Continuous ocean basin widening ultimately gives way to sea floor spreading, establishment of Mid Oceanic Ridge, true basaltic oceanic crust formation, pools of hot brines and sediments accumulation on rifted continental margins
- Present day example Red Sea
- The Red Sea spreads at 1–2 cm/yr since the Pliocene at ~5 Ma

The Red Sea – from rift to drift

- The Red Sea Formation by separation of the African and Arabian Plates since the Late Tertiary
- East African rift system joins Ethiopia continental crust with the Red Sea and Gulf of Aden oceanic rifts.





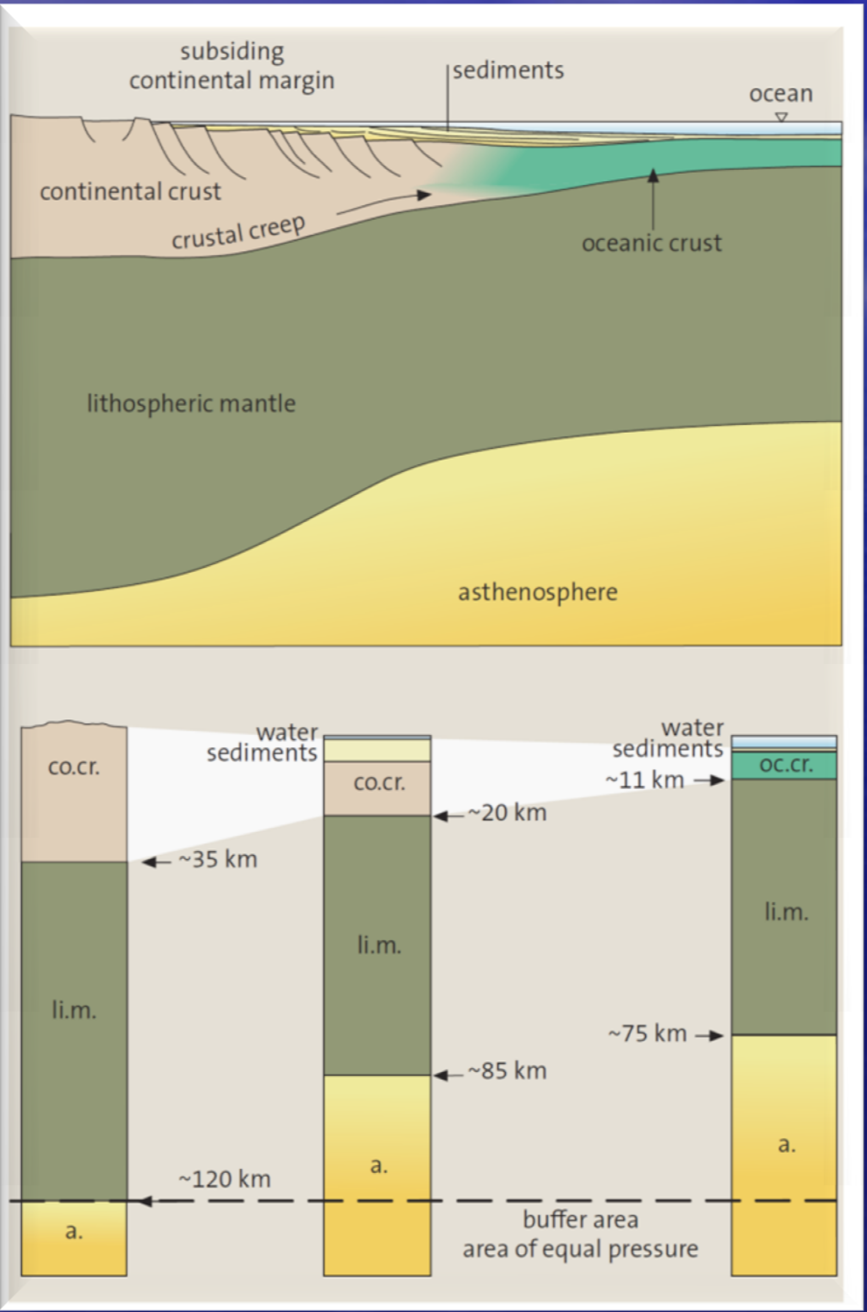
Frisch et al., 2011

Gass, 1972

Stage C or 3 (mature Stage)

- In this stage the ocean basin becomes much widen
- Usually accompanied by Transform Faults and Fracture zones
- These regional structures off set the MOR and magnetic anomalies
- Well established MOR spreading rate varies from 1cm/year to 15cm/year (Frisch et al., 2011)
- Ocean basin usually surrounded by passive continental margins containing largest accumulation of sediments
- Present day examples Atlantic and Indian Oceans

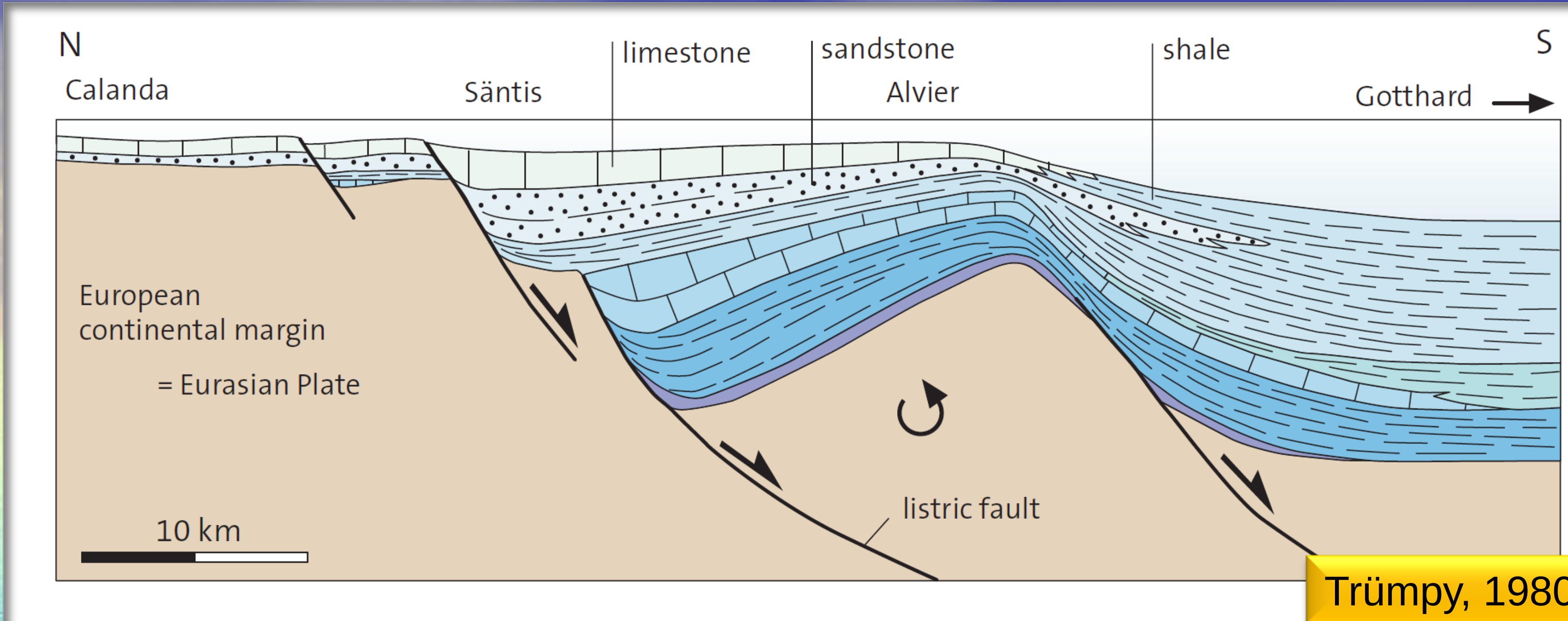
Passive Continental Margin



- Atlantic and Indian Oceanic margins are mostly nonvolcanic

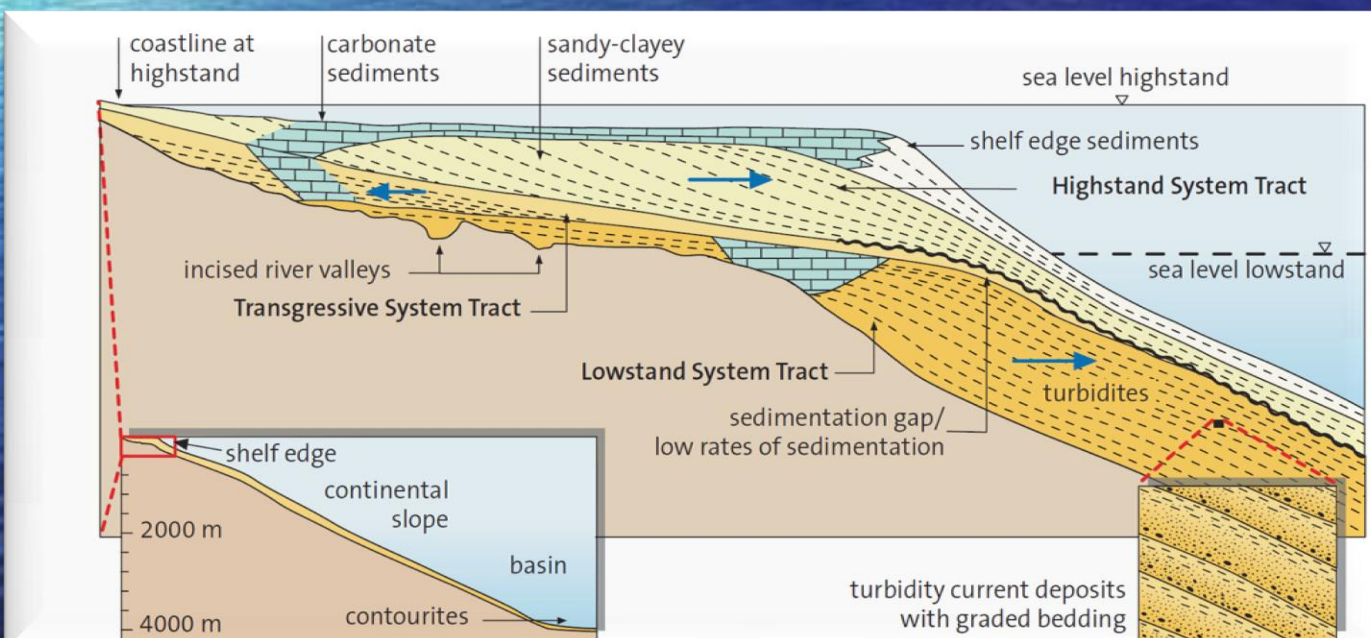
Huge Sediment accumulation causes subsidence and plastic deformation of the lower crust. The ductile flow of the lower crust to the deeper oceanic crust promotes crustal thinning and subsequent subsidence.

Frisch et al., 2011



Trümpy, 1980

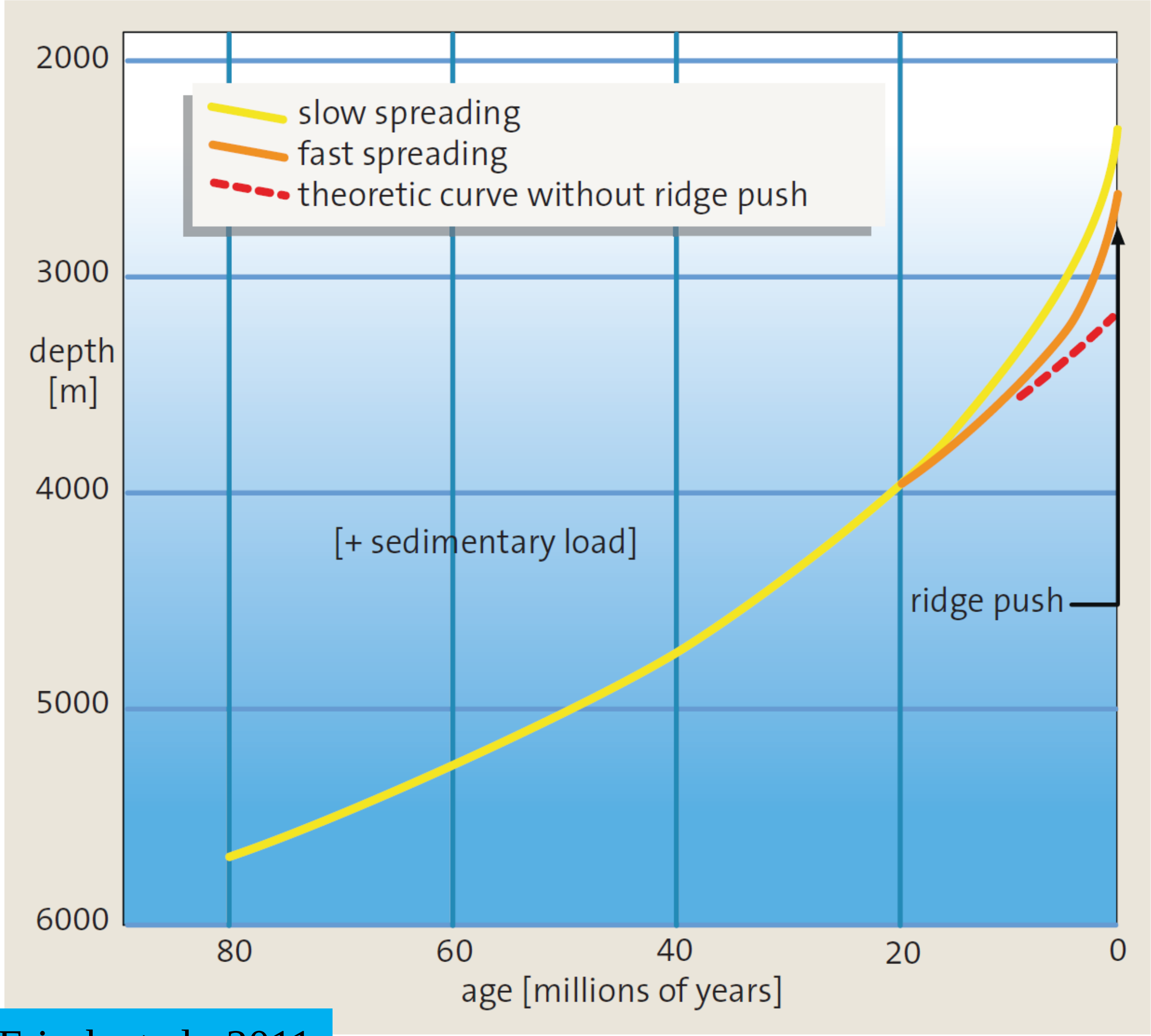
Passive continental Margins



Einsele, 1992

Frisch et al., 2011

Abyssal plains



Frisch et al., 2011

Subsidence increases away from the MORs

Stage D or 4 (Declining Stage)

Subduction zones, island arcs and active continental margins

- Subduction of a denser oceanic crust take place beneath at one or more rifted continental margins
- Collision leads to the Andean type continental margin and Andean-type Orogenic belts above active subduction zones. Note intraoceanic subduction forms Island Arc (e.g. Kohistan Island Arc)
- This stage continues till the complete closure of the intervening oceanic basin and collision of two continents
- Closure of an ocean basin compensates by opening of lithosphere elsewhere
- Therefore the entire ~55,000 km length of worldwide subduction zones, is marginally shorter than ~60,000 km length of the MOR

Example : The Pacific Ocean

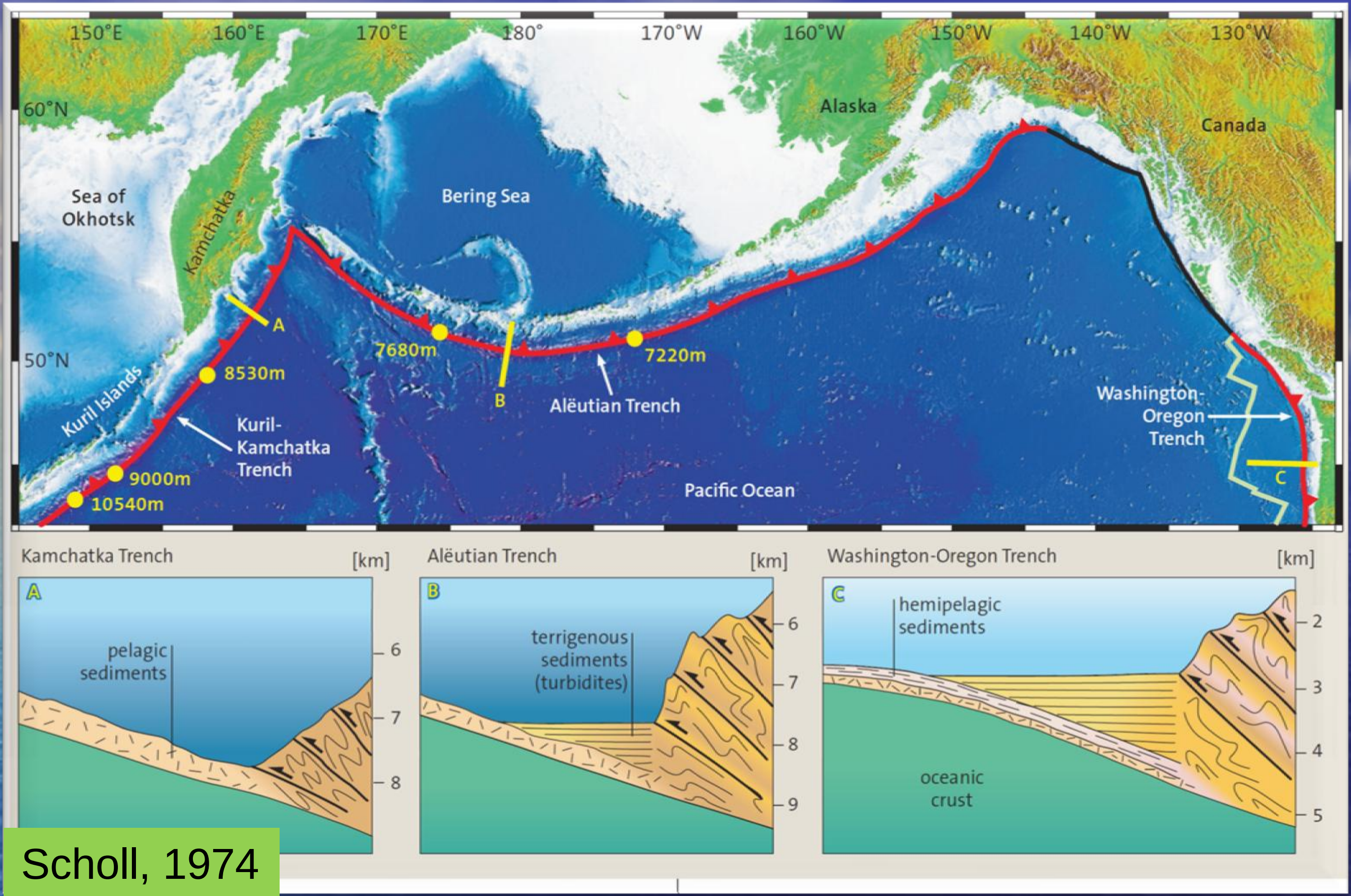
Deep Oceanic trenches as sediment traps

- Deep trenches fill up of pelagic/terrigenous and scraped off sediments. These sediments accumulate in the form of accretionary prism . Landward the accretionary prism follows forearc basin, magmatic arc and back arc basin

- Subducting plate also recycle sediments into the mantle by a process termed subduction erosion

- Thick trench deposits indicate slow subduction

- Thickness of trench filled sediments typically exceed 1 Km (Saffer & Bekins, 2006)



Scholl, 1974

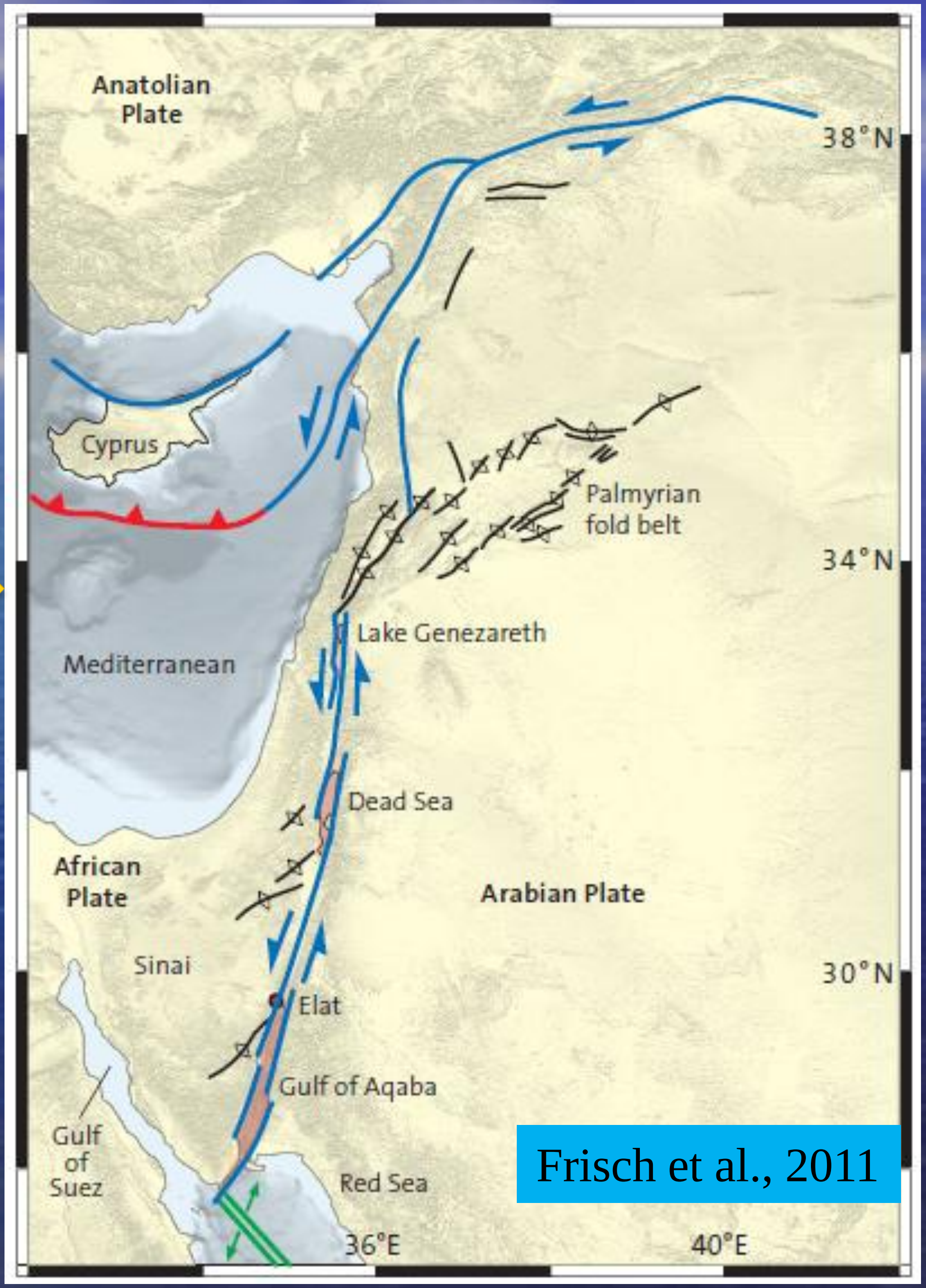
- ➢The Kurile- Kamchatka Trench generally lacks trench turbidites
- ➢The Aleutian Trench is 1–2 km deeper,
- ➢The Washington-Oregon Trench does not show notable trench morphology or difference in depth.

Stage E or 5 (Terminal Stage)

- At this stage most of the intervening oceanic crust between two continents subducts and recycled back into the mantle
- Magma generation along the subduction zone rises to the surface to build Andean/Cordilleran Type magmatic arc
- It is characterized by multiple deformations, metamorphic events, magmatic episodes, gravitational collapse, folds and faults

Example Mediterranean Sea

Terminal Stage

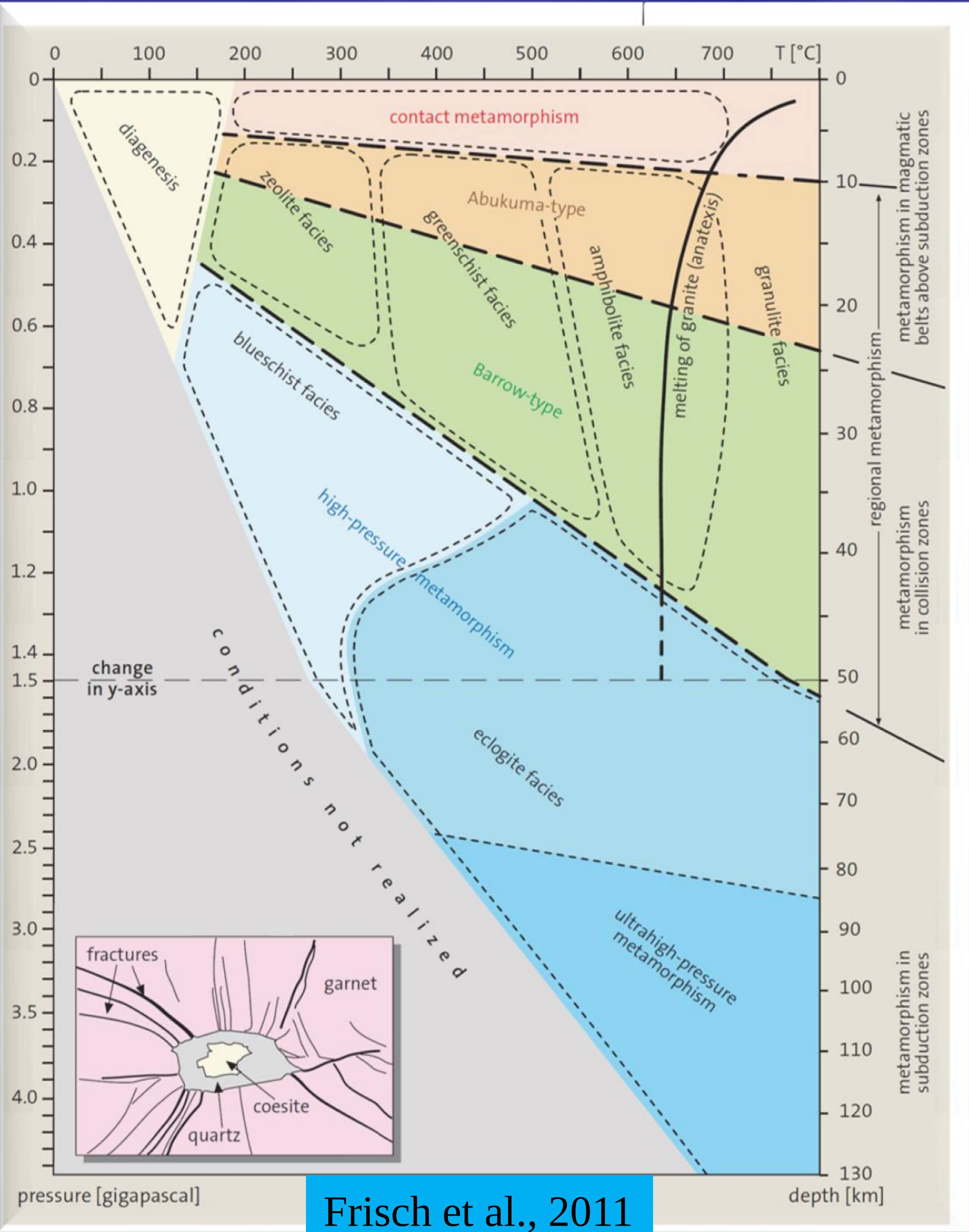


Frisch et al., 2011

Stage F or 6 (Relic Scar/Suturing)

- Continent-Continent collision occur
- The intervening oceanic basin is completely closed
- Crustal thickening and exhumation of deep crustal rocks take place
- Suture zone exposes ultra-high-pressure metamorphic rocks and ophiolites
- This stage is characterized by convergent related regional metamorphism, shearing, seismicity and crustal melting.
- Example Alpine-Himalayan Orogenic Belt, Appalachians

Subduction related metamorphic facies



Frisch et al., 2011