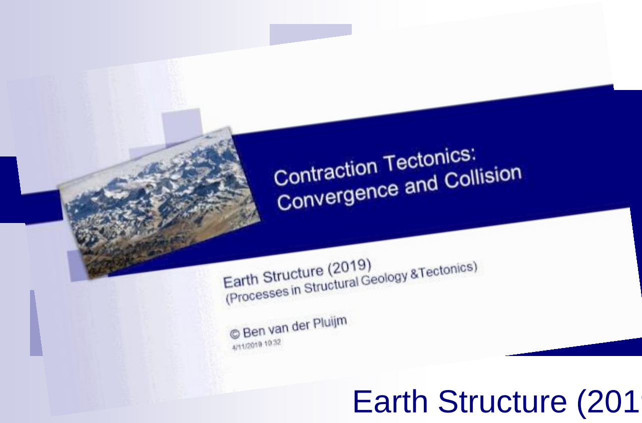

Contraction Tectonics: Convergence and Collision

Earth Structure (2019)
(Processes in Structural Geology &Tectonics)

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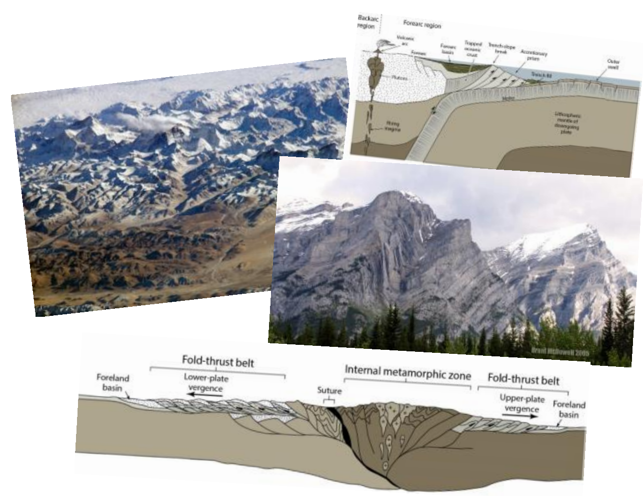
4/23/2019 10:02

We Discuss …

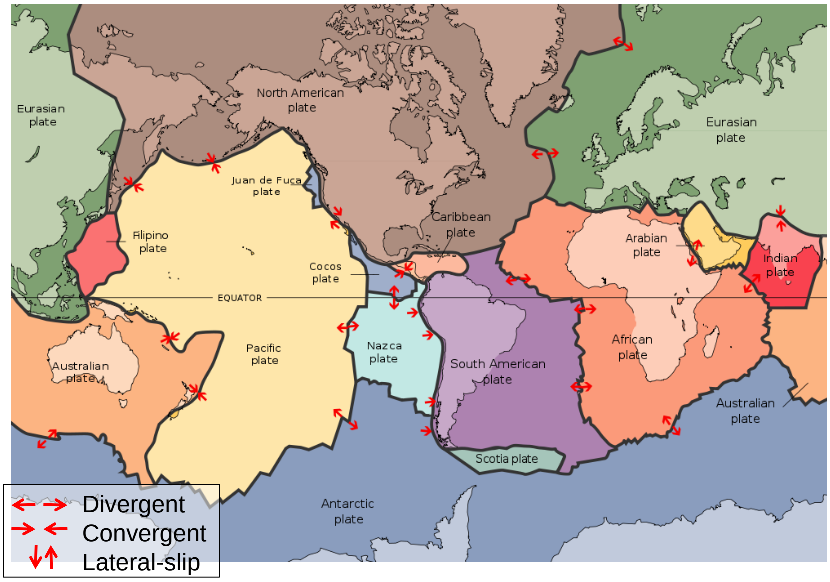
Contraction Tectonics

- Convergent Plate Margins
  - The Downgoing Slab
  - The Trench
  - The Accretionary Wedge
  - The Forearc Basin And Volcanic Arc
  - The Backarc Region
- Stages Of Collision
  - Convergence
  - Suturing
  - Thickening
  - Collapse
  - Delamination
- Structures Of Collision
  - Fold-thrust Belts
  - Fold-thrust Belts Kinematics
- Related Processes
  - Indentation-Extrusion Tectonics
  - Terrane Accretion
  - Orogenic Collapse
  - Intrusion and Delamination

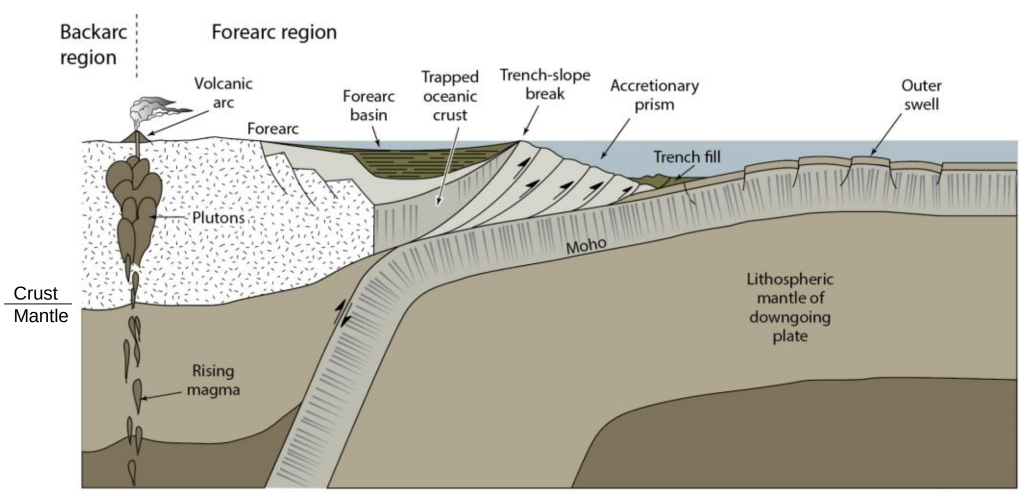


- Orogenic Architecture
  - Synoptic Cross-sections and Orogenic Styles
  - (Curved Orogens (Oroclines))

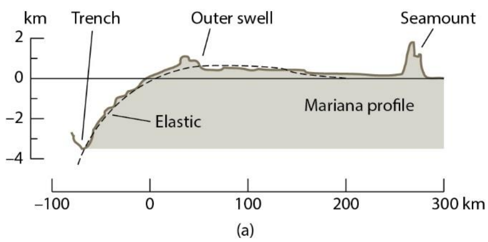
Today's Major and Minor Plates

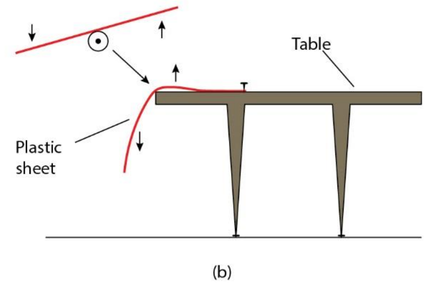


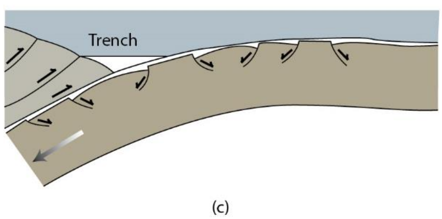
Generalized Cross-Section of a Convergent Margin and Main Structural Elements



The Downgoing Slab and Peripheral Bulge





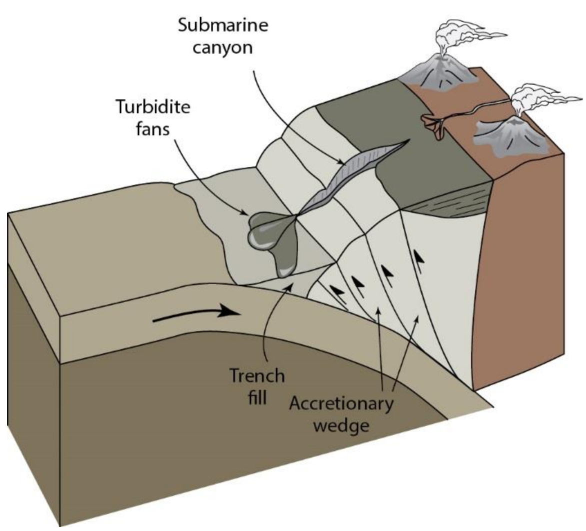


(a) Peripheral bulge (E of Mariana Trench, W Pacific). Solid line is surface of downgoing slab; dashed line is profile of plate as elastic sheet.

(b) Table-top analogy of peripheral bulge.

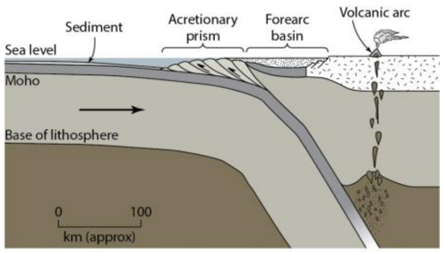
(c) Extension along outer swell produces horsts and grabens (and earthquakes) at surface of downgoing slab
(also called bend-faults ≠ fault-bend folds).

Trench, Trench Fill and Tectonic Mélange

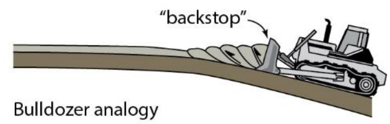


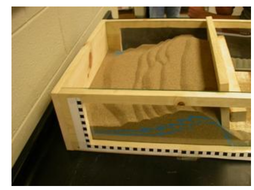
Ancient (Paleozoic Dunnage) trench fill (or tectonic mélange); Gander, Newfoundland

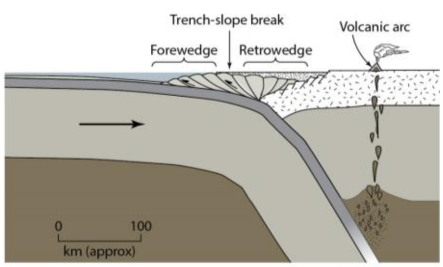
Accretionary Wedge (or Accretionary Prism)



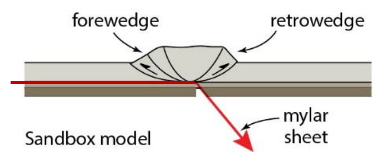
(Univergent) wedge



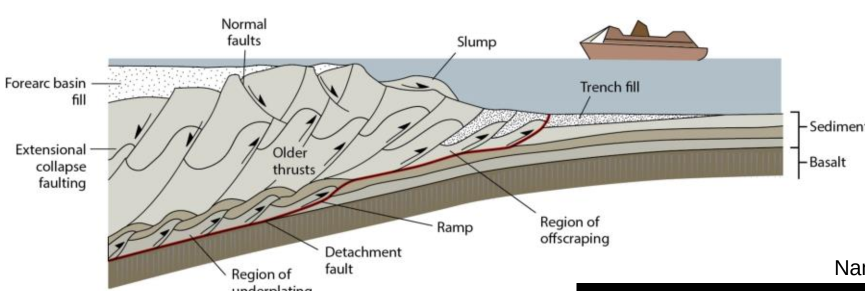


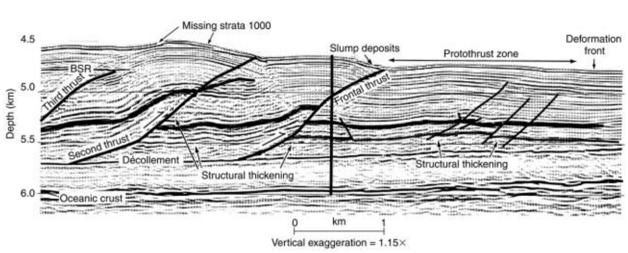


Bivergent wedge

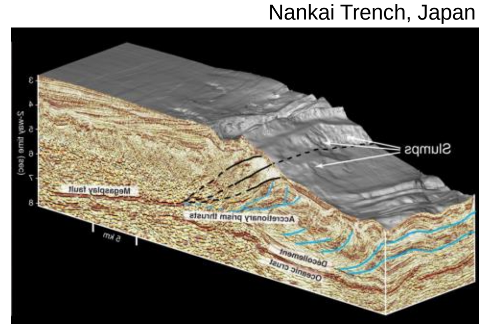


Accretionary Wedge Structures





Nankai Trench, Japan

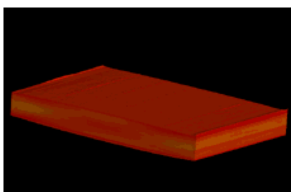


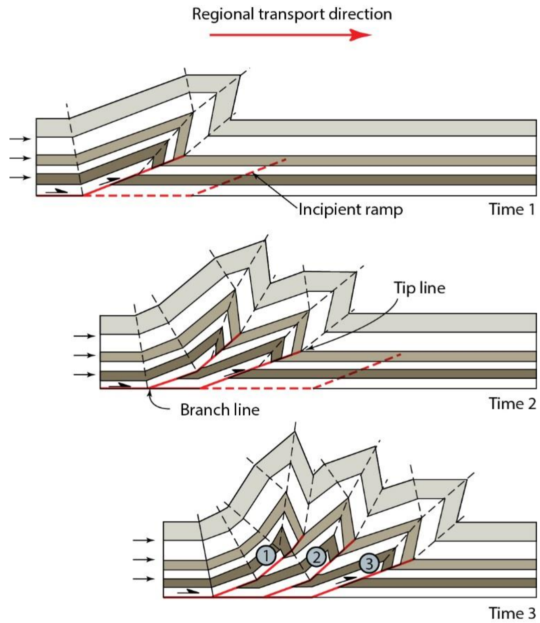
FTB Kinematics: Imbricate Fan Type

Relatively small displacements.

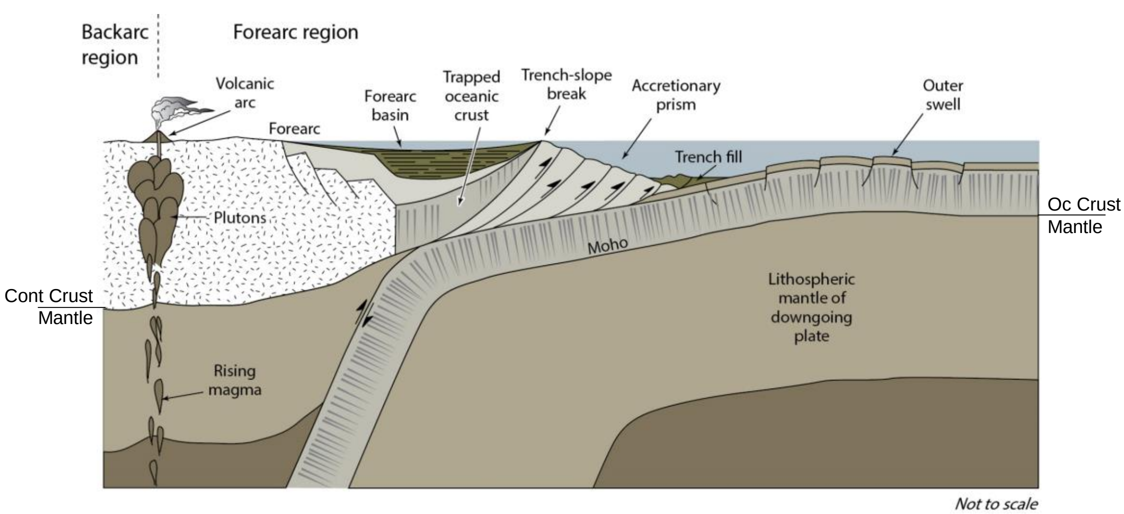
Break-forward ("piggy-back") thrusting. Successively younger thrusts cut into footwall, and older faults and folds become deformed by younger structures.

Typical setting:
Accretionary wedge.

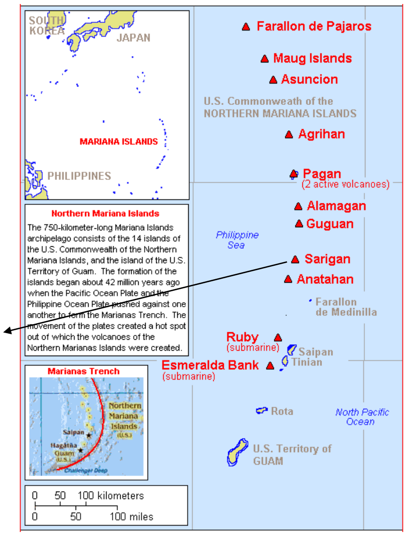




Generalized Cross-Section of a Convergent Margin and Main Structural Elements



Volcanic Arcs



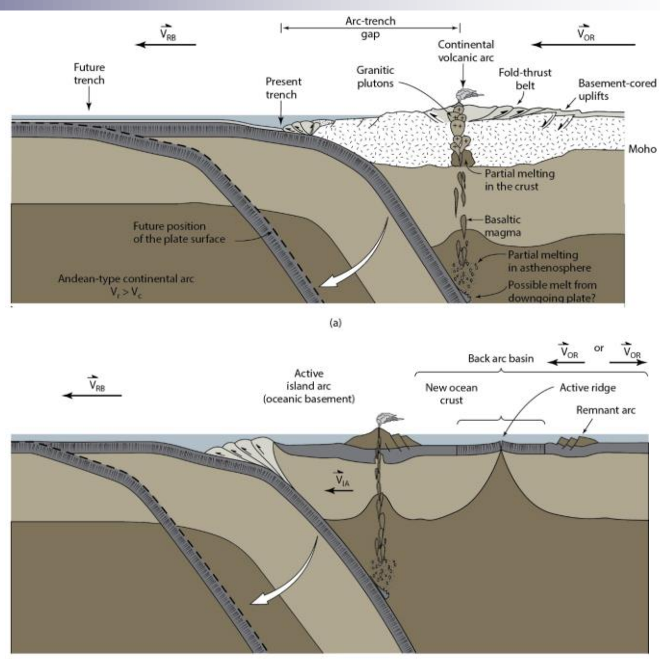
Continental Volcanic Arc (e.g., Cascades)

Oceanic Volcanic Arc (e.g., Marianas)

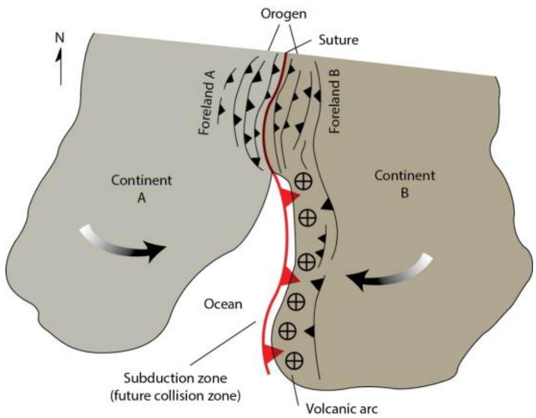
The Backarc Region

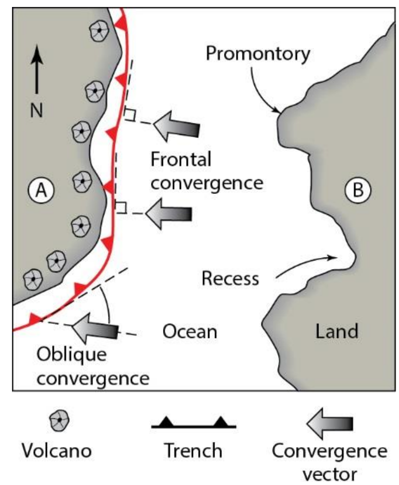
(a) Andean Type with contractional backarc region

(b) Mariana Type with extensional backarc region



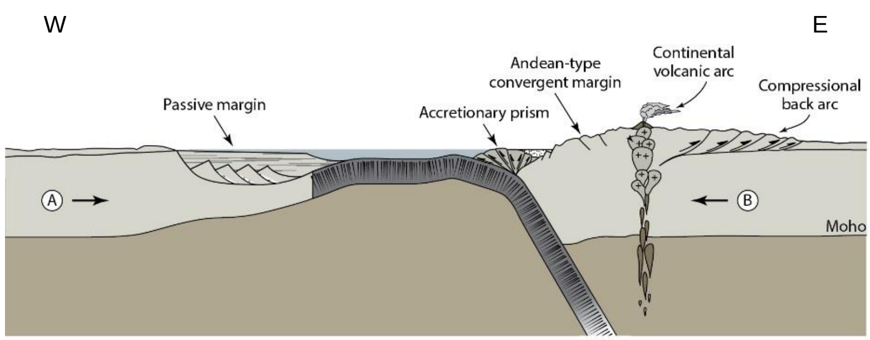
Continent-Continent Collision (map view)





a) Zipper-like collision of continental crust
b) Promontories and Recesses

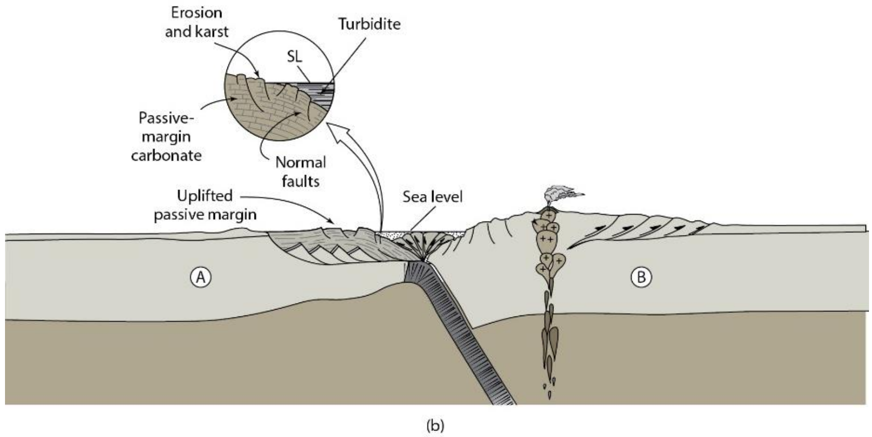
Stages of Collision 1: Convergence



(a)

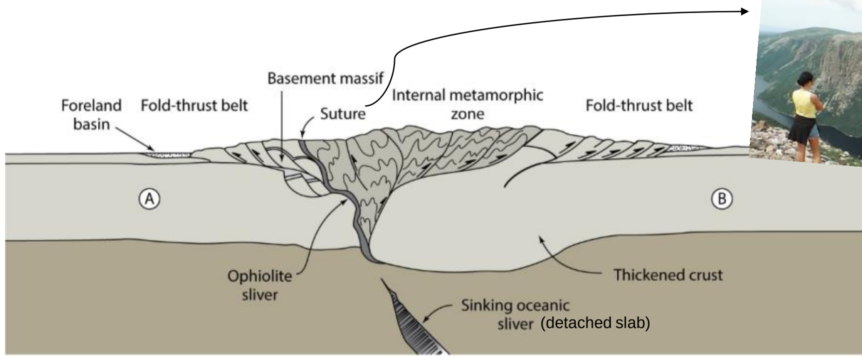
Continent A has passive-margin basin on east coast, while
Continent B has convergent margin (Andean-type) on west coast.

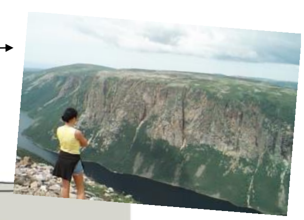
Stages of Collision 2: Abortive Subduction and Suturing



During initial collision, passive margin is uplifted, and an unconformity develops. Turbidites from Continent B bury this unconformity (inset). Normal faults break up the passive-margin basin, due to stretching. Meanwhile, thrusts develop, transporting deeper parts of the basin over shallower parts.

Stages of Collision 3: Thickening, Erosion and Exhumation

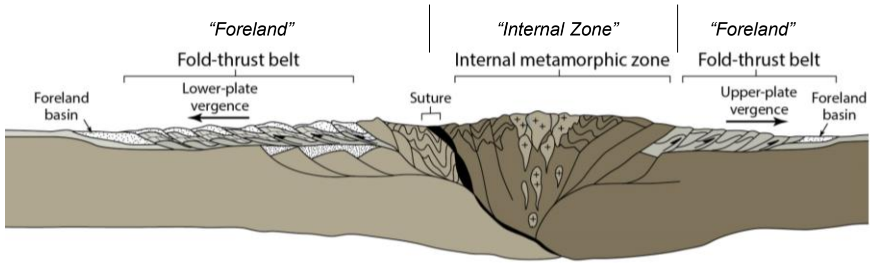




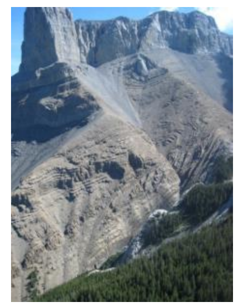
Bay of Islands ophiolite (Newfoundland)

After collisional thickening, exhumation and erosion remove shallower tectonic elements and add new tectonic elements (foreland FTBs). The subducting slab brakes off, while suture (incl ophiolites) is preserved with basement rocks in orogenic interior.

Foreland Fold-Thrust Belts (FTBs) and Foreland Basins



Fold-thrust belt (FTB) lies between foreland basin and metamorphic rocks of internal zone. Thrusting may incorporate foreland basin material into FTB. Foreland basins and FTBs can occur on one or both sides of a collisional orogen.



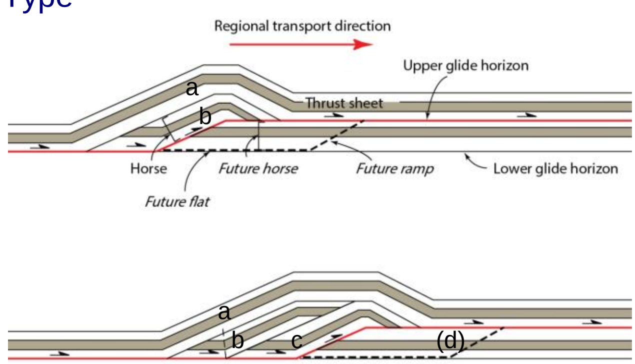
Canadian Rockies (Alberta)

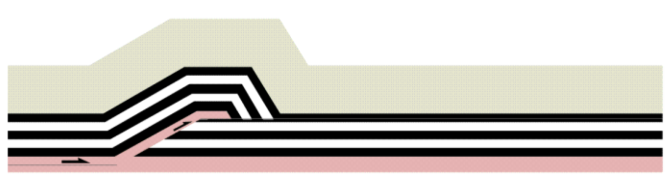
FTB Kinematics: Thrust Duplex Type

Relatively large displacements.

Duplex develops by progressive break-forward faulting. Roof thrust undergoes sequence of folding and unfolding.

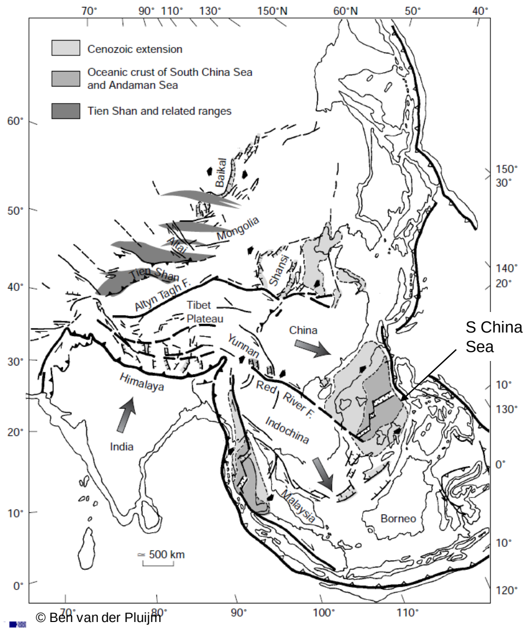
Typical setting: Foreland FTBs.

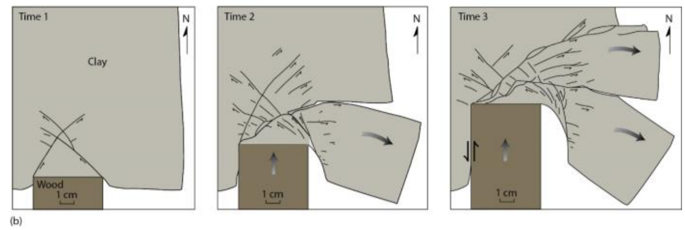




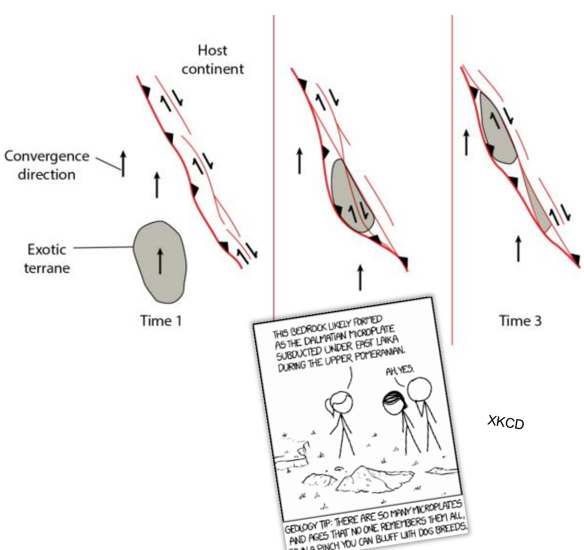
H Fossen

Related Processes: Indentation-Extrusion Tectonics



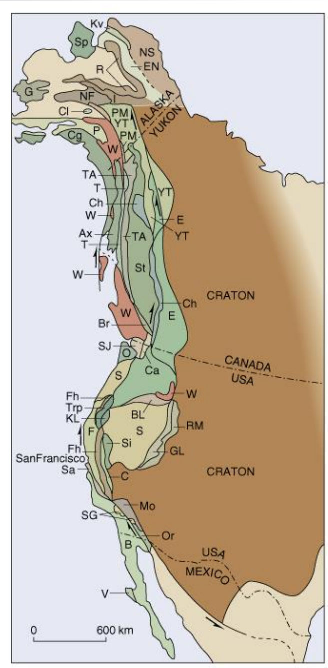


Related Processes:
Continental Accretion ("Terranes") and dismemberment

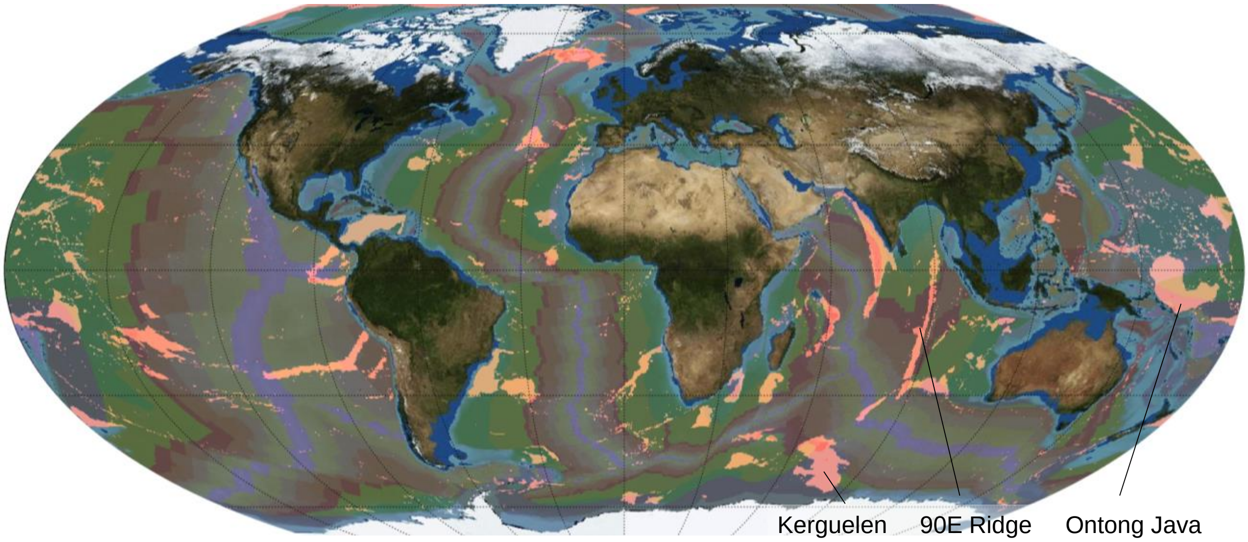


XKCD

Symbol	*Name*
Ax	Alexander
B	Baja
BL	Blue Mountains
BR	Bridge River
C	Calaveras
Cg	Chugach
Ch	Cache Creek
Cl	Chulitna
E	Eastern assemblages
En	Endicott
F	Franciscan and Great Valley
Fh	Foothills Belt
Gl	Golconda
I	Innoko
Kl	Klamath Mountains
Kv	Kagvik
Mo	Mohave
NF	Nixon Fork
NS	North Slope
O	Olympic
P	Peninsular
PM	Pingston and McKinley
R	Ruby
RM	Roberts Mountains
S	Siletzia
Sa	Salinian
SG	San Gabriel
Si	Northern Sierra
SJ	San Juan
Sp	Seward Peninsula
St	Stikine
T	Taku
TA	Tracy Arm
Trp	Western Triassic and Paleozoic of Klamath Mountains
V	Vizcaino
W	Wrangelia
YT	Yukon-Tanana



Future Terranes: Oceanic Plateaus and Seamounts

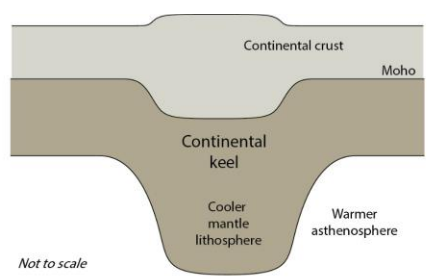


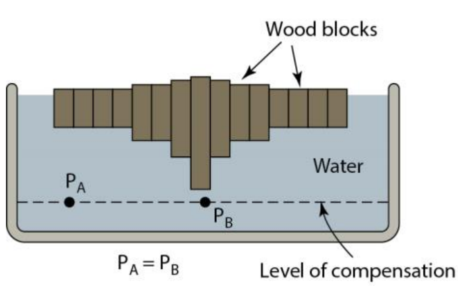
Why are Mountains High?

Application of Archimedes' Law of Buoyancy to Earth:

"the mass of water displaced by a block is equal to the mass of the block"

So, thickening of "block" (lithosphere) from collisions results in higher surface elevation and deeper keel.



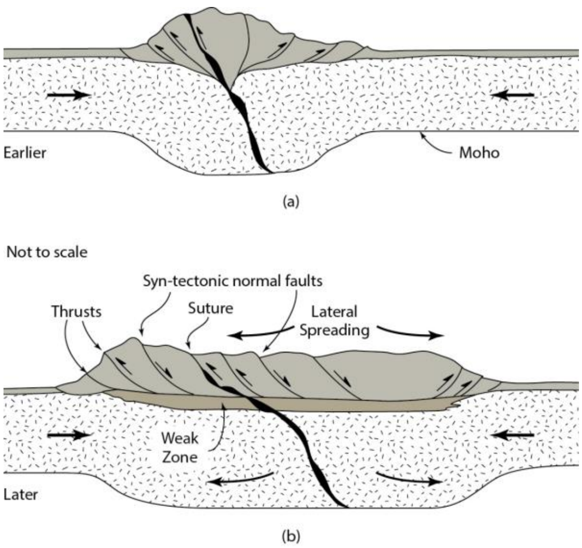


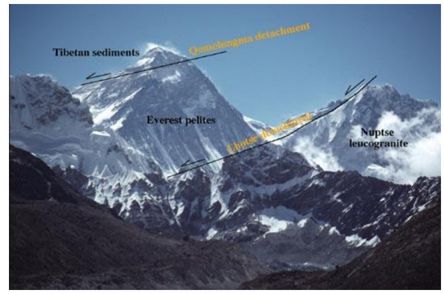
$P_A = P_B$ is isostatic equilibrium

Buoyancy estimates …
- ~1km high continent has ~45km crust
- ~10km high mountain range has 80km crust
-

… matches observations.

Stages of Collision 4: (Syn- to Late-) Orogenic Collapse





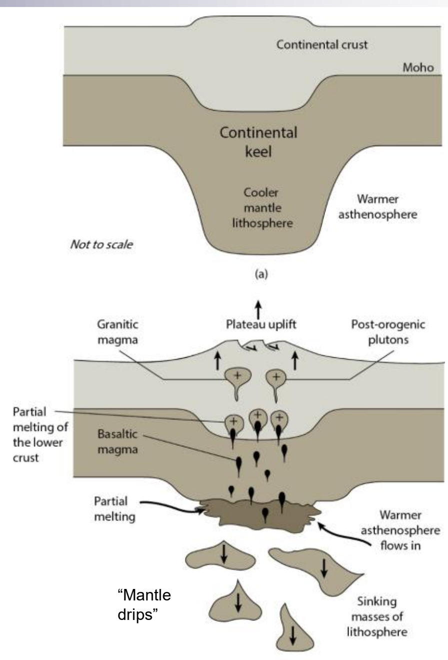
South Tibetan Detachment at Everest. (Mike Searle)

(a) During collision, crust thickens by thrusting.
(b) Later, collapse, when extensional faults develop in upper crust and plastic flow at depth (like brie).

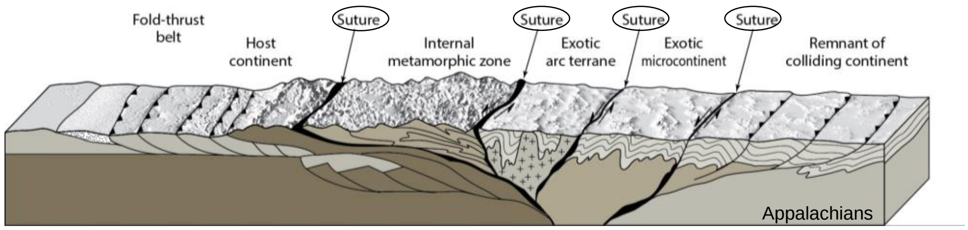
Stages of Collision 5: Intrusion and Delamination

(a) Thickening forms keel-shaped mass of cool lithosphere that protrudes into asthenosphere.

(b) Keel drops off and sinks ("drips"), and is replaced by warm asthenosphere, causing partial melting and formation of post-orogenic plutons.



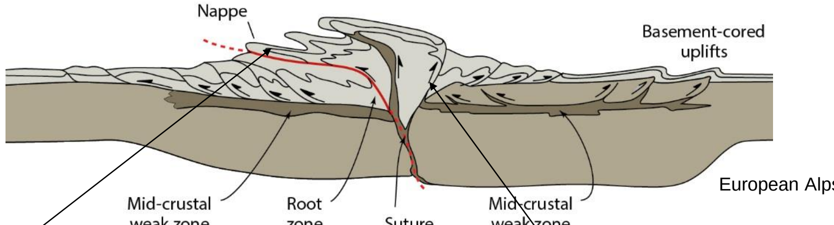
Synoptic Cross-Sections of Collisional Orogens 1:
Foreland FTBs, Terranes and Sutures (“Appalachian Type”)

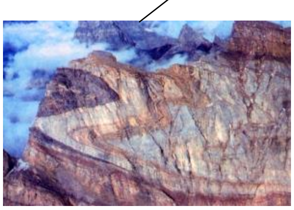


Sutures are fault zones that mark the boundary between once separate plates, typically marked by ophiolite (remnants of oceanic lithosphere).

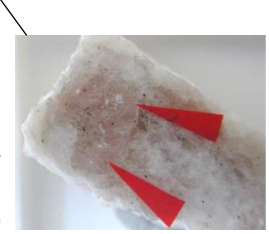
Table Mountain peridotite, part of Bay of Islands ophiolite (Gros Morne, Newfoundland)

Synoptic Cross-Sections of Collisional Orogens 2:
Nappes, Basement Uplifts and Deep Exhumation (“Alpine Type”)





Morcles nappe of the Helvetic Alps (Switzerland)

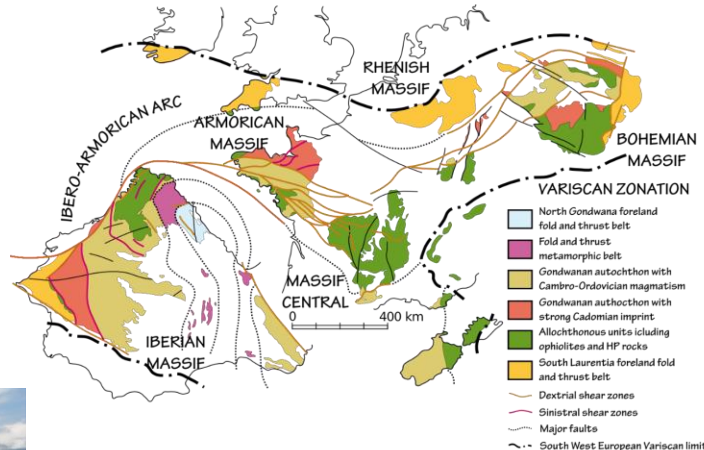


Coesite (Qz polytype) inclusions in near-colorless pyrope (garnet), exhumed from >100km depth (Dora Maira Massif, Italy)

Curved Orogens ("Oroclines")

Map-view Curvature of Orogens:

- Originally curved: primary orocline (like Appalachian promontories and recesses)
- Late curvature: secondary orocline (like Hercynian of Europe)
- Combination of primary and secondary

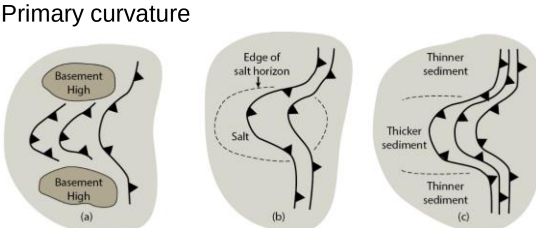


Ibero-Armorican orocline of W Europe
http://goo.gl/EbvI5j

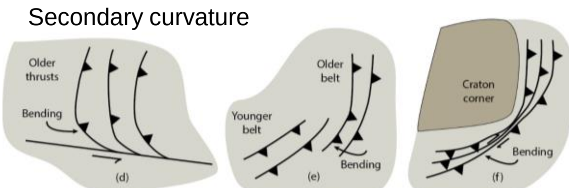
Picos de Europa, N Spain
https://en.wikipedia.org/wiki/Cantabrian_Mountains

Origins of Orogenic Curvature

Primary curvature



Secondary curvature



(a) Interaction with basement highs in foreland. New thrusts forming between highs originate with curved traces.
(b) Lateral pinch-out of a stratigraphic glide horizon. Thrusts propagate further to foreland over weak salt horizon and originate with curved traces.
(c) Lateral variations in stratigraphic thickness. Thrusts propagate into foreland where pre-depositional strata are thicker, so originate with curved traces.

(d) Interaction with strike-slip fault. Motion on strike-slip fault bends thrust traces.
(e) Overprinting of two non-parallel belts. Development of younger belt bends traces of older belt.
(f) Impingement against an irregular cratonic margin. Thrust sheets bend as they wrap around cratonic corner.

Modern and Past (Thermo-)Tectonic Activity