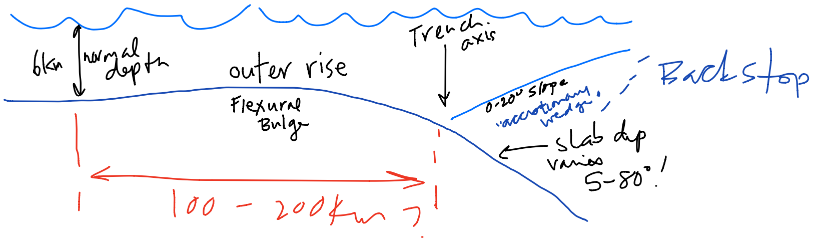
Simply defined - areas of dipping tabular zones of seismicity corresponding to the downward lateral transport of one lithospheric plate beneath another. These are the site of creation of continental crust, either through arc magmatism or sedimentation.

Subducting oceanic lithosphere is often called "a slab" but it may not always be flat - can curve as it dives, or in response to upper plate morphology. Can tear! "trench" is trace of plate boundary surface. Deepest areas of oceans. around Pacific, ocean depth is average 5-6 km but Peru-Chile trench is 7-8 km and Mariana is 10-11.

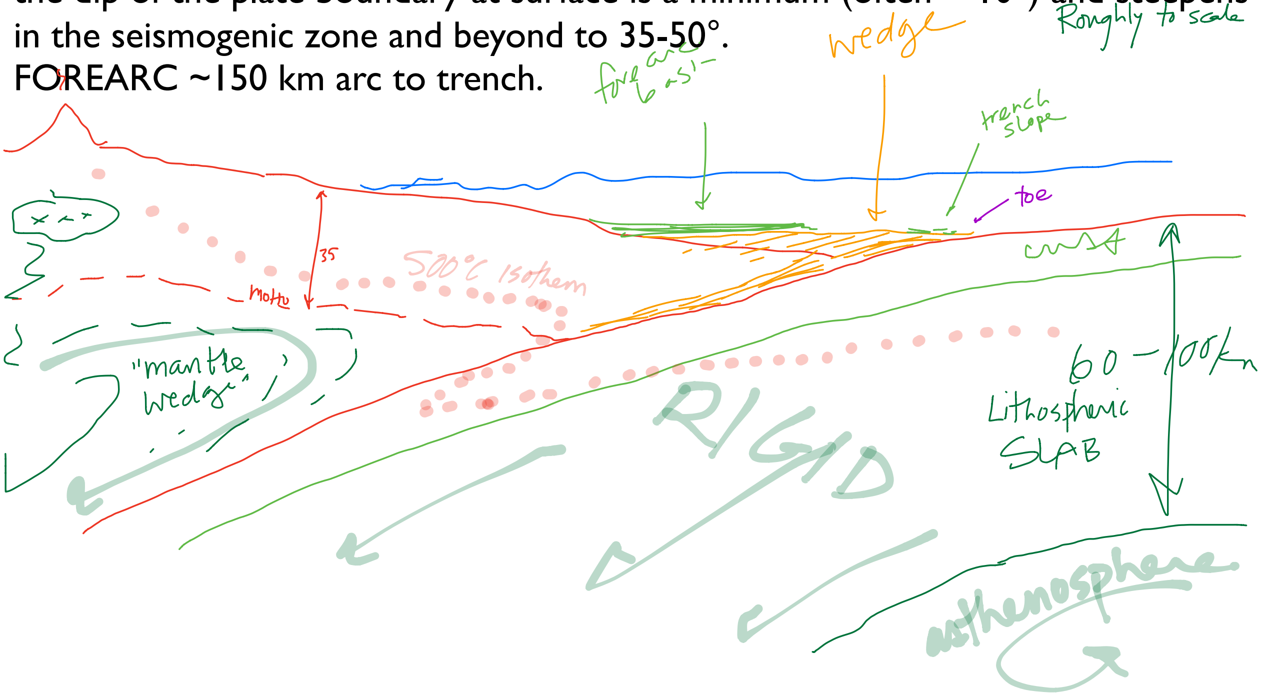
Isostatic balance - there is a direct correlation between the temperature and thickness of the oceanic lithosphere, and its density, which correlates to freeboard. As thickness depends on temperature structure, and temperature varies with age - ocean depth is to a first order predicted by the local age of the lithosphere.

Trench shape:

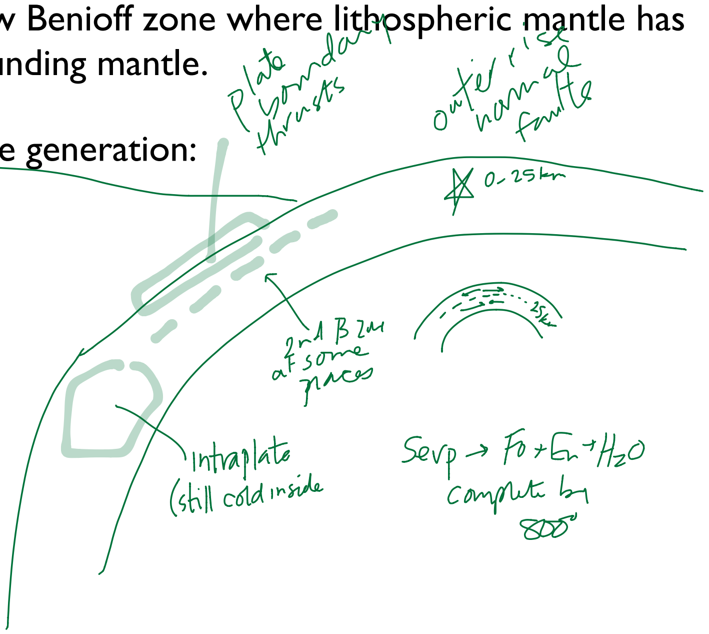


the flexing downgoing plate makes a bulge called the outer rise, then the ocean floor dips gently toward the trench axis. The slab typically continues to steepen landward under the accretionary wedge, so that the dip of the plate boundary at surface is a minimum (often < 10°) and steepens in the seismogenic zone and beyond to 35-50°.

FOREARC ~150 km arc to trench.



Dipping seismic zone - Wadati-Benioff zone. Originally identified as one planar surface, now identified double zones in some places. At depth, ends at the 670 km discontinuity in the mantle. Seismic attenuation studies show high-velocity region about 100 km thick below Benioff zone where lithospheric mantle has high rigidity compared to surrounding mantle.



Actually four areas of earthquake generation:

1. normal faulting earthquakes in the incoming plate, mostly around the outer rise (attributed to flexural stress)

2. Plate boundary zone between 100-400° (give or take 50°) big thrust.

3. sometimes there is a zone parallel to #2, within the plate. might be due to tension within the beam during unbending, also sometimes attributed to phase changes which result in sudden volume changes within the downgoing slab, e.g. dehydration of serpentine.

4. below 300 km depth, sudden cold olivine to spinel transition = anticrack faulting. normal mantle - this transition at 400°, but positive clapyron slope so shallower when colder. this makes slab MUCH denser than surrounding asthenosphere! this puts slab in tension, when lower part is very heavy and falling faster than upper part.

Good evidence for the stress changing down the slab comes from depth plot of focal mechanism solutions. if compressional first motion is down dip, slab is falling into mantle and encountering resistance.

** show original plot from Isacks & Molnar 1971 if possible***

How long does it take a slab to equilibrate with surrounding mantle? basically never mixes, but once thermally equilibrated can be difficult to image. thermal equilibration depends on: rate of subduction, age of slab, thickness of slab, frictional or viscous heating on the way down, conduction rate, adiabatic heating during compression, radioactive sources (minimal in oceanic lithosphere), latent heat of phase transitions inside slab.

UPPER PLATE

there can be compression or extension in the upper plate. to a first order, the distinction is based on whether the slab falls faster than convergence. if so - upper plate is in extension, if not - compression. so loosely correlated to slab dip and also age.

ACCRETION V. EROSION

Some margins form large accretionary wedges, while others done. This could be due to changes in sediment supply to the forearc/trench or could be due to the structural processes controlling faults. at the toe and under the forearc, the position of faults controls the transfer of rock packages from one plate to the other.

ACCRETIONARY WEDGES

Largest "sedimentary basins" on earth! Sedimentation rate similar to a large river delta e.g. amazon fan, but much greater in volume. But adding sediment to a wedge is not a straightforward process.

What sediment enters the trench?
- pelagic/hemipelagic sediments flat-lying on the oceanic crust - low permeability, strongly depth dependent porosity/permeability
- trench sediments - turbidites and slump deposits, contourites. silty to sandy, coarser near rivers
- toe recycling - slumps, deformed deposits associated with faulting between the outer rise, trench region, and faulting in the toe. mud to sand, local conglomerates

Ways to add sediment to a forearc wedge:
- offscraping - snowplow style, where sediment lying on incoming plate gets stopped at contact to wedge. Requires a décollement developed within or at the base of the incoming pile to separate downgoing and offscraping packages. This décollement often forms in a particularly weak or overpressured sedimentary layer within the incoming section. results in landward vergence

*** Show Sitkalidak Fm - Moore and Allwardt 1980

- frontal accretion - normal forward development of new seaward vergent thrust faults in sequence, thrusts develop in incoming section ahead of the deformation

front. results in set of imbricate thrusts with tilted intact sections of sediment, often with hanging wall anticlines well developed.
*** Show seismic line across Nankai **** Park et al. 2002

- underplating - when the sediment lying on the downgoing plate subducts a while, then a new fault strand develops decoupling it from the downgoing crust. if the former décollement above it goes inactive, the subducted sediments are effectively underplated to the base of the accretionary wedge. This often happens as temperature rises and the hydrated materials of the oceanic crust become weaker than the progressively compacting, hardening sediments above. Strongly favored at about 250-300°, regardless of depth.
* Kimura 1989**

- deposition on top of wedge - forearc basin, slope basins constrained by thrust hanging walls.
** Malmesbury group**

SEE accretionarywedgerocks.weebly.com for geological examples of the above types of units

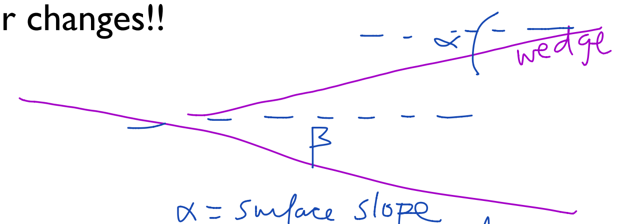
Accretion rates: Wedges develop in episodic periods of accretion. Not uncommon for a wedge to remain static for millions or 10s millions of years with almost no material added - then develop rapidly due to a change in sediment supply or subduction dynamics. The Cretaceous eastern pacific wedges grew massively, corresponding to a period of high levels of activity in the arc. may be correlated to the end of flat slab subduction and a resurgence of fresh mantle flow under the arc. SW Japan - sediments only 1-2 MYO are now 40 km inland of the trench, shows the outward growth by frontal accretion and offscraping has been very active in last few MY. Contrast - Mexico wedge extended 23 km in last 10 my. Costa Rica - no wedge growth at all, all sediments subducted, some possibly from destruction of prior wedge..

"Subduction Erosion" - when an existing wedge looses volume because upper plate sediments are transferred to downgoing plate.
Ways this can happen -
1. oversteepened wedge collapses with debris flows into trench, gets subducted
2. Big asperity (e.g. seamount or ridge) on downgoing plate plows into the wedge and grinds off material

3. opposite of underplating - decollement fault steps up into previously accreted wedge material and transfers it to downgoing plate.

Subduction of a chowed up sedimentary debris flow pile from the forearc creates a sedimentary melange containing older rocks, sometimes metamorphic rocks of same types formed further down subduction zone - creates major ambiguity as to origins of mixing, whether tectonic at depth or sedimentary recycling.

Response of wedge to critical taper changes!!



α = surface slope
β = dip of décollement
$\alpha + \beta$ = wedge taper angle.

Historical TYPES:
Chilean type: shallow dip, young lithosphere, upper plate in compression so that fold-thrust belt is associated with volcanic arc. Ocean under continent.
Marianas type: ocean-ocean, downgoing plate is old and cold, trench rollback, upper plate extension.

WORTH READING:
9.4, 9.5, 9.6 - 9.7 is replaced by lecture notes
252-264