

Continental rifting is often the first stage in construction of a new ocean basin. Rifts may be started by thermal build-up beneath a large continental plate, convection in the asthenosphere adjacent to a subduction zone, or related to the subduction of hot young crust. Rifts often develop as a set of shears at $\sim 120^\circ$ apart from one another—a triple junction one of which may ultimately fail to develop past a set of extensional basins. The developing rift starts with the formation of pull-apart basins and crustal thinning by normal faulting or strike-slip motion; these basins become filled with continental sediments and lake deposits. As the rift matures, a through-going fracture system may allow the episodic intrusion of seawater forming saline lakes, temporary arms of the sea and thick evaporates. Evaporite deposition is followed by marine sediments and the first oceanic crust adjacent to the thinned and hydrothermally altered continental lithosphere. As the rift cools and subsides, sediments eroded from the rift shoulders create an increasingly thick pile of sediments on the margin, forming a shelf, slope and rise topography. The increasing pile of sediments causes the buoyant salt to deform and flow, rising into salt domes that may reach the surface. Salt domes and the structural traps they create accumulate hydrocarbons created by thermal alteration of organic matter in continental sediments. Much of the world's petroleum (gas and oil) comes from “passive” continental margins.

“Passive” versus “active” margins

Why rifting?—plumes, heat trapping continents, and propagating rifts

Rifts develop as triple junctions and failed rifts

Extensional system

- normal faulting,

- transforms

- low-angle normal faults

- Metamorphic core complexes

Uplift of rift shoulders

- crustal thinning, uncompensated loads, underplating,

- depressurization melting

Early rift sedimentation and volcanism—

- Syntectonic sedimentation

- Sea level and facies architecture

- Clinoforms, downlap and toplap

Stretching and formation of transitional crust

- Non-volcanic margins

- Wrench tectonic basins

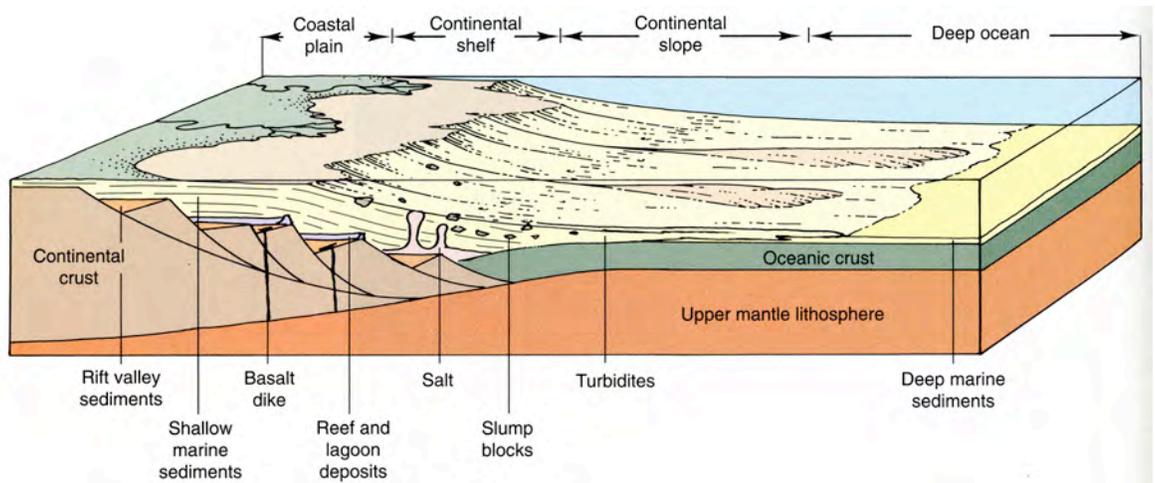
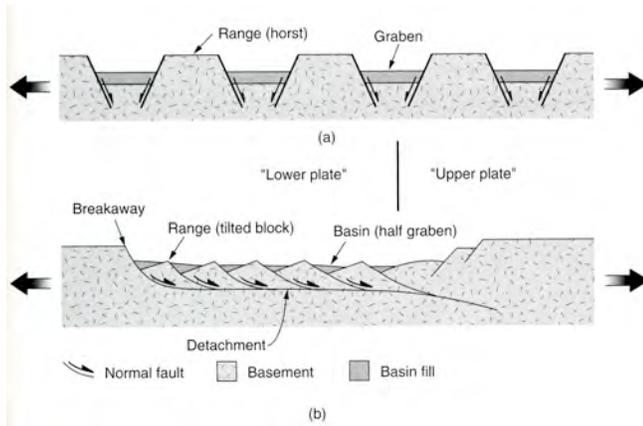
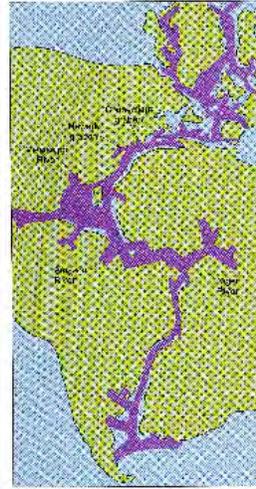
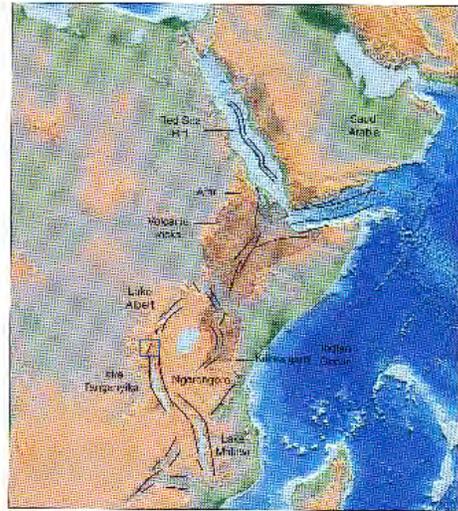
Thermo-tectonic subsidence

Formation of oil

- Source Rocks

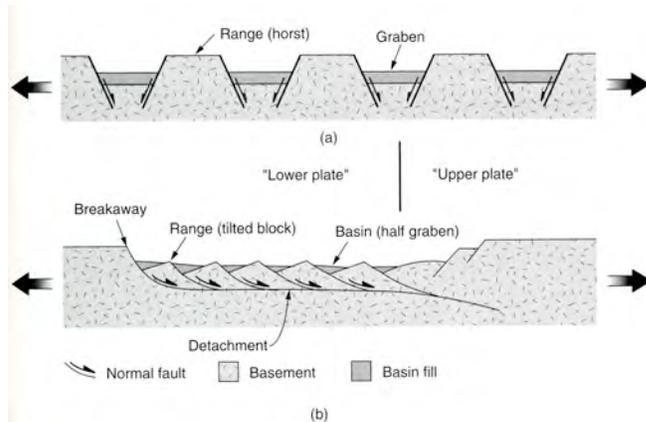
- The “Oil Window” and “Gas Window”

- Oil traps



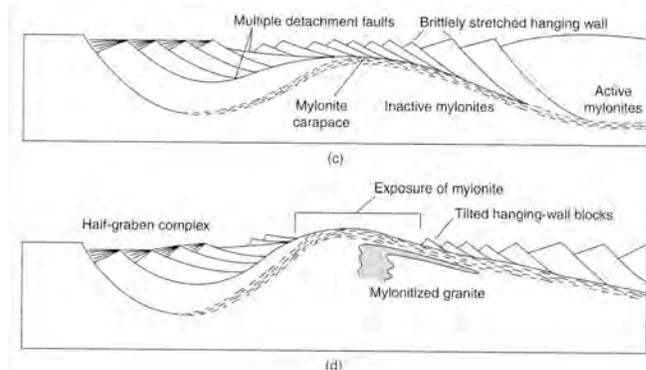
Extensional system with normal faulting, transforms and low-angle normal faults

1. Rifting by lithosphere extension creating **basin & range**
2. Faults can be **high angle**—classic **horst** (high blocks) and **graben** (basins) system
3. Or **faults may become horizontal at depth** (**lystric faults**) and turn into a zone of plastic shear (**décollement, or detachment fault**)
4. Detachments create **rollover structures** and the upper plate ‘rolls’ into the fault plane creating a ‘rollover anticline’



Metamorphic core complexes:

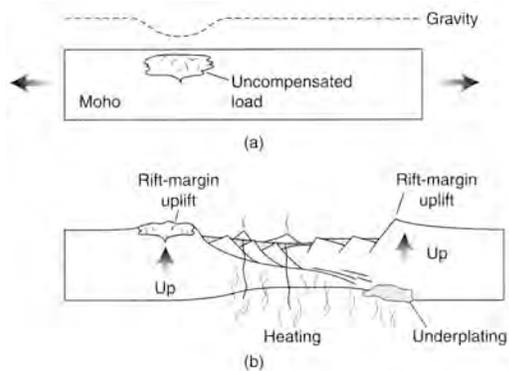
Deep crustal rocks exposed through isostatic uplift beneath a detachment (the metamorphic part)—these also form in oceanic rifts exposing the deep crust or upper mantle.



Uplift of rift shoulders

Uplift of rift shoulders by crustal thinning and decompression melting

Can also have **uplift associated with uncompensated loads** (that are compensated when the stiff plate ruptures in a rift) or due to **underplating** the rift, thickening it and leading to isostatic adjustments

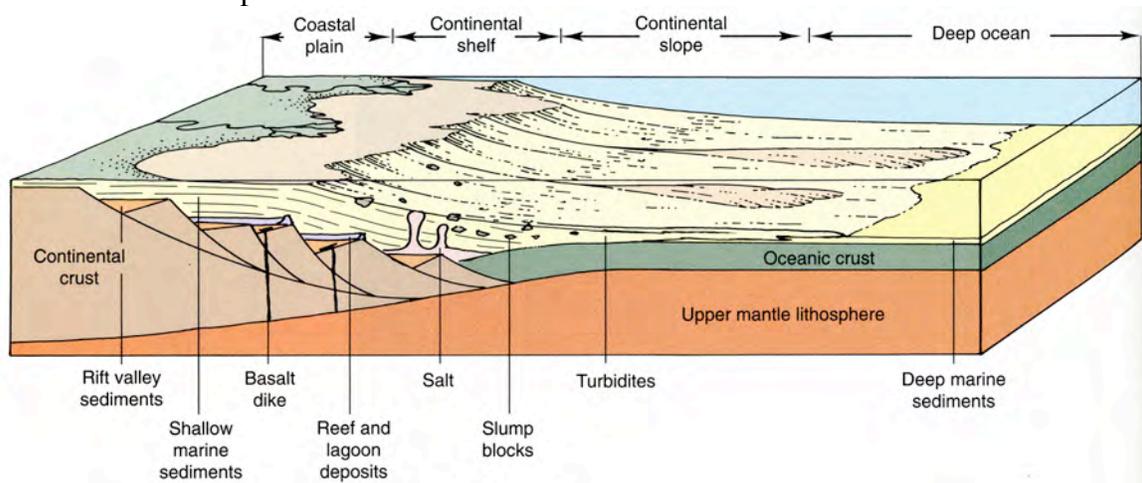


Stretching and formation of transitional crust

1. May be a **mixture of intruded continental crust and basaltic crust**
2. Continental crust may detach from the underlying mantle and leave “sea-floor” composed of exposed mantle rocks—peridotite and serpentinite. This occurs off Portugal where the block-faulted, stretched crust is all exposed mantle
3. We would expect decompression melting to form plutons and volcanic rocks—their absence suggests
 - a. **spreading is very slow** so conductive cooling can prevent decompression melting,
 - b. **lithosphere under the rifted crust is too dense** and cold to undergo much decompression melting, or
 - c. **melting does occur**, but consists of intrusions within the mantle rather than volcanism.

First ocean floor, continued rifting by transform motion and pull-apart basin formation

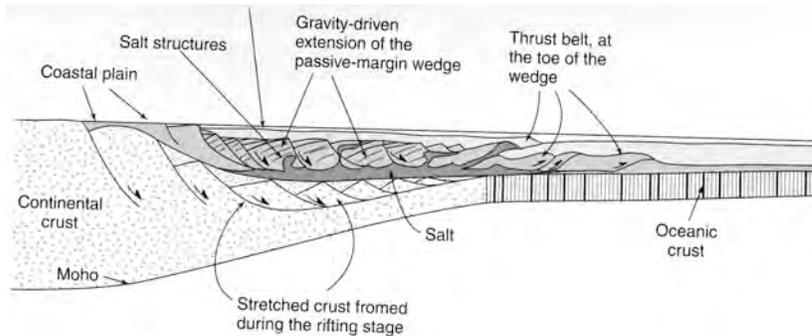
1. **Wrench tectonic basins**—pull-apart basins: deep basin opened between strands of strike-slip faults



Synrift sedimentation and volcanism—

1. Sediments formed at the same time as active rifting
2. Tend to thicken into faults, fill grabens as they form and indicate presence of local topography

- e.g. **alluvial sediments**—fanglomerates and coarse-grained alluvial sediments
- lake deposits**—includes large rift lakes analogous with E African rift. – mixture of facies from deep lake to playa lake sequences
- salt and first marine sediments**—related to episodic flooding of mostly enclosed basins that become closed off by tectonic movements of formation of sediment dams (for example by build up of deltaic or alluvial fan deposits); results in evaporation and salt build-up, particularly in basins far from the main connection to the ocean.
- Also have volcanism**—**basalt** indicating direct mantle source through rifts, and **rhyolite**, indicating magma differentiation in the crust



Post rift sediments—

- Eventually have fully marine sediments—typically deep marine **‘flysch’**—turbidites because the continental shelf is very narrow.
- These sediments show ‘clinoform’ structure, onlap and toplap as sediment prograde over earlier formed synrift sediments
- The upper surfaces of **clinoforms** reflect local sea-level, sediment supply and rates of subsidence
- Show **“growth faults”** that elongate and move continuously due to addition of sediment to the overlying sediment pile—particularly common on rapidly accumulating continental margins

Thermo-tectonic subsidence

Construction of shelf-slope break and continental rise;
modification of the shelf slope break by sea level change

Oil Formation

Oil ultimately derived from “source rocks” rich in organic matter.

- The carbon in source rocks does not originate from dinosaurs but from marine algae.
- Source rocks are frequently thin (10-20 m) and may not be widely distributed.
- Need to be buried sufficiently to form oil.
- But, oil can migrate, so continued burial does not always destroy oil

Source rocks have to be buried or heated enough to break organic matter down into oil and other hydrocarbons

1. Oil forms at temperatures of ~80 to 160°C corresponding to burial depths of 2.5 to 6.5 km.
2. Oil is not stable at temperatures above 160°C.
3. At higher temperatures, breaks down to form Natural gas.
4. The oil and gas windows are the depth/temperature ranges over which oil and gas forms.

Oil and gas are less dense than water so usually flow out of source rocks to 'traps'.

1. Traps are usually structures associated with an impermeable rock (a 'seal') that prevents further fluid or gas migration.
2. In some places these structures are associated with salt domes.
3. Often Anticlines or fault surfaces that act as traps

At present rate of consumption of known (and predicted) oil reserves will not be much left by 2075. Either

1. oil will become much more expensive,
2. we will become more efficient at using it, or
3. we'll have to switch to something else for energy.
4. Of course economics may also make it profitable to go after 'unrecoverable' oil (currently we only get 30-40% of what's there)