3.4. Overlap and nappes:

3.4.1. Introduction:

Fault and fold deformation can occur in mountain ranges:

Rocks previously folded at depth are uplifted by complex tectonic phenomena. These folded rocks can then be faulted: this is known as fold-faulting.

The next stage is the creation of an overlap: as compression continues, the displacement of one block on top of the other becomes greater.

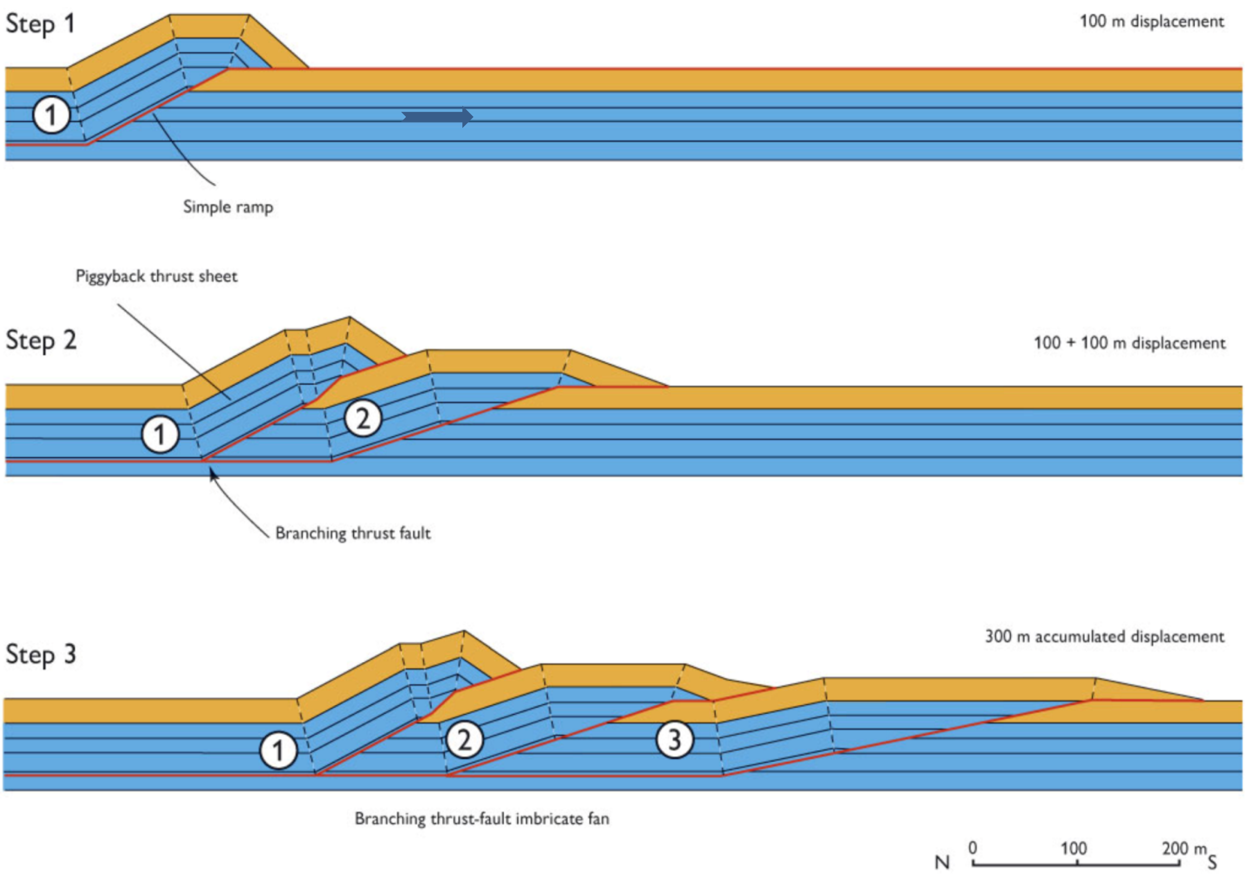


Figure 105: Evolution of a reverse fault to a thrust fault

3.4.2. Definition:

A thrust is a tectonic movement that causes one series of terrains to overlie another by means of an anomalous reverse fault contact.

In geology, a nappe or thrust sheet is a large sheetlike body of rock that has been moved more than 2 km (1.2 mi) or 5 km (3.1 mi) above a thrust fault from its original position. Nappes form in compressional tectonic settings like continental collision zones or on the overriding plate in active subduction zones. Nappes form when a mass of rock is forced (or "thrust") over another rock mass, typically on a low angle fault plane. The resulting structure may include large-scale recumbent folds, shearing along the fault plane, imbricate thrust stacks, fensters and klippes.

The term stems from the French word for tablecloth in allusion to a rumpled tablecloth being pushed across a table.

Overthrusts are tectonic faults that cause geological units (of different ages) to overlap abnormally.

The lower part deforms the upper part as it moves (new folding), while the upper part overlies younger terrain.

Note:

When movements take place over long distances (several kilometers) and involve large areas, we speak of a thrust sheet.

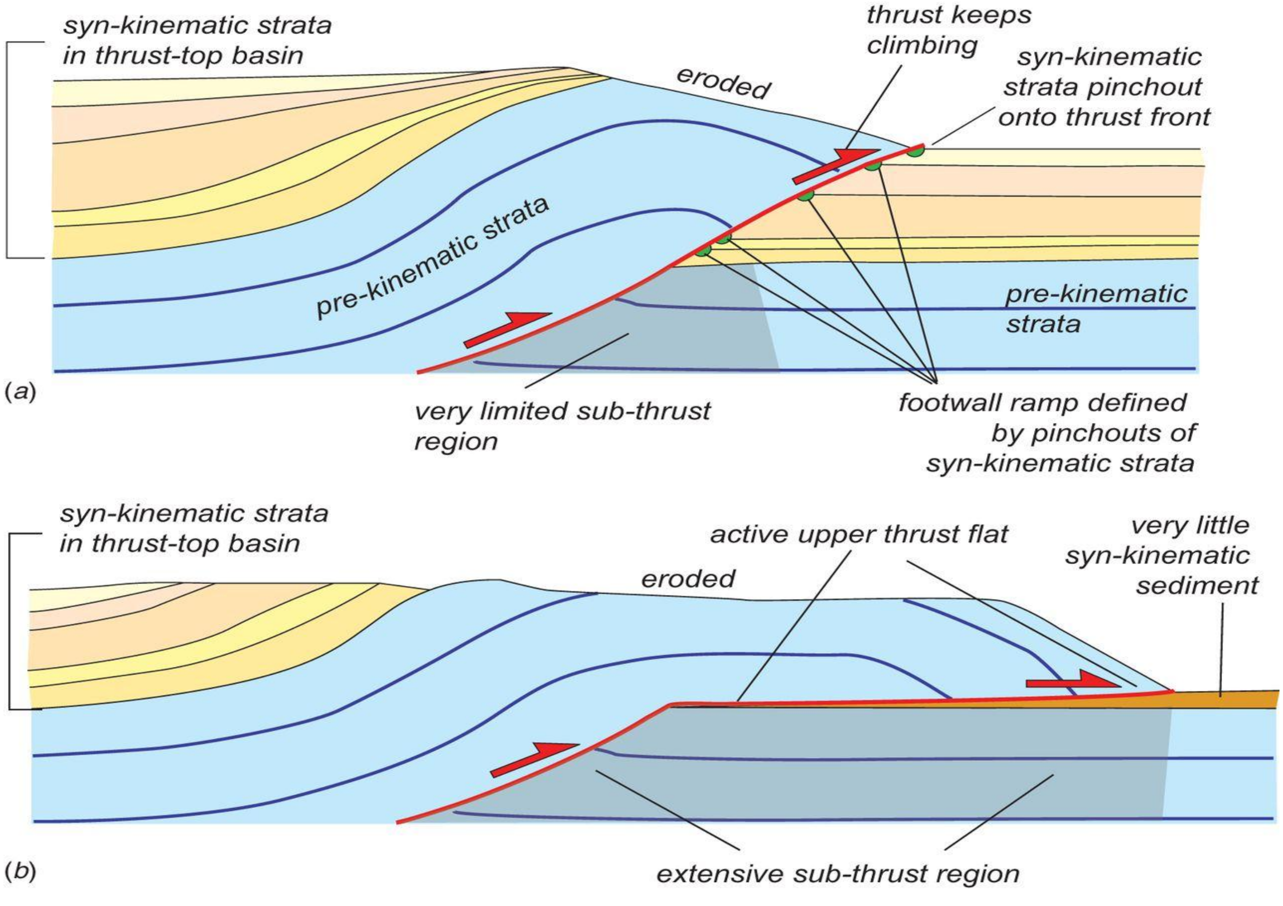


Figure 106: Stages in the formation of a thrust sheet

3.4.3. Characteristics:

* Overriding" and "thrusting" are tectonic concepts that correspond to two facts, the second of which explains the first.

Explanation: What we observe:

The first fact is the vertical superposition of two sets of terrains whose succession is not normal.

* This superposition is referred to as "abnormal contact" and "overlap".

* The second fact is the horizontal movement of one of the two series, explaining the superposition observed, and hence the abnormal contact and overlap;

This corresponds to the very notion of "overlapping" or "thrusting".

We say that:

The upper unit is thrust: allochthonous; this is the thrust sheet;

the lower unit is considered autochthonous: it has not moved.

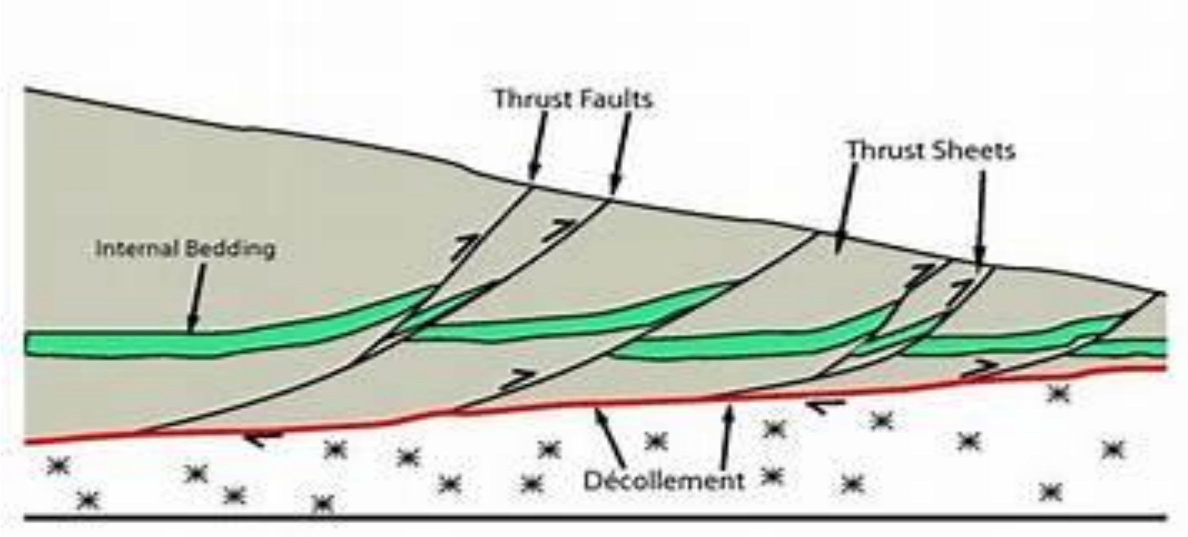
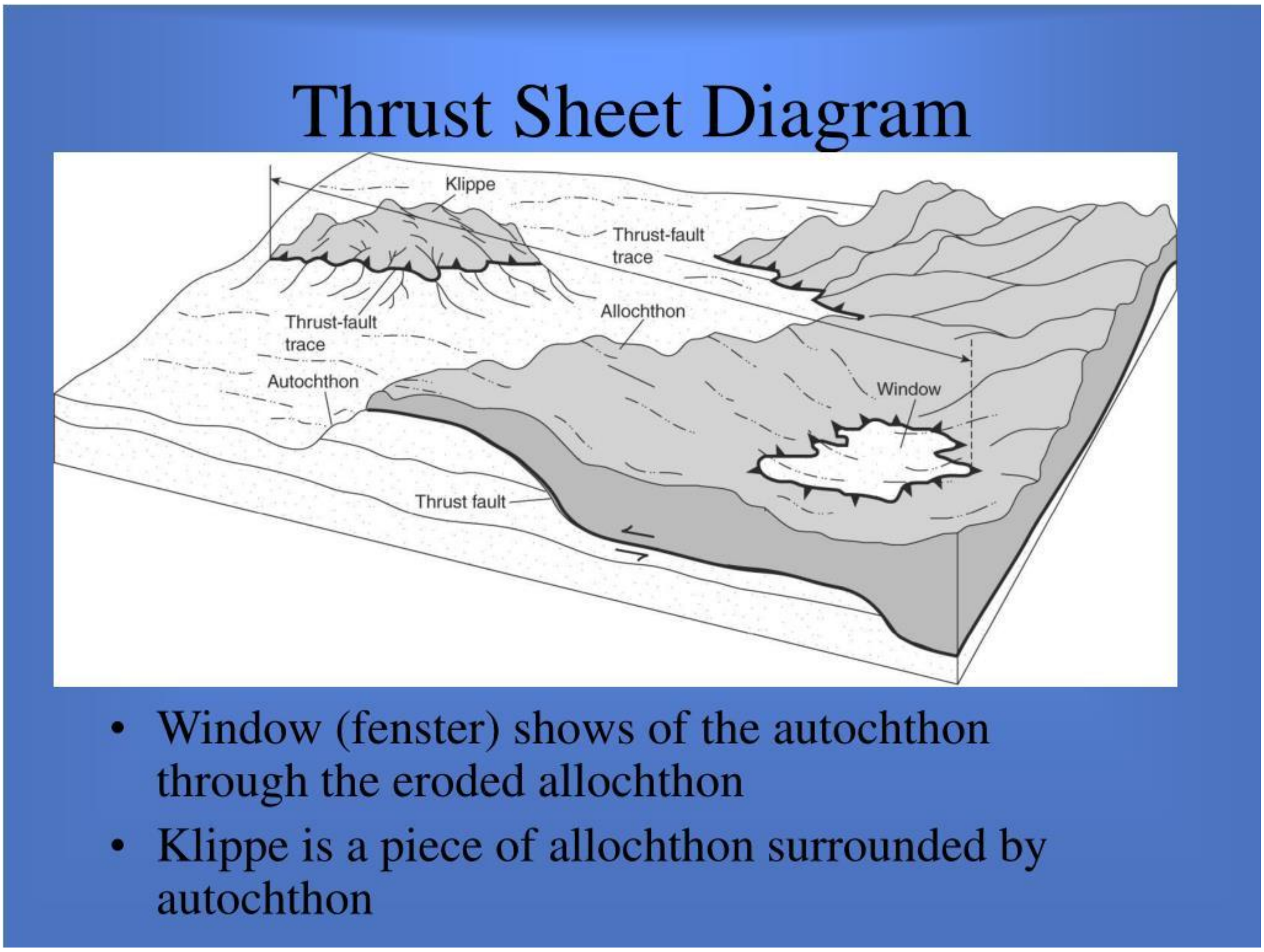


Figure 107: Units of a thrust sheet

3.4.4. Allochthonous and autochthonous units:

The nappes are a collection of allochthonous, uprooted terrains, which rest on an autochthonous bedrock via an anomalous contact:



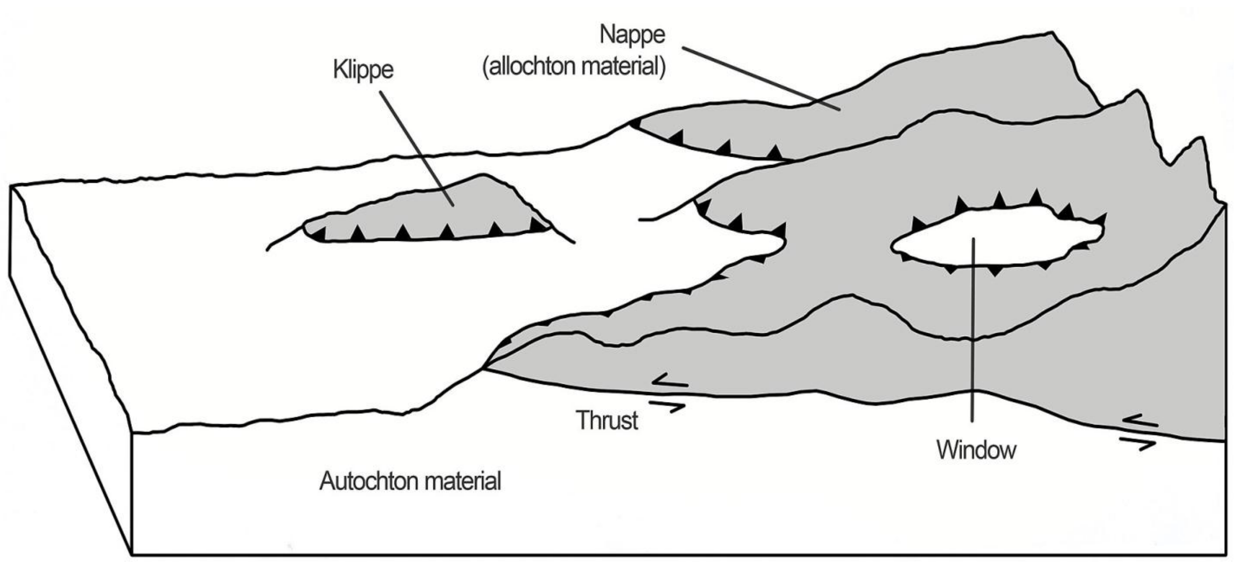


Figure 108: General structure of a thrust sheet

- Klippes: This is the result of clearing the erosion of the front part, the klippe is part of the overlapping unit.

- Windows: this is the result of clearing the erosion of part of the overlapping unit, giving a window onto the overlapped unit.

3.4.5. Different types of nappes :

*** Depending on the nature of the dominant rocks,** there are essentially 3 families:

- Cover nappes:

These are formed solely of sedimentary material detached from its original bedrock.

The rocks may have undergone varying degrees of metamorphism and may be schistose.

- Basement nappes:

- These are formed of metamorphic rocks and may overlie other basement units or sedimentary units.

- Ophiolitic nappes:

- These are composed of oceanic lithosphere (crust and mantle) and associated oceanic sediments.

- Their presence in chains (orogens) materializes the suture of an ancient oceanic domain.

* Depending on the driving force behind nappe displacement:

In addition to compressional forces, which cause thrusting and thrusting?

Gravity also plays a major role in the movement of sediments. This is referred to as a "gravity" sheet.

Note: this phenomenon occurs outside any tectonic context.

Ex. Slip of the sedimentary cover of continental margins.

There are two types of nappe:

- tectonic nappes.

- Gravitational nappes.

3.5. The formation of mountain ranges "orogenesis":

3.5.1 Introduction and definitions:

Mountain formation refers to the geological processes that underlie the formation of mountains. These processes are associated with large-scale movements of the Earth's crust (tectonic plates). Folding, faulting, volcanic activity, igneous intrusion and metamorphism can all be parts of the orogenic process of mountain building. The formation of mountains is not necessarily related to the geological structures found on it.

The understanding of specific landscape features in terms of the underlying tectonic processes is called tectonic geomorphology, and the study of geologically young or ongoing processes is called neotectonics.

See also: List of mountain types

There are five main types of mountains: volcanic, fold, plateau, fault-block and dome. A more detailed classification useful on a local scale predates plate tectonics and adds to these categories.

A mountain chain, or more precisely a folded chain, is a structurally complicated relief whose materials have been subjected to lateral pressure, giving rise to folds of varying complexity.

Chains correspond to compressed and shortened portions of crust, trapped between two plates that are approaching each other, superimposed on a zone of weakness in the crust. This zone generally corresponds to a geosyncline.

Orogenesis or tectogenesis, the birth of a folded chain, e.g. a chain like the Alps may have been folded before being uplifted, or at the same time.

* Orogenesis is the set of phenomena leading to the formation of a mountain chain.

Orogenesis, or orogeny, characterizes the set of geodynamic processes that depend on plate tectonics and lead to the formation of a mountain system in the broadest sense of the term.

An orogen results from the collision of two continental lithospheric plates of different nature and density.

2.5.2. The formation of mountain ranges:

Any model explaining the formation of a mountain range must explain and integrate the following main characteristics (of mountain ranges):

- Sedimentary rocks are very abundant in mountain ranges, and contain fossils of marine organisms:

This implies that the sediments from which they are derived were deposited in a marine environment; furthermore, their composition shows that a large proportion of these sediments were deposited in an ocean basin. First conclusion: before ending up in a mountain range, all the sedimentary material was in an ocean.

- There are also metamorphic rocks in mountain ranges.

These metamorphic rocks occupy a well-defined portion of the mountain range. Second conclusion: metamorphic rocks result from the transformation of sedimentary and igneous rocks of the mountain range, deep in the earth's crust.

- Mountain ranges often contain shreds of oceanic crust (basalts) trapped in faults.

Third conclusion: not only were the sediments that form the mountain range deposited in a marine basin, they were also deposited on basaltic oceanic crust.

- Another important feature (common to all major mountain ranges) is that the rocks are deformed to varying degrees.

Before the theory of plate tectonics, there was a superb debate between the "horizontalists", who believed that mountain ranges were formed by the action of lateral compression forces, and the "verticalists", who of course invoked great vertical forces.

At the time, plate movement was unknown, which left plenty of room for the imagination!

The theory of plate tectonics reconciles horizontalists and verticalists by proposing a model that takes into account lateral compression and uplift of an enormous mass of material, and by identifying the engine responsible for the forces required to form a deformed mountain range.

3.5.3. The main stages in the formation of a mountain range:

3.5.3.1. Obduction case:

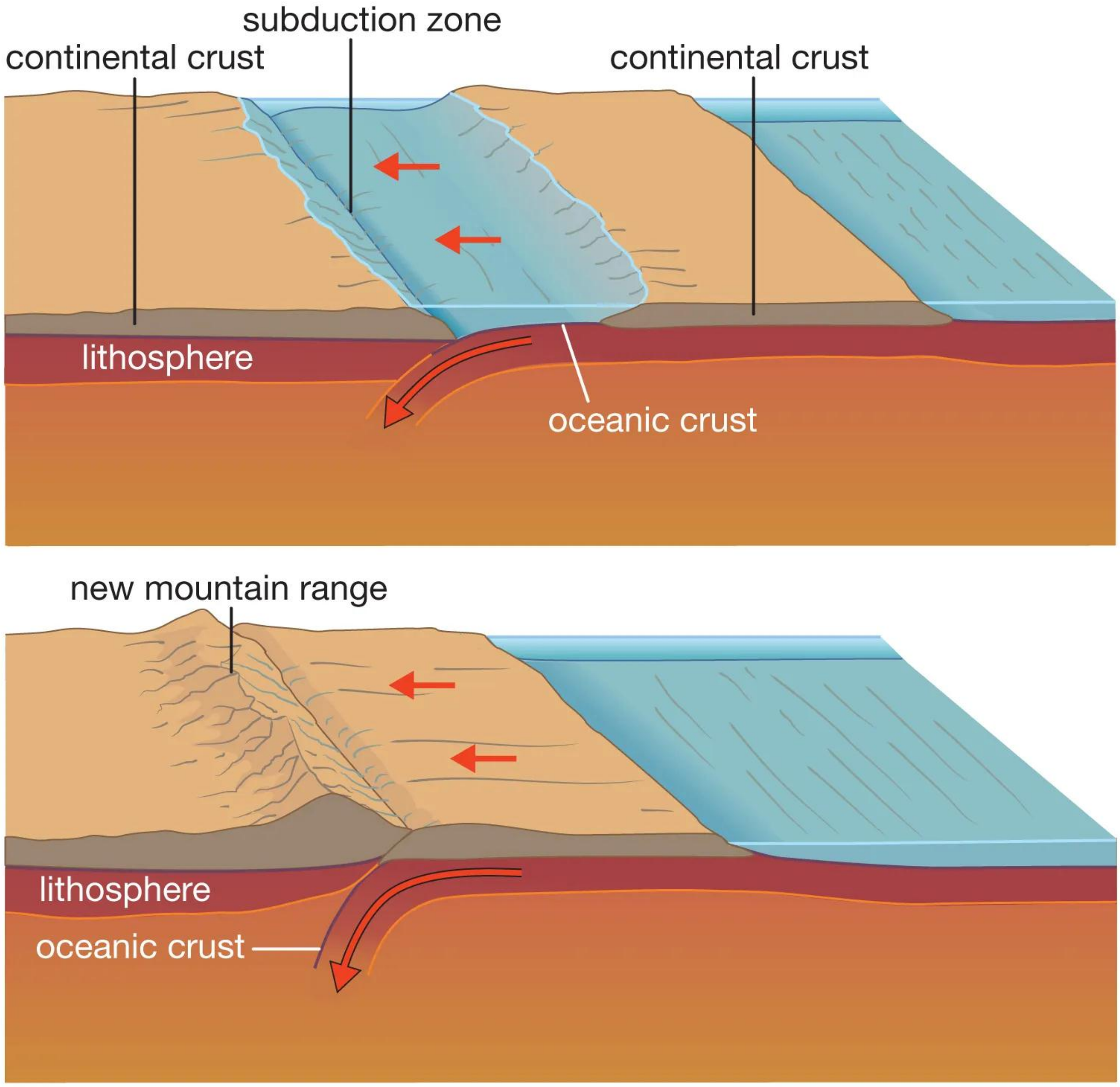
Let's start with a **passive continental margin:**

* A margin where there are no significant tectonic movements.

* Where there is no subduction zone.

* Where a prism of sediments from continental erosion accumulates on the continental shelf and margin.

Continental collision



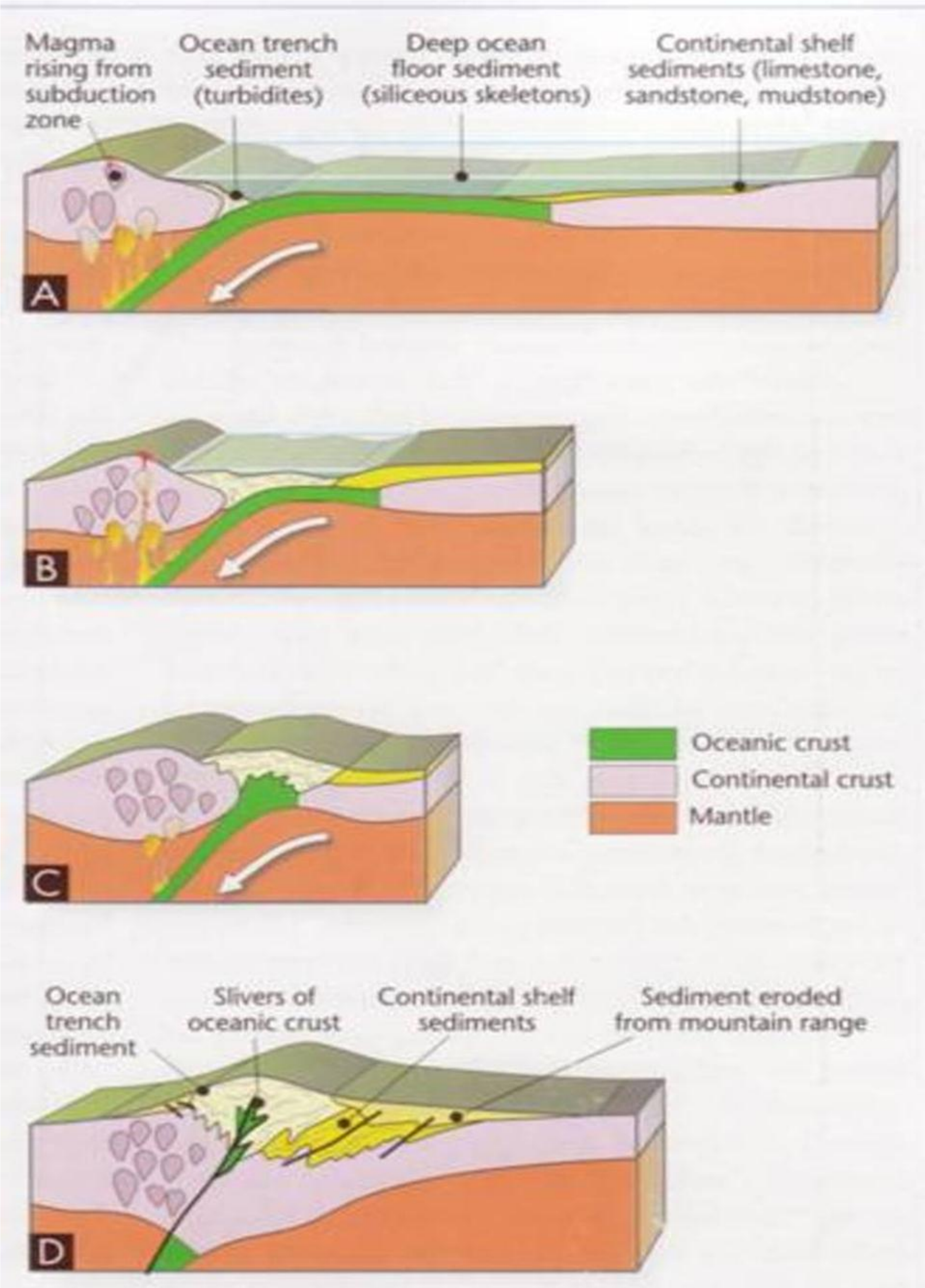


Figure 109: The main stages in the formation of a mountain range

At some point, this lithosphere fractures and one lip sinks beneath the other, creating a subduction zone.

The movement is then transformed into a system of collision between two plates:

We have moved from a passive to an active continental margin.

3.5.3.2. Subduction chains:

These form on active continental margins when an oceanic plate sinks beneath a continental plate. As it travels, the plunging plate rubs hard against the adjacent rocks, generating earthquakes and releasing intense heat, resulting in the formation of magma pockets that feed volcanoes.The continental plate accumulates at the plate boundaries, contributing to the formation of mountain ranges, e.g. the Andes.

The subduction zone becomes an obduction zone:

The collision between the volcanic arc and the continent creates a large overlap of all the material from the accretionary prism onto the continental margin.

Igneous activity ceases, and large masses of igneous rock (in red) can become trapped in the lithosphere.

With the collision of the two plates and the cessation of movement, the chain has reached its maximum height and acquired its characteristics.

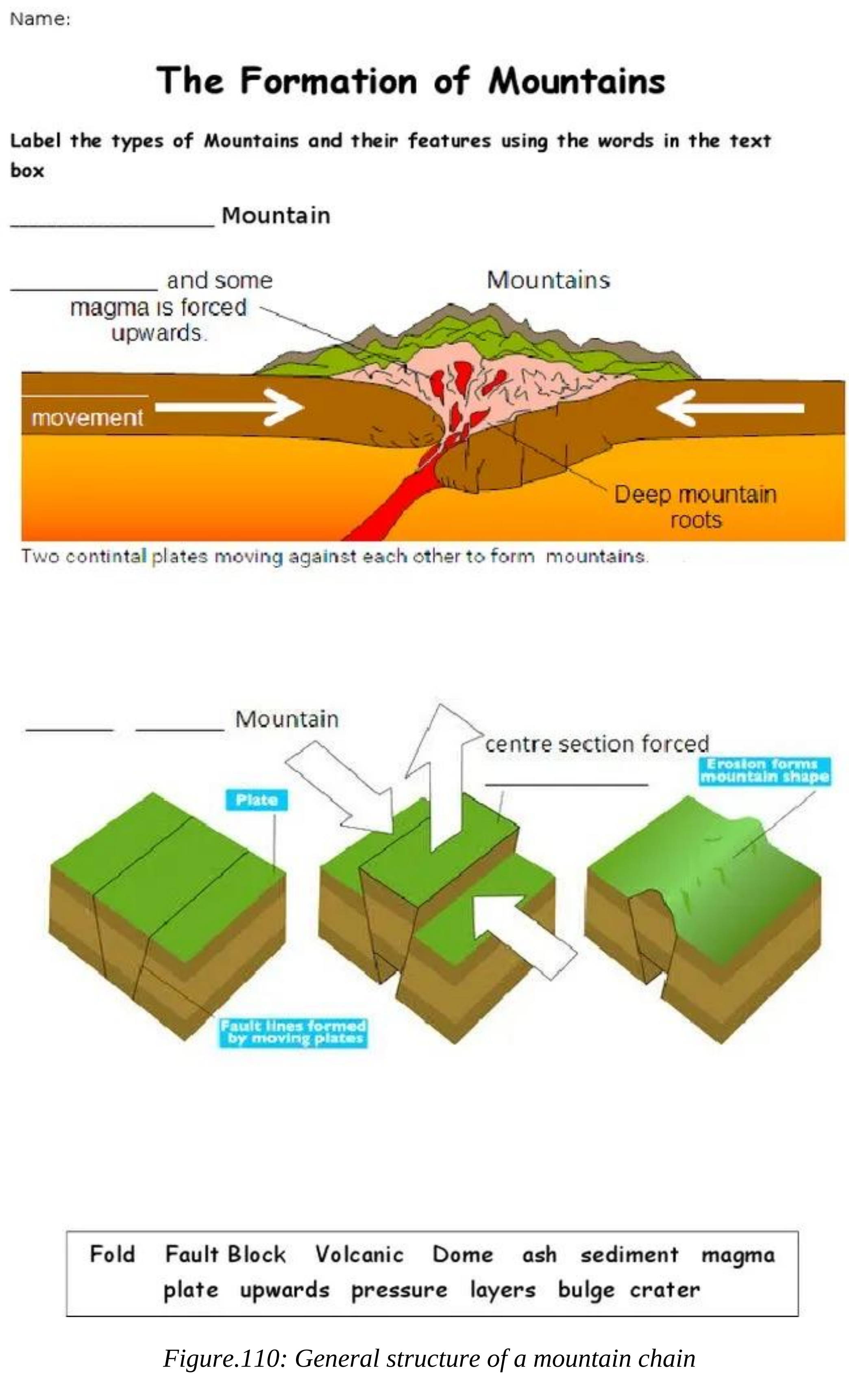


Figure.110: General structure of a mountain chain

Accretionary prism: *superimposition of scales on the front of a plate in certain subduction zones. It results from the planing of sediments (oceanic or eroded from continents) and fragments of* *oceanic crust belonging to the plunging plate, which are stopped by the rigid buffer formed by the overriding plate.*

B. Other cases:

Mountain formation (orogenesis) by continental collision:

1. A mountain range is born in an area of the globe where two tectonic plates converge:

When two continental lithospheres collide ("collision range", such as the Himalayas or the Alps).

When two continental plates of the same type and density collide, the engine of the mechanism stalls.

Because of their low density, it is not powerful enough to push one of the plates into the asthenosphere.

The two plates weld together to form a single plate.

- Obduction chains:

Part of the oceanic crust does not sink beneath the continent, but instead covers it. Obduction results from the blocking of subduction by the sinking of a continent beneath the mantle. C-a - d they form when a continent is drawn into a subduction zone, with the oceanic crust overlapping the continent through a series of thrust sheets. When subduction ceases, these light zones are lifted by isostatic readjustment, e.g. obduction chains in New Guinea.

- Collision chains:

These are the end result of the evolution of subduction and obduction chains. When the two continental blocks brought together by oceanic subduction come into contact, the shock produces the formation of a so-called collision chain, much wider than the initial subduction chain. If plate convergence continues, an intracontinental chain is formed, with a very wide fan-shaped structure. Ex: Himalayas, Tibet.

During collision, sedimentary material is transported upwards to form mountain ranges. At the contact between the two continental lithospheres, compression causes horizontal shortening, and hence vertical thickening, resulting in mountain ranges. Examples include the Himalayas, at the boundary between the Indian and Eurasian plates, and the Alps and Atlas ranges.

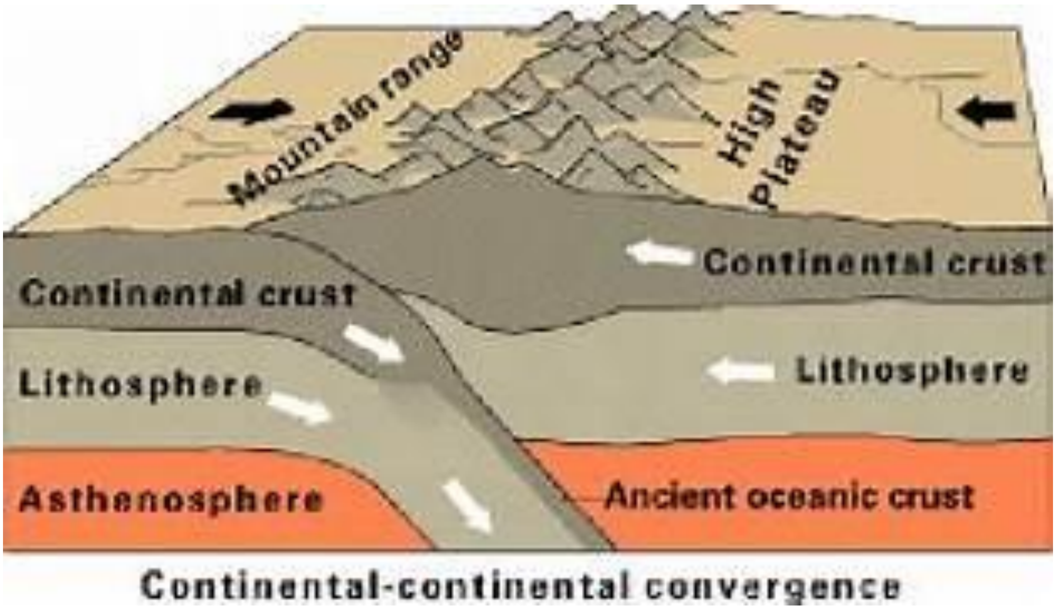


Figure 111: *Stages in the formation of a mountain chain by collision*

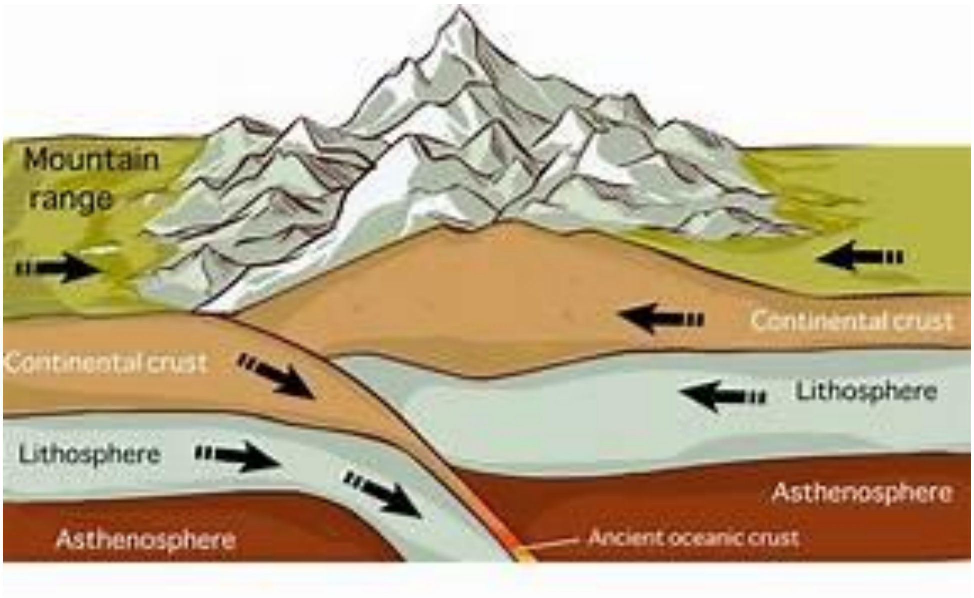


Figure 112: Continental crust thickening

RESULTS:

- Thickening of the crust with presence of a crustal root,

- Presence of ophiolite and partial melting of continental crust rocks.

There will be a zone of undeformed rocks adjoining the deformed rocks of the chain, sometimes symmetrically on either side of the chain. There will also be highly deformed metamorphic rocks at the roots of the chain, as these are formed under very high temperatures and pressures. There will also be shreds of basaltic oceanic crust trapped in faults.

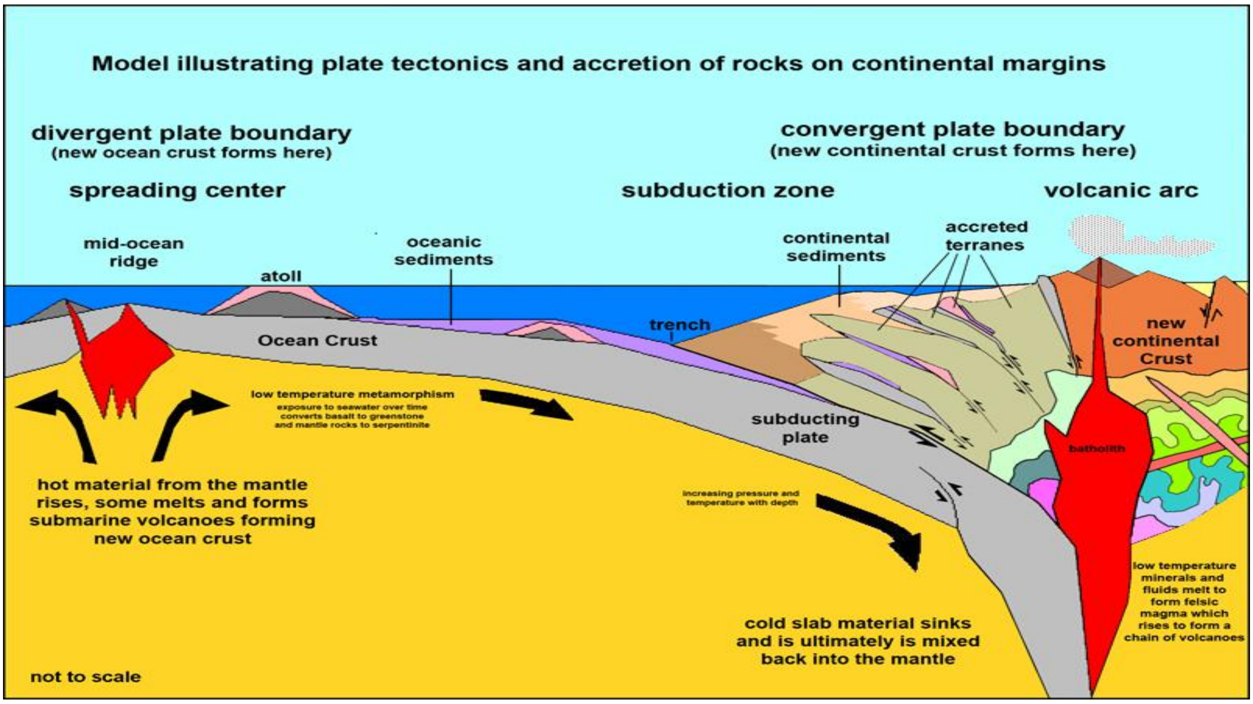


Figure 113: The formation of an accretionary prism

When they collide with a large continental plate, these terrains are torn away from the plate that carries them and stuck to the margin of the large continental plate, as their density is too low for them to be embedded in the asthenosphere. Several of these "exotic" pieces can accumulate in this way.