

Origin of Mountains

DRB/Mountain Group/TU-CDES-Semester II-2019

OROGENESIS

The process of mountain formation, especially by folding and faulting of the Earth's crust and by plastic folding, metamorphism, and the intrusion of magmas in the lower parts of the lithosphere.

Based on its origin there are four TYPES OF MOUNTAINS

1. Fold mountains
2. Block mountains
3. Volcanic mountains
4. Residual mountains

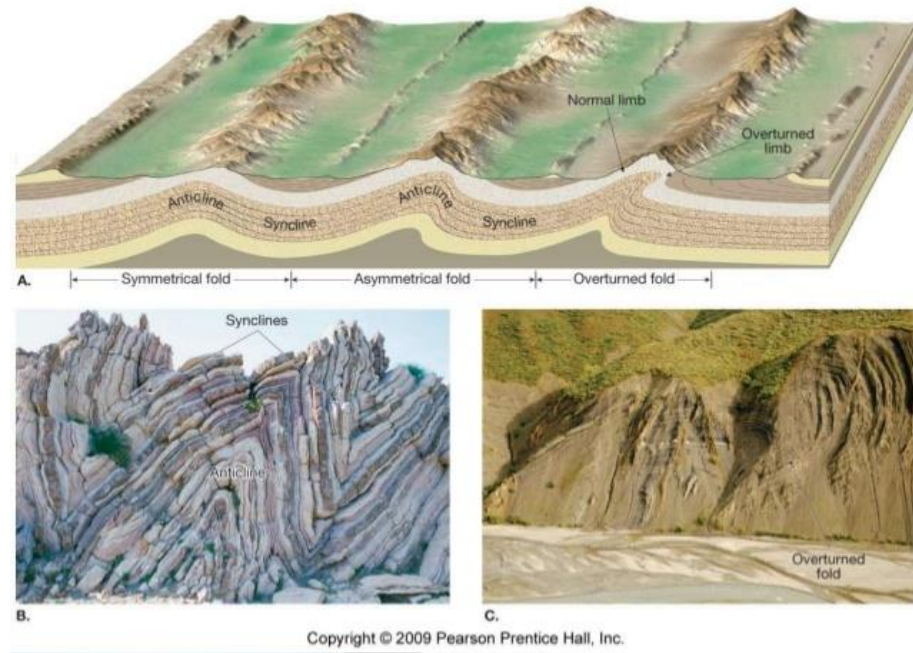
ISOSTASY

The equilibrium that exists between parts of the earth's crust, which behaves as if it consists of blocks floating on the underlying mantle, rising if material (such as an ice cap) is removed and sinking if material is deposited.

FOLD MOUNTAINS: Mountains formed by the effects of folding on layers within the upper part of the Earth's crust. Before either plate tectonic theory developed, or the internal architecture of thrust belts became well understood, the term was used for most **mountain** belts, such as the Himalayas.

Fold Mountains

- Formed due to folding of crustal rocks by compressive force
- When the tectonic plates collide, the edges crumple as they are pushed together and the rock of the Earth surface pushed up to create mountains
- Sediments are found up to great depth
- Examples: Himalaya, Andes, Atlas, etc.





Zagros Mountains © Stefan Jürgenson , Flickr

Block Mountain

- Formed due to faulting by compressive force
- Represent the up standing parts of the ground between two fault or either side of a rift valley
- When cracks in the Earth's surface open up, large chunks of rock can be pushed up while others are pushed down. This creates mountains with a long slope on one side, and a sharp drop on the other.
- Also called horst mountains
- Examples: Sierra Nevada in California



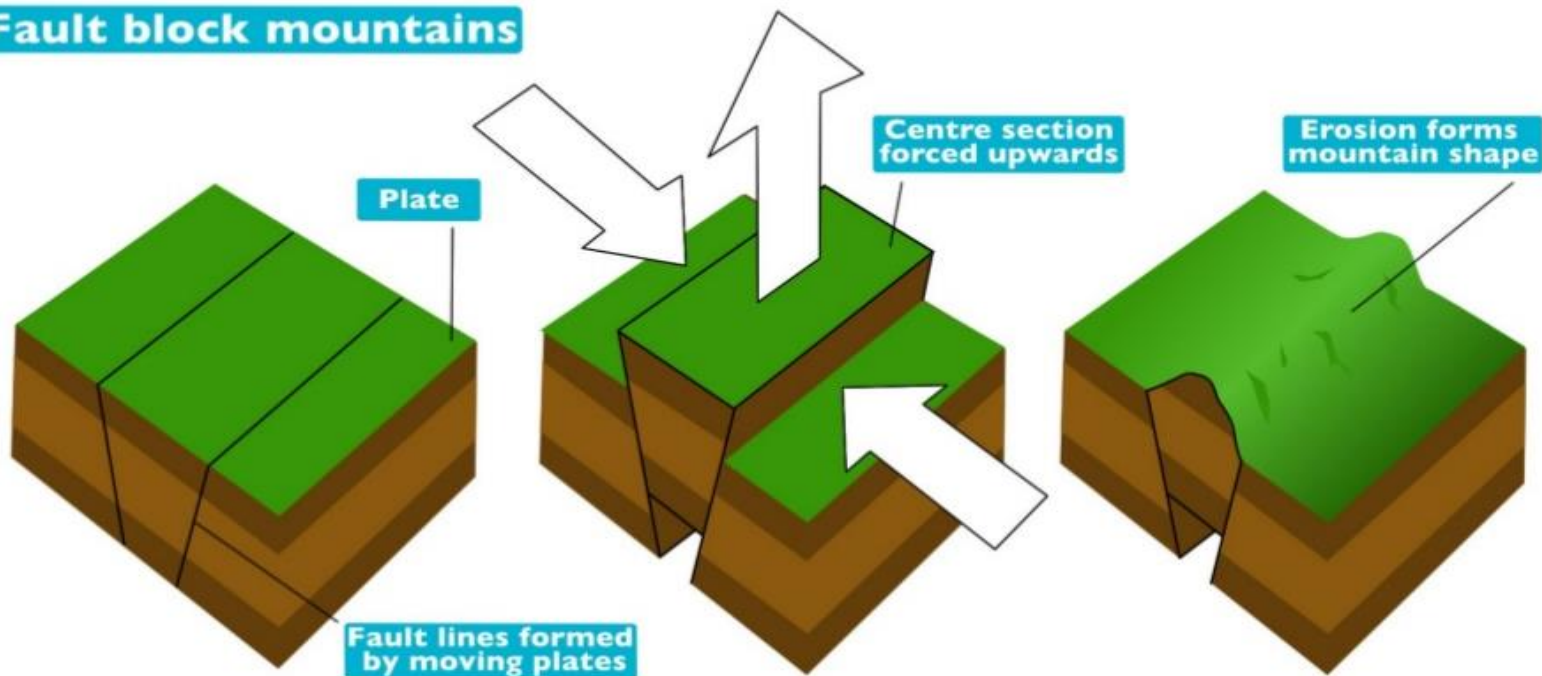
Sierra Nevada

Fault block mountains

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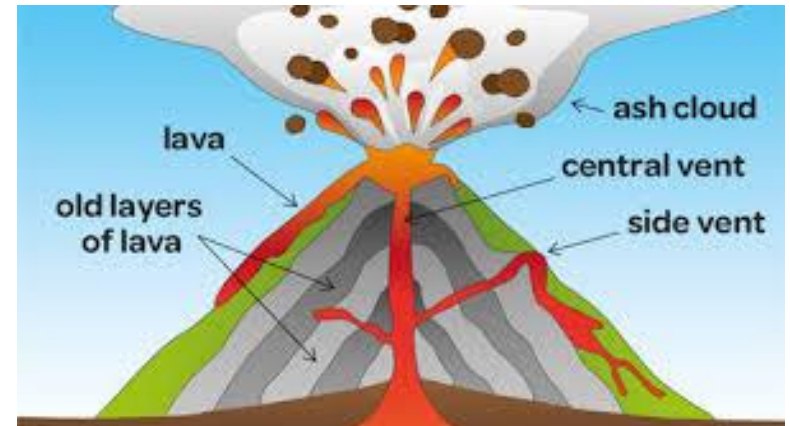
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Fault block mountains



Volcanic Mountains

- Volcanic mountains are smooth and round-looking
- They are formed when magma from the Earth's crust and mantle gets pushed up, but doesn't ever flow out- so, all the magma makes the land bubble up like a balloon.



- Formed around volcanoes, which are vents in the Earth's top layer that let through magma from between the crust and the mantle layers.
- Mountains are made of ash and cooled lava.

Example: Mount Fuji
the highest mountain in Japan at 3,776.24 m It is Active stratovolcano that last erupted in 1707–1708. South-west of Tokyo; Exceptionally symmetrical cone, which is snow-capped for about 5 months a year.



Residual Mountains

- Formed due to difference in weathering process
- Formed because of materials being taken away through erosion, which has left deep valleys or gorges near to the high cliffs.
- Also known as Plateau Mountain
- Example: Aravalli range, Nilgiri range



Theories of Mountain Formation

- **Thermal Contraction Theory:** Harold Jeffery (1891-1989); theory was based on mathematical reasoning; contraction resulting partly from cooling of the earth due to loss of heat through radiation from the earth's surface and partly from the decrease of the speed of the earth's rotation; Opponent of "Continental Drift"
- **Radioactive Theory:** John Joly; The expansion and contraction of the substratum are based on the mechanism of heat generated by radioactive elements of the rocks. History of the Earth, 1925
- **Expansion Theory:** JE Conte 1893
- **Isostatic Theory:** CE Dutton 1855; the earth's crust is supported by underlying denser material, and that the weight of mountains is balanced by light material extending as roots into the denser mantle.
- **Geosyncline Orogen Theory:** Kober

THEORIES OF THE ORIGIN OF MOUNTAIN RANGES.

Prof. Le Conte began by stating those fundamental features of the structure of mountain ranges on which every true theory of their origin must be founded. These features are : (1) Thickness of mountain sediments ; (2) coarseness of mountain sediments ; (3) folded structure of mountains ; (4) cleavage structure ; (5) granite or metamorphic axis ; (6) asymmetric form.

not included under the above heads, are those only found in the Basin and Plateau regions, and therefore termed the Basin region type. In fact, "mountains may be divided into two types, viz. mountains formed by folding of strata, and mountains formed by tilting of crust-blocks.

Summary Statement of the Formal Theory.

(1) "Mountain ranges, while in preparation for future birth, were marginal sea-bottoms receiving abundant sediment from an adjacent land-mass and slowly subsiding under the increasing weight. (2) They were at first formed and continued for a time to grow, by lateral pressure crushing and folding the strata together horizontally and swelling them up vertically along a certain line of easiest yielding. (3) That this line of easiest yielding is determined by the hydrothermal softening of the earth's crust along the line of thickest sedimentation. (4) That this line by softening becomes also the line of greatest metamorphism, and by yielding the line of greatest folding and greatest elevation. But (5) when the softening is very great, sometimes the harder lateral strata are jammed in under the crest, giving rise to fan-structure, in which case the most complex foldings may be near but not at the crest. Finally (6) the mountains thus formed will be asymmetric because the sedimentary cylinder-lenses from which they originated were asymmetric."

What is the cause of Lateral Pressure?

The Contraction Theory.

“The most obvious view of the cause of lateral pressure refers it to the *interior contraction of the earth*. This theory is so well known that I will give it only in very brief outline. It assumes that the earth was once an incandescent liquid, and has cooled and solidified to its present condition. At first it cooled most rapidly at the surface, and must have fissured by tension. But there would inevitably come a time when the surface, being substantially cool, and, moreover, receiving heat also from the sun, its temperature would be fixed, or nearly so, while the incandescent interior would be still cooling and contracting. Such has probably been the case ever since the commencement of the *recorded* history of the earth. The hot interior now cooling and contracting more rapidly than the cool crust, the latter, following down the ever-shrinking nucleus, would be thrust upon itself by lateral pressure with a force which is simply irresistible. If the crust were ten times, yea, one hundred times more rigid than it is, it must yield. It does yield along the lines of greatest weakness, *i.e.* along marginal sea-bottoms, as already explained. As a first attempt at a physical theory, it seems reasonable, and therefore until recently has been generally accepted.”

Criticism to Contraction Theory

(1) “Mathematical physicists assure us that on any reasonable premises of initial temperature and rate of cooling of the earth, the amount of lateral thrust produced by interior contraction would be wholly insufficient to account for the enormous foldings (*Cam. Phil. Trans.*, vol. xii. Part 2, December, 1873).

(2) “Again, Dutton (*Am. Jour.* vol. viii. p. 13, 1874; *Penn. Monthly*, May 1876) has shown that in a rigid earth it is impossible that the effects of interior contraction should be concentrated along certain lines so as to form mountain ranges, because this would require a shearing of the crust on the interior. The yielding would be evenly distributed everywhere, and therefore imperceptible anywhere. This is probably true,

I. Reade's Expansion Theories.

This, the most prominent among alternative theories, was first brought forward in Mr. Reade's book on "Origin of Mountain Ranges." Although I have carefully read all that Mr. Reade has written on this subject, I find it difficult to get a clear idea of his views. But as I understand it, it is in outline as follows: (1) Accumulation of sediments off shore, and isostatic subsidence of the same. (2) Rise of isogeotherms and heating of the whole mass of sediments and of the underlying crust in proportion to the thickness of the sediments. (3) Expansion of the whole mass in proportion to the rise of temperature. If there were no resistance this expansion would be in all directions (cubic expansion). (4) But since the containing earth will not yield to expansion laterally, this lateral expansion is satisfied by folding, and this in turn produces vertical upswelling. Thus the whole cubic expansion is converted into vertical expansion, which is therefore three times as great as the linear expansion in any one direction. (5) Elevation would of course anyhow be greatest along the line of thickest sediment; but this by itself would not be sufficient to produce a mountain. (6) But farther

*II. Dutton's Isostatic Theory.*¹

“Dutton's discussion of isostasy is admirable, but his application of it to the origin of mountains is weak. The outline is as follows :—

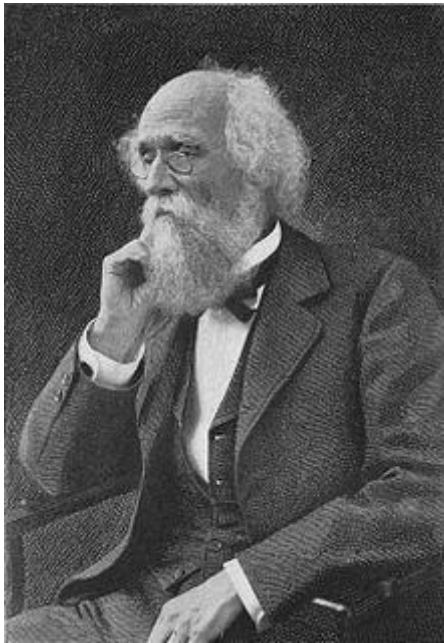
“Suppose a bold coast line, powerful erosion and abundant sedimentation. The coast rises by unloading, and the marginal sea-bottom sinks by loading. Now, if isostasy is perfect, there will be no tendency to mountain formation. But suppose a piling up of sediments—but on account of earth rigidity—without immediate compensatory sinking, and a cutting down of coast land without compensatory rising. Then there would be an isostatic slope towards the land. And the accumulated and softened sediments would slide landward, crumpling the strata and swelling them up into a mountain range.

III. Reyer's Gliding Theory.¹

“Prof. Reyer has recently put forward certain views fortified by abundant experiments on plastic materials. His idea in brief seems to be this: strata are lifted and finally broken through by uprising fused or semi-fused matters, and these appear above as the granitic axis. As the axis rises, the strata are carried upward on its shoulders, until when the slope is sufficiently steep the strata slide downward, crumpling themselves into complex folds and exposing the granitic axis in width proportioned to the amount of sliding.

Conclusion.

“After this rapid discussion of alternative theories, in which we have found them all untenable, we return again to the contraction theory, not indeed with our old confidence, but with the conviction that it is even yet the best working hypothesis we have.”



Joseph Le Conte (1823 – 1901) was a physician, geologist, professor at the University of California, Berkeley and early California conservationist.
1844: travelled for over one thousand miles along the Upper Mississippi River
1845: Graduation in medicine, and practice
1848: entered Harvard Univ., studied natural history
1874: nominated to the National Academy of Sciences
1892: President of the American Association for the Advancement of Science

Geosynclinal Orogen Theory of Kober

- Old rigid masses included: Canadian Shield, Baltic Shield or Russian Massif, Siberian Shield, Chinese Massif, Peninsular India, African Shield, Brazilian Mass, Australian and Antarctic rigid masses
- Eight morphotectonic units can be identified on the basis of the description of the surface features of the earth during Mesozoic era: (i) Africa together with some parts of Atlantic and Indian Oceans, (ii) Indian, (iii) Australian land mass, (iv) Eurasia, (v) North Pacific continents, (vi) South Pacific continents, (vii) South America and (viii) Antarctica etc.
- Identified 6 major periods of mountain building:
Pre-cambrian (4,600 - 541 mi yrs ago) :
Three mountain building periods
Palaeozoic (541 to 252 m yrs ago):
Two major mountain building periods
Tertiary epoch (65 - 63.2 m yrs ago):
One

Geosynclinal Orogen Theory of Kober

- Considered the old rigid masses as the foundation stones of the present continents; present continents have grown out of rigid masses.
- Geosyncline is a geological concept which was developed in the late 19th and early 20th centuries before the concept of plate tectonics was developed. A geosyncline was described as a subsiding linear trough that was caused by the accumulation of sedimentary rock strata deposited in a basin and subsequently compressed, deformed, and uplifted into a mountain range, with attendant volcanism and plutonism.

Kober's Process of Mountain Building

1. Lithogenesis: creation of geosynclines due to the force of contraction caused by cooling of the earth;
2. Orogenesis: Both forelands start to move towards each other because of horizontal movements caused by the force of contraction resulting from the cooling of the earth. The compressive forces generated by the movement of forelands together cause contraction, squeezing and ultimately folding of geosynclinal sediments to form mountain ranges.
3. Gliptogenesis: Gradual rise of mountains and their denudation by fluvial and other processes.

Leopold Kober (1883 – 1970)
Austrian geologist

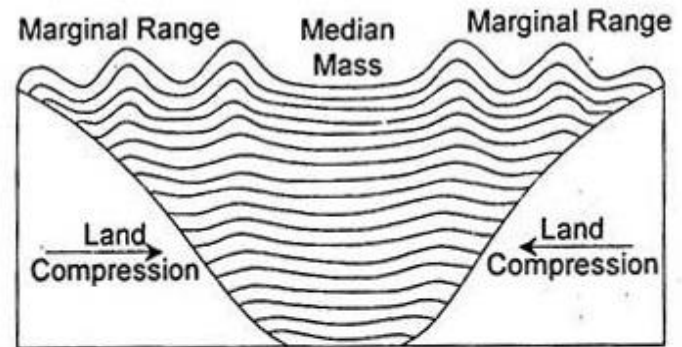


Fig. 11.5: The stage of orogenesis: squeezing and folding of geosynclinal sediments due to compressive forces; the whole of geosynclinal sediments are folded when the compressive forces coming from the sides of geosyncline is enormous and acute.

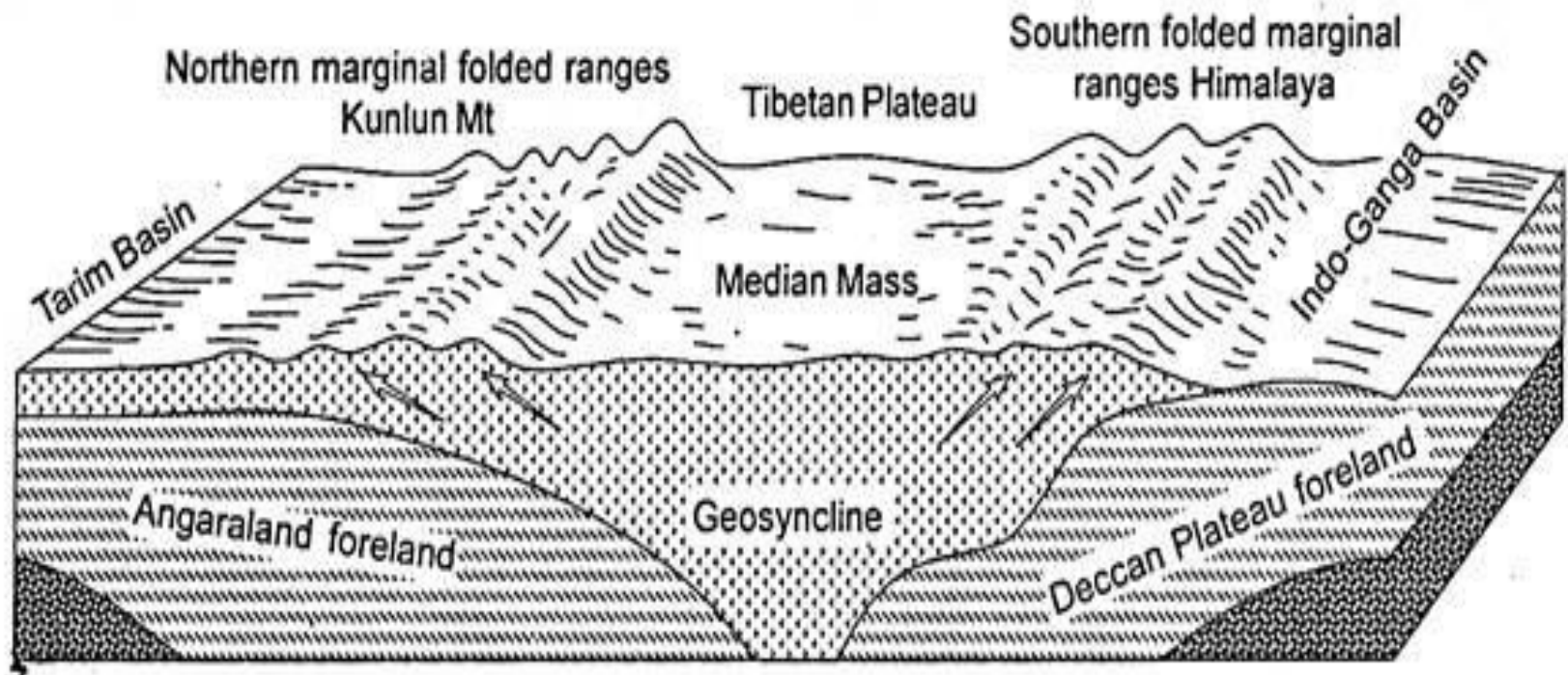
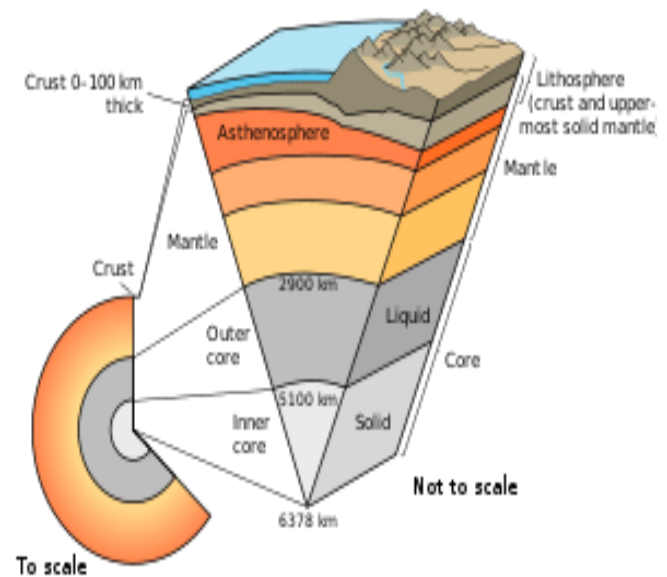


Fig. 11.9 : Illustration of Kober's median mass through Tibetan plateau between Kunlun and Himalaya.

Plate Tectonic Theory

- Alfred Wegener in 1912
- Outcome of combined efforts of many scientists of different countries working together and separately; Came into light in the 1960s; Envisages the formation of mountains due to collision of plate boundaries.
- The rigid lithospheric slabs or rigid and solid land masses having a thickness of about 100km composed of earth's crust and some portion of upper mantle are technically called 'plates'. The term 'plate' was first used by Canadian geologist J.T. Wilson in 1965.



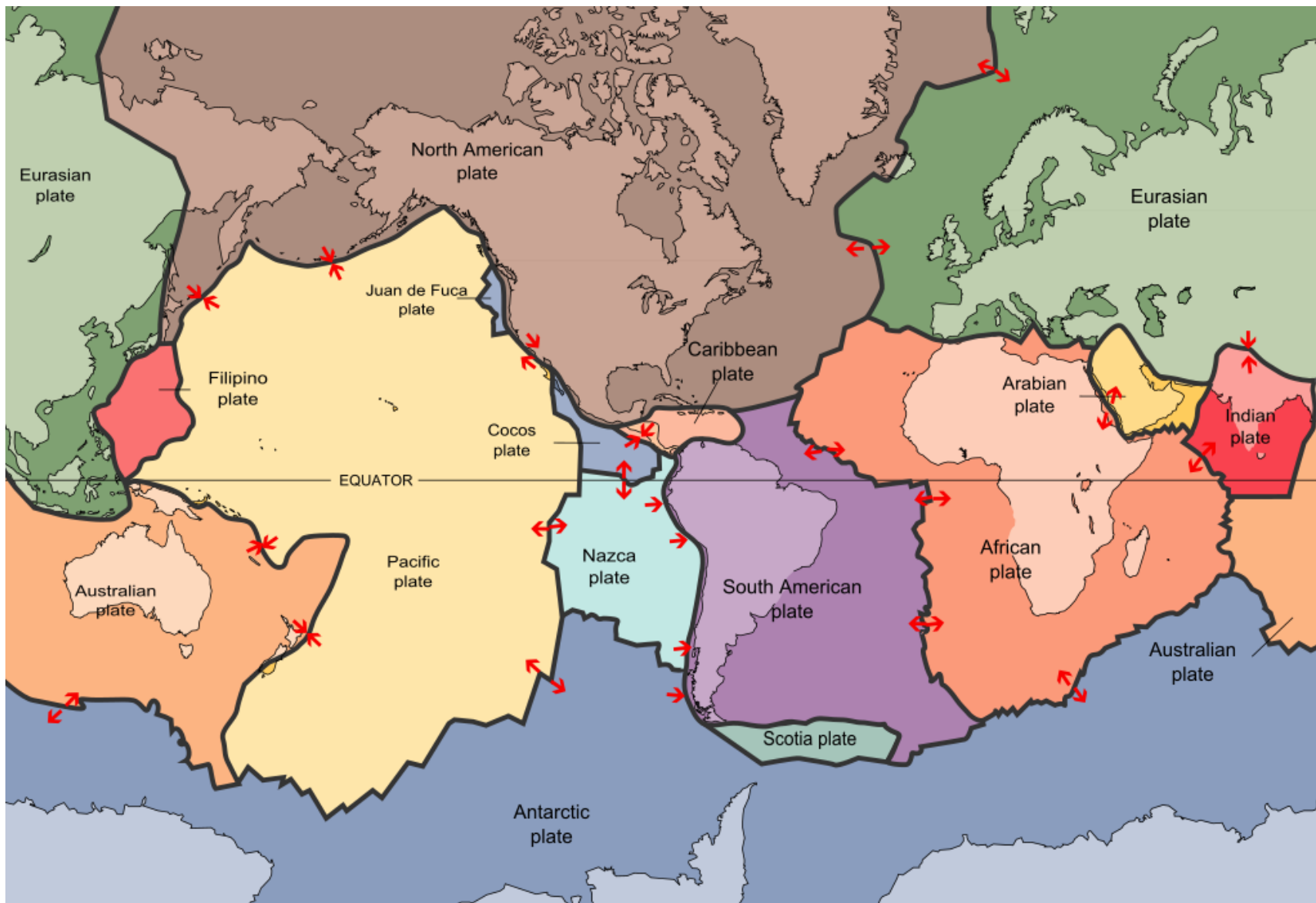


Plate Boundaries

Mountain Formation

- Constructive plate boundaries
- Destructive plate boundaries: boundaries are those where two plates collide against each other and the leading edge of one plate having relatively lighter material overrides the other plate
- Conservative plate boundaries.

According to plate tectonic theory mountains are formed due to collision of two convergent plates. Mountains are always formed along the destructive plate boundaries. It is obvious that the process of mountain building is associated with destructive plate boundaries of two convergent plates.

Suggested Readings:

- Byers AC, Price LW, Price MF. 2013. Introduction to Mountains. In: Price MF, Byers AC, Friend DA, Kohler T, Price LW (Eds.), Mountain Geography: Physical and Human Dimensions, University of California Press, Berkeley, 1-10.
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