Plate tectonic theory and its evidences

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Abstract

Plate Tectonics is the theory which explains the origin, history and movement of rigid tectonic plates of Earth's lithosphere. Global and local plate tectonic activities, for example, movement and shifting of plates creating faulting and folding, and vertical and horizontal displacement of locations in relation to adjacent locations. Seafloor spreading and drifting of continents, mountain building by folding near the coast, creation of deep channels by faults, volcanoes, terraces and cliffs by vertical displacement, ocean trenches, Island archs etc. are explained through this massive idea.

Introduction:

Earth is an active planet and it's surface composed of many individual plates, that move and interact, constantly changing and reshaping Earth's outer layer. Plate tectonics is a scientific theory which exposed and explained the large-scale motion of a number of large rigid blocks and the movements of a larger number of smaller blocks of the Earth's lithosphere which are named as plates (Plate tectonics, Wikipedia). Tectonic theory has built on the conception of continental drift theory, the idea given by Alfred Wegener during the beginning of 20th Century. The geoscientific society received the hypothesis after seafloor spreading was accepted in the middle of 20th Century. These whole processes explained the tectonic processes began about 3-3.5 billion years ago on Earth's lithosphere (Stern, 2007). Numerous research, geological modeling are performed and still going on to find the precise exposure of plates formation, movement and resulting phenomena of plates.

The lithosphere of the Earth's crust is the tenacious outermost shell of a planet (the crust and upper mantle), is broken into tectonic plates. According to the analysis of plate tectonic theory, the Earth's lithosphere is composed of seven or eight major plates and 50 in total with number minor plates (Anderson, 2002). This theory explains the plates are independent to each other i. e. they move with their own mechanism. Where the plates meet, their relative motion determines the type of boundary: convergent, divergent, or transform. Earthquakes, volcanic activity, mountain-building, and oceanic trench formation occur along these plate boundaries. The relative movement of the plates typically ranges from zero to 100 mm annually (Read and Watson, 1975). But the reason behind these boundaries or movements is the process of their formation and the whole system is linked to each other and theirs functional processes.

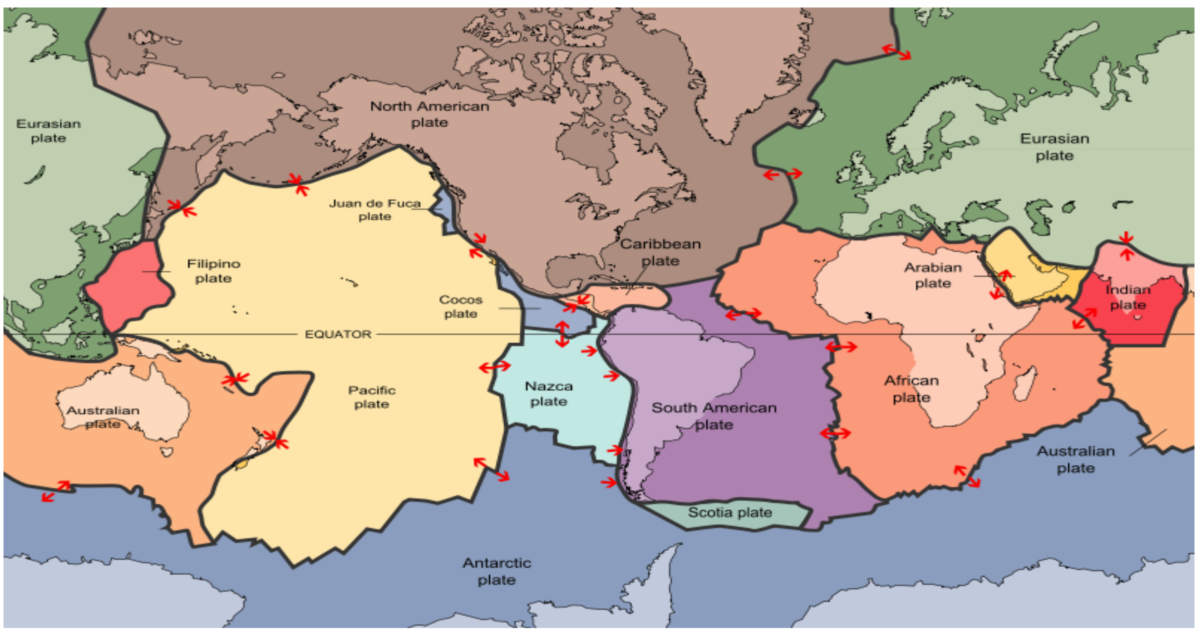

Figure-1: The tectonic plates of the world were mapped in the second half of the 20th century (https://www.livescience.com/37706-what-is-plate-tectonics.html).

Types:

Earth's crust mainly contains two basic types of plates; Oceanic and Continental. Both of them hold the surface but the functions and structural composition is quite different. The oceanic plates are much heavier and denser than the continental plates but it is a lot thinner than the continental plate. The ocean plates are about 8-9 km where continentals are 35-70 km in thickness. These ocean surface blocks made up of heavy basaltic materials which are high in Mg and Fe e.g. basalt, gabbro, peridotite etc. On the other hand continental plates are less dense and less heavier thick blocks which are mainly composed of SiAlic materials e.g. granitic rocks, and quartz, feldspar like lightweight minerals. One of the main variation between these two plates are, the oceanic plates are new because there are always created and destroyed whereas, the continental plates are mostly conserved (USGS).

Plate Boundaries:

The location of the meeting place of two plates is known as Plate boundaries. On Earth there are three types of plate boundaries exist (Meissner, 2002). These plates are characterized by the nature of their movement relative to one another. Plate boundaries are commonly associated with global geological events such as the creation of topographic features such as mountains, oceanic trenches, volcanoes, mid-ocean ridges and also the occurrences of earthquakes (Figure-2). The majority of the world's active volcanoes occur along plate boundaries, such as the Pacific's Ring of Fire. Some volcanoes occur in the interiors of plates, and these have been variously attributed to internal plate deformation (Foulger, 2010) and to mantle plumes. They are associated with different types of surface phenomena. The different types of plate boundaries are (USGS)_

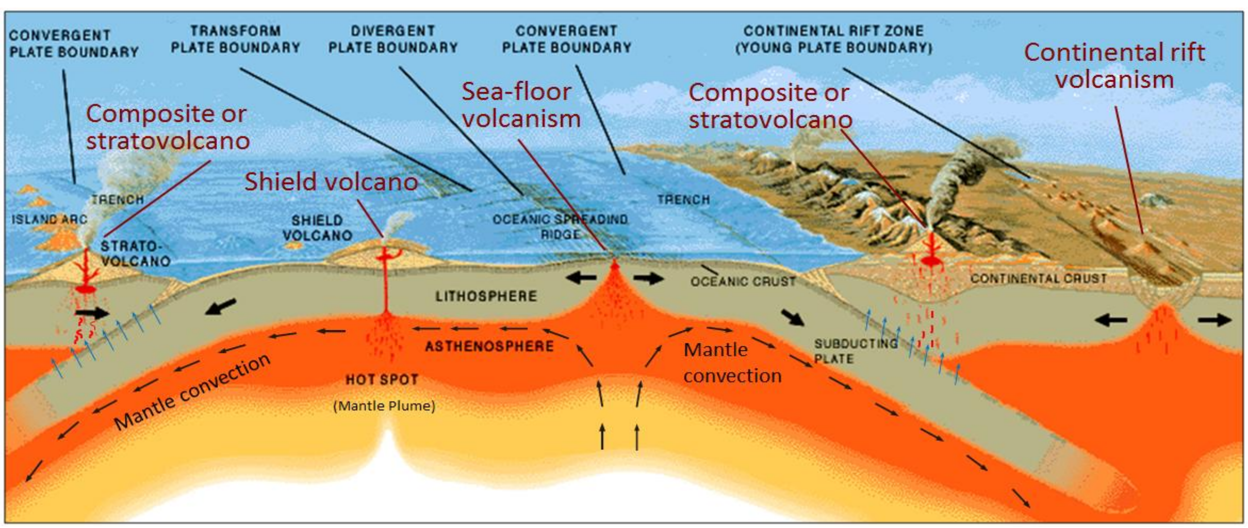

Figure-2: Plate boundaries with formation mechanism

Divergent Boundaries: Divergent boundaries occur along spreading centers where plates are moving apart and new crust is created by magma pushing up from the mantle. When two giant conveyor belts of mantle, facing each other but slowly moving in opposite directions as they transport newly formed oceanic crust away from the ridge crest.

Perhaps the best known of the divergent boundaries is the Mid-Atlantic Ridge. This submerged mountain range, which extends from the Arctic Ocean to beyond the southern tip of Africa. The rate of spreading along the Mid-Atlantic Ridge averages about 2.5 centimeters per year (cm/yr) and the East Pacific Rise is about 16 cm/yr. This rate may seem slow by human standards, but because this process has been going on for millions of years, it has resulted in plate movement of thousands of kilometers. Seafloor spreading over the past 100 to 200 million years has caused the Atlantic Ocean to grow from a tiny inlet of water between the continents of Europe, Africa, and the Americas into the vast ocean that exists today.

Convergent Boundaries: The size of the Earth has not changed significantly during the past 600 million years, and very likely not since shortly after its formation 4.6 billion years ago. The type of convergence called by some a very slow collision that takes place between plates depends on the kind of lithosphere involved. Convergence can occur between an oceanic and a largely continental plate, or between two largely oceanic plates, or between two largely continental plates. The Earth's unchanging size implies that the crust must be destroyed at about the same rate as it is being created, as Harry Hess surmised. Such destruction (recycling) of crust takes place along convergent boundaries where plates are moving toward each other, and sometimes one plate sinks or subducted under another and results oceanic trench.

The location where sinking of a plate occurs is called a subduction zone and where it goes over the continental or oceanic plate it is called obduction. In the convergent boundaries of two oceanic plates, it occurs usually but it is a little rare between oceanic plate obducted over continental plate. Hence, the collision between two continental plates result mountains e.g. Mount Everest.

Transform Boundaries: Transform boundaries occur where two lithospheric plates slide past each other along transform faults, where plates are neither created nor destroyed. The relative motion of the two plates is either sinistral or dextral. Transform faults occur across a spreading center. Strong earthquakes can occur along a fault. The San Andreas Fault, located in California, USA is a great example of a transform boundary exhibiting dextral motion.

Driving forces of Plate's motion:

The mechanism of plate's movement is not very well known. But scientific community has by and largely been accepted that tectonic plates are able to move because of the relative density of oceanic lithosphere and the relative weakness of the asthenosphere. Dissipation of heat from mantle is acknowledged to be the original source of the energy required to drive plate tectonics through convection or large scale upwelling and doming. The current view, though still a matter of some debate, asserts that as a consequence, a powerful source of plate motion is generated due to the excess density of the oceanic lithosphere sinking in subduction zones. When the new crust forms at mid-ocean ridges, the underlying asthenosphere is initially more dense than this oceanic lithosphere, but it becomes denser with age as it conductively cools and thickens. The greater density of old lithosphere relative to the underlying asthenosphere allows it to sink into the deep mantle at subduction zones, providing most of the driving force for plate movement. The weakness of the asthenosphere allows the tectonic plates to move easily towards a subduction zone. Although subduction is thought to be the strongest force driving plate motions, it cannot be the only force since there are plates such as the North American Plate which are moving, yet are nowhere being subducted (BABEL). The sources of plate motion are a matter of intensive research and discussion among scientists. Some of the main points is that the kinematic pattern of the movement itself should be separated clearly from the possible geodynamic mechanism that is invoked as the driving force of the observed movement, as some patterns may be explained by more than one mechanism (van Dijk, 1992). In short, the driving forces advocated at the moment can be divided into three categories based on the relationship to the movement: mantle dynamics related, gravity related (mostly secondary forces), earth rotation related and there is also relative significance of each driving force mechanism.

Evidences of Plate tectonics theory:

The geologists have researched a lot on the Earth's inner and outer surface activities and found quite a lot evidences that exposes the plate tectonic theory. Some are earlier evidences and some are described discovered through modern technologies. Some of these are discussed in short below.

Seafloor spreading: Earlier theories (e.g. by Alfred Wegener) of continental drift were that continents "ploughed" through the sea. The idea that the seafloor itself moves pushes the continents as it expands from a central axis was proposed by Harry Hess in the middle of 20t century (Hess et.al., 1962). It is a process that occurs at mid-ocean ridges, where new oceanic crust is formed through volcanic activity and then gradually moves away from the ridge. Seafloor spreading helps explain continental drift in the theory of plate tectonics. When oceanic plates diverge, tensional stress causes fractures to occur in the lithosphere. Basaltic magma rises up the fractures and cools on the ocean floor to form new sea floor. (Seafloor spreading, Wikipedia)Older rocks will be found farther away from the spreading zone while younger rocks will be found nearer to the spreading zone.

Matching fossils and coastlines and stratigraphy: The man, Alfred Wegener, is also observed how the borders of some continents fit well together and argued that the continents were once all together in a single and massive one. But with the time and plates movement this massive continent broke and gave rise to the current configuration. This also explained easily some fossil distribution in weird patterns that seemed to continue between continents. Not only fossils, but also geological features showed a remarkable continuity between those continents, such as the São Francisco-Congo Craton. This phenomena was called by him "Continental Drift", based on the idea that continents were somehow adrift on the ocean. Stratigraphy is the the branch of geology concerned with the order and relative position of the strata and their relationship to the geological timescale. This section is also an evidence of plate movement.

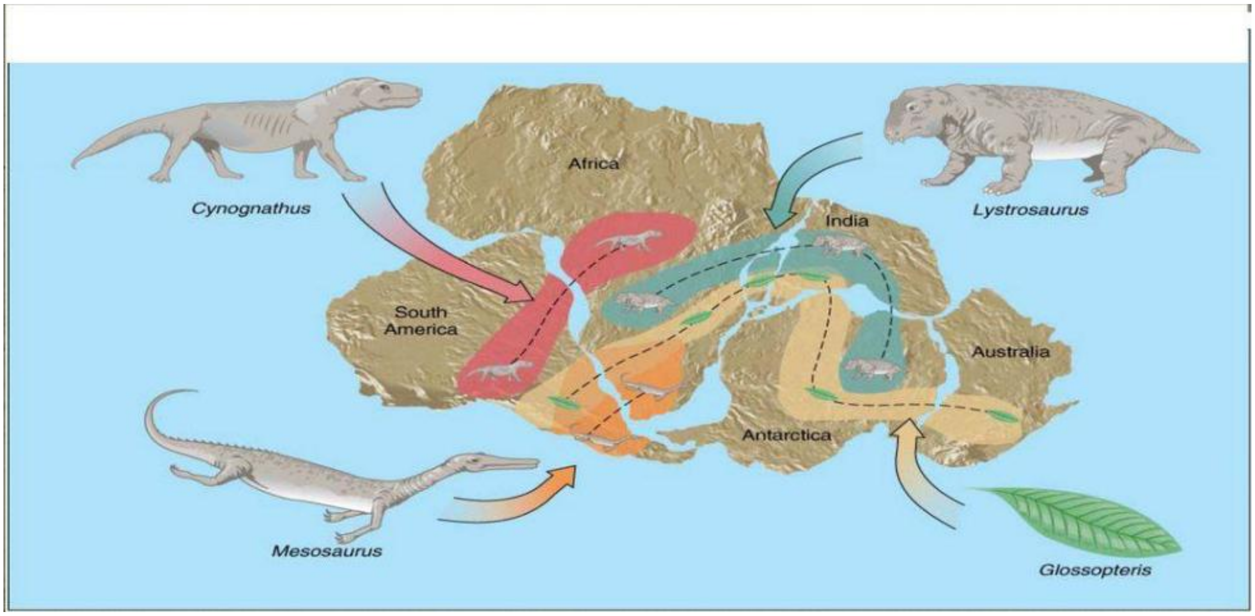

Figure-3: The hypothetical Pangea explained with the matching coastlaines and matching fossils.

Magnetic pole reversal: The Earth has a magnetic field, as can be seen by using a magnetic compass. It is mainly generated in the very hot molten core of the planet and has probably existed throughout most of the Earth's lifetime. By magnetic reversal, or 'flip', we mean the process by which the North pole is transformed into a South pole and the South pole becomes a North pole. Interestingly, the magnetic field may sometimes only undergo an 'excursion', rather than a reversal. Here, it suffers a large decrease in its overall strength, that is, the force that moves the compass needle. During an excursion the field does not reverse, but later regenerates itself with the same polarity, that is, North remains North and South remains South. This phenomena is also known as geomagnetic reversal which is mainly created by the formation of plates.

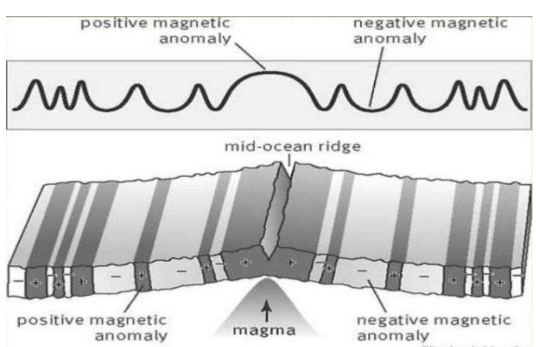

Figure-4: The geo magnetic bar forming with the plates formation.

Age of ocean and continental plates: Scientists got proof that the age of oceanic block are much newer than the age of continents. It is because the oceanic plates are created and destroyed continuously and the continental plates are conserved. This is also explains the movement of these large rigid blocks.

Conclusion:

However this Plate tectonic theory was a hypothetical idea that explaining the structure of the earth's crust and many associated phenomena as resulting from the interaction of rigid lithospheric plates that move slowly over the underlying mantle. But the recent studies and evidences are clearing them out. This is now a major invention of 20th century because this theory explains all the phenomena related to Earth's surface.

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