Is the Empirical Evidence for Plate Tectonics Enough?

Quote:

> Originally Posted by **wiki**
>
> *Outline of the Theory of Plate Tectonics*

Quote:

> Originally Posted by **wiki**
>
> ***Plate tectonics**... is a theory of geology that has been developed to explain the observed evidence for large scale motions of the Earth's lithosphere. The theory encompassed and superseded the older theory of continental drift from the first half of the 20th century and the concept of seafloor spreading developed during the 1960s.*
>
> *The outermost part of the Earth's interior is made up of two layers: above is the lithosphere, comprising the crust and the rigid uppermost part of the mantle. Below the lithosphere lies the asthenosphere. Although solid, the asthenosphere has relatively low viscosity and shear strength and can flow like a liquid on geological time scales. The deeper mantle below the asthenosphere is more rigid again. This is, however, not due to cooler temperatures but due to high pressure.*
>
> *The lithosphere is broken up into what are called tectonic plates—in the case of Earth, there are seven major and many minor plates (see list below). The lithospheric plates ride on the asthenosphere. These plates move in relation to one another at one of three types of plate boundaries: convergent or collision boundaries, divergent or spreading boundaries, and transform boundaries. Earthquakes, volcanic activity, mountain-building, and oceanic trench formation occur along plate boundaries. The lateral movement of the plates is typically at speeds of 0.66 to 8.50 centimeters per year.*
>
> ***Key principles***

The division of the outer parts of the Earth's interior into lithosphere and asthenosphere is based on their mechanical differences and in the ways that heat is transferred. The lithosphere is cooler and more rigid, whilst the asthenosphere is hotter and mechanically weaker. Also, the lithosphere loses heat by conduction whereas asthenosphere transfers heat by convection and has a nearly adiabatic temperature gradient. This division should not be confused with the chemical subdivision of the Earth into (from innermost to outermost) core, mantle, and crust. The lithosphere contains both crust and some mantle. A given piece of mantle may be part of the lithosphere or the asthenosphere at different times, depending on its temperature, pressure and shear strength. The key principle of plate tectonics is that the lithosphere exists as separate and distinct tectonic plates, which ride on the fluid-like (visco-elastic solid) asthenosphere. Plate motions range from a few millimeters per year (about as fast as our fingernails grow) to about 15 centimeters per year (about as fast as our hair grows).

The plates are around 100 km (60 miles) thick and consist of lithospheric mantle overlain by either of two types of crustal material: oceanic crust (in older texts called sima from silicon and magnesium) and continental crust (sial from silicon and aluminium). The two types of crust differ in thickness, with continental crust considerably thicker than oceanic (50 km vs 5 km).

One plate meets another along a plate boundary, and plate boundaries are commonly associated with geological events such as earthquakes and the creation of topographic features like mountains, volcanoes and oceanic trenches. The majority of the world's active volcanoes occur along plate boundaries, with the Pacific Plate's Ring of Fire being most active and famous. These boundaries are discussed in further detail below.

Tectonic plates can include continental crust or oceanic crust, and typically, a single plate carries both. For example, the African Plate includes the continent and parts of the floor of the Atlantic and Indian Oceans. The distinction between continental crust and oceanic crust is based on the density of constituent materials; oceanic crust is denser *than continental crust owing to their different proportions of various elements, particularly, silicon. Oceanic crust is denser because it has less silicon and more heavier elements ("mafic") than continental crust ("felsic"). As a result, oceanic crust generally lies below sea level (for example most of the Pacific Plate), while the continental crust projects above sea level.*

Types of plate boundaries

Three types of plate boundaries exist, characterized by the way the plates move relative to each other. They are associated with different types of surface phenomena. The different types of plate boundaries are:

1. ***Transform boundaries*** *occur where plates slide or, perhaps more accurately, grind past each other along transform faults. The relative motion of the two plates is either sinistral (left side toward the observer) or dextral (right side toward the observer). The San Andreas Fault in California is one example.*
2. ***Divergent boundaries*** *occur where two plates slide apart from each other. Mid-ocean ridges (e.g., Mid-Atlantic Ridge) and active zones of rifting (such as Africa's Great Rift Valley) are both examples of divergent boundaries*
3. ***Convergent boundaries*** *(or active margins) occur where two plates slide towards each other commonly forming either a subduction zone (if one plate moves underneath the other) or a continental collision (if the two plates contain continental crust). Deep marine trenches are typically associated with subduction zones. Because of friction and heating of the subducting slab, volcanism is almost always closely linked. Examples of this are the Andes mountain range in South America and the Japanese island arc.*

Source: http://en.wikipedia.org/wiki/Plate_tectonics

Transform (conservative) boundaries

Because of friction, the plates cannot simply glide past each other. Rather, stress builds up in both plates and when it reaches a level that exceeds the strain threshold of rocks on either side of the fault the accumulated potential energy is released as strain. Strain is both accumulative and/or instantaneous depending on the rheology of the rock; the ductile lower crust and mantle accumulates deformation gradually via shearing whereas the brittle upper crust reacts by fracture, or instantaneous stress release to cause motion along the fault. The ductile surface of the fault can also release instantaneously when the strain rate is too great. The energy released by instantaneous strain release is the cause of earthquakes, a common phenomenon along transform boundaries.

A good example of this type of plate boundary is the San Andreas Fault which is found in the western coast of North America and is one part of a highly complex system of faults in this area. At this location, the Pacific and North American plates move relative to each other such that the Pacific plate is moving northwest with respect to North America. Other examples of transform faults include the Alpine Fault in New Zealand and the North Anatolian Fault in Turkey. Transform faults are also found offsetting the crests of mid-ocean ridges *(for example, the Mendocino Fracture Zone offshore northern California)*.

Divergent (constructive) boundaries

At divergent boundaries, two plates move apart from each other and the space that this creates is filled with new crustal material sourced from molten magma that forms below. The origin of new divergent boundaries at triple junctions is sometimes thought to be associated with the phenomenon known as hotspots. Here, exceedingly large convective cells bring very large quantities of hot asthenospheric material near the surface and the kinetic energy is thought to be sufficient to break apart the lithosphere. The hot spot which may have initiated the Mid-Atlantic Ridge system currently underlies Iceland which is widening at a rate of a few centimeters per year.

Divergent boundaries are typified in the oceanic lithosphere by the rifts of the oceanic ridge system, including the Mid-Atlantic Ridge and the East Pacific Rise, and in the continental lithosphere by rift valleys such as the famous East African Great Rift Valley. Divergent boundaries can create massive fault zones in the oceanic ridge system. Spreading is generally not uniform, so where spreading rates of adjacent ridge blocks are different, massive transform faults occur. These are the fracture zones, many bearing names, that are a major source of submarine earthquakes. A sea floor map will show a rather strange pattern of blocky structures that are separated by linear features perpendicular to the ridge axis. If one views the sea floor between the fracture zones as conveyor belts carrying the ridge on each side of the rift away from the spreading center the action becomes clear. Crest depths of the old ridges, parallel to the current spreading center, will be older and deeper (from thermal contraction and subsidence).

It is at mid-ocean ridges that one of the key pieces of evidence forcing acceptance of the sea-floor spreading hypothesis was found. Airborne geomagnetic surveys showed a strange pattern of symmetrical magnetic reversals on opposite sides of ridge centers. The pattern was far too regular to be coincidental as the widths of the opposing bands were too closely matched. Scientists had been studying polar reversals and the link was made. The magnetic banding directly corresponds with the Earth's polar reversals. This was confirmed by measuring the ages of the rocks within each band. The banding furnishes a map in time and space of both spreading rate and polar reversals.

Convergent (destructive) boundaries

The nature of a convergent boundary depends on the type of lithosphere in the plates that are colliding. Where a dense oceanic plate collides with a less-dense continental plate, the oceanic plate is typically thrust underneath because of the greater buoyancy of the continental lithosphere, forming a subduction zone. At the surface, the topographic expression is commonly an oceanic trench on the ocean side and a mountain range on the continental side. An example of a continental-oceanic subduction zone is the area along the western coast of South America where the oceanic Nazca Plate is being subducted beneath the continental South American Plate.

While the processes directly associated with the production of melts directly above downgoing plates producing surface volcanism is the subject of some debate in the geologic community, the general consensus from ongoing research suggests that the release of volatiles is the primary contributor. As the subducting plate descends, its temperature rises driving off volatiles (most importantly water) encased in the porous oceanic crust. As this water rises into the mantle of the overriding plate, it lowers the melting temperature of surrounding mantle, producing melts (magma) with large amounts of dissolved gases. These melts rise to the surface and are the source of some of the most explosive volcanism on Earth because of their high volumes of extremely pressurized gases (consider Mount St. Helens). The melts rise to the surface and cool forming long chains of volcanoes inland from the continental shelf and parallel to it. The continental spine of western South America is dense with this type of volcanic mountain building from the subduction of the Nazca plate. In North America the Cascade mountain range, extending north from California's Sierra Nevada, is also of this type. Such volcanoes are characterized by alternating periods of quiet and episodic eruptions that start with explosive gas expulsion with fine particles of glassy volcanic ash and spongy cinders, followed by a rebuilding phase with hot magma. The entire Pacific Ocean boundary is surrounded by long stretches of volcanoes and is known collectively as The Ring of Fire.

Where two continental plates collide the plates either buckle and compress or one plate delves under or (in some cases) overrides the other. Either action will create extensive mountain ranges. The most dramatic effect seen is where the northern margin of the Indian Plate is being thrust under a portion of the Eurasian plate, lifting it and creating the Himalayas and the Tibetan Plateau beyond. It has also caused parts of the Asian continent to deform westward and eastward on either side of the collision.

When two plates with oceanic crust converge they typically create an island arc as one plate is subducted below the other. The arc is formed from volcanoes which erupt through the overriding plate as the descending plate melts below it. The arc shape occurs because of the spherical surface of the earth (nick the peel of an orange with a knife and note the arc formed by the straight-edge of the knife). A deep undersea trench is located in front of such arcs where the descending slab dips downward. Good examples of this type of plate convergence would be Japan and the Aleutian Islands in Alaska.

Plates may collide at an oblique angle rather than head-on (e.g. one plate moving north, the other moving south-east), and this may cause strike-slip faulting along the collision zone, in addition to subduction.

Not all plate boundaries are easily defined. Some are broad belts whose movements are unclear to scientists. One example would be the Mediterranean-Alpine boundary, which involves two major plates and several micro plates. The boundaries of the plates do not necessarily coincide with those of the continents. For instance, the North American Plate covers not only North America, but also far eastern Siberia and northern Japan.

Driving forces of plate motion

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 the mantle is acknowledged to be the original source of energy driving plate tectonics, but it is no longer thought that the plates ride passively on asthenospheric convection currents. Instead, it is accepted that the excess density of the oceanic lithosphere sinking in subduction zones drives plate motions. When it forms at mid-ocean ridges, the oceanic lithosphere is initially less dense than the underlying asthenosphere, but it becomes more dense 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 motions. The weakness of the asthenosphere allows the tectonic plates to move easily towards a subduction zone.

Two and three-dimensional imaging of the Earth's interior (seismic tomography) shows that there is a laterally heterogeneous density distribution throughout the mantle. Such density variations can be material (from rock chemistry), mineral (from variations in mineral structures), or thermal (through thermal expansion and contraction from heat energy). The manifestation of this lateral density heterogeneity is mantle convection from buoyancy forces.[1] How mantle convection relates directly and indirectly to the motion of the plates is a matter of ongoing study and discussion in geodynamics. Somehow, this energy must be transferred to the lithosphere in order for tectonic plates to move. There are essentially two types of forces that are thought to influence plate motion: friction and gravity.

Friction:

Basal drag

Large scale convection currents in the upper mantle are transmitted through the asthenosphere; motion is driven by friction between the asthenosphere and the lithosphere.

Slab suction

Local convection currents exert a downward frictional pull on plates in subduction zones at ocean trenches. Although, one could in effect argue that Slab-suction is actually merely a unique geodynamic setting wherein which basal tractions continue to act on the plate as it dives into the mantle (although perhaps to a greater extent—acting on both the under and upper side of the slab).

Gravitation

Gravitational sliding

Plate motion is driven by the higher elevation of plates at ocean ridges. As oceanic lithosphere is formed at spreading ridges from hot mantle material it gradually cools and thickens with age (and thus distance from the ridge). Cool oceanic lithosphere is significantly denser than the hot mantle material from which it is derived and so with increasing thickness it gradually subsides into the mantle to compensate the greater load. The result is a slight lateral incline with distance from the ridge axis.

Casually in the geophysical community and more typically in the geological literature in lower education this process is often referred to as "ridge-push". This is, in fact, a misnomer as nothing is "pushing" and tensional features are dominant along ridges. It is more accurate to refer to this mechanism as gravitational sliding as variable topography across the totality of the plate can vary considerably and the topography of spreading ridges is only the most prominent feature. For example:

1. Flexural bulging of the lithosphere before it dives underneath an adjacent plate, for instance, produces a clear topographical feature that can offset or at least effect the influence of topographical ocean ridges.
2. Mantle plumes impinging on the underside of tectonic plates can drastically alter the topography of the ocean floor.

Slab-pull

Quote:

> Plate motion is driven by the weight of cold, dense plates sinking into the mantle at trenches. There is considerable evidence that convection is occurring in the mantle at some scale. The upwelling of material at mid-ocean ridges is almost certainly part of this convection. Some early models of plate tectonics envisioned the plates riding on top of convection cells like conveyor belts. However, most scientists working today believe that the asthenosphere is not strong enough to directly cause motion by the friction of such basal forces. Slab pull is most widely thought to be the greatest force acting on the plates. Recent models indicate that trench suction plays an important role as well. However, it should be noted that the North American Plate, for instance, is nowhere being subducted, yet it is in motion. Likewise the African, Eurasian and Antarctic Plates. The over-all driving force for plate motion and its energy source remain subjects of on-going research.

Now, after getting a gist of the theory, let us get more into depth so I may pose the debate. To plate tectonics the shape of the Earth, spheroid, is irrelevant as to how the mechanism, "slab-pull" or "convection" affects the crust. The theory rests in the pure physics of convection and tries to explain the observed effects of "plate movement." But how can the fact that Earth is round and spinning be of so little importance to such a theory, and where would such stand when avoiding the Earth's formation, planetary accretion, and multiple body systems? In the conventional misunderstanding of plate tectonics, the general assumption amongst normal working folk is that the interior heat of the Earth is driving the plates; however, this simply is not the case: it's all about temperature difference. (i.e. cold, subducting mantle slabs that have their extents already plunged into the hot mantle interior of the Earth). So, via the slab-pull explanation, the shape of the earth does not matter, theoretical it could work with a cube, triangle, or thick flat plain. It is a matter assertion base on theory that it needn't be a spheroid, but it is an observed fact that not all things about plate movement, plate boundaries, and the crust itself actually fit the theory.

First there is the subduction zones, one of the essential conceptual ingredients of plate tectonics, it asserts that over-thrust or under-thrust, (either or, the theory needn't explain the difference between the two) will destroy ocean floor at near or equivalent to the amount added or 'accreted' to the ridges. This key notion, however, is not supported by empirical evidence; in fact, it seems only to apply to the Pacific margins. For ocean ridges, like the Atlantic and Antarctic margins, subduction zones either don't exist or are quite arguable, Indian and Southern Oceans. In simple terms, there is at least 50% of the worlds continental margin without subduction going on, despite the fact that subduction needs to occur near equally, relative to the "continental shapes," in order for it to be in accordance with the theory. Thus conceptually and empirically this form of boundary is hardly credible, as to plate tectonics states.

Moreover, the case of the Himalayas is an example of the convoluted lengths that have occurred in an exhaustive effort to fit into the puzzle, if you will. The Himalayan front, India, is forced to be explained as riding piggyback on the Indian plate while being pushed into Asia. This "far-field tectonics" is said to be building the mountains of the Himalayan region and uplifting tibet; nevertheless, at the same time they have the Pacific moving westwards, pulling off the Asia to form the back-arc basins' of the Pacific.

The anatomical compartmentalization of the Earth's surface seems to have become, somewhere along the line, an essential premise for the

importance of various parts, where an explanation for each can be made without the need for integration with whole. Each compartmentalization continues to lead to further adjustments of the surrounding parts without necessarily accounting for the last, inventing still more terminology to buttress her position as time goes on ('extrusion tectonic', ' dynamic lifting', 'dynamic forcing' etc.)
Quote:

> Originally Posted by **NASA**
> *Convergent boundaries also explain why crust older than the Cretaceous cannot be found in any ocean basin-- it has already been destroyed by the process of subduction.*

As for convergent/subduction I will make one more note, out of the many that could be made; it is often said that it can explain why crust older than the Cretaceous cannot be found in any ocean basin... . such is only true so long as no other theory, accurately fits the empirical evidence.