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Earth's Dynamic Systems: Plate

Tectonics The Moving Earth

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Plate tectonics (from Latin tectonicus, from Ancient Greek τεκτονικός (tektonikós) 'pertaining to building') is the scientific theory that Earth's lithosphere comprises a number of large tectonic plates, which have been slowly moving since 3-4 billion years ago. The model builds on the concept of continental drift, an idea developed during the first decades of the 20th century. Plate tectonics came to be accepted by geoscientists after seafloor spreading was validated in the mid- to late 1960s.

The processes that result in plates and shape Earth's crust are called tectonics. Earth's lithosphere, the rigid outer shell of the planet including the crust and upper mantle, is fractured into seven or eight major plates (depending on how they are defined) and many minor plates or "platelets". Where the plates meet, their relative motion determines the type of plate boundary (or fault): convergent, divergent, or transform. The relative movement of the plates typically ranges from zero to 10 cm annually.

Faults tend to be geologically active, with earthquakes, volcanic activity, mountain-building, and oceanic trench formation. Tectonic plates are composed of the oceanic lithosphere and the thicker continental lithosphere, each topped by its own kind of crust. Along convergent plate boundaries, the process of subduction carries the edge of one plate down under the other plate and into the mantle. This process reduces the total surface area (crust) of Earth.

The lost surface is balanced by the formation of new oceanic crust along divergent margins by seafloor spreading, keeping the total surface area constant in a tectonic "conveyor belt". While Earth is the only planet known to currently have active plate tectonics, evidence suggests that other planets and moons have experienced or exhibit forms of tectonic activity. Jupiter's moon Europa shows signs of ice crustal plates moving and interacting, similar to Earth's plate tectonics.

The relative importance and interaction of other proposed factors such as active convection, upwelling inside the mantle, and tidal drag of the Moon are subjects of debate. The outer layers of Earth are divided into the lithosphere and asthenosphere.

If new sea floor is being created along the ridges, Hess and Dietz reasoned in the footsteps of Holmes, then crust must be destroyed somewhere else.

Chapter 1: The Discovery of Plate Tectonics

At a subduction zone, the relatively cold, dense oceanic crust sinks down into the mantle, forming the downward convecting limb of a mantle cell, which is the strongest driver of plate motion.

The division is based on differences in mechanical properties and in the method for the transfer of heat. The lithosphere is cooler and more rigid, while the asthenosphere is hotter and flows more easily. In terms of heat transfer, the lithosphere loses heat by conduction, whereas the asthenosphere also transfers heat by convection and has a nearly adiabatic temperature gradient.

This division should not be confused with the chemical subdivision of these same layers into the mantle (comprising both the asthenosphere and the mantle portion of the lithosphere) and the crust: a given piece of mantle may be part of the lithosphere or the asthenosphere at different times depending on its temperature and pressure. The key principle of plate tectonics is that the lithosphere exists as separate and distinct tectonic plates, which ride on the viscoelastic asthenosphere.

Plate motions range from 10 to 40 millimetres per year (0.4 to 1.6 in/year) at the Mid-Atlantic Ridge (about as fast as fingernails grow), to about 160 millimetres per year (6.3 in/year) for the Nazca plate (about as fast as hair grows). Tectonic lithospheric plates consist of lithospheric mantle overlain by one or 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 distinction between oceanic crust and continental crust is based on their modes of formation. Oceanic crust is formed at sea-floor spreading centers. Continental crust is formed through arc volcanism and accretion of terranes through plate tectonic processes. Oceanic crust is denser than continental crust because it has less silicon and more of the heavier elements than continental crust. As a result of this density difference, oceanic crust generally lies below sea level, while continental crust buoyantly projects above sea level.

Average oceanic lithosphere is typically 100 km (62 mi) thick. Its thickness is a function of its age. As time passes, it cools by conducting heat from below, and releasing it radiatively into space. The adjacent mantle below is cooled by this process and added to its base. Because it is formed at mid- ocean ridges and spreads outwards, its thickness is therefore a function of its distance from the mid-ocean ridge where it was formed.

For a typical distance that oceanic lithosphere must travel before being subducted, the thickness varies from about 6 km (4 mi) thick at mid-ocean ridges to greater than 100 km (62 mi) at subduction zones. For shorter or longer distances, the subduction zone, and therefore also the mean, thickness becomes smaller or larger, respectively. Continental lithosphere is typically about 200 km (120 mi) thick, though this varies considerably between basins, mountain ranges, and stable cratonic interiors of continents.

The location where two plates meet is called a plate boundary. Plate boundaries are where geological events occur, such as earthquakes and the creation of topographic features such as mountains, volcanoes, mid- ocean ridges, and oceanic trenches. The vast majority of the world's active volcanoes occur along plate boundaries, with the Pacific plate's Ring of Fire being the most active and widely known. Some volcanoes occur in the interiors of plates, and these have been variously attributed to internal plate deformation and to mantle plumes.

Tectonic plates may include continental crust or oceanic crust, or both. For example, the African plate includes the continent and parts of the floor of the Atlantic and Indian Oceans. Some pieces of oceanic crust, known as ophiolites, failed to be subducted under continental crust at destructive plate boundaries; instead, these oceanic crustal fragments were pushed upward and were preserved within continental crust. 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: Divergent boundaries (constructive boundaries or extensional boundaries). These are where two plates slide apart from each other. At zones of ocean-to-ocean rifting, divergent boundaries form by seafloor spreading, allowing for the formation of new ocean basin, e.g.

As the ocean plate splits, the ridge forms at the spreading center, the ocean basin expands, and finally, the plate area increases causing many small volcanoes and/or shallow earthquakes. At zones of continent-to- continent rifting, divergent boundaries may cause new ocean basin to form as the continent splits, spreads, the central rift collapses, and ocean fills the basin, e.g., the East African Rift, the Baikal Rift, the West Antarctic Rift, the Rio Grande Rift.

Convergent boundaries (destructive boundaries or active margins) occur where two plates slide toward each other to form either a subduction zone (one plate moving underneath the other) or a continental collision. Subduction zones are of two types: ocean-to-continent subduction, where the dense oceanic lithosphere plunges beneath the less dense continent, or ocean-to-

ocean subduction where older, cooler, denser oceanic crust slips beneath less dense oceanic crust.

After all these considerations, plate tectonics (or, as it was initially called "New Global Tectonics") became quickly accepted and numerous papers followed that defined the concepts:

In 1965, Tuzo Wilson who had been a promoter of the sea floor spreading hypothesis and continental drift from the very beginning added the concept of transform faults to the model, completing the classes of fault types necessary to make the mobility of the plates on the globe work out.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.