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How did plate tectonics emerge on Earth?

Tectonic plates move relative to one another on the Earth's surface. But what caused this division into separate plates, which led to plate tectonics? In an article published on the website of the journal *Nature* dated 6 April 2014, Yanick Ricard, a CNRS researcher at the Laboratoire de Géologie de Lyon: Terre, Planètes et Environnement (CNRS/Université Claude Bernard Lyon 1/ENS de Lyon) and David Bercovici from Yale University propose the first model to explain how the Earth's surface divided into plates. This model accounts for the emergence of plate tectonics as we know it today, and also explains why this phenomenon did not occur on Earth's sister planet, Venus.

The lithosphere[1], the Earth's outermost mobile layer, is divided into a small number of rigid plates that move over the asthenosphere, the part of the Earth's mantle located immediately beneath it. This system is responsible for geological phenomena such as earthquakes and volcanic activity. It also affects our planet's climate, and played a crucial role in the emergence of life.

How did this division into plates occur? Although the earliest evidence for deformation of the lithosphere dates back four billion years, division into individual plates and the onset of plate tectonics in its current form probably took place a billion years later. This was the amount of time it took for weak zones in the lithosphere to form and join up, and thus make up plate boundaries, according to a model proposed by two geophysicists, Yanick Ricard from the Laboratoire de Géologie de Lyon (CNRS/Université Claude Bernard Lyon 1/ENS de Lyon) and his colleague David Bercovici (Yale University, US).

The model assumes that the lithosphere is a medium made up of two types of grain, reflecting the mineral composition of peridotite, the main rock in lithospheric plates. It takes into account the forces exerted on the rock by the underlying asthenosphere, and includes experimental data about the properties of the rock and its deformation.

According to the model, the lithosphere becomes weaker due to interaction with mantle convection, i.e. the very slow motion of the rock that makes up the asthenosphere[2]. Downwelling in the asthenosphere stretches the rock in the overlying lithosphere. As a result of this deformation, the size of the grains making up the minerals in the rock decreases. This in turn makes the grains even more deformable, causing a weak zone to form. Convective motion migrates through the mantle over the course of time, creating new

[1] The lithosphere is the rigid rocky shell that makes up the surface of the Earth. It comprises the crust and the upper part of the mantle.
[2] This motion takes place as a result of temperature differences (the deeper, hotter rock tends to rise, while the cooler rock in contact with the lithosphere moves downward).

weak zones. However, those that are no longer subject to deformation tend to 'heal', since the mineral grains grow when deformation ceases.

According to the model, because of the moderate temperature of the Earth and the presence of different minerals, which impede each other's growth, it takes far longer for the lithosphere to heal (1 billion years) than to weaken (10 million years). Changes in mantle convection were therefore slow enough to damage the lithosphere locally, but fast enough to prevent complete healing, thus allowing enough weak zones to accumulate for plates to form.

In this model, the Earth's lithosphere accumulates enough damaged zones for it to divide into tectonic plates after a period of approximately one billion years, which is consistent with geological history.

The researchers also explain why Venus, whose mass, size and composition are nevertheless similar to the Earth's, has never undergone plate tectonics. According to their model, its lithosphere, which is very hot due to an extreme greenhouse effect, heals too quickly (in ten million years) to be able to split up into tectonic plates.

Reference

Plate tectonics, damage and inheritance. David Bercovici & Yanick Ricard. *Nature*, published on-line 6 April 2014. DOI: 10.1038/nature13072

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