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The Mechanism of Changes in Mantle Volume

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Abstract

The crust floats above the mantle, and the volume change of the mantle is the driving force of crustal movement. The increase in mantle volume leads to crustal extensional movement, resulting in continental crust rupture and oceanic crust expansion. The decrease in mantle volume leads to crustal compression movement, resulting in continental crust superposition, folding, and oceanic crust subduction. The factors that contribute to the increase in mantle volume include a change in material state, where solid material in the mantle melts into liquid material. The factors leading to a decrease in mantle volume include: oceanic crust uplift, crustal crystallization, volcanic eruptions, magma intrusion, and hydrothermal upwelling. The change in mantle volume dominates the evolution pattern of the crust. When the mantle volume increases unidirectionally, the crust only has horizontally crystallized continental crust. When the volume of the mantle changes in both directions, blocky layered oceanic crust is formed. The expansion and subduction of oceanic crust, as well as the stretching and compression of continental crust, are the supporting mechanisms for changes in Earth's surface area caused by changes in mantle volume.

Keywords

Earth Formation, Mantle Volume, Crustal Movement

1. Introduction

The crust floats above the mantle and is constantly moving. The causes of crustal movements such as folding, faulting, earthquakes, volcanoes, expansion, and subduction are topics worth exploring. This article proposes the mechanism of changes in mantle volume to explain the driving force behind crustal movement.

The crust floats on top of the mantle, and changes in the volume of the mantle cause changes in the surface area of the Earth, known as crustal movement. The volume change of the mantle is bidirectional. When the volume increases, the

crust undergoes tensile motion, while when the volume decreases, the crust undergoes compressive motion.

The factors that contribute to the increase in mantle volume include: material state change, which refers to the melting of solid matter in the mantle into liquid matter, resulting in an increase in state change and causing the volume of the mantle to increase. The factors that contribute to the decrease in mantle volume include: oceanic crust toppling, crustal crystallization, volcanic eruptions, magma intrusion, and hydrothermal upwelling. In addition to crustal crystallization, all of them are caused by the spatial displacement of materials, resulting in a decrease in mantle volume.

The decrease in mantle volume is related to the spatial displacement of matter, that is, the displacement from mantle space to crustal space. Solid matter melts into liquid matter, and under the action of material differentiation, material displacement is the way of material redistribution. To study crustal movement, it is necessary to study the laws of material movement.

The increase in mantle volume is related to the increment of material state change, that is, the volume increment generated when solid material changes to liquid material. The basis of the transformation of matter is related to the process of the formation of the Earth. The formation and evolution of the Earth is the process of solid matter aggregation, melting, and recrystallization. Studying crustal movement requires studying the formation process of the Earth. The formation process of the Earth provides the material basis for the changes in mantle material states, material differentiation, and material displacement. The volume changes of the mantle on this basis drive crustal movement and the evolution of the Earth.

2. Earth Formation

The formation of the Earth, like other planets, is the result of material motion. Divided into five periods: polymerization period, melting period, crystallization period, collision swelling period, and forming period [1].

1) Aggregation period: The matter in the Earth's orbital space begins to aggregate under the influence of gravity. The aggregation period mainly consists of material accumulation, with meteorites and asteroids as the main components.

2) Melting period: Under the influence of pressure and material decay, the temperature inside the Earth rises and begins to melt the early aggregated material, resulting in a molten magma state inside the Earth. Under the influence of gravity, the high-density solid material in the upper part sinks towards the center of the earth, and magma from within the earth rushes towards the surface, enveloping the earth with melted magma.

3) Crystallization period: Surface magma begins to crystallize when the temperature drops, forming early continental crust. According to the current land crust area, the diameter of the Earth during the crystallization period is only 6886 kilometers. Part of the continental crust overlaps or is submerged by seawater, and the diameter of the Earth during the crystallization period is greater than 6886

kilometers.

4) Inflation period: A large number of meteorites and asteroids collide with the crystalline Earth, resulting in a unidirectional increase in mantle volume and only a continental crust on the Earth's surface. The increase in mantle volume leads to the continuous tearing of crystalline crust, forming a continental crust pattern with thick central and thin edges.

5) Forming period: The volume of the Earth has already formed, and the volume of the mantle has entered an era of bi-directional changes (increasing or decreasing). The expansion and compression of the crust coexist, and the continental crust and oceanic crust evolve simultaneously.

The formation and evolution of the Earth is a process of material motion, following the laws of material motion. The continental crust is the result of crystallization and thickening of mantle magma, while the oceanic crust is the result of changes in mantle volume.

3. Factors Contributing to the Increase in Mantle Volume

The factor causing the increase in mantle volume is the transformation of solid material into liquid material in the mantle. There are two types of solid matter: one is the impact material during the early formation of the Earth, and the other is the subducting continental crust and oceanic crust that entered the mantle during the Earth's evolution period.

The melting of solid materials into liquid materials will increase the volume. By measuring six types of igneous rocks, the average linear expansion coefficient from room temperature to 1200 degrees is 2.1515% [2], with a volume increase of 9.9591%.

The evolution of the Earth involves the crystallization of molten magma in both the crust and core. The crust is the crystallization of light matter, while the core is the crystallization of heavy matter. The volume of the Earth after complete melting is 1102.4 billion cubic kilometers, which is 19.2 billion cubic kilometers larger than its current volume. The diameter is 12,808 kilometers, which is 66 kilometers larger than the current diameter.

During the 4.3 billion year evolution process, the average melting rate of solid matter inside the Earth is 256 cubic kilometers per year, and the crystallization rate of liquid matter is 45 cubic kilometers per year. The melting rate is 211 cubic kilometers faster than the crystallization rate, and the annual increase in mantle volume is 21 cubic kilometers. The Earth's surface area increases by 6592 square meters in the expansion zone of the oceanic crust every year.

According to the drilling results, the average rate of oceanic crust expansion is 2.5 centimeters per year, indicating that the melting rate inside the Earth is uneven. The early stage of Earth's evolution was the formation of a hot melt environment, with a slower melting rate. In the later stage of the formation of a hot melt environment, the rate of solid material melting inside the Earth is 8037 cubic kilometers per year, the annual increase in mantle volume is 796 cubic kilometers,

and the Earth's surface area increases by 250,000 square meters per year in the expansion zone, with a daily increase of 685 square meters.

The rate of expansion of oceanic crust varies greatly, with the Pacific Ocean's Hess Deep. On the 147th voyage of drilling, the expansion rate of the oceanic crust reached 13 centimeters per year [3]. The Atlantic Ocean is only 2 - 4 centimeters per year, while the Southwest Indian Ocean is less than 2 centimeters per year [4]. Calculating with an expansion rate of 2.5 centimeters per year, adding 685 square meters per day is a relatively conservative calculation. In fact, the increase in mantle state and the increase in Earth's surface area are both greater than the calculations mentioned above.

The above calculation is an estimate, and can only be accurately calculated based on the specific length of the expansion zone and the expansion speed of each group of oceanic shells. The evolution of the Earth is a very complex process, influenced by many factors. The above calculations illustrate the process of Earth's evolution, where the extensional movement of the crust is caused by an increase in the volume of the mantle.

The increase in mantle volume is related to the melting rate and is a slow incremental process, manifested by a gentle and prolonged extensional movement.

4. Factors Contributing to the Reduction of Mantle Volume

The factors that contribute to the decrease in mantle volume include the top of the oceanic crust, magma crystallization, volcanic eruptions, magma intrusion, and water and gas infiltration. The decrease in mantle volume means that mantle material becomes crustal material. Under the action of material differentiation, melted light matter moves towards the surface of the mantle and enters the crustal space under the action of buoyancy.

The top of the oceanic crust is a newly generated oceanic crust in the spreading zone, which enters the oceanic crust space from the mantle space under the action of buoyancy. The width and volume of the oceanic crust are related to the temperature of seawater [5]. The temperature determines the crystalline thickness of the expanding oceanic crust, the crystalline thickness determines the width of the overlying oceanic crust, and the width determines the volume of mantle space reduction. The width of the top of the ocean crust in the North Atlantic is 76 kilometers, and the width of the top of the ocean crust near the Pacific equator is 66 kilometers [6].

Magma crystallization refers to the magma at the top of the mantle, which crystallizes into the crust under the action of temperature reduction. Crystals below the continental crust form the continental crust, while crystals below the oceanic crust form the oceanic crust. The rate of crystallization is related to the thickness of the crust and is controlled by temperature. The average crystallization rate of the continental crust is 0.00875 millimeters per year, which is 875 meters per billion years. The crystallization rate of oceanic crust is 0.04 millimeters per year, 4000 meters per billion years, which is 4.57 times the crystallization rate of

continental crust.

Among the factors leading to a decrease in mantle volume, magma crystallization, intrusion or eruption to the surface is the transfer of mantle material to crustal material. From a spatial perspective, it is a process of reducing mantle material while exerting compressive pressure on the crust. This phenomenon is very obvious, as long as there is a volcanic eruption, there will be earthquakes.

The top of the oceanic crust is also the transfer of material from the mantle space to the crustal space. Due to its large volume, the crust bears greater compression force, causing the oceanic crust to subduct beneath the continental crust. For the mantle, it is the volume of the subducting oceanic crust that replaces the volume of the overlying oceanic crust, and an additional solid material to be melted is added to the mantle. The process of subduction of the oceanic crust compresses the continental crust, which is a peak period for volcanoes and strong earthquakes.

The decrease in mantle volume is a way of material movement. The disorderly and disorderly accumulation of materials is rearranged according to their density on the basis of melting, which is known as material differentiation. The process of material differentiation leads to spatial displacement, which inevitably leads to a decrease in the volume of the mantle.

The reduction of mantle volume is a process of material spatial transfer, with a shorter time for material spatial transfer and a shorter and more intense squeezing motion.

5. The Evolution and Movement of the Crust

The crust floats above the mantle and forms from the crystallization stage. Under the influence of changes in mantle volume, it gradually evolved into the current continental and oceanic crust.

The continental crust is a horizontal crystalline crust formed during the crystallization period. The volume of the mantle increases and is pulled apart, and new crust is formed by recrystallization at the location of the fracture. This cycle forms a pattern of thick edges along the thin edges in the middle. The thinner parts along the edges are compressed, overlapped, or subducted downwards, while the thicker parts in the middle are mainly formed by oceanic crust compression, displacement, and integration, forming the current continental crust pattern.

Ocean crust is a block shaped crystalline crust formed during the formation period. The volume of the mantle changes in both directions, and when it becomes larger, the crust is pulled apart, forming a new crystalline crust, which is the expansion zone of the oceanic crust. When the crust becomes smaller, it is compressed, and the denser crystalline oceanic crust subducts beneath the continental crust, which is the subduction zone of the oceanic crust. The oceanic crust is a window for mantle volume changes, and the expansion, top placement, and subduction phenomena of the oceanic crust are the supporting mechanisms for changes in the Earth's surface area.

From the perspective of the mechanism of mantle volume change, the increase in mantle volume is a slow process of thermal melting increment, manifested by a long time of extensional movement. The reduction of mantle volume is a rapid process of material spatial transfer, manifested by a short time of compressive movement.

Crustal movement is caused by changes in the Earth's surface area, while changes in the Earth's surface area are caused by changes in the volume of the mantle, The change in mantle volume is caused by changes in material states and material displacement. The evolution and movement of the Earth's crust is a part of the Earth's evolution, and crustal movement is the external manifestation of the Earth's evolution. The laws of material movement inside the Earth are the essence. To study crustal movement, it is necessary to understand the formation process and evolution laws of the Earth. Only in this way can we understand the Earth and the essence of crustal movement.

6. Conclusions

1) Changes in mantle volume are related to the history of Earth's formation. All materials on Earth undergo a process of material transformation and differentiation in the hot melt environment of the mantle. The change in material state led to an increase in mantle volume, while material differentiation caused spatial displacement. Through material state change and differentiation, the current Earth was formed.

2) The change in mantle volume is related to the total energy of the Earth's internal hot melt environment. The heat energy inside the Earth comes from pressure and material decay, and has a long accumulation process. In the late stage of Earth's formation, the thermal energy reached its maximum value, and the state variables of matter reached their maximum value. When the volume of the mantle changes significantly, the surface area of the Earth also increases, manifested as a high incidence period of severe crustal movement. Based on the history of continental crust movement and the expansion rate of oceanic crust, the time period of the highest value of Earth's thermal energy can be calculated.

3) The increase in mantle volume is a process of changing the quantity of mantle volume. The increase in material state is a gradual and uninterrupted process. The increase in mantle volume causes the crust to bear tension, tearing apart the weakest part of the crust, which is the expansion zone of the oceanic crust. During periods of thin development of the continental crust or fault zones, it can also be torn apart, resulting in oceanic crust and pushing continental crust displacement, known as continental drift.

4) The decrease in mantle volume is the process of decreasing mantle mass. Namely, the transformation of mantle material into crustal material, oceanic crust toppling refers to the transformation of mantle solid material into oceanic crust solid material, rock crystallization, volcanic eruptions, and magma intrusion refers to the transformation of mantle liquid material into crustal solid material,

hydrothermal infiltration refers to the transformation of mantle liquid material into crustal and gas sphere material, and the reduction of mantle volume refers to the changes in material space and form. The emission of mantle material is the spatial displacement of matter, from mantle space to crustal space, which is a rapid and brief process. The volume of the mantle decreases, and the crust bears compressive pressure. The compressive pressure is highest in the subduction zone of the oceanic crust, which is transmitted to the continental crust to produce folds and fractures.

5) The increase or decrease in mantle volume is a cyclical process. The change in material state leads to an increase in mantle volume, while material displacement leads to a decrease in mantle volume, as shown in Figure 1.

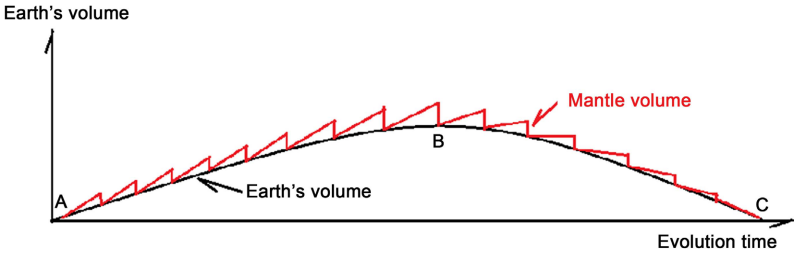

Figure 1. Schematic diagram of mantle volume change.

Point A in the figure represents the volume of Earth's solid material when it has not melted, point B represents the volume of Earth's mantle when it has the most liquid material, and point C represents the volume of Earth's mantle material when it becomes solid. The process from the formation of the Earth to the end of its evolution is the process of solid matter transforming into liquid matter and then back into solid matter. When the local mantle is liquid material, there is crustal movement; when the local mantle is solid material, there is no crustal movement. The same applies to other planets.

6) Mechanisms of mantle volume increase and decrease, It's about material state change and material displacement. Material state change and material displacement both change the volume of the mantle, and the volume change of the mantle leads to a change in the surface area of the Earth, which is known as crustal movement. So, the change in mantle volume is the driving force behind crustal movement.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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