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A Review on the Study of Continental Drift and Numerical Simulation Associated with the Early Earth Core-Magma Angular Momentum Exchange

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Abstract

According to the drive of planetary-scale upper magma fluid motions associated with the core-magma angular momentum exchange in the early Earth's interior, this paper reviewed the results of continental drift studied over the last three decades. The theoretical speculation is in good fit to the traces of geological events left on the Earth's surface. A northeastward drift directionality of the Australian, African, and South American continents relative to the Antarctica Continent in the Southern Hemisphere is reanalyzed according to the slowing down of the early Earth's rotation. Six traces of significant back-and-forth drifts of the Australian and Asian continents left respectively on the Southwest and Northwest Pacific seafloors are reidentified according to the gradually decreasing amplitude of core-magma angular momentum exchange during early geological evolution. Finally, the thickening and shortening of different continents during the early drift processes are re-simulated by using a simple magma fluid dynamical model.

Keywords

Continental Drift, Driving Force, Directionality, Numerical Model, Angular Momentum Exchange

1. Introduction

Mechanisms of continental drift and orogeny are two fundamental scientific topics in geodynamics. In 1620, Francis Bacon, an English philosopher proposed the possibility of connecting the Western Hemisphere with Eurasia and Africa based on the first accurate maps of the continents [1] [2]. Early explanations on the continental drift were not convinced. From 1910 to 1930, the German meteorologist Alfred Wegener attempted to add credibility to his theory of continental drift [3] [4] [5]. His theory of continental drift was based on evidence maps from geological, geographical, paleontological, and paleo-climatological phenomena across the Atlantic Basin. He suggested that the lighter continents drifted across the denser material of the Earth's mantle and the ocean floor. He proposed that the driving forces behind continental drift were derived from known forces such as the rotation of the Earth, precession of the Earth's axis, and tidal friction. The Earth's rotation would produce the slow drifting of the continents away from the poles, and the westward drift of the continents. Wegener used these forces to explain the mountain ranges that extend from the Alpine-Mediterranean area across the Iranian Plateau and into the Himalaya and Southeast Asia [6]. The mountain ranges formed due to the convergence of Eurasia, which was drifting southward from the North Pole, and the southern continents of Africa and India. The westward drift from the Earth's rotation formed the high mountain ranges along the western coast of the Americas by frontal compression. However, these forces are speculated too small to explain the continental drift and orogeny. According to his Earth's rotation triggering mechanism, the convergence of the Eurasian Continent with the southern continents of Africa and India should have occurred at the equator, not in what is currently subtropical southern Eurasia. Also, he was never able to convince a skeptical audience who demanded more proof, especially an explanation for the mechanism what propelled the long-distance drift of continents [7] [8].

With the development of paleomagnetism in the 50-60s of the 20th century, new evidence was found in the sedimentary geomagnetic record of mid-ocean ridges [9] [10] [11]. Thus, a hypothesis of the seafloor spreading was proposed in the 1960s [12] [13]. The idea 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. The phenomenon is known today as plate tectonics. In locations where two plates move apart, new seafloor is continually spreading at mid-ocean 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. The motivating force for seafloor spreading ridges is tectonic plate slab pull at subduction zones, rather than magma pressure, although there is typically significant magma activity at spreading ridges [14]. The driver for seafloor spreading in plates with active margins is the weight of the cool, dense, subducting slabs that pull them along, or slab pull. The magmatism at the ridge is passive upwelling, which is caused by the plates being pulled apart under the weight of their own slabs [15]. These explanations are complex and the first driving force for the seafloor spreading is argued to be convection currents in the mantle. However, the mantle convection is initially caused by the local mantle plume. The mantle plume hypothesis proposes that there are localized upwellings of abnormally hot and buoyant material from the Earth's mantle to the surface. One limitation of the hypothesis is the lack of direct observational evidence because it is inferred based on surface features such as volcanic activity and hotspot tracks [16] [17]. While mantle plumes can contribute to localized uplift in volcanic regions, they are not considered a mechanism for the formation of entire mid-ocean ridges. The debate on plate and plume [18] is an issue on two space scales between planetary scale (or basin scale) and local scale.

What exactly are the forces that produce planetary-scale continental drift and orogeny? Two facts are certain. The first fact is that the Earth's rotation rate slows down since the geological evolution. The second fact is that the current Earth's landscape of continents and oceans is a series of traces left by planetary-scale continental drift and orogeny. At the beginning of the Cambrian approximately one-half billion years ago, a day was two and a quarter of hours shorter and one year had 400 days [6]. The cause may be tidal friction of ocean that slows down the Earth's rotation. The tidal friction exists not only between the solid Earth and ocean but also between the inner solid core and mantle layer [19] [20]. Recently, Yang and Song [21] found that there is differential rotation which is associated with the angular momentum exchange from the core and mantle to the surface. The oldest crustal age observed on the Earth is about 4.54 billion years [22]. Prior to this, the Earth was in an astronomical evolutionary stage. During that stage, the formation of original Earth's iron-rich cores generally occurred very early in planetesimals, the building blocks of proto-Earth, within about 3 million years [23]. The terrestrial planetary accretion involved violent and energetic giant impacts among different-sized objects and planetary embryos. Because of the impact heating, the early Earth was at times partially or wholly molten, increasing the likelihood for high-pressure and high-temperature equilibration among core- and mantle-forming materials. In the early stage, melting would have caused denser substances to sink toward the central core in a process called planetary differentiation, while less-dense materials would have migrated to the outside magma fluid layer. At the end of the Earth's astronomical evolution and the start of the Earth's geological evolution, the inner solid core and the outside molten magma layer became a conservation system of angular momentum because no materials entered the Earth from sky. Starting from the geological evolution the tidal friction should be formed between the inner core and the magma layer [19]. Before the end of the Earth's astronomical evolution, the Earth and its inner solid core rotated faster [20]. Thus, before 4.54 billion years ago, one year should be more than 700 days.

Wegener's theory of continental drift contemplates the long-term slowdown in the Earth's rotation but does not consider for the core-magma angular momentum exchange in the early Earth's geological evolution. Thus, his theory speculated that the rotation of the Earth would produce polar escape, the slow drifting of continents away from the poles, and the westward drifting of continents due to the Coriolis effect [6]. But it is hard to find what forces cause the polar escape because continents are part of the Earth with the same inertia. More recently, our study considered the core-magma angular momentum exchange that existed in the early geological evolution, revealing the directionality of continental drift [24]. There was a directional alteration or reversal in the exchange of angular momentum between the inner core and magma layer. Since the formation of the current oceanic crust, the directionality of multiple core-magma angular momentum exchanges was recorded on the geomagnetic stripes of the mid-ocean ridge [9] [10] [11]. We pay particular attention to the core-magma angular momentum exchange in the early geological evolution (3.0 billion to 4.54 billion years ago), which formed the directional motion of magma fluids and drove significant back-and-forth drifts of continents for several times. These drifts of directionality formed early supercontinents through adjacent continent combinations. The mechanism by which this supercontinent forms is not the mantle convection, the seafloor spreading, and the Wilson Cycle. The spatial scale of the mantle convection as the first driving force is too small and piecemeal to open the seafloor spreading and to form the Wilson Cycle. The latter is a hypothesis model that describes the opening and closing of ocean basins and the subduction and divergence of tectonic plates during the assembly and disassembly of supercontinents [25] [26]. The current mid-ocean ridge of the Atlantic Ocean is the trace left on the oceanic crust after the early continents drifted eastward and then back westward [24]. In our study, early breakup continents floated above magma fluids. Floating continents collide with each other, creating orogeny or mountain uplifts [27]. Since the moving velocity of magma fluids is not uniform in spatial distribution, thickening and shortening of numerical simulation occur on floating continents [28]. Three decades ago, the spatial distribution of continents and islands over the Southern Hemisphere associated with the deceleration of the Earth's rotation was revealed [29]. Descripting the directionality of continental drifts [29] [30] and the back-and-forth drifts of continents [31], as well as the numerical simulations of thickening and shortening continents [28], all consider the drive of magma fluids. However, none of these studies were unified into the dynamic framework of core-magma angular momentum exchange in the early stages of geological evolution. Thus, under this dynamic framework, this paper will review several aspects of previous works. The purpose is trying to confirm that the first driving force of continental drift was the core-magma angular momentum exchange during the early geological evolution. Section 2 introduces the distributions of initial and current continents on the Earth. Section 3 re-analyzes the directionality of continental drift in the Southern Hemisphere. Section 4 recognizes again the back-and-forth drift traces of Australian and Asian continents on the western Pacific Seafloor. The thickening and shortening continents are simulated by a numerical model in Section 5.

2. Initial and Current Distributions of Continents

At the end of the Earth's astronomical evolution, the Earth's surface temperature reaches its highest [23]. At that time, the Earth's interior is composed of the Earth's core and external molten magma. Since the Earth orbits the Sun about

700 days a year, the Earth's rotation rate is twice that of nowadays, so that the geopotential height of the two poles is maximum, while the low geopotential height is along the equatorial zone. The beginning of a drop in the Earth's surface temperature marks the beginning of geological evolution. Thus, the Earth's crust or lithosphere is gradually thickened. The crust formed by the cooling lies above the magma fluid layer, with the polar regions being the thickest and the equatorial zone thinnest. Due to the thin crust in the early stages of geological evolution, angular momentum exchange still mainly occurs between the core and magma. When the core loses angular momentum, the magma gains angular momentum. The mechanism of angular momentum exchange is planetary-scale vertical circulations or cells within magma fluids [24]. When the magma fluids first gain angular momentum, the magma fluids have a speed of eastward movement. Magma fluids moving eastward will have Coriolis forces toward the equator. As a result, driven by the upper magma fluids, the primordial continents at the two poles split. **Figure 1** shows the original continents at the two poles and the fragmented continental blocks before 4.54 billion years ago. Here, continental blocks are different from continental plates. Continental plates are currently pieces of Earth's crust and uppermost mantle that consist of lower-density felsic granitic rocks. The African Plate and Indian Plate cover not only the above-sea-level continents but also the nearby oceanic crusts. In this study, the term "continental block" considers only the above-sea-level continents. At the earliest stage of geological evolution, the cooling of the Earth's surface formed the two oldest above-sea-level continental caps at the north and south poles, while the below-sea-level oceanic crust zone formed at the tropics. The primordial continent located in the Northern Hemisphere was divided into four continental blocks including the Asian, European, Greenland, and North American blocks. Islands of Japan and the Philippines are the eastern marginal splinters of the Asian continental block. The primordial continent in the Southern Hemisphere split into five continental blocks including the African, Indian, Australian, Antarctic, and South American blocks. Before the division of the primordial continents, the south and north crustal poles were respectively located in south of the African block and in Siberia of the Asian block. The original Antarctic block was not located in the south pole.

In **Figure 1**, the division of the two primordial continental blocks considers the marginal relationship with current continental blocks, as well as the spatial distribution of mineral deposits and paleontological remains [32] [33]. When the core first loses angular momentum, the global magma fluids move eastward and are affected by the Coriolis force. Finally, the magma fluids in the Northern Hemisphere move southeastward, and the magma fluids in the Southern Hemisphere move northeastward. This dynamical description differs from the speculation of Wegener's polar escape and westward drift of continents. This dynamic is also different from the Wilson Cycle. Because the blocks of the original continent splitting are not uniform, their drift above the magma fluids towards the equator and east causes the angular momentum of the magma fluids to change. The continental blocks of both hemispheres eventually drift not exactly to the equator but reach either side of the magma fluid tropical convergence zone (TCZ), located near the equator. The magma fluid TCZ is indicated by the red dashed line in **Figure 2**. The atmospheric TCZ is also not along the equator due to the irregular distribution of land, sea, and mountain terrain. The atmospheric masses and horizontal areas on both sides of the atmospheric TCZ are approximately equal. Similarly, the continental masses and areas as well as the upper magma fluid masses on either side of the magma fluid TCZ should also be approximately equal.

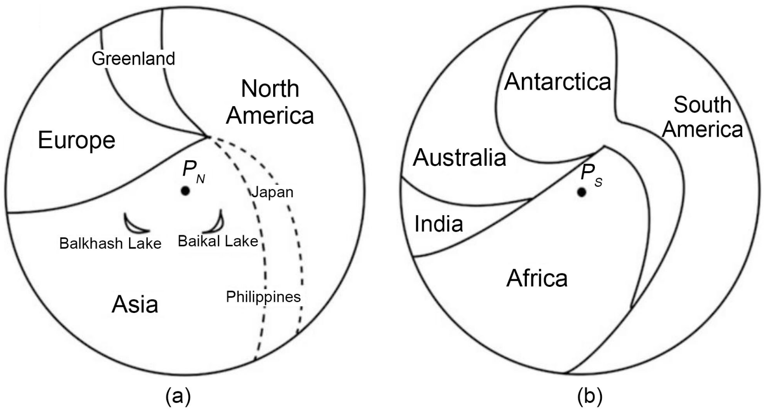


Figure 1. Maps of the two original continents in (a) the Northern Hemisphere and (b) the Southern Hemisphere with different split continental blocks centered at the two crustal poles ("P_N" and "P_S") of the Earth. In (a), the dashed area is the eastern edge of the Asian block. It is modified from Qian [32] [33].

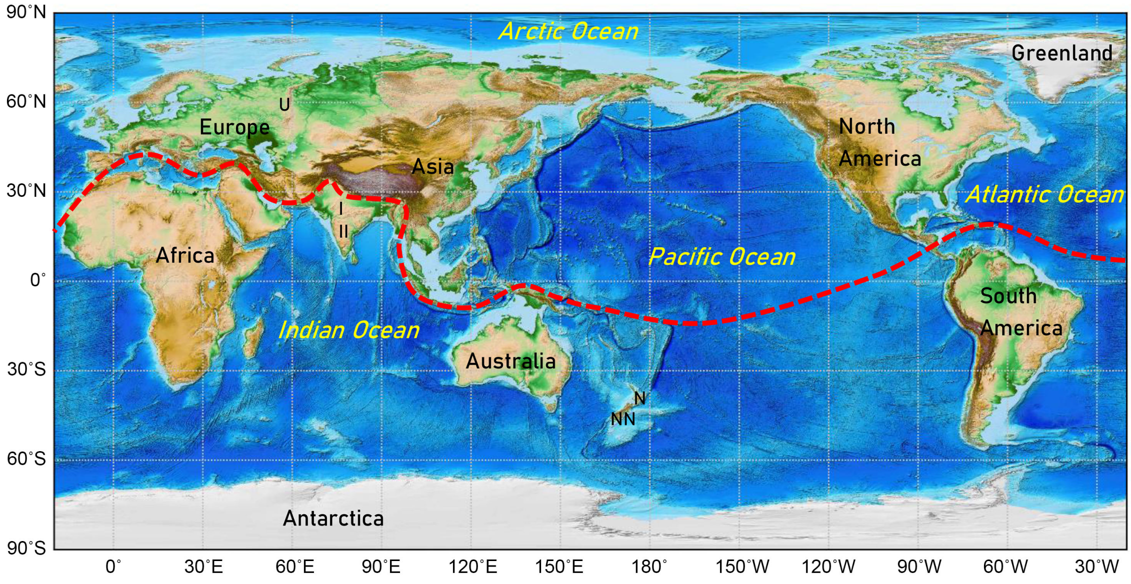


Figure 2. The current distribution map of global seas and lands. The red dashed line indicates the upper magma fluid TCZ in the early stages of Earth's geological evolution. Letters "I" and "II" indicate two highlands over the Indian block. Letters "N" and "NN" indicate two parts of the New Zeeland Islands. The letter "U" indicates the Ural Mountains.

In the early stages of Earth's geological evolution, magma fluids can reach depths of several thousand kilometers. The horizontal movement of upper magma fluids is the direct driver of the continental block drift. It could be spiculated from **Figure 2** that the horizontal movement of magma fluids in the two hemispheres can reach the TCZ but cannot cross out. The northernmost location of magma fluid movement in the Southern Hemisphere can reach the Mediterranean Sea. The southernmost location of magma fluid movement in the Northern Hemisphere can reach the Tonga Islands. The upper magma fluids and continental blocks converging along the magma fluid TCZ formed the Tibetan Plateau, the Iranian Plateau, and the Armenian Plateau in southern Asia [27]. Because the speed of upper magma fluids is a function of latitudes the Coriolis force is varied so that the drift speed, geopotential height and peripheral morphology of continental blocks also change. The moving speed of magma fluids is inversely proportional to latitude. The continental blocks were rotated when they drifted from the poles to their current positions. Mountains at the edge of a continental mass reflect the collision of adjacent continental blocks or the extrusion of continental blocks with oceanic crusts during drift.

From the primordial continental blocks at the two poles (**Figure 1**) to the current continental blocks (**Figure 2**), we can still distinguish the connection before and after they drift. Eurasian block first collided with Indian and Arabian blocks along the magma fluid TCZ. Driven by the upper magma fluids, the drift of the African block towards magma TCZ forms the backing of the movement and collision of the Indian and Arabian blocks. The magma fluids driving the continental blocks collided orthogonally at the magma fluid TCZ [27]. The distribution of the current landforms around the globe in **Figure 2** is the result of multiple-time drifts and collisions of continental blocks.

3. The Directionality of Continental Drift in the Southern Hemisphere

As showed in **Figure 2**, there are three continents with nearby islands in the mid-low latitude of Southern Hemisphere. Islands are located on the east or northeast side of their continents, while there are no islands on the western side. The Madagascar Island, the Arabian Peninsula, and the Indian Peninsula separate from the African Continent on the east-west orientation. It means that they tend to drift northeastward relative to the African Continent. Thus, as early as 30 years ago, an idea about the drift directionality of continents and islands in the Southern Hemisphere was proposed [29]. The fact that the Earth's rotation is slowing down has been used to explain the directionality of the continental drifts in the Southern Hemisphere. It is thought that the slowdown in the Earth's rotation was due to the tidal friction effect of the ocean fluids. In 2020, the back-and-forth drift traces left by the Australian Continent and the Asian Continent began to be thought were driven by the movement of the upper magma fluids [31]. Until recently, we have understood that the early slowdown in the Earth's rotation comes mainly from the angular momentum exchanges and frictional effects between the Earth's inner spheres [24]. Therefore, it is necessary to introduce the dynamic idea of core-magma angular momentum exchange in the Earth's early period and re-describe the directionality of continental drifts in the Southern Hemisphere.

Of the four continental blocks in the Southern Hemisphere, the Antarctic block is smaller in size than the African block and the South American block, but larger than the Australian block. Changes in the angular momentum distribution of global magma fluids and continental masses led to the drift of Antarctic Continent from an original outside block to the current geographic Antarctic position. There is relative drift between the four continental blocks in the Southern Hemisphere. Therefore, we can use the Antarctic block as a reference frame to investigate the relative motion of the other three continental blocks. **Figure 3** is a map of land and sea distribution at mid- and high-latitudes in the Southern Hemisphere. The current Antarctic block is covered in ice and snow, surrounded by two large marginal seas (the Weddell Sea and the Ross Sea). The circumpolar ocean belt separates the Antarctic block from three other continental blocks including the African block, the Australian block, and the South American block. There are three large ocean basins in the circumpolar ocean belt. They are the Indian Atlantic Antarctic Basin, the Eastern Indian Antarctic Basin, and the Pacific Antarctic Basin. In the latitude direction, the Atlantic Ocean, Indian Ocean, and Pacific Ocean separate the African block, the Australian block, and the South American block. The Madagascar Island and the New Zealand Islands are located on the eastern side of the African block and the eastern side of the Australian block, respectively. We need to dynamically explain the symmetrical characteristics of these land and sea distributions on the Earth's surface.

From the perspective of core-magma angular momentum exchange and the slowdown of the core rotation, the moved direction of upper magma fluids during the early geological evolution is generally eastward, so the upper magma fluids caused by the Coriolis force have the equatorward component of movement. As a result, the moved direction of the upper magma fluids in the Southern Hemisphere points to the northeast in the early period. The speed of upper magma fluids pointing to the northeast varies with latitude from the zero at the south pole. The margin of Antarctic block can rotate clockwise under the drive of the upper magma fluids. The topographic features of the Antarctic Peninsula and the Oates Land reflect the directional trend of drift at the margin of Antarctic block. According to the directionality of continental drift [29], the African block, the Australian block, and the South American block relative to the Antarctic block should respectively come from the Indian Atlantic Antarctic Basin, the Eastern Indian Antarctic Basin, and the Pacific Antarctic Basin. They are indicated by the red dashed-line arrows in **Figure 3**. Thus, we can pull the three continental blocks back into the marginal ocean basins surrounding the Antarctic block. Conversely, the African block, the Australian block, and the South American block drift out in a northeastward direction from their position of the

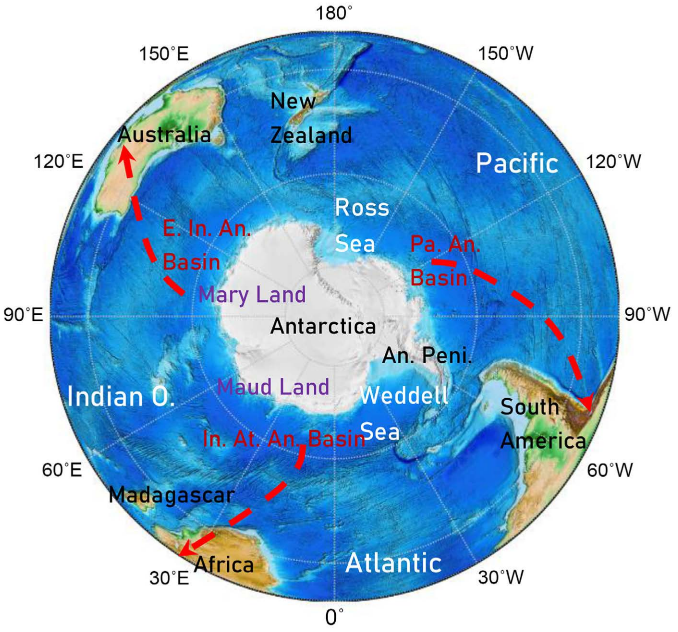


Figure 3. Directional drift map of the African block, the Australian block, and the South American block relative to the Antarctic block in the Southern Hemisphere. The red dashed-line arrows indicate that the three continental blocks come from the Indian Atlantic Antarctic Basin, the Eastern Indian Antarctic Basin, and the Pacific Antarctic Basin. The map is modified from Qian [31].

above three ocean basins. The distribution of the three ocean basins and the three continental blocks relative to the Antarctic block before and after drift is symmetrical. A review of the directionality of continental block drift shows that the relative drift between continental blocks in the Southern Hemisphere has an inherent symmetrical beauty.

Of course, the rotation of the Antarctic block has gradually slowed down relative to the inner core, and the three surrounding continental blocks have also drifted forth and back many times relative to the Antarctic block. After each time of the back-and-forth drifts, the newly formed oceanic crust is cooled and thickened, so that continental blocks can no longer return to their original positions. As a result, the back-and-forth drift of continental blocks on oceanic crusts leaves traces of different eras. The island of Madagascar is a trace left after the African block drift westward. The New Zealand Islands are a trace left after the Australian block drift westward. The southern tip of the African block is drifted northeastward from the Weddell Sea. The southern tip of the South American block is drifted northeastward from the Ross Sea. The southern edge of the Australian block is split apart and drifts off near the Mary Land on the eastern edge of the Antarctic block. There is evidence closely linked between the Australian Continent and the African Continent and the Antarctic Continent [34] [35] [36]. In **Figure 2**, the Mid-Atlantic Ridge is also a trace left by continental block drifts [24].

The above provides a preliminary description of the relative drift between continental blocks in the Southern Hemisphere from a large perspective. This directionality of relative drift between continental blocks illustrates the global nature of the forces driving continental split and drift. There is a general trend and directionality for large-scale continental drifts during the early geological evolution. Due to the tidal friction effect between different spheres in the Earth's interior, the amplitude of the core-magma angular momentum exchange decreases. Traces of multiple-time-scale drifts of the Australian block should remain in the Pacific and Indian Ocean basins. Taking the example of the Australian block drift, we go on to describe the traces left by its back-and-forth drifts on the Pacific Basin.

4. Traces of Continental Blocks Drifting Back and Forth in the Western Pacific

The world's largest ocean is the Pacific, which covers half sea surface of the world's oceans. The Pacific Ocean is wide at low- and mid-latitudes, with the equatorial latitude zone spanning up to 150 degrees of longitude. The topography of the seafloor in the tropical Northwest Pacific and tropical Southwest Pacific is very complex. Roughly from the Hawaiian Islands in the Northern Hemisphere to the Gambier-Line Islands in the Southern Hemisphere, the Pacific Ocean can be divided into eastern and western parts. The western part is rich in ridges, trenches, archipelagos, and volcanic chains. The eastern part is relatively simple and flat in the basin. In the western part, there are large-scale tectonic systems closely linked by island arcs and trenches. In the eastern part, there are corresponding trenches only near the mountains on the western edge of North and South America. The western part is further categorized into three major island groups: Melanesia, Micronesia, and Polynesia.

Figure 4 shows the distribution of topography and geomorphology in the western Pacific Seafloor at low- and mid-latitudes. The dotted red line in **Figure 4** represents the remained tropical convergence zone (TCZ) of upper magma fluids that formed in the early stages of geological evolution. The tropical convergence zone separates the Northwest Pacific Seafloor from the Southwest Pacific Seafloor. In the Northwest Pacific Seafloor, the easternmost location is the Hawaiian Islands which stand on a line of seamounts in a northwest-southeast direction. To the west, there are islands which stand on a line of seamounts that run northwest-southeast direction through the Johnston Atoll. To the south of the island of Japan, there are north-south oriented island arcs with two lines of seamounts which pass through the islands of Mariana and Guam, respectively. On their western flank, there is a north-south oriented line of seamounts that passes through Palau Island. The Philippine-Borneo islands are located on the westernmost side of the seafloor. The six group locations of islands mentioned above are obvious geographical indications zonally present on the oceanic crust of the tropical Northwest Pacific Seafloor. Studies on the geometry of the ocean basin have given evidence of a collision preserved in the western and southwestern Pacific oceans [37].

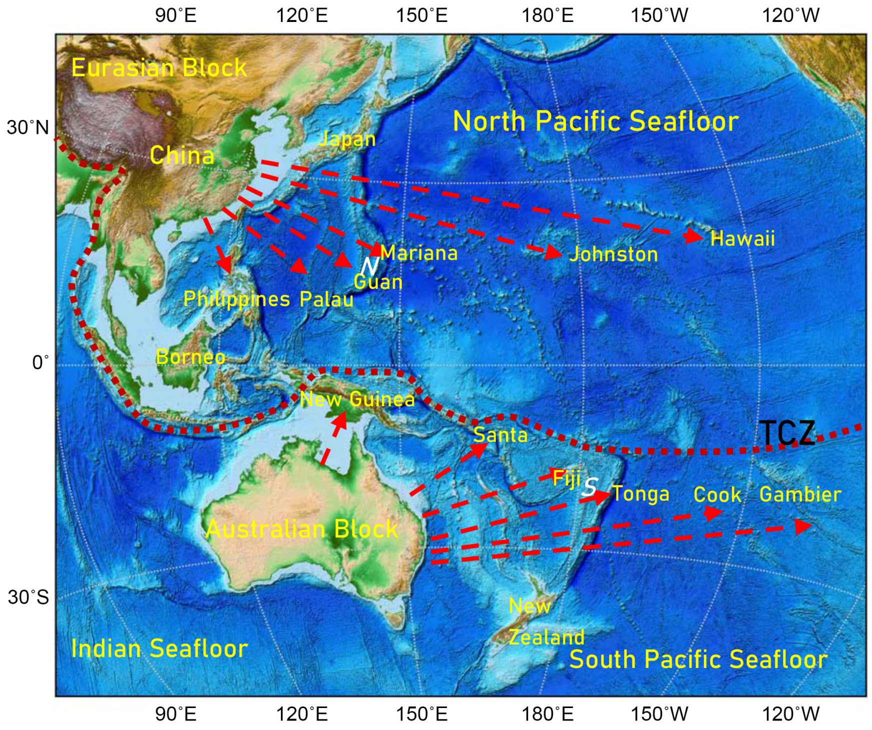


Figure 4. A map of continental drift traces left on the western Pacific Seafloor. The red dotted line indicates the tropical convergence zone (TCZ) of the upper magma fluids. Six red dashed-line arrows indicate the arrived locations of continental eastern edge respectively in the Northwest Pacific Seafloor and the Southwest Pacific Seafloor. The white letter N indicates that there is a pair of meridional lines of seamounts through the islands of Mariana and Guan. The white letter S indicates that there is a pair of meridional lines of seamounts through the islands of Tonga and Fiji.

In the tropical Southwest Pacific Seafloor, there are also zonally six island groups or island arcs which stand on lines of their seamounts arranged from the Gambier Islands in the easternmost and westward to the Cook Islands, the Tonga Islands, the Fiji Islands, the Santa Islands, and the New Guinea Island. The island groups or island arcs are closer to the Australian block, their horizontal width and height gradually increase. The island groups with lines of their seamounts are distributed in an arc shape, like the position once reached by the eastern edge of the Australian block. The island groups with lines of seamounts in the central basin show a meridional distribution, while the island groups with lines of seamounts in the westernmost basin are mostly distributed in the latitudinal zone.

When two original supercontinents centered on the polar regions first drifted into the tropics, the tropical oceanic crust was thin. The split Australian block in the Southern Hemisphere can drift a long distance northeastward to reach the upper magma fluid TCZ. The longest red dashed-line arrow on the east side of Australia points to the Gambier-Line islands. When the Australian block reached the TCZ position, the core-magma angular momentum exchange altered their relative movement. The moved direction of the upper magma fluids is then westward. Driven by the Coriolis force of the upper magma fluids, the

Australian block drifts southwestward. Traces of Gambier-Line islands have been left on the tropical Southwest Pacific Seafloor. The eastward movement of the upper magma fluids drove the Australian block to drift northeast again, reaching the line of seamounts where the Cook Islands are located, as indicated by the sub-long red dashed-line arrow. Subsequently, the core-magma angular momentum exchange changed directionally, and the movement of the upper magma fluids drove the Australian block to drift southwestward, leaving traces of the Cook Islands with a line of seamounts.

For the third time of the upper magma fluids driving the Australian block to drift northeastward, its eastern margin reached the location of Tonga Islands and New Zealand Islands. As the oceanic crust cools and thickens, it becomes more difficult for the continental block to drift northeastward. The result showed that its eastern edge is also blocked by the oceanic crust, so the marginal crust is thickened. When the core-magma angular momentum exchange underwent a directional alteration, the Australian block drifted southwestward, leaving behind thickened fragments of continental margins, such as the New Zealand Islands. Driven by the upper magma fluids, the Australian block underwent its fourth northeastward drift, with its eastern edge reaching the location of the Fiji Islands. When the core-magma angular momentum exchange altered its direction, the Australian block drifted southwestward, leaving the ridge-trench system along the Fiji Islands as indicated by a red dashed-line arrow. The difference in distance reached by the northeastward drift of the Australian block between the third and fourth times was small, indicating that the core-magma angular momentum exchange and the drift speed of the upper magma fluids were not uniform. These two-time drifts left two adjacent meridional traces of seamounts on the Southwest Pacific Seafloor, as indicated by the white letter *S* (**Figure 4**).

Driven by the upper magma fluids, the Australian block underwent the fifth northeastward drift, with its northeastern edge reaching the Santa Islands. When the core-magma angular momentum exchange altered its direction, the Australian block drifted southwestward, leaving the Santa Islands with a line of seamounts as indicated by a red dashed-line arrow. As the Earth's crust cools, the drift distance of the Australian block to the northeast driven by the upper magma fluids gradually shortens. The last significant northeastward drift of the Australian block reached only the location of New Guinea. When the core-magma angular momentum exchange altered its direction, the Australian block drifted back southwestward. The shortest red dashed-line arrow, indicated the New Guinea Island, is the marginal part left by the drift back of the Australian block. Topographically, the concave part of the northern edge of the current Australian block, the Gulf of Carpentaria, coincides with the island of New Guinea. The back-and-forth drift of the Australian block driven by the upper magma fluids, left six distinguishable bands of seamounts or arcs of islands on the tropical Southwest Pacific Seafloor.

The Asian block, including the Tibetan Plateau, is the size about the Australian block. The Asian block is subject to the collision from the Indian block south of the TCZ and to the southeastward drift driven by the upper magma fluids [27]. According to the symmetry of the direction and speed of upper magma fluid motion on both sides of the TCZ, the location of the first southeastward drift of the Asian block should be symmetrical with the location of the first northeastward drift of the Australian block. This location is on the line of seamounts where the Hawaiian Islands are located. In that era, the Australian block first converged with the Asian block near the TCZ to form a supercontinent. Corresponding to the northeastward drift of the Australian block to the Cook Islands, the second southeastward drift of the Asian block should reach the seamount location where the Johnston Atoll is located. Thus, the second time of supercontinent may be formed when the two-side continental blocks converged to the upper magma fluid TCZ.

In the tropical Southwest Pacific, the third time and fourth time northeastward drifts of the Australian block reached to the two island arcs of Tonga and Fiji, respectively. Similarly, in the tropical Northwest Pacific, the third time and fourth time southeastward drifts of the Asian block reached two adjacent meridional island arcs where the islands of Mariana and Guam are located, respectively, as indicated by the white letter *N* in **Figure 4**. The Asian block, driven by the southeastward movement of the upper magma fluids, drifted southeastward for the fifth time to reach the location of Palau with a meridional line of seamounts. The last southeastward drift of the Asian block reached the location of the Philippine Islands. When the mainland drifted back northwestward again, it separated the Philippine-Borneo Islands, forming the South China Sea. These islands correspond to locations in the South China Sea from the southeast edge of the Asian block. From the Japan Islands to the Philippine-Borneo Islands, their locations in the east edge of Asian Continent can be globally identified from **Figure 1** and **Figure 2**. In **Figure 4**, the last trace showed that the Australian block with the New Guinea Island and the Asian block with the Philippine-Borneo Islands converged together near the upper magma fluid TCZ and formed the last supercontinent.

On both sides of the magma fluid TCZ, the drift of New Guinea relative to the Australian block is symmetrical with the drift of the Borneo-Philippines Islands relative to the Asian block. This was the final separation of the Asian-Australian supercontinent. Other symmetrical pairs of two island arcs respectively extend northward from the New Zealand Islands and southward from the Japan Islands (white letters *S* and *N* in **Figure 4**). Due to the orogenic movement formed by the drift and collision of multiple continental blocks, the mountain-root torque causes redistribution of upper magma fluids and produces local disturbances of upper magma fluids [24]. The movement of magma fluids at different scales makes the edge traces left by the drift of continental blocks no longer perfectly symmetrical. Cooled oceanic crusts were also driven by the upper magma fluids so there produced other lines of seamounts. Nevertheless, we can identify the symmetrical features of early geomorphological structures on both sides of the magma fluid TCZ from the relatively chaotic distribution of current topography and geomorphology on the tropical western Pacific Seafloor. The above description shows that there is deep-level order and internal law in seemingly complex or chaotic system of geological formations.

The above is a description of the early back-and-forth drifts of the Australian block and the Asian block using the drive of the global upper magma fluids under the dynamic framework of core-magma angular exchange. On both sides of the upper magma fluid TCZ, the North and South American blocks and the African block had also back-and-forth drifts driven by the upper magma fluids. The back-and-forth drifts of these continental blocks have also left traces during the early periods on the eastern Pacific Seafloor and the Atlantic Seafloor. In the early geological evolution, the closing-opening processes of the Mediterranean Sea were associated with the back-and-forth drifts of nearby continental blocks.

5. A Simple Dynamical Model for Simulating Continental Drifts

Under the dynamic framework of core-magma angular momentum exchange, the continental block drift driven by the upper magma fluid has meridional and zonal components. The meridional component of the continental block drift forms mountain uplifts along the magma fluid TCZ. The zonal component of the continental block drift creates mountain uplifts near the eastern and western edges of the continental block. The uneven distribution of the speed of the upper magma fluids on different latitude and longitude grid points should also lead to thickening and shortening of continental blocks. In 20 years ago, topographic changes which were driven by magma fluid motion have been simply simulated in examining the thickening and shortening of ideal blocks [28]. Now, we can incorporate this model into the dynamic framework of core-magma angular momentum exchange to re-simulate the variation of continental blocks in more detail.

In the early geological evolution, the dynamical model describing the motion of upper magma fluids relative to the inner core is given by [28],

$$\frac{\partial u}{\partial t}=-u\frac{\partial u}{\partial x}-v\frac{\partial u}{\partial y}-g\frac{\partial z}{\partial x}+2\Omega\sin\varphi\cdot v+k\Delta u+\tau_x\,, \tag{1}$$

$$\frac{\partial v}{\partial t}=-u\frac{\partial v}{\partial x}-v\frac{\partial v}{\partial y}-g\frac{\partial z}{\partial y}-2\Omega\sin\varphi\cdot u+k\Delta v+\tau_y\,. \tag{2}$$

In Equation (1), the term $\frac{\partial u}{\partial t}$ is the local variation of upper magma fluid velocity u at the zonal direction from west to east as positive, the two terms $-u\frac{\partial u}{\partial x}-v\frac{\partial u}{\partial y}$ are the horizontal advection, the term $-g\frac{\partial z}{\partial x}$ is the horizontal pressure gradient associated with gravity g and geopotential height z, the term $-2\Omega\sin\varphi\cdot u$ is the Coriolis force associated with the Earth's rotation Ω and the fluid velocity u at latitude φ, the term $k\Delta u$ is the internal diffusion of velocity u associated with the diffusive coefficient k and the Laplace operator Δ, the last term τ_x is the boundary stress between the inner core and the magma fluid layer at the zonal direction. All terms in Equation (2) have similar meaning but at the meridional direction for velocity v from south to north as positive.

The above two equations are not closed so it needs a continuity equation as,

$$\frac{\partial z}{\partial t}=-\frac{\partial uz}{\partial x}-\frac{\partial vz}{\partial y}. \tag{3}$$

In the above three equations, energy equation is not considered because we only consider the effect of the inner core on the magma fluid motion through frictional torque and then the upper magma fluids driving the continental block drifts and the orogenic movement.

After we have the global speed field of upper magma fluids, the moving direction and trend of continental blocks can be calculated through following transform equation,

$$\frac{\partial s}{\partial t}=-u\frac{\partial s}{\partial x}-v\frac{\partial s}{\partial y}+k'\Delta s+G. \tag{4}$$

Here, the variable s denotes material mass (continental block) contained over the upper magma fluids, the term $k'\Delta s$ is the internal diffusion of material mass associated with the diffusive coefficient k', the last letter G indicates the dissipation or accretion of material mass near the boundary between two blocks. Equations (1)-(4) illustrate a dynamical model with internal diffusion and external friction similar as used in the local sediment model [38].

A set of Equations (1)-(4) can be used in the description of material mass driving through horizontal motion of upper magma fluids. Although equations are all non-linear, but we can obtain their numerical solution and predict the future location and geopotential height of each block. Before the crust or lithosphere formed, upper magma fluids moved westward and poleward relative to the inner core, so all lighter materials converged to two polar areas. During the early cooling stage of the Earth, the magma fluids would obtain an increasing angular momentum relative to the decreasing angular momentum of the inner core. The angular momentum exchange was through the frictional torque between the inner core and the magma fluids vertically associated with meridional and zonal cells. Thus, the upper magma fluids moved eastward and equatorward relative to the inner core so the two original supercontinent caps would split apart and drift away from the two polar areas to the magma fluid TCZ.

For the upper magma fluids, it should have planetary-scale spatial motion and its timescale about million years (Ma). Recently, we have built a dynamic framework for the core-magma angular momentum exchange [24]. According to this dynamic framework, the equation of magma fluid motion can be written as a format of vector,

$$\frac{\mathrm{d}\boldsymbol{V}}{\mathrm{d}t}=-g\nabla z-2\boldsymbol{\Omega}_c\times\boldsymbol{V}+\boldsymbol{g}+\frac{\mathrm{d}\boldsymbol{\Omega}_c}{\mathrm{d}t}\times\boldsymbol{r}. \tag{5}$$

Here, Ω_c is the rotation rate of the inner core, the speed $\boldsymbol{V}=u\boldsymbol{i}+v\boldsymbol{j}+w\boldsymbol{k}$

is a vector which can project to three orthogonal directions, and the vector $\boldsymbol{r}$ is the distance of magma fluids to the Earth's center so the last term is the angular momentum exchange between the inner core and the magma fluid layer in the early Earth period.

Equation (1) can write at local coordinates but only considering the large-scale horizontal motion of magma fluids at zonal direction,

$$\frac{\partial u}{\partial t}=-u\frac{\partial u}{\partial x}-v\frac{\partial u}{\partial y}-g\frac{\partial z}{\partial x}+2\Omega_c\sin\varphi\cdot v-\alpha_{cm}\frac{\mathrm{d}\Omega_c}{\mathrm{d}t}r\cos\varphi\,. \tag{6}$$

Here, the coefficient $\alpha_{cm}=I_c/I_m$ is a ratio of the moment of inertia of the inner core I_c to that of the magma fluid layer I_m [24].

For this slow-speed magma fluid movement, the two terms of horizontal advection and internal diffusion can be omitted. The zonal stress term τ_x in Equation (1) is the boundary stress between the inner core and the magma fluids so it takes the last term from Equation (6)

$$\tau_x=-\alpha_{cm}\frac{\mathrm{d}\Omega_c}{\mathrm{d}t}r\cos\varphi\,. \tag{7}$$

At the meridional direction, the stress term is proportional velocity v with a coefficient ε,

$$\tau_y=-\varepsilon v\,. \tag{8}$$

For Equation (4), the internal diffusion and external friction are not considered here so only the effect of material mass (continental block) advection is,

$$\frac{\partial s}{\partial t}=-u\frac{\partial s}{\partial x}-v\frac{\partial s}{\partial y}\,. \tag{9}$$

Equations (1) and (2) are finally simplified as,

$$\frac{\partial u}{\partial t}=-g\frac{\partial z}{\partial x}+2\sin\Omega\varphi\cdot v-\alpha_{cm}\frac{\mathrm{d}\Omega_c}{\mathrm{d}t}r\cos\varphi\,, \tag{10}$$

$$-g\frac{\partial z}{\partial y}-2\Omega\sin\varphi\cdot u-\varepsilon v=0\,. \tag{11}$$

Thus, we have a set of simplified Equations (3), (9), (10) and (11). They together construct a simple model which can be used to simulate the continental drift and block height variation forced by the upper magma fluids associated with the relative motion between the inner core and the magma fluids.

Some parameters are taken as $\alpha_{cm}=10$, $r=6371110\ \mathrm{m}$, $\varepsilon=1/\Omega$, $\Omega=3.14159/43082\ \mathrm{s}^{-1}$, $\frac{\mathrm{d}\Omega}{\mathrm{d}t}=\frac{\Delta\Omega}{\Omega}\cdot\frac{\Omega}{\Delta t}$. According to the observation, $\frac{\Delta\Omega}{\Omega}\approx10^{-8}\sim10^{-9}$. Thus, $\frac{\mathrm{d}\Omega}{\mathrm{d}t}\approx10^{-20}\ \mathrm{s}^{-2}$. The model's spatial longitude-latitude grid intervals are $\Delta x=5^{\circ}$ (degrees) at zonal direction and $\Delta y=4^{\circ}$ (degrees) at meridional direction, and time interval is $\Delta t=3600\times24\times365\times10^{7}\ \mathrm{s}$.

It is a channel two-dimension model with its two boundary latitudes at 74˚N and 74˚S. Its integral scheme, from Equation (9) as an example, is first to calculate advection at the grid (*i*, *j*) at the time point *n*,

$$\begin{aligned}\mathrm{AS}_{i,j}^{n} &= -\left(u_{i+1,j}+u_{i-1,j}\right)/2\cdot\left(s_{i+1,j}+s_{i-1,j}\right)/\left(2\Delta x\right)\\ &\quad -\left(v_{i+1,j}+v_{i-1,j}\right)/2\cdot\left(s_{i,j+1}+s_{i,j-1}\right)/\left(2\Delta y\right).\end{aligned} \tag{12}$$

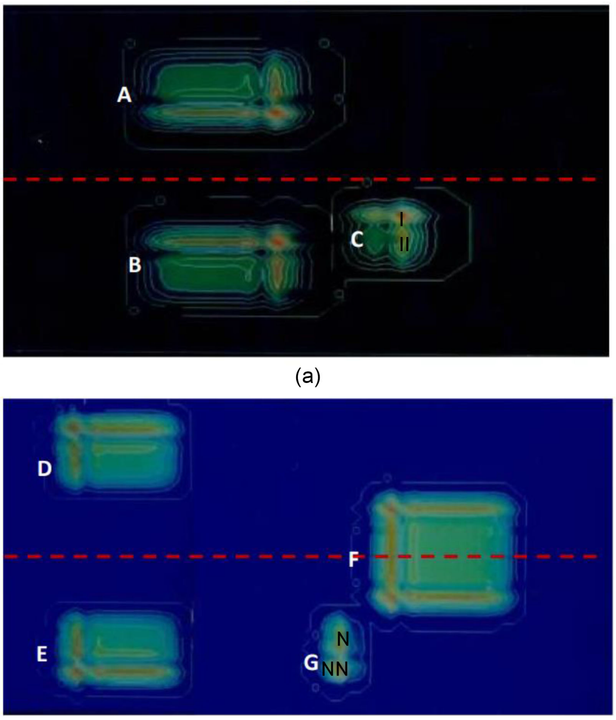
Here, the term $\mathrm{AS}=-u\dfrac{\partial s}{\partial x}-v\dfrac{\partial s}{\partial y}$ is the material mass (continental block) advection. For the term $\dfrac{\partial s}{\partial t}$ in Equation (9), the time integration scheme of central difference is used at three time points ($n-1$, n, and $n+1$) as,

$$s_{i,j}^{n+1}=s_{i,j}^{n-1}+2\left(\mathrm{AS}\right)_{i,j}^{n}\Delta t\,. \tag{13}$$

The conservation of material mass is satisfied during the integrated process. This model was used in our previous simulation [28] but only considering the dynamic framework of core-magma angular momentum exchange in this paper.

Using the above model, this paper examines the geopotential height variation of continental blocks driven by the upper magma fluids after two supercontinent caps have been split apart from the two polar areas. An ideal fluid numerical experiment is carried out first for initial flat blocks, which are some rectangular blocks with their depth 5 meters. The real crust thickness can reach tens of kilometers. Whether continental blocks are taken a few meters or tens of kilometers thick, their model experimental results are similar. This is because we only examine the relative change in block heights. In initial time, two large blocks with its zonal length longer than its meridional width are symmetrically placed on the north and south sides of the magma fluid TCZ while a small block with its zonal length shorter than its meridional width is placed on the south side of the magma fluid TCZ. In the previous simulation [28], five blocks were used but here only three.

Figure 5(a) shows the simulated result at time 24 Ma, which is driven by eastward and equatorward movement of magma fluids during the core losses its angular momentum. The simulated block surface is not so flat but shows that some places are higher than 5 m in height and others are lower than 5 m in height. The feature of thickening and shortening heights is clearly simulated. We first examine the height variation of block A. The block A has become four parts after simulation. The highest part of the height above 5 m is in the southeast. If the original-flat block A is similar as the Eurasian Continent, the highest part in the simulated block A is similar as the Tibetan Plateau located in the southeast part. The southern and eastern parts of simulated block A are respectively similar as the Alps in southern Europe and meridional mountains in eastern Asia. The largest low-height area below 5 m is in the northwest corner of the block A, which is equivalent to the current Europe Continent. In fact, the average height of the current Europe Continent is lower about 300 m above sea level. The relative low height distribution simulated in **Figure 5(a)** from the block A can be well compared to the European Continent in **Figure 2**.



(a)

(b)

Figure 5. Simulated block locations and topographical distribution (red shading above 5 m, height interval is 1 m) at 24 Ma (a) when the upper magma fluids move eastward and equatorward associated with the inner core losing angular momentum and (b) when reversal with that the inner core receives angular momentum. The red dashed line indicates the equator or the upper magma fluid TCZ. In (a), letters "I" and "II" indicate two highlands as similar in the Indian Peninsula. In (b), letters "N" and "NN" indicate two islands as similar in the New Zeeland Islands.

The block B is symmetrically related to the block A on the two sides of the magma fluid TCZ. The highest part in the block B is in the northeast. If the original-flat block B is similar as the African block, the simulated highest part is the Arabian Peninsula located in the northeast part. Its eastern part can be seen as the East African Plateau and the northern part is the North African Plateau. The Red Sea and the East Africa Rift are low zones simulated in the block B where two adjacent parts are easier to be separated. The simulated height distribution in the block B can be compared with the topography from the Northeast Africa to the Arabian Peninsula in **Figure 2**.

In **Figure 5(a)**, the block C is similar as the Indian Peninsula with two highlands marked by letters "I" and "II" in **Figure 2**. The north part might be subducted or collided to form the Tibetan Plateau driven by the upper magma fluids. If we combine the highest part in the block C overlapping with the highest part in the block A together, the formed reason of the Himalayas as the highest plateau can be well explained. The moved distance of the Indian block during the 24 Ma can be identified from the height variation in **Figure 5(a)** indicated in the block C. It should be noted that the model described here the motion of the fluids and the change in the material mass, rather than the rigid continental block motion.

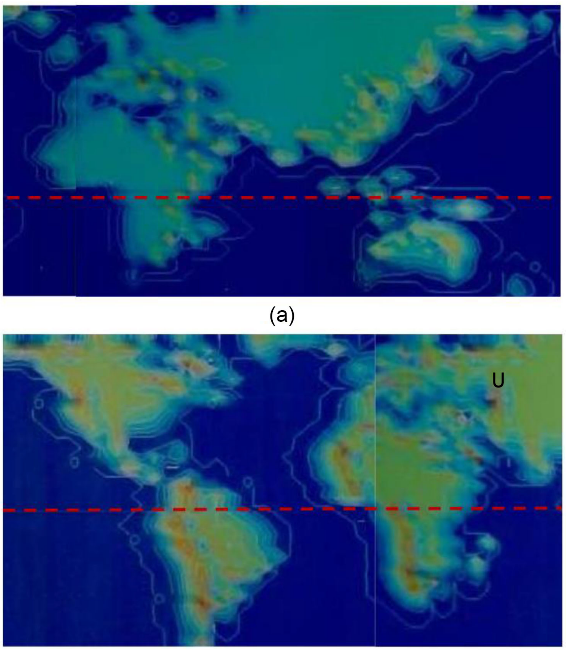
Similarly, Figure 5(b) shows the simulated result at time 24 Ma, which is driven by westward and poleward movement of upper magma fluids during the core gains angular momentum. This experiment has not been run in previous work [28]. Originally, four flat blocks D, E, F and G are placed on the upper magma fluids. The blocks D and E are symmetrical distribution relative to the equatorial zone or the upper magma fluid TCZ. The block F is also symmetry relative to the upper magma fluid TCZ. The block G is a long block at the meridional direction on the south side of the upper magma fluid TCZ.

We first examine the simulated block F where a significant feature is the meridional mountain ranges with the wave-like height distribution formed in the western part of the symmetrical block relative to the upper magma fluid TCZ. The highest two parts are located on the crossing place from two subtropical-zonal mountain ranges and a meridional mountain range in the west edge. This feature can be compared with the meridional Rocky Mountain in the western North America and the meridional Andes Mountain in the western South America.

The simulated two blocks E and B can be used to compare with the Australian block where the topography in western and eastern parts of Australia is higher with mountains than that in the central part. The highest part simulated in the block D can also be compared with the mountains in North Europe. The two higher centers "N" and "NN" simulated in the block G can be compared with the New Zealand Islands indicated in Figure 2. It is noted that simulated blocks have not interacted with nearby blocks so there is no complex boundary topography. The reason is that several initial flat blocks are placed apart each other in the numerical experiment.

Figure 6 shows results which are similar as illustrated in Figure 5 only except taking the original continents as 5 m height covered actual land areas without topographical mountains and then the model is respectively simulated to 30 Ma. This experiment has also not been reported in previous study [28]. We illustrate the simulated result when the upper magma fluids move eastward and equatorward during the core loses angular momentum (Figure 6(a)). On the north side of the upper magma fluid TCZ, the simulated orogenic movement shows that mountains are mainly located in southeastern part and southern part of Eurasian block. On the south side of the upper magma fluid TCZ, simulated mountains are in eastern part of Africa, and northern and eastern parts of Australia. If the model is run to 44 Ma, simulated mountains in the eastern part of Eurasian block becomes arc-like islands separated to the Asian continent. This can infer how the Japan Islands and all islands in Southeast Asia come from. This simulation can compare in Figure 1(a) and Figure 2 from Japan to Philippines.

The simulated result when the upper magma fluids move westward and poleward during the core gains angular momentum is shown in Figure 6(b). The



(a)

(b)

Figure 6. Same as in **Figure 5** except for the original blocks taken 5 m height are actual land areas without topography and then the model is respectively simulated to 30 Ma (a) when the upper magma fluids move eastward and equatorward and (b) when the upper magma fluids move westward and poleward. In (b) the letter "U" indicates the Ural Mountains.

wave-like height distribution of the meridional Rocky Mountains in western North America and the meridional Andes Mountains in the western South America is well simulated. Some details such as hills surrounding the Hudson Bay are well simulated. Simulated a meridional low land is in the central part of South America which can compare from the observation in **Figure 2**. The simulated meridional mountain range in western Africa can also be used to compare with the observation. In the Eurasian block, the model simulated a meridional mountain range is along the Ural Mountains which can compare in **Figure 2** and **Figure 6(b)** indicated by the letter "U".

From the above simple numerical test results, continental blocks are a planetary-scale drift driven by the upper magma fluids. In the process of continental block drift, the drive of upper magma fluids also forms the height rise or fall in different parts of a block. There is certainty variation in the height and edge of continental blocks during the drift of early geological evolution.

6. Discussion

Geodynamic research has a history of 400 years. From Bacon in 1620 to Wegener in 1912, they simply tried to explain the marginal relationship between the continental blocks from geographical maps. True geodynamic studies began with the interpretation of geomagnetic stripes on both sides of mid-ocean ridges since the 1950s. These explanations developed some hypotheses in the 1960s such as seafloor spreading, plate tectonics, and the Wilson Cycle. These hypotheses have not given specific traces of cycles and timescales in geological history. There are many hypotheses in astronomy and geology. But none of astronomical hypotheses can be extended to one of geological theories, and none of geological theories can be traced back to one of astronomical theories. The Earth has undergone a process from astronomical evolution to geological evolution. These hypotheses do not consider the early internal structure of the Earth and its evolution over time. The inner solid core and outer liquid core (magma fluid layer) still exist in the interior of the current Earth. But on the outside of them, due to the cooling of the Earth, a 2900 km thick lithosphere-mantle layer has formed. However, in the early stages of geological evolution, the Earth only had an inner solid core and magma fluid layer in addition to the relative thick continental crusts and the thin oceanic crusts. Earth's early core-magma angular momentum exchange was the fundamental cause of the continental crust fragmentation and drift. The Earth's core-magma angular momentum exchange has undergone multiple directional transformations in the early geological evolution. The directional change of upper magma fluid motion has driven many-time back-and-forth drifts of continental blocks, leaving traces of the separation and merger of some supercontinents. As mentioned in the previous study [24], the time interval of the angular momentum exchange between the core and the magma should have lasted for at least 0.1 billion to 0.2 billion years. Thus, six-time back-and-forth drifts of continental blocks were completed in 3.0 billion to 4.5 billion years ago. This era is much earlier than the events described in the above hypotheses. The amplitude of the core-magma angular momentum exchange decreases gradually. The geological events described by previous hypotheses or theories, in addition to short in time scales and late in occurrence, were also small in space scales. The Wilson Cycle describes continental drift at the ocean basin scale, so it is difficult to describe the global characteristics of continental block drift. Therefore, one new geodynamic theory needs to cover the multi-time scale in the whole process of the formation of the Earth and the multi-space scale in the three-dimensional Earth evolution.

In the early stages of geological evolution, the thickness of magma fluids reached thousands of kilometers, in which there were planetary-scale magma fluid circulations, the magma fluid TCZ, basin-scale magma fluid vortex and local-scale magma fluid disturbances. Only about 10 km thick Earth's atmosphere, there also vertically exists planetary-scale Hadley cells, Walker cells, TCZ and polar fronts. Tropical storms (typhoons and hurricanes) form on planetary-scale atmospheric fluid TCZ. Extratropical cyclones form on planetary-scale atmospheric polar fronts. Tropical storms and extratropical cyclones similar as hot spots and volcanic activity that occur in the Earth's interior, are local-scale disturbances. Atmospheric disturbances (tropical storms and extratropical cyclones) can appear in clusters, so the planetary-scale atmospheric fluid TCZ is the circulation background or an organizer. Similarly, disturbances (hot spots and volcanic activity) in the Earth's interior can be arranged in clusters, so the planetary-scale magma fluid TCZ is also the circulation background or an organizer. On the leeward side (east side) of the Qinghai-Tibet Plateau, the dry-cold airflows of the north branch and the warm-humid airflows of the south branch bypass the plateau and form an east-west oriented plateau-scale TCZ in East Asia. On this plateau-scale TCZ, subtropical cyclones are frequently appearance, forming stormy convective weather. The plateau-scale atmospheric TCZ is the circulation background and the organizer for subtropical cyclones. Similarly, the first drift of the Asian block reached the Hawaiian Islands, leaving behind a continental-scale magma fluid TCZ. Local-scale convective systems, such as hot spots and volcanic activity, can frequently occur on continental-scale magma fluid TCZs. This series of comparisons can clarify the debate on plate and plume [18].

As an application, we can explain that the Hunga Tonga-Hunga Ha'apai volcano was eruption on 15 January 2022 [39] [40]. A question raised is why such strong submarine volcano occurred at the southernmost latitude over the subtropical Southwest Pacific Seafloor? This place can be clearly observed from **Figure 2** and **Figure 4** where it is the place of the southernmost crossing zonal-meridional magma fluid convective zones. Zonally, the place is near the southernmost latitude of tropical convergence zone in the upper magma fluids. Meridionally, the place is along the Tonga ridge-trench system which is a trace remained by the westward drift of the Australian block.

The planetary-scale land-sea distribution, regional-scale plateau-ocean distribution, large-scale ridge-trench system, and local-scale hotspot-volcanic distribution that can be observed on the Earth's surface are the result of the splitting and drifting of continental blocks, and the result of multi-scale block-block interaction driven by upper magma fluids in geological history. These geomorphological features at different scales reflect the traces left by block movements at different space and time scales. To correctly understand the formation of these traces, we need to establish a worldview and methodology based on the geological historical evolution. For all large-scale tectonic movements, such as plateau uplift, plate subduction, and the formation of ridge-trench system, they are necessary to consider the driving of upper magma fluids to continental blocks in the early Earth period. For small-scale mantle convection, the principle of orthogonal collision caused by horizontal convergence of magma fluids needs to be introduced into the dynamical model [24] [27]. A simple dynamic model and its simulation results presented in this paper or the previous work [28] is an example of geodynamical research in this worldview. We don't yet fully understand the structure and physical properties of the current Earth's interior matter. Through the simple model simulations in this paper, we believe that mantle convective models need to consider both planetary-scale and region-scale early tectonic movements of the Earth. For orogeny at the continental (block) margin, the vertical shear stress excited by orthogonal collisions in the horizontal movement of magma fluids needs to be introduced into dynamical models [24].

7. Conclusions

The current global distribution of land, sea and terrain is intricate, which is the result of many-time continental drifts and orogenic movements since the geological evolution. The formation of the Earth has gone through a period of astronomical evolution and a period of geological evolution. The oldest crust on the Earth has formed in 4.54 billion years ago, which is the beginning of geological evolution. At the beginning of geological evolution, the rotation rate of the Earth was twice that of today, so the first formation of the high-geopotential crust was located at mid-high latitudes as two primitive continental blocks, while the tropics were a low-geopotential oceanic crust zone. At the beginning of geological evolution, the core lost angular momentum, and the eastward movement of magma fluids and the Coriolis force drove the splitting and drifting of the primordial continents from the two polar areas. The primordial continent of the Northern Hemisphere split into 4 continental blocks. The primordial continents of the Southern Hemisphere split into 5 continental blocks. These continental blocks drifted back and forth several times driven by the upper magma fluids during the early geological evolution. Their overall drift direction is eastward and toward magma-fluid TCZ. Although the magma fluid TCZ has deviated from the equator, the areas of continental blocks on either side of the TCZ are equal. Since the geological evolution, the two original flat continental blocks become the current complex continental blocks and mountain uplifts through split and drift and interaction. Continental drift and orogeny processes mainly occurred in the early geological evolution.

During the early period of geologic evolution, continental drifts driven by upper magma fluids have their directionality. The fact showed that the Earth's rotation is slowed down since the geological evolution. It also implied that the rotational rate of the inner core is also slowed down for a long time relative to the magma fluid layer and the current lithosphere-mantle layer. As a result, the magma fluids have an eastward velocity relative to the core and an equatorward velocity under the action of the Coriolis force. Driven by the eastward and equatorward motion of the upper magma fluids, the continental blocks of Africa, Australia, and South America in the Southern Hemisphere relative to the Antarctic block undergo a northeastward drift. The islands in the Southern Hemisphere are located on the east and northeast sides of their continental block. The current three continental blocks drifted northeastward can be regained their original locations in the three ocean basins around the Antarctic block. These traces suggest that the directionality of continental drift forms a symmetrical distribution of current continents. Due to the inhomogeneity of split blocks and orogeny, the angular momentum of magma fluids is changed during the convergence of these continental blocks to the equator, which makes the TCZ deviated from the geographical equator. This deviation also changed the geographical location of the Antarctic block since the geological evolution.

The core-magma angular momentum exchange symmetrically caused the drift direction and drift path of the continental blocks on both sides of the upper magma fluid TCZ. On the world's largest tropical western Pacific Seafloor, drift traces of the Australian and Asian blocks in the early stages of geological evolution are left there. The Australian block drifted farthest northeast to the seamount line of Gambier-Line Islands. The Asian block drifted southeastern most to the seamount line of Hawaii Islands. The remained traces on the tropical western Pacific Seafloor revealed that the core-magma angular momentum exchange showed six times of distinct directional change (differential rotation between layers) in the early stages of geological evolution. Six times of directional change also existed in the movement of the upper magma fluids. As a result, the Australian block and the Asian block experienced six times of significant back and forth drifts. Among them, two-time drifts simultaneously formed two adjacent island arcs passing the New Zealand Islands in the Southern Hemisphere and the Japan Islands in the Northern Hemisphere. The last significant back-and-forth drift of the Australian block separated the island of New Guinea. The last significant back-and-forth drift of the Asian block separated the Philippines-Borneo islands. On the tropical western Pacific Seafloor, there should be six-time traces of the Asian-Australian supercontinent left during the early geological evolution.

The directional movement of the upper magma fluids not only drove the drift of continental blocks, but also changed the height and range of continental blocks. When the upper magma fluids move eastward and towards TCZ, the continental height of the Northern Hemisphere will rise in east and south sides, particularly in southeast side, while the northwestern part of height decreases. Symmetrically, when the upper magma fluids move eastward and towards TCZ, the continental height of the Southern Hemisphere will rise in east and north sides, particularly in northeast side, while the southwestern part of height decreases. These height distributions explain well the actual terrains such as the Eurasian Continent, the African Continent, the Indian Peninsula, and the New Zealand Islands. When the upper magma fluids move westward and toward the pole, the western height of the continental block rises, the height of the north and south edges of continental blocks also rises, while the height of the intermediate region decreases. Such a change in altitude explains well the distribution of mountains in the western part of the North and South American continents. Taking the current global distribution of land and sea, only removed mountains on all continents, the simple simulation formed height variation which can explain the current topographic distribution of different parts in the world. As the upper magma fluids move eastward and toward TCZ, the height rises on the southern and eastern margins of Eurasia, on the eastern edge of Africa, and on the northern and eastern margins of Australia. If the upper magma fluids move westward and toward the pole, a wave-like topographic distribution appears in the western part of the North and South American continents. The above results confirm that the first driving force of continental drift was the core-magma angular momentum exchange during the early geological evolution.

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Conflicts of Interest

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

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