DYNAMIC MECHANISM OF THE PLATE TECTONICS

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Received March 12, 1980.

There are two fundamental problems about the behaviour of the earth crust motion. The first one is the structural traces and their pattern of combination, and the second one is the analysis of the tectonic stress field and its inftrence on the dynamic mechanism. Although the plate tectonics persuasively reveals much of the behaviour at plate boundaries, it ignores the role played by combination of such structural traces as oceanic ridges, transform faults and oceanic trenches together with their genetic correlations. As a result there arise some difficulties in the explanation of the global tectonic motions and dynamics[1-3].

From the regularity of the pattern of structural fractures on the sea floor, and the calculation of elastic theory and model experiments, we propose here a dynamic mechanism of plate tectonics.

I. THE COMBINATION FEATURE OF FRACRURE NETS AT THE BOTTOM OF THE OCEAN—A WEB-FRACTURE SYSTEM

Two extensional ridges mark the global sea floor extension and crust creation. Each of these ridges stretches continuously up to an order-of-magnitude of 10^4 km and forms a big loop which is crosscut by a series of big linear faults into many broken segments.

The first loop begins from Gorda-Juan Da Fuca ridge in SE Alaska, passes the Mendocinoka Cape to the continent of N. America, then dips into the sea along the Gulf of California as a submarine ridge of the east Pacific Ocean. It stretches to the Antarctic, turns around the south of Australia and then northwestward to meet the Lotkaliss' Fault.

The second loop begins from Red Sea-Aden Gulf to the Lotkaliss' Fault, turns southwestward to the west of Indian Ocean and around the southern tip of Africa to finally connect the mid Atlantic ridge stretching straight to Iceland (Fig. 1).

There are smaller concentric loops inside these two big loop-shaped ridges[4]. It is interesting to note that concentric loop-shaped magnetic anomalies coincide with that of ridge expansion described above.

The big linear faults crosscutting the loop-shaped ridges extend radially, converging to the middle of the loop. Together with the extensional ridge, they form a web-fracture system which is another spectacular feature of the sea floor structure.

In the Antarctic and the two subpolar regions, there are also concentric radial

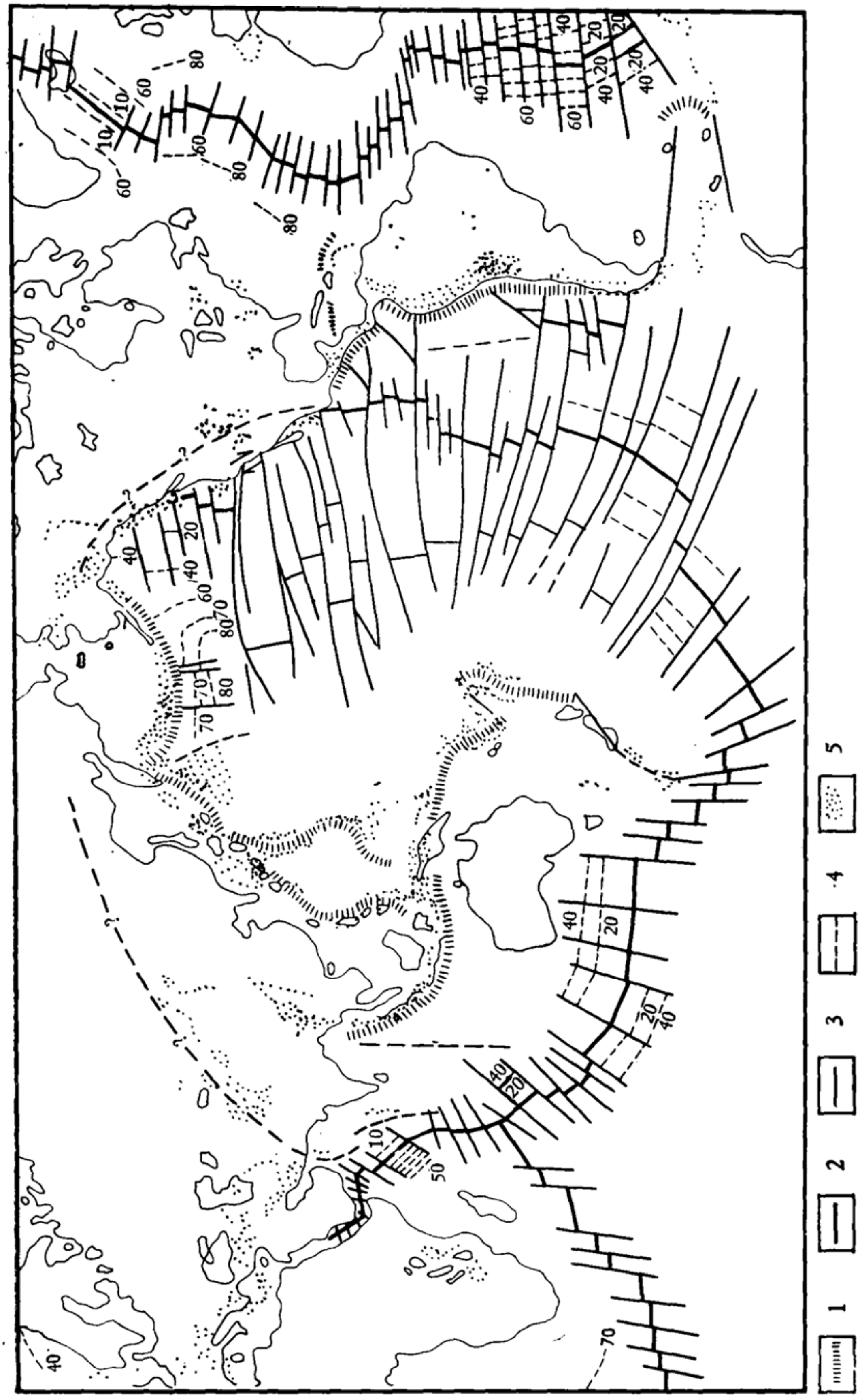

Fig. 1. Sketch of sea floor structure of the Pacific Ocean, the Atlantic Ocean and the Indian Ocean (according to J. Heirtzler, R. L. Parker & Fan Shiqing).

1—submarine trench; 2—submarine ridge; 3—transform fault; 4—magnetic lineation (number indicates age in million years); 5—epicenters.

fractural systems formed in Mesozoic-Cainozoic era[5].

The oceanic trenches that accompany the island arc or coastal mountain ranges such as Peru-Chile trench, Tonga trench, Diarter-Ogber trench and Java's trench are also loopshaped, partly in parallel to the oceanic ridge, almost all these trenches possess fractures of normal fault terraces in the form of graben structures. It suggests that these trenches were transformed from tension faults into compression faults during the growth of ocean bottom and that underthrusting occurred under the sea floor.

To sum up, there exists a submarine web-fracture system in a global scale which is governed by certain dynamic mechanism and controlled by the related tectonic stress field.

II. A Mechanical Model

To seek the mechanical cause on the formation of the fault system, we assume the crust to be a homogeneous and continuous isotropic plate, its thickness much less than its lateral dimension. We consider the fault distribution of a thick elastic circular plate with its boundaries is fixed and subjected to a force vertically upward at the centre. Mathematically, this is equivalent to Eq. (1) under boundary conditions (2) and (3)[6]:

$$\frac{d}{dr}\frac{1}{r}\frac{d}{dr}r\frac{dW}{dr}=\frac{P}{2\pi D}, \tag{1}$$

$$r=0,\ \frac{dW}{dr}=0, \tag{2}$$

$$r=a,\ W=0,\ \frac{dW}{dr}=0, \tag{3}$$

where W is the deflection; P, force at $r=0$; r, 0, polar coordinates; a, radius of circular plate, and

$$D=\frac{Eh^3}{12(1-\nu^2)}.$$

The solution obtained is

$$W=\frac{P}{8\pi D}\left[r^2\ln\frac{r}{a}+\frac{1}{2}(a^2-r^2)\right],$$

and

$$\sigma_r=-\frac{3PZ}{h^3\pi}\left[1+(1+\nu)\ln\frac{r}{a}\right],$$

$$\sigma_\theta=-\frac{3PZ}{h^3\pi}\left[\nu+(1+\nu)\ln\frac{r}{a}\right],$$

$$\tau_{r\theta}=0.$$

σ_r, σ_θ are the radial and tangential normal stresses in polar coordinates.

Since the shearing stress $\tau_{r\theta}$ is zero, σ_r, σ_θ are principal stresses. The stress trajectories are shown in Fig. 2.

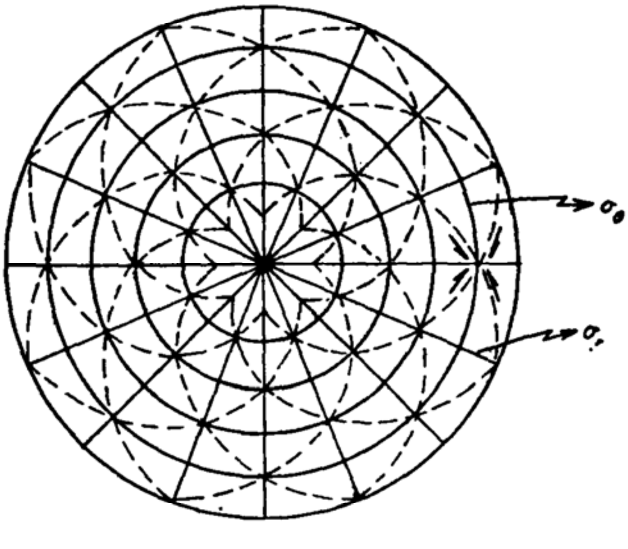

Fig. 2. Stress trajector of mechanical model.
—— principal stress line;
- - - maximum shearing-stress line.

At $Z = h$ (> 0), which is the earth surface, the stress is extending to all directions, and $\sigma_r - \sigma_\theta < 0$, $d\sigma_\theta/dr < 0$. It can be seen that the radial tension faults first appear at the centre and spread outward. When $Z = -h$, the stress becomes compressive in all directions, and $\sigma_r - \sigma_\theta > 0$, $d\sigma_r/dr > 0$, the faults first appear at the boundaries, spreading inward as circles toward the centre. There may also be two systems of wrench faults with the bisector of the acute angle in the direction of σ_r.

Model experiments with paraffin wax, resin, etc. gave the following results[7,8].

(1) As the model was being vaulted up, a dome appeared with tension fractures developed from the centre and extended radially in all directions. At the base there appeared simultaneously concentric fractures developed from the boundary to the centre. All these agree with the mathematical statement described above.

(2) As the vaulting amplitude increases, tangential or arc-shaped fractures developed as a result of radial tension on every fan sector which was dissected by radial fractures already formed. They often staggered apart and did not connect each

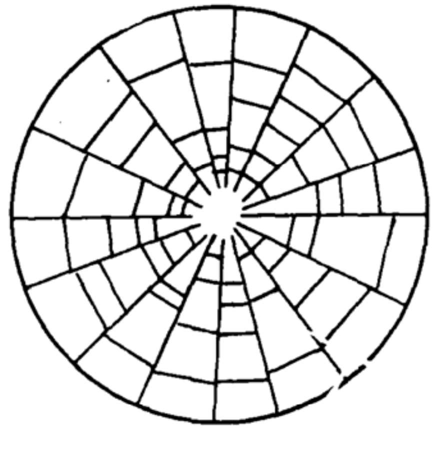

Fig. 3. Sketch of web-fracture system.

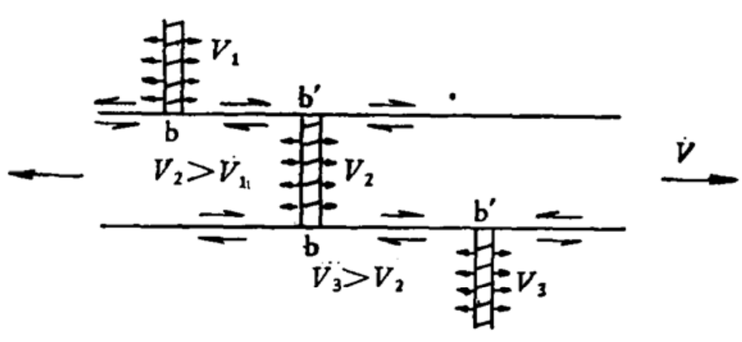

Fig. 4. Sketch of shear fractures.

other, forming a web-fracture system (Fig. 3). At the base were radial tension fractures cutting the concentric fractures previously formed.

(3) The fractures on the top part of the model are tension fractures, while those at the bottom part are compression ones.

III. Dynamic Mechanism of the New Global Plate Tectonics

According to the above-mentioned elastic solution and model experiments, the synthetic feature of the web-fracture system in the sea floor shows that although distribution of the crust matter is discontinuously inhomogeneous and anistotropic, it may be treated otherwise as a whole. Therefore we propose a dynamic mechanism of the global plate tectonics as follows.

1. *The Massive Structural Domes and Deep Energy Source*

The web-fracture system in the sea floor suggests that there is a massive dome in the lithosphere being pushed up by an energy source deep underneath. A large amount of heat energy collects and transforms from radioactive elements underneath the crust and from disintegration of the mantle matter. The difference in heat flow distribution also helps to form a powerful concentrated thermal stress origin like a "plume", which acts upon the lithosphere to form the massive dome. Because the shear strength of the lithosphere is many times stronger than the tensile strength and the crust is under tension in all directions, a web-fracture system is developed as the main form of faults. Further development of the dome produces the loop-shaped fractures which cut through the lithosphere[8]. What follows is the high pressure heat flow penetrating through the fissures to the top of the dome. Energy is then liberated at the crest of the dome, the internal pressure lowered and the relative equilibrium between the weight of the dome and the internal pressure reestablished. However, such an equilibrium is unstable, isostasy will then cause the internal pressure to increase and the mantle hot matter to move along the circular loop-shaped fractures where the stress is low. This in turn will bring about crevasse volcanic eruptions and dome subsidence, enhance the radial tension along the circular loop-shaped fractures, and finally build up the expansion zones with the mid-oceanic ridges as their mainstay. In the Pacific-Indian loop, the centre of the dome is the Darwin mid-oceanic rise in the middle west Pacific Ocean[10].

Thus the vertical motion of the dome will be transformed into horizontal motion of sea floor extension.

2. *The Sea Floor Spreading and Plate Formation*

The horizontal expansion of the loop-shaped fractures will result in a forceful compression of the ladder-shaped blocks which were dissected by web-form structures. Thus they form the subduction zones consisting mainly of loop-shaped fractures on both sides of the mid-oceanic ridges and trenches. The development of the oceanic crust is concentric and convergent toward the central part of the loop. The expansion occurred at the two oceanic ridge sections that are offset by the radial fractures and the difference in the expansion rate of the two will transform the radial tension fractures into shear fractures. As shown in Fig. 4, if bb′ is a strong shear zone, the offset and the relative motion at the two farther sides of bb′ section will be determined by the difference of expansion rate of the two blocks. It has been confirmed repeatedly by measurements[11] such as on certain EW transform faults in the Atlantic Ocean and the magnetic data of Medocino and Murray transform faults on the west coast of N. America.

Further development of subduction zone of the lithosphere promotes the trench system and breaks the web-form blocks into plates of different sizes along the mid-oceanic ridges, trenches and transform faults.

It is seen from the above argument that radial tension fractures lead to development of transform faults; the spreading sea floor transforms the tensional motion in the crust to shear motion. The plates are discrete bodies coming from the web-form fractures. The breaking up of the dome structures should occur with no exception over all the continental crust. Interaction of the different stress fields of the dome structures, such as the northeastern Pacific Ocean or the northwestern Indian Ocean is the main cause which complicates the strain field at the junction of the two big loops.

The author wishes to thank Prof. Zhang Wenyou for his guidance and encouragement in the preparation of this paper.

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