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Continental Drift Theory and Its Basic Considerations – A Review

Vipul Garg*

M.Sc., Department of Geography

Abstract – Astronomers take immense delight in enumerating the various motions that we partake even as we are apparently stationary on the surface of the earth. Geophysicists, the people who apply the principles of physics to investigate the earth, gleefully add that the surface of the terra firma itself is not steady but responds pliantly to many causes in the earth's interior and on its surface as well as to a few causes in the solar system.

Occasionally, we can feel the motion of the earth's surface directly for brief periods, as during a major earthquake or when a heavy object moves near us. But ordinarily, we become aware of the restlessness of the earth's surface with the help of suitably sensitive seismometers and gravity meters or through repeat geodetic measurements which provide estimates of changes in the coordinates of points marked for the purpose. Recent geodetic data, notably the satellite-based GPS (Global Positioning System) observations, confirm that, even as you read these lines, the continents are moving at the rate of a few centimeters per year relative to a coordinate system rotating with the earth as well as relative to each other. The limited GPS data for the Indian subcontinent indicate that it is moving approximately northward at 5-6 cm per year currently relative to the earth fixed coordinate system.

Key Words : Continental Drift Theory, GPS etc.

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INTRODUCTION

Several types of evidence in rocks on land and on the seafloor and in the animal and plant kingdoms may be explained simply if we assume that the continents, which are now widely separated, may have been together in the past. Thus, it is surmised that all the present continents of the world may have been joined in a single super continent called Pangea circa 200 Ma, where Ma stands for mega annum or million years. Starting from a position in the Southern Hemisphere, the Indian subcontinent may have drifted over a distance of about 5000 km to reach its present position north of the equator.

The possibility of continental drift has been suggested off and on ever since reasonably accurate maps of continental coasts have been available. But the credit for the theory is given to Alfred Wegener because he first provided a detailed and reasoned exposition of the theory of continental drift. He defended his theory against a chorus of cri ticism for about two decades and constantly sought evidence to strengthen it. I recall here some ideas and events related to Wegener's theory and its subsequent metamorphoses.

WEGENER'S THEORY OF CONTINENTAL DRIFT

Wegener started toying with the concept of continental drift in 1910 when, looking at a new atlas, he was impressed afresh with the remarkable similarity in the coastlines across the South Atlantic Ocean. He thought that the similarity might arise because South America and Africa were parts of the same landmass in the past and had drifted apart subsequently. In late 1911, Wegener read about similarities in many fossils from Brazil and West Africa. He saw that these too would be explained if the two continents had been joined together in the past. Wegener collected from the published literature other lines of geological evidence, such as close similarities in rock formations, which tended to confirm contiguity of continents in earlier times. He also noted that the apparent differences between the present and inferred past climates of different lands could be explained by postulating that the continents had shifted north south by suitably large distances.

Wegener assumed that the earth consisted of concentric layers in which density increased with depth. Continents, forming the outermost incomplete shell, floated in the material of the

second layer in accord with the concept of isostasy. Under the oceans, this layer occurred beneath the sediments. Sometimes the continents drifted apart, as in the case of South America and Africa, and sometimes they collided as in the case of India and Asia. The Rocky Mountains and the Andes were pushed up as the North and South American continents ploughed through the material of the second layer and the Himalaya were pushed up due to the collision of the subcontinent with the main mass of Asia.

Wegener suggested that continents drift in response to two forces. He called the first force the Pollflucht or pole-flight force, ascribed its origin to rotation of the earth and suggested that it pushed continents from the poles towards the equator. He thought that the continents drifted east or west in response to the tidal forces of the sun and the moon. Wegener admitted that both were weak forces.

Wegener first presented his theory of continental drift publicly in a lecture on January 6, 1912. He wrote The Origin of Continents and Oceans dealing with the theory in 1915. The book was revised in 1920, 1922 and 1929 in response to criticisms of the theory and advances in earth sciences.

Continental Drift Idea through the 1930s and 1940s

Earth science community at large was not moved by Wegener's longitude data. During the 1930s and 1940s only a handful of enthusiasts kept faith in the idea of continental drift, and most of them had worked in the Southern Hemisphere. Alex due to it was the foremost geologist among this group. Keeping in mind the criticism of Wegener's geological evidence for drift, he identified 17 tests on exposed rocks to establish pre-drift contiguity among the now separated landmasses. Arthur Holmes was among the few geologists from the northern hemisphere to champion this idea in that period. One of his major contributions was to suggest that continental drift could be driven by convection in the earth's mantle.

THE MOVING SEAFLOOR

The discussion so far has revolved around the evidence obtained from continental areas. Exploration of the seafloor had been in progress at a slow but gradually accelerating pace during the nineteenth century and the first four decades of this century. There was a rapid increase in geological and geophysical exploration of the seafloor after the Second World War. Hess suggested in 1958 that seafloor too may be in motion and, in fact, it may be carrying the continents with it. He gave his idea the sobriquet of geopoetry partly to muffle criticism from the hordes opposing the theory of continental drift. Hess's idea explained neatly why the drifting continents did not leave any scars on the seafloor. It also shifted the spotlight from the mechanism of continental drift that had bothered Wegener greatly. In time, Hess's geopoetry became known as the seafloor spreading hypothesis.

PLATE TECTONICS VERSION OF CONTINENTAL DRIFT

The concept of continental drift and the seafloor spreading hypothesis were incorporated in the theory of plate tectonics proposed in 1968. It is assumed in this theory on rheological considerations that, down to a depth of about 700 km, the earth may be divided into a lithosphere and an asthenosphere. The lithosphere comprising the earth's crust and upper mantle has variable thickness of up to about 200 km. The material of the lithosphere can support and transmit non-hydrostatic stresses of a few hundred MPa, or a few thousand atmospheres, for long periods of time. On the other hand, the material of the asthenosphere exhibits creep and viscous flow when subjected to non-hydrostatic stresses on the time scale of 1000 to 10000 years and longer. Thus convection currents can occur in the asthenosphere on such time scales.

The lithosphere is divided into a number of large and small plates. Their boundaries have been demarcated by considering the geographic distribution of earthquake epicentres and hypocentr.es. Most lithospheric plates span continental areas as well as portions of the seafloor. The plates are in relative motion constantly due to convection currents in the asthenosphere. Plates diverge from each other above the rising limbs of adjacent convection cells and converge towards each other over their descending limbs. They slide past each other horizontally along transform faults.

According to the theory of plate tectonics, the continents drift because the lithospheric plates of which they are parts are moving. The inferred speeds of different lithospheric plates, and thus also of the continents 'drifting' with them, are in the range of 2 to 15 cm per year. See Box 1 for plate tectonics based chronology for the drift of the Indian subcontinent.

ANTIQUITY OF CONTINENTAL DRIFT

Wegener visualized that there was only one phase of continental drift. It began with the breakup of Pangea and is still continuing. Telltale signs in rocks have been deciphered, within the plate tectonics framework, to conclude that continents have been coming together and then fragmenting and drifting apart for billions of years. Only, as we move back in time, it gets more and more difficult to be specific about these continental motions.

PHILOSOPHICAL IMPLICATIONS

In an erudite but extremely readable monograph entitled Drifting continents and shifting theories, Le Grand suggests that a thorough historical analysis of the idea of continental drift can provide valuable insights into the practice of science generally. He finds that the events leading up to the plate tectonics revolution of 1968, including the above developments related to continental drift, do not conform to Kuhn's definition of a 'scientific revolution' as a convulsive replacement of one world-view with another. This is because, in his opinion, until that time, there never was a single overriding world-view in geology. Le Grand feels rather that these events and developments conform more closely to Laudan's view that a 'scientific revolution' occurs when a new research programme is formed which has a high initial rate of progress such that scientists subscribing to competing research programmes can no longer ignore it.

CONCLUSION

In retrospect, it was an important day in 1912 when Wegener proposed his theory. Le Grand views the subsequent developments related to the idea of continental drift as the stuff of myth and legend. In one inspired paragraph, he equates· continental drift with Cinderella, and its critics with her vain stepsisters. He compares the geophysicists of the 1950s and early 1960s with Cinderella's Fairy Godmother who waved the Magnetic Wand (sic). Cinderella went to the Ball and married the Prince represented by the seafloor spreading hypothesis and the plate tectonics theory.

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Corresponding Author

Vipul Garg*

M.Sc., Department of Geography

vipgupta785@gmail.com