PROGRESSIVE WAVE THEORY after WILLIAM WHEWELL

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STATIONARY WAVE THEORY after Dr. R.A. HARRIS

ITEMS	DESCRIPTIONS
Subject Name	Geography
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Objective	To understand the origin of Tides

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Origin of Ocean Tides

The origin of tides in the oceans is primarily concerned with the gravitational forces of the sun and the moon. It may be pointed out that the earth rotates from west to east and revolves around the sun following an elliptical orbit.

Theories of Ocean Tides

Numerous theories have been put forth from time to time to explain the origin of ocean tides. These theories include Equilibrium theory by Issac Newton (1687), Dynamical theory by Laplace (1755), Progressive wave theory by William Whewell (1833), Canal theory by G.B. Airy (1842), Stationary wave theory by R.A. Harris etc.

Progressive Wave Theory

The 'progressive wave theory' of William Whewell propounded in the year 1833 and 'the canal theory' of G.B. Airy postulated in the year 1842 to explain the origin of ocean tides are based on the following facts:

(i) The earth is a heterogenous body and not a perfect fluid.

(ii) Tide occurs at different times at different places on same longitude.

(iii) There is a lagging of time of tides away from the source.

(iv)There is variation in the magnitude and amplitude of tides at different places.

(v) Tide is in the form of tidal wave which travels from east to west.

The crests and troughs of such tidal waves become tides and ebbs respectively. These waves are originated in the oceans under the influence of tidal force of the moon. The length and velocity of tidal waves depend on the depth of seas and oceans. In a globe completely surrounded by water the tidal waves would travel freely from east to west but the position of land and water hinders the velocity and direction of these waves.

Since the continents roughly stretch from north to south and hence they hamper the free movement of tidal waves. These waves are least hampered in the oceans surrounding the Antarctic continent, thus, tidal waves are generated in the southern ocean in the southern hemisphere under the influence of tide-producing force of the moon. These waves are called ***primary waves*** which move from east to west in the form of forced waves. These waves are obstructed by the continents and are consequently refracted northward.

Secondary waves are generated when the west ward movement of primary waves is obstructed by land masses. These northward moving waves are called secondary waves or derived waves which also move from east to west. Further minor waves are generated from these secondary waves. These secondary and minor waves progressively move northward though there is gradual decrease in their magnitude and amplitude but these waves generate tides every- where.

It may be pointed out that the primary waves are influenced by the moon but the minor waves move freely. It is, thus, apparent that the tidal waves after being originated in the southern ocean progressively move northward with continuous lag of time and dissipation of wave energy. In other words, the arrival of these progressive waves at successive places northward along the same longitude is also progressively delayed.

This is why there is difference of time of tide at different places on the same longitude. In other words, the time of tides is progressively delayed northward along the longitude. These progressive waves become ineffective after reaching North Pole. The crests and troughs of these waves after reaching the coasts cause tides and ebbs respectively. Fig.1 depicts the ***co-tidal lines*** (the lines joining the points of high waters occurring at the same hour are called co-tidal lines) of the Atlantic Ocean.

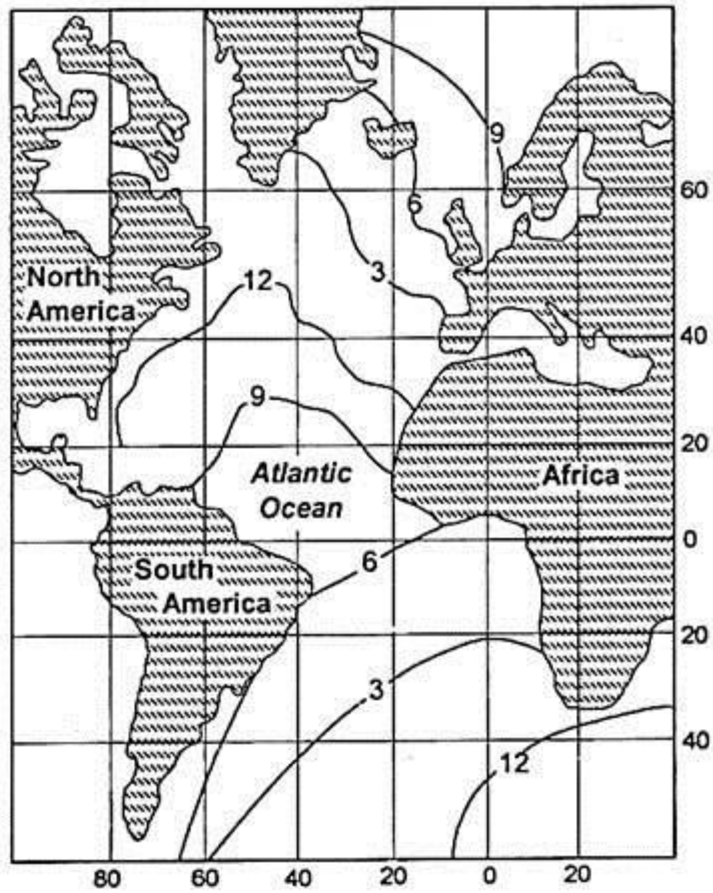

Fig.1- Co-tidal lines of the Atlantic Ocean

Evaluation of the Theory

According to the progressive wave theory the age of tides increases northward. In other words, if tide is generated in the south on a particular longitude it reaches quite late at the points located further north on the same longitude. On the other hand, the data available so far about the time of tides denote that the time of spring tides is almost the same from Cape Horn to Greenland in the Atlantic Ocean. Normally, the tides are local or regional phenomena rather than phenomena originating in the southern ocean and moving progressively northward. At some latitudes daily and semi-diurnal, both types of tides are observed. Further, there is spatial variation in the irregularity of tides in different oceans. These variations cannot be explained on the basis of progressive wave theory.

Stationary Wave Theory

R.A. Harris of the *U.S. Coast and Geodetic Survey* propounded the concept of stationary waves as opposed to the progressive waves. This theory offers almost satisfactory explanation for local differences in tides, their types and their age. According to Harris tide phenomena are not due to progressive waves which originate in the southern oceans as claimed by William Whewell but are due to stationary waves which originate independently in each ocean.

In other words, tide phenomena are regional phenomena. The stationary wave theory can be explained with the help of an experiment. If a rectangular tank or '***developing tray'*** containing water is rocked from one side to the other or is simply tilted, the water level rises along one side of the tray but falls along the other side. This generates oscillation in the water contained in the tray. Such oscillations in the water are called ***stationary waves***. There is such a centre in the middle of the tray where there is no change in the level of water. This point is called ***nodal point***. The water level moves rhythmically from one end of the tray to the other end along a line which is called ***nodal line***.

The period of oscillation of water in the tray depends on the length and depth of the tray and the force of shocks applied to the tray. The aforesaid example is the case of ***uninodal*** system (fig. 2) but there may also be ***binodal*** oscillation system.

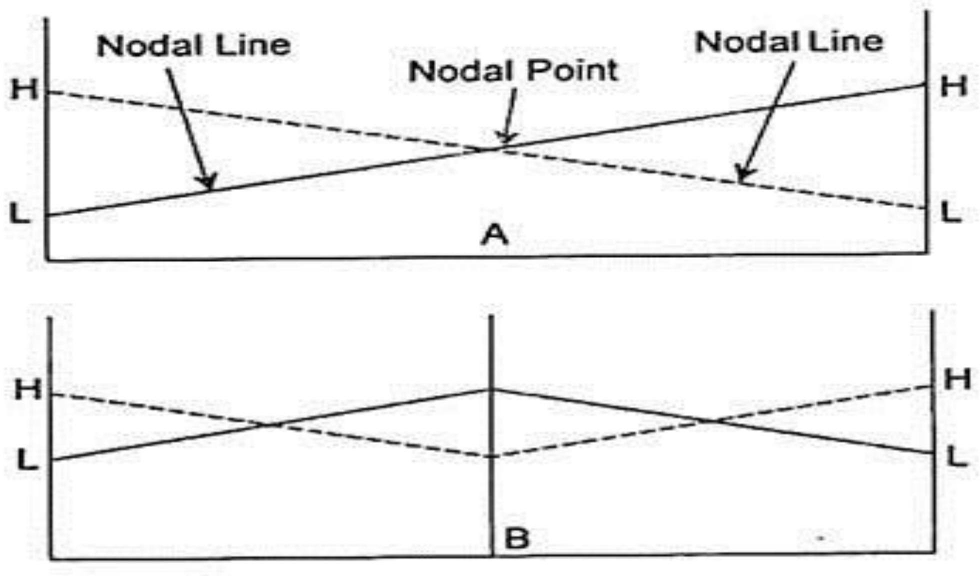

Fig.2 – (A) Uninodal and (B) binodal oscillation system

Based on above analogy, different oceans of the earth are like giant water containing trays. The tidal forces of the sun and the moon cause oscillations in the oceanic waters but the oscillations do not occur along straight limes as in the case of the tray rather they occur around a central point because of the rotational force of the earth, with the result several amphidromic points are generated.

The oceanic water remains calm and stationary at these points whereas water level changes around them. This mechanism results in the formation of waves which move in anti-clockwise direction around these amphidromic points. Such oscillatory mechanism of water occurs in every ocean and is collectively called as oscillation system. Numerous stationary waves are generated from these amphidromic points.

Every stationary wave has a definite time of its oscillation. The oscillation system and mechanism are affected by the depth, configuration and length of the ocean basins and the rotational speed of the earth. The stationary waves after being originated from the amphidromic centres move towards the coasts.

The forward movement of these waves is hampered by the continental peninsulas, islands, bays etc. When these waves reach the coasts, their crests and troughs cause tides and ebbs respectively. There is positive correlation between the depth of the oceans and the height of tides. In other words, if the depth of the ocean becomes greater, higher stationary waves are generated and high waves generate high or spring tides. Low tides are caused in shallow seas because of lower height of stationary waves.

Water Currents Generated by Ocean Tides

Water currents are generated by ocean tides due to upward and downward movement of sea level in the open and near shore regions. The coastward movement of tides causes flood currents which pile up seawater against the sea coast. The currents caused by returning tides are called ebb currents. Thus, flood currents move coastward while ebb currents move away from the coasts.

The currents associated with tides in the open ocean are called rotary currents which turn in counter clock wise direction in the northern hemisphere and clock wise in the southern hemisphere. When the rotary currents enter the shallow water of near shore areas they suffer from friction and ultimately they change to alternating or reversing currents.

The velocity of rotary currents in the open sea is very slow, around one kilometre per hour, but the reversing currents move very fast with the velocity of 44 kilometres per hour. The reversing tidal currents assume greater velocities in the region of irregular coastlines, in narrow and constricted bays, and in narrow coastal rivers. The rise and fall of tides, and flood currents and ebb currents have greater potentials for the generation of electricity wherever there are bays with narrow openings and constricted tidal inlets or narrow estuaries.

SELECTED REFERENCES

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