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DIAGRAM TO ILLUSTRATE THE ACTION OF TIDE-GENERATING FORCE, ESPECIALLY THE INTEGRATION OF THE TANGENTIAL COMPONENT. (MOON OVER THE EQUATOR.)

By J. RUTHVEN, ESQ., late Commodore of the Orient Line.

THE central figure represents the earth as seen from a distant point vertically over the South Pole, rotating on its axis in the direction of the arrow.

The outer ring is an attempt to show graphically the varying value of the tangential component and how it is integrated under the moon and at the point most remote from her. The tapering of the ring is meant to illustrate the gradual increase and decrease in the tangential pressure not only in the surface water under it, but also in every layer thence to the bottom of the ocean. At A the spot under the moon and at B, C and D the tangential component is zero, the whole tide-generating force at these points acting normally—outwards at A and B, and inwards at C and D. In the centre of each quadrant tangential force is a maximum.

The difference between the moon's attraction upon any particular particle and her average attraction is so small (its maximum value is only one eight and three-quarter millionth part of terrestrial gravity) that by itself it could produce no appreciable alteration in the level of the water, but if we imagine this symbolic ring divided into a series of graduated weights, with the pressure accumulated, or integrated in both directions from C and D towards A and B, in exactly the same way as in a vertical pile of weights standing on the ground where the pressure increases as it approaches the bottom of the column, we have a very fair representation of how the tangential component is integrated at any moment from the circle of quadrature towards the points under and opposite the moon.

Whilst the maximum value of the normal component at A and B is greater than the tangential, its effect is not magnified to anything like the same extent by integration. The particles in the vertical column of water under the moon press upwards upon one another in consequence of her attraction, just as the weights in a pile press down upon those beneath them under the influence of gravity, but the integration is at most through five miles depth of water, instead of through 6,000 miles of what is known as "fictitious horizontal depth" (on the equator and in open water).

At A and B where tidal force on the particles is a maximum and where although there is no tangential component its *effect*

is a maximum through integration, the greatest elevation will take place to form the apices of the tidal cones. In the diagram the cones are purposely exaggerated and slightly detached to indicate that they do not rotate with the earth but remain under and opposite the moon. Rotation in the direction of the arrow would produce the same effect as if the moon and the graduated ring revolved in the opposite direction. On a globe covered

DEPRESSIONS NOT SHOWN.

with water the cones would accompany the apparent motion of the moon, the water forming them gradually but continually changing by the rising of particles in front of her path and the subsidence of those left behind.

On our actual world where these conditions obtain in the Great Southern Ocean, observation shows that the same results are found along the 45th parallel (and farther north where there is sufficiently open water) except in the neighbourhood of the South American Continent, which stretches down to Lat. 56° to obstruct the progress of the tidal wave.

It will readily be seen by the diagram that a lake or sea of limited dimensions can only coincide at any given moment with a small fraction of the ring representing tangential force. In this case it is obvious that at the ends of the lake H.W. will not be under the moon, but when she is three hours East or West of its centre bringing the portion of the ring where tangential force is greatest over the sheet of water. Integration throughout the *whole* quadrant is always greatest where it meets the other quadrant, however the weights (or pressure) are distributed, just as the lowest weight of an irregular column bears the pressure of all those above it, no matter how they are arranged, but over a small arc integration must necessarily be more effective where the weights (or pressure) are a maximum, which in this case is obviously in octant. In the centre of the lake, however, which remains at mean level while H.W. occurs at the ends, the greatest elevation will be when the moon is vertically over it.

New Proofs.

The Co-tidal Charts have always shown the tide under the moon in the Southern Indian Ocean, including the islands of Amsterdam and St. Paul. The Admiralty Tide Tables for 1912 place the tide under the moon at Tristan D'Acunha and at a number of small islands south of New Zealand. It has always been to these islands standing as Nature's tide gauges in the only deep and unobstructed waters of the globe that we have looked with confidence for such confirmation as must convince the most sceptical. They have no land for thousands of miles either to the eastward or the westward to cause retardation and so may be considered a fair and conclusive test.

On the other hand, the tides of islands several hundred miles eastward both of Patagonia and New Zealand, such as S. Georgia and Chatham Is. suffer considerable retardation from the land in front of the tidal wave. Stewart Island is not only a proof of our main contention, but also an excellent example of the rapidity with which retardation is produced by land and shallowing sea-floor. Too small to be an obstruction until the tide arriving with the moon is in actual contact with the island, the friction of its shores causes 70 minutes retardation in the H.W. of Paterson Inlet on the East Coast and at Mason Bay on its Western side.