TOWARD AN UNDERSTANDING OF THE TIDAL FLUID MECHANICS ASSOCIATED WITH THE GENESIS FLOOD

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KEYWORDS

ABSTRACT
Tidal fluid mechanics associated with a global ocean are investigated using numerical analysis and computer simulation. Tidal waves, with their shallow water wave characteristics, are shown to be perfect candidates for the role of sediment transport and deposition associated with the buildup of thick sequences of sedimentary strata. The global ocean in the tidal context is shown to be near resonance which, if present, would augment the load-carrying ability of the tidal waves. Pertinent variables of fluid friction, ocean depth, and bottom relief are studied to ascertain their role in the tidal action in a global ocean.

INTRODUCTION
Even though many sedimentary strata sequences are now tilted and folded, it is still the most reasonable inference that the great bulk of these sequences were originally laid down horizontally. Because the main geometric characteristic of free-surface water is its horizontality, it easily follows that water action was responsible in forming the sequences. A second important characteristic of these sequences is the conformity of successive strata. Although this characteristic has been used to infer excessive age, it is possible to interpret the strata and their contents as having been laid down within hours of each other, resulting in a relatively short period of time for the construction of the whole sequence.

The flood of Genesis must be considered global if it is to be used to explain extensive crustal features. The questions then center around the fluid mechanics of a global ocean. What will a global ocean do? What would be the influences on such a large uninterrupted body of water? Fluid bodies can be moved by one or more of three mechanisms: pressure gradients, gravitational attraction, and boundary movements. Of these three, gravitational attraction presents itself as the primary mover of a global ocean. Newton's universal law of gravitational attraction requires that the water in that global ocean respond to the bodies neighboring the ocean. The closest most dominant neighbor would have been the large land mass beneath the ocean. This attraction is vertically downward and is responsible for the horizontal water surface. The second closest most dominant neighbor would have been the moon. The sun, although larger, is farther away and has less than half the lunar influence. The gravitational attraction of the earth-moon-sun system causes the tides. In this paper, only the influence of the lunar tides on the global ocean will be investigated.

As the earth rotates under the moon, the water, being easily moved by the lunar attraction, tends to move up toward the moon forming a tidal bulge. Due to centrifugal effects of the earth-moon system (rotating about the system's mass center located within the earth), a second, nearly equal, bulge is generated on the opposite side of the earth. The moon is relatively stationary in the earth-moon system, revolving about the earth only once a month. Since the tidal bulge stays under the moon, it moves like a wave when the observer is stationed on the earth. Hence, it is said that there is a semi-diurnal tidal wave circumnavigating the earth. The wavelength is half the circumference of the earth at any particular latitude. The amplitude of the wave is its crucial feature and the focal point of this paper.

One possible mechanism for the formation of the great bulk of strata sequences in the earth's crust is the wave action of the tides in the global flood of Genesis. The tidal waves in the oceans today range from 1 or 2 meters to more than 15 meters, depending on many factors. It should be noted that today's oceans differ greatly from the global ocean associated with the Genesis Flood. That ocean, most significantly, had no boundaries to interrupt the action of the tidal waves. Today's tidal waves operate in restricted basins of various sizes, some very large. But the tidal action is discontinuous, being stifled by the continental boundaries which form the basins. The continuity of the wave action in the global flood would have been
especially beneficial in increasing the load-carrying capacity of the tidal waves by augmenting their amplitude. Large wave amplitude is desirable because the ability of the wave to envelop, transport, and deposit large sediment loads is enhanced by the associated larger velocity fields. A second, perhaps crucial, feature connected with the continuity of the wave action is the possibility that it would have been instrumental in developing resonance in the tidal action. Any cyclic system can develop the large amplitudes associated with resonance if certain criteria are met. In the global ocean context, equality of the free and forced wave speeds is necessary [1]. The free wave speed, associated with the speed with which a disturbance would propagate in the ocean, is dependent on the ocean depth; the forced wave speed, associated with the relative speed of the tidal bulge, is dependent on the rate of rotation of the earth.

A global ocean with bottom relief subjected to variable earth/moon gravitational forces is a complex system for which there are many (and, in some situations, unknown) governing parameters. To understand the fluid mechanics associated with it requires use of the relevant fluid dynamic relations, the principles of numerical analysis, and appropriate computers to evaluate the resulting mathematics. Using these tools, the fluid mechanic events associated with the Genesis Flood can be reproduced and studied. Thus, the immediate goals of this paper are to learn more about global ocean fluid mechanics and to determine the best parameters to use to calculate global ocean characteristics. An ultimate goal of this project is to use such results to analyze the sequences of sedimentary strata generated by the global ocean described in Genesis.

GOVERNING BASIC FLUID MECHANIC EQUATIONS

The most appropriate simulation of a global ocean would be constructed using a three-dimensional spherical-coordinate model with the governing equations fitted to that geometry. A textbook listing of the radial, longitudinal, and latitudinal momentum equations and continuity equation for incompressible flow for the spherical-coordinate system would show many, many terms. In 1775, Laplace was able to tailor these equations specifically for the tidal problem [6]. His simplified equations, shown in Fig.1, are called the Laplace Tidal Equations (LTE). Since any solution in his day had to be analytical, it was necessary to simplify the LTE in all possible ways. He was able to eliminate the radial momentum equation by assuming the hydrostatic pressure condition in the radial direction in conjunction with the shallow water wave condition (i.e., no variation in velocity in the radial (vertical) direction). He also eliminated the viscous terms. Present day solutions by numerical methods allow a more rigorous solution to be considered; accordingly, the equation set used to obtain solutions in this paper essentially restored the friction terms to the LTE. These modified LTE forms, shown in Fig.2, are due to Estes [2], from whom the computer code used in the calculations was obtained. The friction terms used by Estes were proposed by Zahel [9]. As these equations

\[
\begin{align*}
\frac{\partial u}{\partial t} - 2\omega v \sin \phi &= -\frac{g}{R \cos \phi} \frac{\partial}{\partial \lambda} (\xi_u) + F_u, \\
\frac{\partial v}{\partial t} - 2\omega u \sin \phi &= -\frac{g}{R \cos \phi} \frac{\partial}{\partial \phi} (\xi_v) + F_v, \\
\frac{\partial \xi}{\partial t} &= \frac{1}{R \cos \phi} \left[ \frac{\partial}{\partial \lambda} (H u) + \frac{\partial}{\partial \phi} (H v \cos \phi) \right]
\end{align*}
\]

were restored to the LTE. As these equations

Hydrostatic equation \( p = \rho g \xi \) applies in radial direction :: \( u \) and \( v \) are independent of \( r \)

where

- \( H = h(\phi, \lambda) + \xi_u - \xi_v \)
- \( \phi = \) latitude
- \( \lambda = \) longitude
- \( u = \) eastward component of velocity
- \( v = \) northward component of velocity
- \( F_u, F_v = \) components of tidal force
- \( g = \) acceleration of gravity
- \( R = \) mean earth radius
- \( \omega = \) rotational velocity of the earth

Fig. 1. Laplace Tidal Equations - Shallow Water Equations on a Sphere.
\[
\frac{\partial u}{\partial t} - 2\omega v \sin \phi = \left(1 + \frac{k_l}{R} - \frac{H}{R} \right) \frac{\partial^2 u}{\partial \alpha^2} - C_r \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} + C_v \frac{\partial^2 u + \partial^2 v}{\partial \phi^2} + \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} \frac{\partial^2 u + \partial^2 v}{\partial \phi^2} + \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} \frac{\partial^2 u + \partial^2 v}{\partial \phi^2} + \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} \frac{\partial^2 u + \partial^2 v}{\partial \phi^2}
\]

\[
\frac{\partial v}{\partial t} + 2\omega u \sin \phi = \left(1 + \frac{k_l}{R} - \frac{H}{R} \right) \frac{\partial^2 v}{\partial \alpha^2} - C_r \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} + C_v \frac{\partial^2 u + \partial^2 v}{\partial \phi^2} + \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} \frac{\partial^2 u + \partial^2 v}{\partial \phi^2} + \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} \frac{\partial^2 u + \partial^2 v}{\partial \phi^2} + \frac{\partial^2 u + \partial^2 v}{\partial \alpha^2} \frac{\partial^2 u + \partial^2 v}{\partial \phi^2}
\]

\[
\frac{\partial^2 u}{\partial t} + \frac{1}{R \cos \phi} \left( \frac{\partial (Hu)}{\partial \alpha} + \frac{\partial (Hv \cos \phi)}{\partial \phi} \right) = 0
\]

where

- \( \Gamma \) = tidal potential
- \( k_l, h_l \) = Love numbers
- \( C_r \) = coefficient of friction (Zahel)
- \( C_v \) = horizontal eddy viscosity (Zahel)
- \( \Delta \) = horizontal Laplacian

\[
\Delta = \frac{1}{R^2 \cos^2 \phi} \frac{\partial^2 u}{\partial \alpha^2} + \frac{1}{R^2} \frac{\partial^2 u}{\partial \phi^2}
\]

**Fig. 2. Modified Laplace Tidal Equations.**

stand, they cannot be solved analytically for any global ocean problem. In order to achieve such solutions, these partial differential equations will be converted to partial difference equations.

Water waves are primarily categorized by the depth to wave length ratio into deep, intermediate, and shallow water waves. In his classic book, Stoker [8] has said "It might seem incredible at first sight that the shallow water theory could possibly be accurate for the oceans, since depths of five miles or more occur. However, it is the depth in relation to the wave length of the motions under consideration which is relevant. . . . the tidal waves result in waves having wave lengths of hundreds of miles; the depth-wave length ratio is thus quite small and the shallow water theory should be amply accurate to describe the tides." The shallow water wave characteristic so welcome in the context of sediment transport and deposition is the nearly uniform velocity profile with depth. Hence, this feature makes the tides a perfect candidate for the role of developing thick sequences of sedimentary strata. The surface velocity that is generated by the tides is also present and of equal magnitude at the bottom to move the sediment.

**NUMERICAL ANALYSIS**

The success of a finite-difference numerical analysis stems from the ability to cast the temporal and spatial derivatives found in the governing equations into temporal and spatial difference form. The time and space steps are made small enough so that the solutions of the difference equations approach the solutions of the differential equations. If there are no known solutions to the full differential equations, the schemes are matured on simpler problems where solutions by other means are available. As can be seen in the mesh sketches in Fig. 3, the space domain is subdivided into many small parts, and all governing equations are solved for each mesh. Estes used the Hansen grid [3] where both the eastward and northward velocity components and the tidal elevation are computed at staggered mesh points.

Special boundary conditions need to be imposed on all coast lines. Even though a global ocean is the goal, the meshes at the higher latitudes become so small (the circumference at these high latitudes decreases while the number of meshes remains constant) that excessively small time steps are required to keep the computations stable. To avoid small time steps (and large computer times), an appropriate coastal boundary is placed at high latitude. The coastal boundary conditions are represented in the Hansen grid by horizontal and vertical lines which pass through points denoting velocity components. In this paper, the coastal boundaries are limited to horizontal lines which follow a given limiting latitude (see Fig. 3). These horizontal lines pass through \( V \) (northward velocity) grid points; at these points, the vanishing perpendicular velocity requirement forces the \( V \)-velocity component on the coast to be zero at all times.

The finite-difference forms of Estes' equations are given in Fig. 4. Now there are many more terms to be calculated. The time domain must be traversed slowly enough to keep the computations stable. The form of the equations is called 'explicit' because the equations need only to be solved once at each time step in contrast to the implicit form where an iterative solution meeting some closure criterion is necessary. The terms in the equations which drive the solution are associated with the components of the tidal force \( F_{\lambda} \) and \( F_{\phi} \). These expressions are written at the bottom of Fig. 4 for the semi-diurnal lunar (species III) tide. A graphical depiction of the spacial variation of these forcing functions at a given time (12 minutes into the tidal period) is given in Fig. 5. The \( F_{\lambda} \) variation, as a function of latitude limit, is shown in the middle row of sur-
face plots and the $F_k$ variation in the top row. A coefficient which contained the time step was eliminated prior to plotting so as to be able to compare the forcing function for various parameter sets; the mesh spacing (in the form of the $\Delta x/2$ and $\Delta y/2$) was retained in the plots. As an aid to understanding the surface plots in Fig.5 (and all subsequent surface plots), an orientation sketch is shown in Fig.6.

To indicate the effect of the position of the horizontal coastal boundary at the high latitudes, a series of calculations were made at an ocean depth of 7938 m, using a parameter set consisting of a 3 deg mesh and a 1 min time step (3d,1m). The calculations were started with the limits of -87 and +87 deg latitude (note that, when the limit is set at 87 deg, the first calculations are made one mesh lower, i.e., at 84 deg) but they were found to be unstable, undoubtedly because of the small mesh size at this latitude. The next smaller limit (-84, +84) was calculated successfully with this parameter set. Additional smaller limits down to -72, +72 by 3 deg increments were also calculated. The surface plots of the tidal surface during the fifth tidal period for selected latitude limits in this sequence are shown in the bottom row of Fig.5. The maximum tidal amplitude during this period decreased with decrease in latitude limit (2.740 m, 2.717 m, 2.663 m, 2.532 m, and 2.265 m for latitude limits from 84 deg to 72 deg, respectively). Graphically, it is obvious that the tidal amplitude varies considerably more along the coastal boundary at the lower latitude limits. The unstable situation at the 87 deg latitude limit was re-investigated by reducing the time step from 1 min to 0.5 min. The calculations were then stable, and the results at the left of Fig.5 were obtained. Clearly, this representation creates the least variation at the upper latitude limit. The main, although not necessarily the only, reason for this increase in tidal variation along the coastal boundaries as the limiting latitude is decreased is to be found in the way in which the forcing functions are imposed. The forcing functions are simply truncated at the limit (see the upper two rows in Fig.5). Clearly, the coastal variation is reduced as the poles are approached. As previously stated, however, the computer effort becomes excessive for small meshes. Therefore, a set of parameters is always sought by which a suitable compromise can be achieved.

HOUGH'S PREDICTIONS

The 1897 work of Hough [5] served as a starting point in this investigation of tidal action in a flat-bottom, global ocean context. Hough solved the LTE using semi-analytical, series-solution methods. He calculated the ratios of the tidal height to the equilibrium height for various flat-bottomed global ocean depths. The term 'resonance' was not used but the term 'critical depths' was. He said "We see, then, that though, when the period of forced oscillation differs from that of one of the types of free oscillation by as little as a minute, the forced tide may be nearly 25 times as great as the corresponding equilibrium tide. . . . The critical depths for which the lunar tides become infinite are found to be 26,044 ft and 6,448 ft. Consequently, this phenomenon will occur if the depth of the ocean be between 29,182 and 26,044 ft or between 7,375 and 6,448 ft." Here then, Hough, with spherical governing equations but without friction, was able to show resonant conditions at reasonable ocean depths. Since Hough's work had goals similar to those of this paper (the assessment of situations where large tidal amplitudes occur on a completely flooded, flat-bottomed ocean), it was decided to repeat Hough's calculations using numerical analysis.
\[ \xi(\phi, \lambda, t) = \xi(N, M, t_{\ast}) = \xi(N, M, t) + \]
\[ \frac{\Delta t}{R \cos(\phi(N))} \left\{ \frac{1}{2} \left[ (h(N, M) + h(N, M - 1) + \xi(N, M, t_{\ast}) + \xi(N, M - 1, t_{\ast}) - h(N, M + 1, t_{\ast} + \xi(N, M + 1, t_{\ast}) \right] \frac{\Delta \lambda}{\Delta \xi} \right. \]
\[ - \frac{1}{2} \left[ (h(N, M + 1) + h(N, M) + \xi(N, M, t_{\ast}) + \xi(N, M + 1, t_{\ast}) - h(N, M - 1, t_{\ast} + \xi(N, M - 1, t_{\ast}) \right] \frac{\Delta \lambda}{\Delta \xi} \]
\[ \left. + \frac{1}{2} \left[ (h(N, M) + h(N - 1, M) + \xi(N, M, t_{\ast}) + \xi(N - 1, M, t_{\ast}) - h(N, M + 1, t_{\ast} + \xi(N, M + 1, t_{\ast}) \right] \frac{\Delta \lambda}{\Delta \xi} \right\} \]
\[ u(\phi, \lambda, t) = u(N, M, t_{\ast}) = \]
\[ \left\{ 1 - C_s \Delta t \sqrt{u(N, M, t_{\ast})^2 + \frac{1}{16} \left[ v(N, M - 1, t_{\ast}) + v(N, M, t_{\ast}) + v(N + 1, M - 1, t_{\ast}) + v(N + 1, M, t_{\ast}) \right]^2} \right\} \]
\[ \frac{1}{2} \left[ (h(N, M) + h(N, M - 1) + \xi(N, M, t_{\ast}) + \xi(N, M - 1, t_{\ast}) - h(N, M + 1, t_{\ast} + \xi(N, M + 1, t_{\ast}) \right] \frac{\Delta \lambda}{\Delta \xi} \]
\[ \cdot u(N, M, t_{\ast}) + 2 \omega \Delta t \sin(\phi(N)) \]
\[ + \frac{1}{4} \left[ (v(N, M - 1, t_{\ast}) + v(N, M, t_{\ast}) + v(N + 1, M - 1, t_{\ast}) + v(N + 1, M, t_{\ast}) \right] \]
\[ + C_s \Delta t \left\{ u(N - 1, M, t_{\ast}) + u(N, M, t_{\ast}) + u(N - 1, M + 1, t_{\ast}) + u(N, M + 1, t_{\ast}) + u(N, M, t_{\ast}) \right\} \]
\[ \frac{\Delta \lambda}{\Delta \xi} \]
\[ + \frac{u(N + 1, M, t_{\ast}) + u(N - 1, M, t_{\ast}) - 2 u(N, M, t_{\ast})}{R \Delta \phi^2} \]
Fig. 5. Top: Forcing Functions $F_\alpha$ and $F_\phi$. Bottom: Tidal Free Surface Plots Showing Effect of Latitude Limit.

Fig. 6. Orientation and Definition Sketch for a Typical Free Surface Plot.
NUMERICAL RESULTS

Hough's Upper Critical Depth. The first calculations used Hough's upper critical depth of 7938 m (26,044 ft). A 6d,6m parameter set was used. To match Hough's inviscid condition, the friction coefficient, $C_r$, and the coefficient of lateral turbulent viscosity, $C_{HV}$, (see Fig.2) for water were arbitrarily divided by 800. Hereafter, it is dubbed NWF/800 where NWF stands for nominal water friction. These and all subsequent calculations were started at time zero with the initial conditions of zero tidal amplitude and zero velocity components for all meshes. At tidal period intervals (approximately 750 min), output files were updated. One file contained the tidal amplitude at all meshes and the maximum tidal amplitude in that field. After a number of tidal periods, the program was stopped and the results perused. Sufficient data were retained so that the program could be restarted. These period maximums are shown in Fig.7 in the curve labeled NWF/800. After one dwell (near 16,000 min), the curve quickly ascends off-scale in a dramatic show of resonance. To show evidence of computational stability, a sequence of smooth surface plots of tidal amplitude are shown at the top in Fig.8.

![Graph showing maximum tidal amplitude as a function of time for Hough's Upper Critical Depth.](image)

Fig. 7. Maximum Tidal Amplitude as a Function of Time for Hough's Upper Critical Depth.

Using the same parameter set, viscous situations NWF/4, NWF/2, and NWF were also calculated. The maximum tidal amplitude variations with time are also shown in Fig.7, and a sequence of surface plots for NWF/2 is shown at the bottom of Fig.8. Only the NWF case was overdamped which led to a steady-state tidal amplitude of some 3 m. The other less viscous cases were underdamped and resonance resulted.

The 6-deg mesh subdivision produces some 27 latitude lines and 60 longitude lines on the globe, a somewhat coarse subdivision. The 6-min time step allows some 125 subdivisions of the tidal period, a somewhat rapid stepping in time. The calculations remained stable and smooth as seen by the surface plots, a fact that could be attributed to the absence of variability in the bottom relief and the relegation of the straight coastal boundaries to the high latitudes. There is, however, a question as to whether the calculations are producing the correct answer.

To more closely approach the mathematical concept of a derivative, the space or time steps or both can be reduced. Replacing the 6d,6m set with a 6d,2m set requires 3 times the computational effort. For the inviscid case, this change results in the maximum amplitude-time plot of Fig.9 and the surface plots shown in the middle of Fig.8. The ocean is underdamped, resonance still occurs, but it takes longer to develop. Several oscillations occur before the amplitudes become excessive. A third parameter set (4d,2m) was used for the inviscid case. Now the computational effort is over 6 times that of the original set. The result in Fig.9 is nearly the same as the 6d,2m result, having essentially the same oscillation frequency and magnitude.
One more comparison at Hough's upper critical depth was made. The NWF case was calculated using three different parameter sets and the results are compared in Fig.10. While the 6d,6m set shows a highly oscillating result, both the 4d,2m and the 3d,1m sets give essentially the same steady-state amplitude of about 3 m after only one large and several smaller oscillations. From these results, it would seem justified to conclude that the 3d,1m set should be used to obtain accurate results from Estes' code.

Hough's Lower Critical Depth. Turning to Hough’s lower critical depth of 1975 m (6,448 ft), a similar pattern of calculations was followed. In Fig.11, the NWF/800 case, calculated using the 6d,6m set, shows a series of small oscillations for the first 12,000 min and then a continuous upward sweep to resonance. Viscous situations of NWF/8, NWF/4, NWF/2, and NWF were also calculated with this set and the results plotted in Fig.11. Of these cases, only the NWF/8 case was underdamped and resonated; the rest were overdamped and went toward steady-state. The surface plots at selected times for the inviscid case are shown at the top of Fig.12. In contrast to the two-peak plots of Fig.8, additional tidal bulges and peaks occur away from the equator. Furthermore, the maximum tidal amplitude is not always located at the equator. As with the upper critical depth, a 6d,2m parameter set was used to calculate comparison results for the inviscid case. The results are included in Fig.11 and 12. The maximum amplitude curve, similar to the upper critical depth case, showed a resonance which took longer to develop. The times chosen to plot the surface configuration were those which had nearly identical maximum tidal amplitudes in the 6d,6m plots in the top row. It is seen that the two sets of plots are nearly identical in appearance.
Fig. 9. Comparison of the Variation of the Maximum Tidal Amplitude with Time for Various Computational Situations for Hough's Upper Critical Depth.

Fig. 10. Maximum Tidal Amplitude Results for Three Different Parameter Sets Compared. Hough's Upper Critical Depth with Nominal Water Friction.
A Non-Critical Depth. Thus far, Hough's 1897 semi-analytical methods for calculating global ocean resonances seem to be vindicated. It was thought to be of interest to see what would happen with a non-critical depth. Accordingly, a depth halfway between the two critical depths was used with the 6d,6m set for the inviscid case. The results are shown in the top curve in Fig.13 using the time scale at the bottom. At first glance, the saw-toothed character of the plot and the increasing size of the teeth would indicate that the solution was becoming unstable. On closer examination, however, evidence for a stable solution was found using the surface plots and the maximum tidal heights between the tidal period times. The tidal amplitudes for 6d,6m are increasing rapidly toward resonance after 40,000 min. The surface plots at four times during the tidal period starting at 60,000 min are shown in the bottom row of Fig.12. These plots show no evidence of numerical instability. The original maximum amplitude-time curves in Fig.13 were plotted using only the values output at intervals of the tidal period. For a 750-min period and a 6-min time step, there are 125 maximum amplitudes at times intermediate between those plotted. Furthermore, because of the peculiar manner in which the tidal surface is configured at this depth, the location of the maximum amplitude can shift back and forth between equator and somewhere near mid-latitude. To show some of these intervening data, the 6-min amplitude-time plot was expanded using the time scale at the top of Fig.13. Both equator and mid-latitude maximums are plotted. The curves show a smooth variation with time and also show the maximum amplitude sometimes at the equator and sometimes at mid-latitude. The surface plots corresponding to this expanded time scale are shown at the bottom of Fig.12. The tidal bulge at the equator waxes and wanes very dramatically during this sequence while there is a much smaller variation at the mid-latitudes. Furthermore, there seems to be a difference in period between these two oscillations. Additional 6-deg calculations at 4 and 2 min and NWF/800 were also made and are plotted in Fig.13. Both of these calculations were stable and both eventually indicated a slow rise toward resonance. The difference in the character of the tidal action in this case as contrasted with the two Hough critical depths is striking. The causes for the difference are, as yet, inexplicable.

A General Depth-Effect Study. The three depths studied thus far were special depths selected in relation to the work of Hough. A need was felt to develop a more general picture of the effect of depth on the configuration and amplitude of the tidal surface on a flat-bottomed global ocean. To develop the most realistic and accurate results, the NWF case and the 3d,1m set were selected along with latitude limits of -84, +84 deg.
Initially, depths of 1,000, 3,000, 5,000, 7,000, and 9,000 meters were calculated. When results at these depths were plotted, additional depths were needed to plot a definitive curve. Accordingly, many additional depths were added especially near the depths of greatest interest, 2,000 and 7,000 meters. Once a depth was selected for inclusion in the set, the program was run using that depth until the largest maximum tidal amplitude had been determined. In some instances, only a few tidal periods were needed; in others, many. Fig.14 shows the maximum tidal amplitude as a function of depth of ocean. Two features stand out in this figure: A resonant-like peak at a depth of 7,140 m and a cusp near 2,000 m. It cannot be said that a resonance occurs when the maximum amplitude is only 9 m, but the characteristics of the curve in this vicinity have all the attributes of a resonant peak. The nearness of this peak to Hough's inviscid depth of 7,938 m is striking and possibly significant. Of course, the NWF values for the friction coefficients were responsible for the peak magnitude being only 9 m. As the position of the curve near 2,000 m was being determined, it was suspected that, due to parallelism with Hough's results, there would be a second, smaller peak there. In the end, only the cusp or change in slope of the curve could be deciphered.

To help in understanding these occurrences, the amplitude-time relations for most of the depths are shown in Fig.15. There is a distinct change in character of these curves as the depth changes: Near the overall peak at 7,140 m, the ocean seems to be critically damped; the curve bends over and gradually reaches the peak without ever oscillating. For the deeper oceans (8000 m and 9000 m) and for the shallower oceans
Fig. 13. Maximum Tidal Amplitude as a Function of Time for an Intermediate Depth.

(6,000 m and below), all of the curves oscillate. For some, the first oscillation contains the maximum tidal amplitude; for others, the largest amplitude occurs after 5 or 6 oscillations. For those cases below 2,000 m, the oscillations are not nearly as uniform in magnitude as those with depths 2,000 m and above.

Additional understanding of the tidal actions in this set of depths is gained from the surface plot. As can be seen in Fig. 16, there are significant changes in the surface configuration with depth. For the larger depths (top row), the two major tidal bulges which are present are established right from the start of the calculations. It looks as though the $F_\lambda$ forcing function on the U-velocity is dominating this tidal action since two distinct bulges also appear in Fig. 3 for $F_\lambda$. For the smaller depths, the dominance of $F_\lambda$ seems to have been replaced by strong contributions from both $F_\lambda$ and $F_\sigma$ since the global surfaces have patterns with several extra bulges. One pair near the equator dominates in most cases and one or two on either side of that pair occur near mid-latitude. To add to the complexity, there seems to be a difference in periods of these bulges. For the most part, temporal sequences of surface plots show that the tidal bulges straddling the equator make the largest excursions in amplitude; those at mid-latitudes vary much less.

**Bottom Relief.** The purpose of the foregoing flat-bottom ocean results has been to learn about the basic fluid mechanics of a global ocean in its simplest context and to determine the most appropriate approach to the numerical analysis from the standpoint of calculational parameters. However, it is not likely that the global ocean of Genesis had a flat bottom. What bottom relief that ocean did have originally is not readily known. Estes' computer code, however, is capable of setting any desired bottom relief and of placing the land and ocean boundaries in any desired position.

To start, the simplest bottom relief to program (a mid-longitude pole-to-pole ridge) was used. A 6d,6m set with NWF gave the results shown in Fig. 17 for Hough's upper critical depth (7938 m, 26,044 ft). The relief sketches in the figure are approximately to scale horizontally but exaggerated vertically. The ridge is 40 deg long at the base. The one-half and three-quarters ridge depths show moderate increases in tide heights. When the ridge was barely submerged, a considerable increase in tidal amplitude (in excess of 10 m) was obtained. In all cases, the tidal action was overdamped with all curves moving towards steady-state.
Fig. 14. Maximum Tidal Amplitude as a Function of Depth.

Fig. 15. Maximum Tidal Amplitude as a Function of Time for the General Depth-Effect Study.
A second case of bottom relief, one where there is a smooth continual variation in depth, was calculated using a sinusoidal pattern (varying with longitude; invariant with latitude). A D/A ratio (amplitude of sine wave to depth of ocean) of four was selected along with NWF and two parameter sets (6d,3m and 3d,1m) for Hough's upper critical depth of 7938 m (26,044 ft). The data were first analyzed (Fig.18) using the maximum surface amplitude which was outputted at tidal period intervals (750 minutes). Except for the drooping of the 6d,6m curve after 40,000 minutes, the two curves show essentially the same result. These results are, in general, similar to those calculated for similar depths for a flat-bottom ocean (cp Fig.10). Of course, there are many more data than those shown in Fig.18, and the results take on added meaning (and possibly greater sedimentary transport significance) when a closer look is given these intervening data.

In the Fig.18 insert, the tidal amplitudes during the last tidal period (from 58,227 min to 58,934 min) for the 3d,1m set are plotted on an expanded time scale. Here, a considerable variation in amplitude is evident. It is a situation similar to that already encountered in Fig.13 with the Hough intermediate depth where it was found that the equatorial tidal bulge was oscillating freely during the tidal period. Now, however, the action is global; the free surface of the whole ocean is pulsing up and down each period. This action can be seen in the sequence of surface plots for this time span in Fig.19. To help in understanding the action, both the actual surfaces and their negative images are given since in some cases the significant part of the plot has disappeared from view. At the start of the sequence, the tidal bulges are for the most part not seen (but seen well in the image). As time progresses, these bulges appear, maximize, and again disappear. An overall lowering of the free surface is seen during the first half of the period and then a gradual recovery during the last half. This variation is a manifestation of the principle of mass conservation: With a fixed amount of water in the ocean throughout the calculations, it should follow that, when the water bulges up near the equator and mid-latitudes, this water must come from the regions of the poles so the elevations there will be lowered. The opposite situation occurs when a negative bulge occurs near the equator.

Some complex interaction takes place between the water moving in relation to the sinusoidal bottom relief and the forcing of the water by the complex (essentially sinusoidal) lunar forcing functions. The tidal amplitudes are seen to have ordinary magnitudes in these two cases. The additional period by period pulsing of the whole ocean is a new phenomenon. Additional wave action of this kind has not been considered in the development of the sedimentary strata sequences. These pilot calculations indicate the need for additional work to determine the general surface and subsurface occurrences in the general context of bottom relief. Other non-sinusoidal variations would be more apropos. Most beneficial would be some sort of Pangean bottom relief to see how such a configuration would effect the tidal dynamics.
DISCUSSION

The numerical analyses described in the preceding section were made in an attempt to answer the question "What will a no-boundary global ocean do when subjected to the lunar attraction forces?" Knowing the fluid mechanics for that situation will better enable us to understand the relation between the water action in the Genesis Flood and the sedimentary strata sequences that resulted from it. The greater the tidal action the greater would be the amount of work that could be done with the sediments. From the huge volume of sedimentary rock extant on the earth, it must be postulated that the responsible mechanism was of broad scope and great power. The phenomenon of resonance has been put forth as one means of increasing the ability of the tides to do the work. In the calculations, the global ocean resonated only when the fluid friction was reduced. Situations producing reduced friction (like increased temperature) could be postulated. It is also possible that a better representation of the frictional terms in the governing equations would allow resonance with nominal water friction to occur. Several different formulations have been found in the literature [4,7]. Considerably more computer effort would be required if Schweiderski's friction equations were used but the more accurate representation of the bottom friction might be well worth the effort.

Because the global ocean context offers extensive distances over which the fluid variables change very slowly, the numerical analyses were relatively free of instability problems. The 6-deg mesh spacing did produce results that oscillated more than results from the 3-deg spacing. The oscillations in the tidal amplitude with time could be the natural dynamic response of the system or the result of the initial conditions that were used. The method used to start a given computer run was somewhat artificial. In the real world, it would be like having a quiescent global ocean without the presence of the moon and then instantaneously placing the moon (and its force system) in its position. The initial conditions used could also be looked at as suddenly disturbing a quiescent global ocean with a strike from a giant drum-stick, the drumhead (ocean surface) reverberating from the strike; the reverberations eventually dying out with time.

While it was deemed necessary to spend the time understanding the flat-bottomed ocean before moving on to the more realistic ocean with bottom relief, the real Genesis Flood simulation must contain a rather complex bottom relief. The simple representations of relief considered in this paper showed that a Pandora's box is opened when the depth is allowed to vary. The sinusoidal bottom relief results revealed the entirely new phenomenon of whole ocean pulsation in each tidal period. This calculation, made with Hough's upper critical depth, produced a very complex situation. If this calculation were repeated with his lower critical depth, there would possibly be increased interaction with the closer bottom. Many additional simulations must be made before our understanding of the Genesis Flood fluid mechanics is anywhere near complete.

Fig.17. Variation of Maximum Tidal Amplitude with Time for a Pole to Pole Mid-Longitude Ridge of Various Heights. Hough's Upper Critical Depth.
CONCLUSIONS

On the basis of the numerical studies of global ocean tidal mechanics reported in this paper, the following conclusions can be drawn: Even though the interaction between the moon and a completely flooded planet earth is multifaceted and complex, this action follows the basic laws of mechanics and, hence, can be analyzed and at least partially understood using computer simulation principles. The action of the tides on a global ocean would have been powerful, omnipresent, and recurring, causing dynamism and cyclicity throughout the ocean depth (because of the shallow water wave characteristics). It could have been a potent determinate in what happened in the sedimentary processes.

In the numerical analysis, there are preferred parameter sets (mesh size, time step) which maximize the fidelity of the results and minimize computer effort; progress towards the proper selection of these sets has been made in the situations studied herein. Tidal amplitude closely correlates with bottom surface velocity in the shallow water wave category. It was selected as the critical variable to be studied when the ultimate aim is to establish a correlation between the fluid mechanics of the global ocean and the sedimentary strata sequences which resulted from the water action in that ocean. Resonance would have augmented the tidal amplitudes which, in turn, would have augmented the velocity fields, especially near the bottom where sediment transport and deposition would have occurred. Herein, resonance has been shown to occur but only when reduced friction was employed in the calculations. It is hoped that a better representation of this crucial friction variable can be programmed into the code which could alter the resonance results. Ocean depth is also a critical variable whose role in the tidal action has been illucidated in this analysis. A start has been made on understanding the variation in tidal action caused by bottom relief. The additional pulsing of the tidal free surface, occurring within a tidal period and being directly attributable to the bottom relief, is the type of event that can only be discovered by computer simulation. Other phenomena, which could dramatically effect the sedimentary processes, could also be uncovered by future studies of this nature.
Fig. 19. Temporal Sequence of Tidal Free Surface Plots During One Tidal Period. Sinusoidal Bottom Relief and Hough’s Upper Critical Depth.

BIBLIOGRAPHY


