3-D Finite Element Simulation of the Global Tectonic Changes Accompanying Noah's Flood

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Abstract

This paper presents a mechanism for the large-scale tectonic change that accompanied Noah's Flood. It assumes that the onset of the Flood only a few thousand years ago correlates with the notable stratigraphical and paleontological discontinuity of the Precambrian-Cambrian boundary. This implies that the geological history recorded in the rocks usually classified as Paleozoic and Mesozoic unfolded in a catastrophic manner within a few months time. It also suggests that the primary energy source for the catastrophe was the gravitational potential energy of the pre-Flood ocean lithosphere relative to the base of the mantle. The geological and geophysical data suggest that subduction of the pre-Flood ocean lithosphere began around the margin of a pre-Flood supercontinent. It is proposed that the mantle's viscosity at that time was lower than at present to permit rapid sinking of the lithosphere into the mantle and that the sinking rate was enhanced by a thermal runaway effect associated with a temperature-dependent rheology and localized shear heating near the slabs. Rapid replacement of the cold, dense pre-Flood oceanic lithosphere with hot, less dense mantle material from below resulted in significant elevation of the ocean floors relative to the continental surfaces causing a temporary rise in the world sea level by as much as 1,500m. Huge volumes of sea water were converted to pressurized steam where the ocean floors rifted apart to produce intense global rain. The deformations induced in the mantle pulled the supercontinent apart, opened the present Atlantic and Indian Oceans, and caused large vertical tectonic motions that strongly influenced sedimentation patterns on the continents. A 3-D spherical finite element simulation of the dynamics of this catastrophe is described.

Keywords

Noah's Flood, Subduction, Lithospheric Slabs, Thermal Runaway, Numerical Experiment

Introduction

Straightforward reading of the Bible allows no place for large-scale destruction of life on earth prior to the Flood of Noah. The scarcity of multicellular fossils in Precambrian rocks and the abrupt initial appearance in Lower Cambrian rocks of a wide diversity of complex multicelled lifeforms, frequently in high concentrations, seems therefore logically to demand that the onset of the Flood catastrophe corresponds to this striking feature in the paleontological record.

If the earliest Cambrian rocks mark the beginning stage of Noah's Flood just a few thousand years ago, then most of the subsequent geological record, from Cambrian to recent, must be the product of a global catastrophe of a magnitude beyond the ability of the human mind to imagine. This catastrophe must involve, for example, deposition of more than a mile of sediment on the average on top of the normally high-standing continents, uplift and erosion of mountain belts like the Appalachians, uplift of all the young mountain belts like the Andes, Alps, and Himalayas, formation of all the coal and oil deposits, formation of all the present day ocean floor, and separation of continents by several thousands of kilometers. The timescale for the most intense phase of the catastrophe is constrained by the biblical description to be months, although it likely required centuries for the earth to return to what one would consider a state of reasonable tectonic and climatic stability.

The primary objective of this paper is to present a physical explanation for this catastrophe. I shall assume the pre-Flood earth had essentially the same mass and radius as the present earth (that is, no expansion of the earth will be invoked), a very similar internal constitution and temperature profile as at present, and a distribution of continental crust similar to published reconstructions of Pangea (Figure 1). The assumption of a single pre-Flood supercontinent

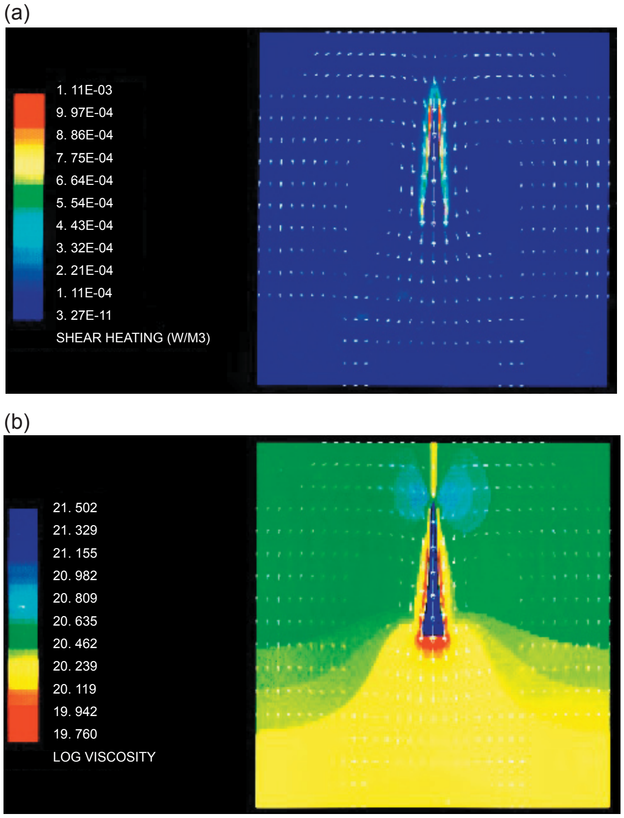


Figure 1. Snapshot from a calculation of the sinking of a vertical slab in a temperature-dependent viscous fluid just prior to thermal runaway. (a) Contours of shear heating rate show heating is strongly localized in zone next to slab. (b) Contours of the logarithm of viscosity show contour of minimum viscosity enclosing bottom of slab. Arrows denote the velocity field.

is suggested by Genesis 1:9, “Then God said, ‘Let the waters below the heavens be gathered into one place, and let the dry land appear;’ and it was so.”

For the benefit of those readers with limited background in the earth sciences, let me attempt to define at least a few of the most critical terms. One of the most important is lithosphere. The earth’s lithosphere is its outer skin, the layer of rock extending from the surface down to a depth of about 50 miles where the rock is sufficiently cool to behave over long periods of time more or less as an elastic solid. At greater depths temperatures are high enough that silicate rock responds more like a plastic solid when slowly deformed. In the present earth, the lithosphere is divided into a dozen or so patches, or plates, that behave more or less as rigid units. Along certain portions of the plate boundaries, the plates are converging, with one of the plates sinking into the earth beneath the other plate. This process is referred to as subduction. Some plates have part of their area covered with a 20 mile thick layer of lower density rock. These areas with this lighter rock layer represent the continents. Areas without this layer comprise the ocean basins. The buoyancy of the continental areas prevents these portions of the lithosphere from sinking or subducting. In contrast, oceanic lithosphere, which has an average chemical composition similar to the warmer rock beneath it, has a natural tendency to sink because of its lower temperature and higher density relative to the rock below. Hence it is the oceanic lithosphere that subducts. Along other portions of the plate boundaries, the plates are diverging and new plate area is formed as magma rises from below and cools to fill the gap. This process is referred to as sea-floor spreading. It is now taking place along the 40,000 mile long mid-ocean ridge system. Currently the plates are moving relative to one another with velocities on the order of a few centimeters per year. Seismological data indicate that silicate rock extends to a depth of about 1,800 miles or 2,900 km, which is slightly less than half the earth’s radius. This silicate portion of the earth is known as the mantle. The ideas of lithospheric subduction, sea-floor spreading, and solid-state flow of mantle rock are abundantly supported by objective geological and geophysical observation.

What events and processes could possibly be responsible for transforming a pre-Flood earth, that supported all the living organisms that now form the planet’s coal and oil deposits, to an earth similar to that of today in a matter of months or even centuries? In summary, I argue that the central process was the rapid sinking of the pre-Flood ocean lithosphere into the deeper mantle. It was the stored gravitational potential energy of this cold, dense layer of rock relative to the base of the mantle that served as the primary energy source for the catastrophe. What triggered this event? One possibility is that processes internal to the earth caused stresses in the lithosphere sufficient to produce rupture and initiate its sinking. Another possibility is that impact of an extraterrestrial body disrupted the lithosphere and started the sinking. Once begun, however, the sinking instability was sufficiently strong to lead to catastrophic transformation of the earth within a few weeks time, including the destruction of almost all the air-breathing life on the planet.

What are some of the consequences at the earth’s surface of such a sinking event? Subduction of the pre-Flood ocean lithosphere within a period of a few weeks implies plate velocities measured in meters per second instead of centimeters per year. If plate motions today generate magnitude 8 earthquakes and large volcanic eruptions at plate boundaries, it boggles the imagination to contemplate the intensity of tectonic upheaval that accompanied plate velocities more than ten million times higher. One can be sure that the level of seismic energy released was sufficient to generate chaotically violent tidal wave activity along every coastline on the planet. With magma rising to fill gaps some 50 miles deep and tens of thousands of miles long and widening at rates of meters per second as oceanic plates pulled apart, the level of volcanic violence is even more difficult to imagine. Staggering quantities of volcanic ash, water vapour, and CO_2 would be ejected into the atmosphere. The volume of water converted to pressurized steam along belts of rapid sea-floor spreading is easily enough to produce rain over the entire surface of the earth at a rate of a meter per hour continuously for the 40 days and nights mentioned in Genesis 7.

Another notable consequence of the rapid sinking of the pre-Flood ocean lithosphere is a quickly altered sea level. New sea floor formed at spreading ridges has a much higher average temperature and lower density than old sea floor that is subducted. This is the reason that on today's earth the mid-ocean ridges display an elevation some 2,000 m higher than that of the abyssal plains where the lithosphere is relatively much colder. Applied to the Flood model, this observation implies that rapid subduction of the old ocean lithosphere would lead to a reduction in the mean depth of the ocean basins of between 2,000 and 3,000 m, depending on the thickness of the pre-Flood ocean lithosphere, and produce a rise in the world sea level of between 1,200 and 1,800 m. Such an increase in sea level would of course inundate most of the continental areas. As the newly formed ocean floor cooled, the result would be a deepening of the ocean basins and a runoff of the flood waters from the continents.

In summary we note that rapid subduction of the ocean lithosphere produces several consequences consistent with the biblical account of the Flood. It generates a huge amount of rainfall, it causes a major but temporary rise in the world sea level, and it leads to a level of tectonic violence sufficient to destroy almost every ecological habitat on the planet. Furthermore, rapid subduction of the pre-Flood ocean lithosphere is a logical requirement of the correlation of the onset of the Flood with the Precambrian-Cambrian boundary, because no ocean floor older than Mesozoic can be found on today's earth. No pre-Flood (that is, Precambrian) ocean floor, which presumably covered some 60% of the earth's surface area, can be identified anywhere (except possibly as rare ophiolite formations in continental environments). It is therefore logical to conclude that essentially all the pre-Flood ocean lithosphere has sunk into the mantle since the onset of the Flood just a few tens of centuries ago (Baumgardner, 1986).

Physics of Sinking Lithospheric Slabs

Most people are aware that most materials are less dense when they are hot than when they are cold. Most know, for example, that hot air rises and cold air sinks. This behavior is also characteristic of the silicate material that forms the earth's mantle. Ocean lithosphere, with an average chemical composition close to that of the underlying mantle but an average temperature that is hundreds of degrees lower, has a resulting higher density and thus a tendency to sink. The style of sinking is for a patch or slab of this thin layer to peel away from the surface and quickly to assume a near vertical orientation as it sinks into the viscous deeper mantle.

Because the ocean lithosphere has a higher density than the underlying material, it possesses gravitational potential energy relative to the mantle below. The amount of this energy per unit volume is given by the product of the density difference, the gravitational acceleration, and the depth it can sink. The density difference is the product of the density, the temperature difference, and the volume coefficient of thermal expansion. If we use representative value for these quantities of $3{,}400\,\mathrm{kg/m^3}$ for the density, 600 K for the temperature difference, $2.5\times10^{-5}\,\mathrm{K^{-1}}$ for the volume coefficient of thermal expansion, $10\,\mathrm{m/s^2}$ for the gravitational acceleration, and 2,800 km for the effective depth of the mantle, we obtain a value of $1.4\times10^9\,\mathrm{J/m^3}$ for the gravitational potential energy density. This may be compared with the energy per unit volume required to melt silicate rock, $5.6\times10^9\,\mathrm{J/m^3}$, and with the energy per unit volume needed to boil cold water at atmospheric pressure, $2.7\times10^9\,\mathrm{J/m^3}$. Considering the volume of oceanic lithosphere to be layered 80 km thick covering 60% of the earth's surface, we obtain a value of $3.4\times10^{28}\,\mathrm{J}$ for the amount of associated gravitational potential energy. If released near the earth's surface, this amount of energy is sufficient to melt a layer of silicate rock 12 km thick or to boil away a layer of water 25 km deep over the entire earth. It is equivalent to the kinetic energy of 170,000 asteroids, each 10 km in diameter and travelling at 15 km/s. If even a tiny fraction is released near the earth's surface in the span of just a few months, massive catastrophe is implied. Certainly this energy source is easily sufficient to produce the surface tectonic upheaval associated with the Flood.

At this point the reader may be wondering why, since subduction of oceanic lithosphere is presumably occurring now and the gravitational potential energy of the oceanic lithosphere is approximately equal to that just calculated, we are not undergoing a major catastrophe at this present moment? In other terms, one could be asking what was different about the earth at the time of the Flood compared with today that allowed this catastrophe to unfold? The answer to this fundamental question almost certainly involves the issue of the mantle's rheology, that is, its deformational behavior.

Experimental investigations of the rheological properties of silicate minerals have demonstrated that they undergo plastic deformations under stress through the migration of minute defects or dislocations. These studies show that the deformation rate is strongly dependent on the temperature. The rate has an exponential temperature dependence of the form $\exp(E^*/RT)$, where E^* is an activation energy per mole, R is the universal gas constant, and T is the absolute temperature. As an example, the mineral olivine has a value for E^* of about 5.0×10^5 J/mol (Weertman, 1970), which implies the deformation rate increases by more than a factor of 36,000 as the temperature changes from 1200 K to 1500 K. This illustrates the crucial role temperature plays on the rates silicate rock deform and flow.

Another important observation is that mechanical work is converted to heat when materials undergo plastic deformation. Coupled to the strong dependence of the deformation rate on temperature, this deformational heating leads to the possibility of a mechanical instability. As a conceptual aid in understanding this instability, let us consider the idealized problem of a rigid sphere sinking under the influence of gravity in a fluid which has a strong temperature dependence of viscosity. Assume that both are initially at a single uniform temperature. As the sphere begins to sink, a volume of fluid surrounding the sphere undergoes significant deformation and is therefore heated. The heating in this volume in turn leads to an increased temperature and diminished viscosity. The lower viscosity in the vicinity of the sphere leads to a concentration of the deformation in the volume with elevated temperature, which in turn leads to more concentrated heating, higher temperature, yet lower viscosity, and higher sinking velocity. There is a competing process that acts to moderate or even inhibit this situation, however. Diffusion or conduction of heat from warmer regions to cooler ones operates to reduce nonuniformity of temperature. In order for the instability to be expressed, the time involved in heating the strongly deforming volume must be short compared with the time required for cooling the volume by thermal diffusion.

It is instructive to view the instability from an energy balance standpoint. In the regime in which the instability is not expressed and the sphere sinks at constant velocity, the gravitational potential energy of the sphere is being converted to mechanical work to deform the fluid, and this work done on the fluid appears as heat. In this case, all the gravitational potential energy is converted to heat. On the other hand, if heating reduces the viscosity, less energy is needed to deform the fluid, and the remaining gravitational energy is converted to kinetic energy of the sphere, that is, the sphere is accelerated to a higher velocity. So long as there continues to be more gravitational energy available than needed to deform the surrounding medium, the velocity of the sphere will increase. If increasing the velocity continues to keep the deformational energy less than the available gravitational energy, the velocity will increase with limit in a runaway fashion.

At what point does thermal diffusion cease to be a restraining influence and allow this instability to be expressed? It is when the time interval the sphere resides in a local region of fluid, given roughly by D/v, where D is the diameter of the sphere and v is its velocity, is much less than the characteristic thermal diffusion time, given by L^2/κ, where L is the diffusion length and κ is the thermal diffusivity of the medium. For our purposes, we can take the radius R of the sphere as the characteristic length L. The sinking velocity of a sphere in a constant viscosity medium is given by $0.22R^2\Delta\rho g/\eta$, where $\Delta\rho$ is the density difference between the sphere and the fluid, g is the gravitational acceleration, and η is the dynamic shear viscosity. The condition that the time interval D/v be much less than L^2/κ is then equivalent to the requirement that η be much less than $0.11R^3\Delta\rho g/\kappa$. If we choose $R=100$ km, $\Delta\rho=\rho\alpha\Delta T=(3{,}400\,\mathrm{kg/m^3})(2.5\times10^{-5}\mathrm{K^{-1}})(600\,\mathrm{K})=51\,\mathrm{kg/m^3}$, $g=10\,\mathrm{m/s^2}$, and $\kappa=1\times10^{-6}\mathrm{m^2/s}$ and assume "much less than" is a factor of 0.01, we find that the dynamic shear viscosity needs to be on the order of 5×10^{20} Pa•s or less for the instability to be expressed.

A set of numerical experiments were performed using a two-dimensional finite element code to explore the conditions under which this instability occurred for a slab-like body. The problem domain consisted of a rectangular box 1,280 km wide by 2,560 km high with reflective side boundaries and free-slip top and bottom boundaries. The cells in the 128×128 mesh had a 10 km width and 20 km height. The slab was 80 km wide and 500 km high. Other parameters were slab temperature 900 K, background temperature 1500 K, background density 3,400 $\mathrm{kg/m^3}$, volume coefficient of thermal expansion $2.5\times10^{-5}\mathrm{K^{-1}}$, thermal diffusivity 1.0×10^{-6}, gravitational acceleration 10 $\mathrm{m/s^2}$, and an activation temperature (E^*/R) of 60000 K. These experiments show that for values of dynamic shear viscosity of 1.0×10^{21} Pa•s and larger there is no instability. However, for values of 5.0×10^{20} Pa•s and smaller, the instability is clearly evident. Figure 2 displays the distribution of shear heating and viscosity just before the onset of the instability for the case of $\eta=3.0\times10^{20}$ Pa•s. As expected, a zone of intense shear heating and reduced viscosity envelopes the slab. In these experiments, once the instability begins, the sinking velocity increases without limit. However, in the real earth it is almost certain that additional physics such as melting would serve to limit the sinking velocity to a finite value.

This type of thermal runaway instability in a viscous fluid with temperature-dependent viscosity was studied over 25 years ago by Gruntfest (1963) who approached the problem using an energy balance analysis and a simplified form for the exponential temperature term, $\exp[-a(T\text{-}To)]$, where To is a reference temperature and a is equivalent to E^*/RTo^2. He found that for values larger than a critical number for a dimensionless parameter $G=a\sigma^2L^2/k\eta$, the temperature of a viscous fluid subject to constant shear stress increases without limit. Here s is shear stress, L the thermal diffusion length, k the thermal conductivity, and η the fluid's intrinsic dynamic shear viscosity apart from shear heating. For a planar slab the critical value for G is 0.88. The parameter G represents the ratio t_c/t_v of two characteristic times; t_c is the thermal of a fluid under constant shear stress without any conductive heat loss, given by $c\eta/a\sigma^2$, where c is the specific heat. Gruntfest's analysis demonstrates clearly that whether or not the runaway instability occurs depends on the relative strengths of viscous heat production and the heat loss due to thermal diffusion. This conclusion is the same as the preceding analysis which made use of the knowledge of the amount of gravitational energy available for viscous heating instead of assuming the shear stress to be constant.

The idea that thermal runaway could occur in the earth's mantle has been addressed by several workers since Gruntfest. Anderson & Perkins (1974), for example, proposed that thermal runaway of chunks of lithosphere in the low viscosity regions of the upper mantle might produce surges of hot material that rise and pond against the base of the lithosphere and cause dramatic episodes of igneous activity at the surface. They speculated that the widespread and complex pattern of Cenozoic volcanism in the southwestern United States might be a consequence of such thermal runaway events. With the estimate of $5\times10^{20}\,\mathrm{Pa}\bullet\mathrm{s}$ for the threshold of the instability obtained from the numerical experiments described above, however, not only is it plausible that it can operate in the upper mantle, but it is also conceivable that the instability could occur the entire depth of the mantle, were mantle temperatures just a few hundred degrees warmer. Estimates for the lower mantle viscosity are on the order of 10^{22}–$10^{23}\,\mathrm{Pa}\bullet\mathrm{s}$, or only about a factor of 100 larger than the threshold. It appears that the earth at present is just a little bit too cool for the instability to occur on a mantle wide basis. On the other hand, this instability appears just what is required to account for the catastrophic tectonic changes that accompanied the Flood.

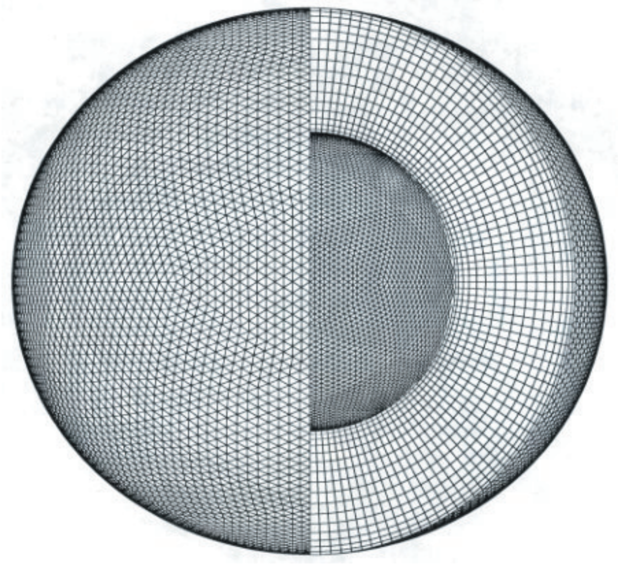


Figure 2. Cutaway view of the computational mesh for spherical shell used in 3-D finite element calculation. Mesh has 17 layers of cells with 10,242 cells in each layer.

A Numerical Experiment

A global numerical model for the mantle including its cold upper boundary layer, the lithosphere, will now be described. This model is embodied in the 3-D spherical finite element code named TERRA, first developed as part of the author's dissertation research. The code uses a special spherical mesh constructed from the regular icosahedron and employs a multigrid method for solving the momentum conservation equations for the velocity field at each time step. The mesh consists of 17 radial layers each with 10,242 cells (Figure 2). For each of the cells the code solves the conservation equations for momentum, mass, and energy in terms of the variables velocity, density, and temperature using a Newtonian rheological law and general equation of state. The details are described elsewhere (Baumgardner, 1983, 1985; Baumgardner & Frederickson, 1985).

In the case model, the mantle is treated as nearly incompressible, constant viscosity fluid with uniform properties except in the surface layer. The portion of the surface layer designed as continent is given a density $150\,\mathrm{kg/m^3}$ less than the remainder of the volume. In addition, the continental area is given an elastic/plastic rheology and divided into nine blocks corresponding to the present continents mapped to their Pangean locations. The lower density prevents the volume representing continental material from sinking into the mantle, and the elastic/plastic rheology causes the continental blocks to behave as more or less rigid units and thus preserve their shape approximately as they move in response to the velocity field in the mantle below. The remainder of the surface layer is treated just like the interior volume. The inner and outer boundaries of the spherical shell corresponding to the core-mantle boundary and the earth's surface, respectively, are treated as isothermal and traction free.

For a better perspective on the meaning of the calculations it is useful to note some of the model's main limitations. One of its most prominent is its restriction to constant viscosity, since the thermal runaway depends on a strongly temperature-dependent rheology. In the 3-D model, the higher velocities implied by thermal runaway of sinking lithospheric slabs are obtained in a crude manner by reducing the viscosity everywhere by nine orders of magnitude. This, of course, mostly eliminates the large gradients in velocity, temperature, and shear heating that otherwise would appear if the strongly temperature-dependent rheology were used. On the other hand, very much higher spatial resolution would be necessary to capture these extreme gradients. Such increased resolution makes such 3-D global calculations beyond the capabilities of even the largest supercomputers currently available. One must therefore for now be content to perform the highly resolved variable viscosity calculations in two dimensions and to apply more approximate treatments in 3-D investigations.

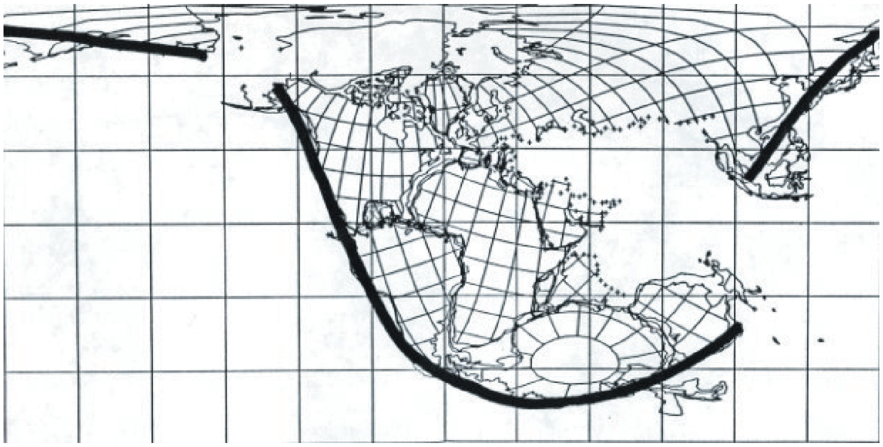


Figure 3. Reconstruction of Pangea published by Smith, Hurley, & Briden (1981). The dark band indicates the distribution of initially subducting ocean lithosphere in the 3-D calculation.

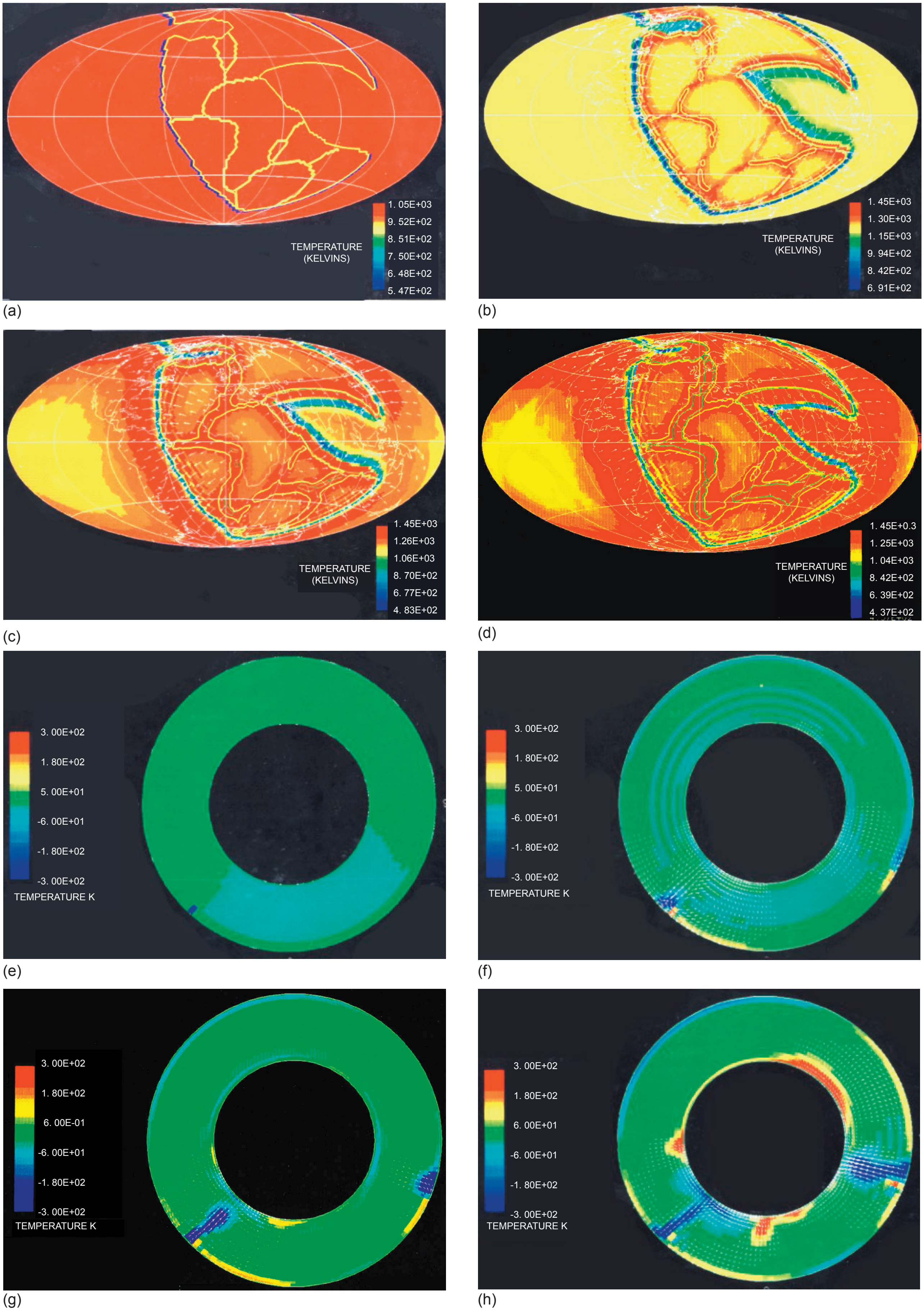
In a manner similar to the simple scaling of viscosity, two other physical parameters were also adjusted by large factors from their nominal values for the present earth. These two parameters are the radiogenic heating rate and the thermal conductivity, which were both increased by a factor of 108. Such scaling of the radiogenic heating rate is reasonable, it would seem, given the diverse evidence that a huge amount of radioactive decay occurred during the Paleozoic and Mesozoic portion of the geological record, which unfolds in a matter of months in the computer simulation. Scaling of the thermal conductivity by this factor is done mainly to smooth temperature gradients that otherwise would not be resolved by the mesh. However, an increased value for the thermal conductivity by this factor is done mainly to smooth temperature gradients that otherwise would not be resolved by the mesh. However, an increased value for the thermal conductivity is consistent with the hydrothermal enhancement of heat transport in zones of rapid seafloor spreading. It is just in these zones that diffusion-like transport of heat plays the greatest role in the calculation.

The limitations of incompressibility and spatially constant parameters mean that physics such as mineral phase transitions which occur between depths of 400 and 700 km in the mantle is not included. Although phase transitions are almost certainly important in mantle dynamics, most numerical investigations presently do not include them. Finally, the treatment of the lithosphere, although sophisticated by current standards, is still rather crude compared with the real earth.

These limitations and approximations notwithstanding, a 3-D calculation was performed to explore the response of a Pangean distribution of buoyant continental lithosphere to the sinking of the ocean lithosphere surrounding it in the framework of a Flood timescale. The reconstruction for Pangea is that of Smith, Hurley, & Briden (1981) shown in Figure 3. The black band in the figure represents the zone of initial subduction. The calculation uses a density of 4,500 kg/m^3, a dynamic shear viscosity of 2×10^{13} Pa•s, a coefficient of thermal expansion of 2.5×10^{-5} K^{-1}, a thermal conductivity of 4×10^{-4} W/kg, a gravitational acceleration of 10 m/s^2, an inner boundary temperature of 2300 K, and an outer boundary temperature of 300 K. This case required approximately 900 time steps to reach a problem time of 100 days.

Figure 4(a) shows the initial temperature distribution at a depth of 74 km together with the

Figure 4 (right). Snapshots from a 3-D calculation to investigate the consequences of initial subduction about a Pangean supercontinent. (a) Initial temperature contours and outlines of continental units that are treated as separate elastic/plastic blocks. (b)–(d) Solution after 20, 40, and 60 days, respectively, at a depth of 74 km. Finer lines are temperature contours, coarser lines are the 80% of initial continental thickness contour, and arrows represent the velocity field. (e)–(h) Equatorial cross-sections of the equal area views of (a)–(d),


1. 05E+03
9. 52E+02
8. 51E+02
7. 50E+02
6. 48E+02
5. 47E+02
TEMPERATURE (KELVINS)
(a)
1. 45E+03
1. 30E+03
1. 15E+03
9. 94E+02
8. 42E+02
6. 91E+02
TEMPERATURE (KELVINS)
(b)
1. 45E+03
1.26E+03
1.06E+03
8. 70E+02
6. 77E+02
4. 83E+02
TEMPERATURE (KELVINS)
(c)
1. 45E+0.3
1. 25E+03
1. 04E+03
8. 42E+02
6. 39E+02
4. 37E+02
TEMPERATURE (KELVINS)
(d)
3. 00E+02
1. 80E+02
5. 00E+01
-6. 00E+01
-1. 80E+02
-3. 00E+02
TEMPERATURE K
(e)
3. 00E+02
1. 80E+02
5. 00E+01
-6. 00E+01
-1. 80E+02
-3. 00E+02
TEMPERATURE K
(f)
3. 00E+02
1. 80E+02
6. 00E-01
-6. 00E+01
-1. 80E+02
-3. 00E+02
TEMPERATURE K
(g)
3. 00E+02
1. 80E+02
6. 00E+01
-6. 00E+01
-1. 80E+02
-3. 00E+02
TEMPERATURE K
(h)

outlines of the continental blocks mapped to their Pangean locations. Cold temperatures occur inside the tightly concentrated contour lines and correspond to the initial distribution of subducting lithosphere. Figure 4(b)–(d) are snapshots of the computed solution at 20, 40, and 60 days, respectively, at the same depth of 74 km. Arrows denote the material velocity field, the finer contours represent the temperature distribution, and the coarser lines are the 80% of initial continental thickness contour. Because of the asymmetrical sinking of surface material into the mantle at the continental margins due to the buoyancy of the continental areas, there exists the tendency of the zones of subduction to drift backward, in the direction away from the continent. The resulting pattern of flow acts to pull the supercontinent apart. Including the elastic/plastic treatment of the pre-defined blocks concentrates the strain into the zones between the blocks. The pattern of motion that develops resembles in a qualitative sense the motions of the continents on the earth since the time of Pangea. A noteworthy and unexpected feature in this calculation is the rapid movement of the Indian block to the northeast.

This experiment provides a general sense of the consequences of most of the ocean lithosphere sinking around the perimeter of a supercontinent resembling Pangea. Seismic tomography studies (Dziewonski & Woodhouse, 1987) indicate the existence of a band of material near the base of the mantle with high seismic velocity, presumably indicating cooler temperature, forming a ring around the present Pacific Ocean. These data argue strongly that a substantial amount of material has indeed been subducted around what was once Pangea and that a process similar to that evident in the numerical experiment has indeed taken place in the earth. Together, the geophysical observations and the computer results argue that such a pattern of subduction of the ocean lithosphere must have occurred in a Flood catastrophe that generated most of the Phanerozoic geologic record. Coupled with the potential of thermal runaway of lithospheric slabs and the huge source of energy in these slabs available to perform tectonic work, the case that this is the primary physical mechanism responsible for the large scale tectonic changes associated with the Flood seems to be a reasonable one.

Conclusion

Because no ocean floor on the present earth is older than Mesozoic, a Flood whose beginning correlates with the Precambrian-Cambrian boundary that produces the geological change associated with the Paleozoic and Mesozoic portions of geologic history must necessarily involve the subduction of all the pre-Flood ocean lithosphere. This appears to be a logical imperative, assuming there has been little or no differential expansion of the earth. If this subduction occurs within the several month time frame of the Flood, it seems likely that it involved a thermal runaway instability that can occur in a viscous material with a temperature-sensitive rheology in a gravitational field. The threshold for this instability is not far removed from mantle conditions in the present earth. The gravitational potential energy available to drive the instability and to perform the Flood's tectonic work at the earth's surface is easily sufficient. Rapid sinking of the ocean lithosphere during the Flood was shown to produce an intense period of rainfall, a major but temporary rise in sea level, and tectonic activity sufficient to accomplish the dramatic geological change recorded in the Paleozoic and Mesozoic rocks. Numerical simulation of this process in 3-D spherical shell geometry suggests that subduction of the pre-Flood ocean lithosphere around a pre-Flood supercontinent resembling Pangea leads to a distribution of continents similar to today's earth. It is concluded that rapid sinking of the pre-Flood ocean lithosphere played a central role in the tectonic aspects of Noah's Flood.

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Discussion

Models for subduction of pre-Flood oceanic crust continue to be explored by Dr. Baumgardner. These models offer an excellent mechanism explaining the tectonics and sedimentation associated with

Noah's Flood. The gravitational potential energy possessed by the pre-Flood oceanic crust does appear to have been large enough to accomplish the colossal tectonics of the Flood. Furthermore, the mechanism of catastrophic subduction of oceanic crust is shown to be possible if values of mantle viscosity and thermal conductivity are assumed.

Details of the model will, no doubt, be debated. For the most part the framework of assumption within which the model is constructed is representative of current creationist thinking. The assuming of the primary tectonics of the Flood to Paleozoic and Mesozoic, for example, is consistent with what I believe to be correct.

The assumption concerning the configuration of Pangea in early Paleozoic time will need to be substantiated by further research. Are there evidences for Cambrian rifting of Pangea?

Steven A. Austin, PhD
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Closure

I appreciate the positive comments from Dr. Steve Austin. In regard to his question about the configuration of the continents before and during early Paleozoic time, I would say that there is a wide diversity of opinion among secular geologists on this matter. For example, in a recent issue of *Science News* (April 27, 1991, Vol. 139, pp. 266–267), there is an article reviewing the work of two geologists who are proposing a late Precambrian supercontinent in which Antarctica is joined to what is today southwestern North America. In setting the context for such a startling notion, the author points out that "At present, reliable paleomagnetic evidence from the Precambrian period is scant, leaving geologists free to propose almost any conceivable orientation during that period."

My own view is that the pre-Flood continental configuration was likely similar to reconstructions of Pangea as indeed I suggest in my paper. This conviction is based on geological considerations as well as geophysical ones. Geological observations indicate the Paleozoic Caledonian orogeny indisputably involved North America and northern Europe. This Caledonian upheaval involves the opening and closing of a proto-Atlantic, but the spatial relationship between North American and Europe prior to this event does not seem to be significantly different from what it was afterward. I suspect a similar sort of early Paleozoic tectonic upheaval occurred among the five southern continents (Africa, South America, Antarctica, Australia, and India) that formed Gondwanaland. Although their late Precambrian spatial relationships are a matter of debate and speculation as the *Science News* article indicates, since they display so many common geological features and a distinctive Paleozoic flora and fauna, it is almost certain that the five blocks were in close proximity in the late Precambrian, that is, at the onset of the Flood. My view is that the Pangean configuration for their arrangement is the most likely choice.

Furthermore, geophysical evidence concerning the existence of a band of cold, dense material in the present-day lower mantle coincides with the notion that vast areas of lithosphere subducted around the margins of Pangea and sank into the lower mantle to produce the observed density distribution. The simplicity of this pattern obtained by seismic tomography is suggestive that the subduction occurring during Paleozoic time was similar to what has occurred since. Nevertheless, I freely concede that the pre-Flood continent configuration may have had differences from the Mesozoic on, and that the tectonic dynamics may have been more complex than I indicate in my paper. Hopefully, more observation data and more detailed modelling in the future will help to resolve these uncertainties.

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