Catastrophic Plate Tectonics:
The Physics Behind the Genesis Flood

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Abstract
The wealth of new data, mostly from the ocean bottom, that precipitated the acceptance of plate tectonics during the 1960s simultaneously also opened the door for the first time in more than 200 years to a technically credible defense of the Genesis Flood. From the mid-1700s through the days of Hutton, Lyell, and Darwin to the 1960s, it overwhelmed the human mind to imagine a mechanism that could possibly deliver, in a single brief event, the magnitude and complexity of geological change evident in the continental rock record above the point where fossils first appear. However, with the new awareness that the earth's interior could participate in the process and that the stiff layer of rock some 50 miles thick beneath the oceans could be recycled into the earth, the stage was set for a breakthrough in regard to the mechanism for the Flood cataclysm. The crucial final piece of the puzzle has come from laboratory experiments that have carefully measured the way in which silicate minerals deform under conditions of high temperature and high stress. These experiments reveal silicate material can weaken dramatically, *by factors of a billion or more*, at mantle temperatures and for stress conditions that can exist in the mantles of planets the size of the earth. The scenario in which all the earth's ocean lithosphere is rapidly recycled into the mantle via a runaway process, enabled by this stress-weakening behavior, is now known as catastrophic plate tectonics (Austin, 1994). Evidence in the geological record is compelling that such a cataclysmic episode indeed has occurred in the earth's recent past. A reasonable inference is that this event corresponds to the Flood described in the Bible and other ancient sources. I report new computational results from 2-D and 3-D simulations of this catastrophic plate tectonics process. In particular, I describe how fundamental advances in computational techniques now make it possible to advance the numerical solution successfully through the most extreme phase of the runaway regime.

Keywords
Genesis Flood, Catastrophic Plate Tectonics, Runaway Subduction, Mantle Rheology, Stress-Weakening

Introduction
At least as far back as the early 1960s it has been known that the phenomenon of *thermal runaway* can potentially occur in materials whose effective viscosity is described by an Arrhenius-like (Levine, 1995) relationship. The viscosity of such materials varies as $e^{(E^*/RT)}$, where T is absolute temperature, E^* is the activation energy, and R is the gas constant. A large variety of materials, including silicate minerals, have viscosities that vary with temperature in this manner. In 1963 I. Gruntfest showed for a layer subject to constant applied shear stress and a viscosity with Arrhenius temperature dependence, both the deformation rate and the temperature within the layer can increase without limit, that is, runaway (Gruntfest, 1963). The criterion for runaway to occur is that the time constant associated with viscous heating be much less than the characteristic thermal diffusion time of the layer. Several investigators in the late 1960s and early 1970s explored the possibility of thermal runaway of lithospheric slabs in the mantle. Anderson & Perkins, (1974), for example, suggested that the widespread Cenozoic volcanism in the southwestern US might be a consequence of thermal runaway of chunks of lithosphere in the low-viscosity upper mantle. They conjectured that surges of melt associated with such runaway events might account for episodes of volcanism observed at the surface. Lithospheric slabs, because they display an average temperature some 1000 K or more lower than that of the upper mantle but have a similar bulk chemical composition, are several percent denser than the surrounding upper mantle rock and therefore have a natural ability to sink. The gravitational body forces acting on a slab lead to high stresses, especially within the mechanical boundary layer surrounding

the slab. As a slab sinks, most of its gravitational potential energy is released in the form of heat in these regions of high deformation. If conditions are right, the weakening arising from heating can lead to an increased sinking rate, an increased heating rate, and greater weakening. This positive feedback associated with thermal weakening can result in runaway provided the criterion mentioned above is met (Baumgardner, 1987).

Experimental studies of the deformational behavior of silicate minerals over the last several decades have revealed the strength of such materials not only depends strongly on the temperature but also on the deformation rate. At shear stresses on the order of 10^{-3} times the low-temperature elastic shear modulus and temperatures on the order of 80% of the melting temperature, silicate minerals deform by a mechanism known as dislocation creep in which slip occurs along preferred planes in the crystalline lattice (Kirby, 1983). In this type of solid deformation, material strength depends on the deformation rate in a strongly nonlinear manner, proportional to the deformation rate to approximately the minus two-thirds power. At somewhat higher levels of shear stress, these materials display another type of deformational behavior known as plastic yield, where their strength decreases in an even more nonlinear way, in this case, inversely with the deformation rate (that is, proportional to the deformation rate to the minus one power). When these deformation-rate-weakening mechanisms are combined with the temperature weakening discussed above, the potential for slab runaway from gravitational body forces is enhanced dramatically. A point many people fail to grasp is that these weakening mechanisms can reduce the silicate strength *by ten or more orders of magnitude without the material ever reaching its melting temperature* (Kirby, 1983).

Breakthrough in Numerical Modeling of the Runaway Mechanism

Numerical methods now exist for modeling and investigating this runaway mechanism. Considerable challenge is involved, however, because of the extreme gradients in material strength that arise (Baumgardner, 1991, 1994). W.-S. Yang, a graduate student with whom I worked closely, focused much of his PhD thesis research effort at the University of Illinois on finding a robust approach for dealing with such strong gradients in the framework of the finite element method and an iterative multigrid solver. He showed what is known as a matrix dependent transfer multigrid approach allows one to treat such problems with a high degree of success. Although his thesis dealt with applying this method to 3-D spherical shell geometry, he subsequently developed a simplified 2-D Cartesian version capable of much higher spatial resolution. Details of this method together with some sample calculations are provided in a recent paper (Yang & Baumgardner, 2000).

This new formulation of the multigrid solver represents a breakthrough in treating large local variations in rock strength and allows the mantle runaway process to be modeled to completion for the very first time. Results I have reported in previous ICC papers only tracked the runaway to its earliest stages. Beyond that point available numerical methods failed. Although the underlying equations themselves indicated runaway most certainly would occur, computer methods were not available that could handle fully developed runaway conditions. Moreover, the new solver technique now allows a regime of rock deformation known as plastic yield that involves an even greater degree of instability. This important plastic flow regime, because of the increased level of instability it introduces, had not been included in previous efforts to model the runaway process.

Figure 1 is a plot of the primary deformation regimes as determined by many careful laboratory experiments for the common mantle mineral olivine. The heavy lines separate the three main regimes: diffusion creep, dislocation, or power-law creep, and plastic yield. Finer lines of constant shear strain rates are plotted as a function of temperature and shear stress. (For readers unfamiliar with the terminology, strain has to do with the amount of deformation per unit length and so is dimensionless. Strain rate is the change in strain per unit time and so has units of inverse time. Stress has units of force

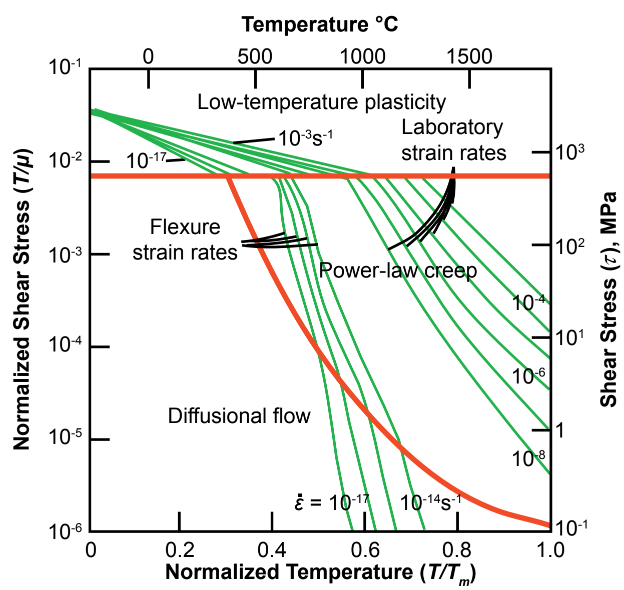

Figure 1. Deformation map for the mineral olivine at 1 mm grain size. Shear strain rates $\dot{\gamma}$ (in s^{-1}) are plotted versus shear stress τ normalized by elastic shear modulus μ and versus absolute temperature T normalized to the melting temperature T_m (after Kirby, 1983).

per unit area, the same as pressure.) Note that the rates of strain, or deformation, displayed in this plot for these solid olivine crystals vary over fourteen orders of magnitude! This range of deformation rate easily brackets the rates observed in the runaway calculations. (A tectonic plate moving 10 m/s, or 22.4 mph, relative to some substrate below, with a 10 km thick weak zone in between, implies an average shear strain rate of 10^{-3} within the weak zone, for example.) In regard to the three regimes, diffusion creep involves migration of point defects (extra or missing atoms) through the crystalline lattice in response to applied stress, while dislocation creep involves planes of atoms moving relative to each other in a more or less coherent way. In the plastic yield regime, such large numbers of dislocations emerge that huge increases in deformation rate occur with very little increase in shear stress.

It is relatively simple to represent these three deformation regimes as analytical expressions that can be incorporated into a numerical model. To do this, based on these experimental data, an effective viscosity is defined as a function of shear stress, shear strain rate, and temperature. On each time step a new viscosity field is computed based on the current values of these quantities. This effective viscosity field is then used in the finite element procedure to compute the new velocity field on the next time step that in turn is applied to update the temperature field and compute new stresses and strain rates.

Figure 2 includes three snapshots from a 2-D calculation in which runaway occurs. The vertical dimension of the 2-D box is 2,890 km, equal to the thickness of the earth's mantle. The vertical viscosity structure in the absence of runaway includes a strong upper layer with a viscosity on the order of 10^{30} Pa•s, a weak upper mantle/asthenosphere with a viscosity on the order of 5×10^{20} Pa•s, and a relatively strong lower mantle with a viscosity on the order of 3×10^{24} Pa•s. The surface velocities before runaway begins are in the range of those observed for the earth today. The initial temperature distribution includes relatively strong thermal boundary layers at both top and bottom boundaries. The internal temperature for this calculation is initialized to be 2000 K, and the top and bottom boundary temperatures are 300 K and 2700 K, respectively. A modest lateral temperature gradient is included to induce motion within the box. Under these conditions it is the bottom boundary layer that goes unstable first to produce a runaway upwelling plume along the sides of the box. This upwelling plume in turn causes the top boundary layer to go unstable and also to run away. Note that runaway plumes emerge from both top and bottom boundaries. It is the release of gravitational potential energy stored in both these boundary layers that drives the ensuing motion.

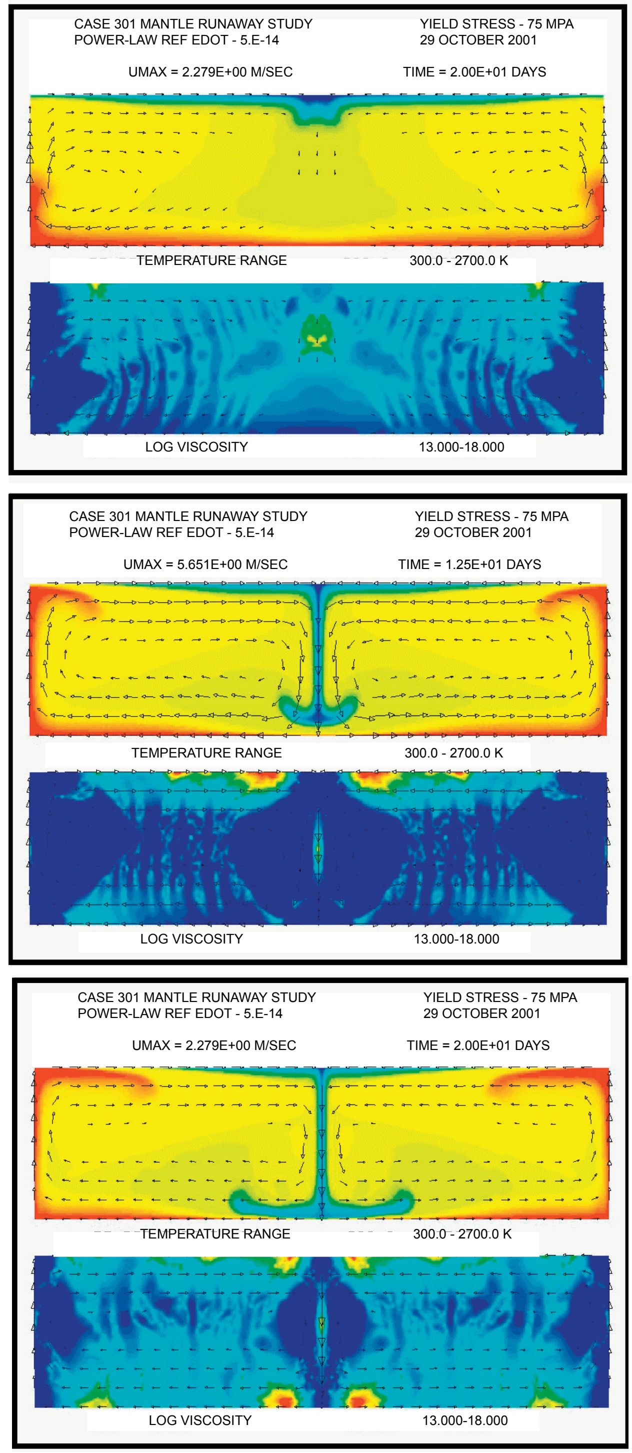

Figure 2. Three snapshots from a 2-D mantle runaway calculation in a box 11,560 km wide by 2,890 km high at times of 5.0, 12.5, and 20 days. Arrows denote flow velocity scaled to the peak velocity "umax." Contours represent temperature in the top panels and base 10 logarithm of viscosity in the bottom panel. The viscosity range in the bottom panel plots is therefore 10^{13} to 10^{18} Pa•s.

Such upwellings from the bottom boundary have dramatic implications for transient changes in sea level during the Flood since they produce a temporary rise in the height of the ocean bottom by several kilometers. Similarly, downwellings from the top boundary cause a temporary depression of the boundary. Because downwellings are generally beneath continental regions, they result in a temporary depression of the continental surfaces by similar amplitudes as the upwellings. Note in Figure 2 that during the runaway the viscosities throughout most of the volume of the box are reduced by factors on the order of one billion below their non-runaway values. Log viscosity values between 13 and 18 correspond to viscosities between 10^{13} and 10^{18} Pa•s, whereas the nominal viscosity at mid-depth in the box before the runaway episode was 3×10^{24} Pa•s. Note that this energy-conserving formulation that accounts for deformational heating shows no evidence of extreme temperatures associated with the runaway process. This is because the rate of deformational heating is proportional to the viscosity, which is diminished on the order of a billion-fold by the weakening associated with the runaway. Finally, this calculation, in showing that the beginning instability can arise in the mantle's lower boundary layer, adds to the number of possible ways such a catastrophe might have begun.

One reason most researchers in the mainstream geophysics community have not yet obtained such dramatic runaway solutions is that a deformation law that accommodates realistic levels of weakening has yet to be included in their models. Moresi & Solomatov (1998), however, reported a regime in 2-D geometry very close to the runaway solution described above, one they refer to as the "episodic overturn regime." This convective regime is intermediate between a "stagnant-lid regime" in which the upper thermal boundary layer is so strong it does not participate in the convective flow and a "mobile-lid regime" in which the upper thermal boundary layer is sufficiently weak that it deforms and moves with the underlying flow. Their deformation law included plastic yield, and the strength of the thermal boundary layer was governed by the stress level at which plastic yielding occurs. In their episodic overturn regime the boundary layer deforms only slowly as it thickens by cooling until its negative buoyancy reaches a critical value. At this point this cold layer peels away from the top boundary and sinks rapidly as a blob to the bottom. The process then repeats itself in an almost periodic fashion. The sinking velocities they report are modest because the weakening they allowed was much less than that measured in mineral physics experiments. Nevertheless, their calculations clearly demonstrate the process by which a planetary boundary layer can grow and then suddenly become unstable and quickly release its stored gravitational potential energy.

New 3-D Results

Next I would like to briefly describe results from a 3-D spherical shell calculation that builds upon these 2-D results. Details of the theoretical formulation and numerical methods are summarized in a paper I presented at the 1994 ICC (Baumgardner, 1994). The case presented here has a horizontal resolution at the earth's surface of about 120 km, which is twice spatial resolution of the case described in the 1994 paper. As in the earlier work, the approach is to solve equations of mass and energy conservation and a balance of forces for each cell in the computational grid. The forces include, first of all, a buoyancy body force that arises from gravity acting on density variations due to the variations in rock temperature. These buoyancy forces in turn are balanced by the forces arising from rock deformation and from the local variations in pressure. The underlying formulation is conceptually very simple in that it conserves the mass and energy moving into and out of each cell and balances the various forces acting upon each cell.

In addition to this standard treatment of the conservation equations, there is a special method for treating tectonic plates at the top boundary of the spherical shell domain. Each plate is represented by a set of particles that move with the plate over the top surface. A set of rules for the particles governs the interactions of the plates at their boundaries. Where plates diverge, new particles are added in a manner that represents symmetric cooling on either side of the existing plate boundary. Where plates converge, particles are removed to represent subduction if ocean plate lies on at least one side of the common boundary. Where one side is continent and the other side is ocean, it is the ocean plate that disappears.When both sides are ocean, symmetric removal of plate is enforced. If both sides are continent, equal and opposite normal forces are applied to both plates to model continent-continent collision.

The initial shape and extent of plates, including the distribution of continental crust, is specified as an initial condition. In the case presented here, the initial plate configuration is an approximate reconstruction of Pangea derived from shapes of the present-day continents and data from the present-day ocean floor. In addition, an initial temperature perturbation within the spherical shell domain is required to initiate motion. For this a temperature perturbation of −400 K to a depth of a few hundred kilometers is introduced around most of the perimeter of the supercontinent. Otherwise, the initial temperature within the interior of the shell is laterally uniform.

Solving the equations of mass and energy conservation and force balance from this initial state yields a solution in which subduction of ocean plate occurs around most of the margin of the initial supercontinent and the continent blocks comprising this supercontinent are pulled apart. Snapshots are

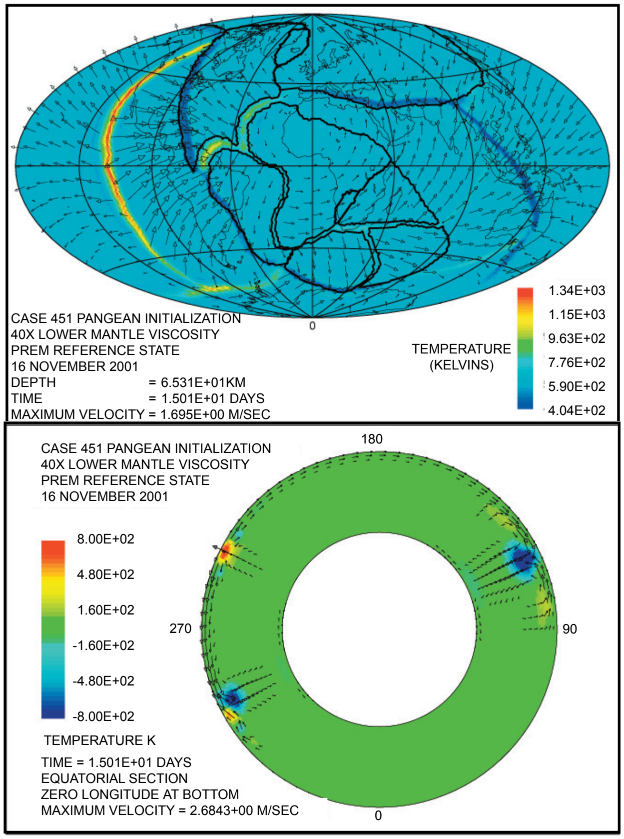

Figure 3(a). Snapshot of 3-D solution after 15 days. The upper plot is an equal area projection of a spherical surface 65 km below the top surface in which grayscale denotes absolute temperature. Arrows denote velocities in the plane of the cross section. Arrows denote velocities. The dark lines denote plate boundaries where continental crust is present or boundaries between continent and ocean where both exist on the same plate. The lower plot is an equatorial cross section in which the grayscale denotes temperature variation from the mean at a given depth.

shown in Figures 3(a) and 3(b) for times of 15 and 25 days, respectively. The resulting pattern of seafloor spreading and continent motion, while not identical to what is inferred from today's earth, is remarkably similar, particularly given the simplicity of the model and the relative deficit of detail in the initial conditions. The short timescale is a direct consequence of using the same reduced viscosity observed to occur during a runaway episode in the 2-D calculations. Simulating runaway conditions directly requires the high spatial resolution currently feasible only in two dimensions. Again, the reason most researchers in the mainstream geophysics community have not obtained such runaway solutions is that a deformation law that accommodates realistic levels of weakening has not yet been included in their models.

This 3-D calculation is intended only as an illustration of the style of the catastrophic tectonics and mantle motions that unfolded during the Genesis Flood. The calculation obviously does not capture the earliest portion of the cataclysm that correlates with the Paleozoic part of the geological record. In particular, it should be emphasized that the initial condition used for the calculation does not represent an initial state for the pre-Flood earth. Instead it represents a state roughly mid-way into the actual Flood cataclysm corresponding to the early Mesozoic point in the record. To be sure, a comprehensive Flood calculation ideally would begin from an initial state resembling the pre-Flood earth and the calculation would include the dynamics that unfolded during the Paleozoic portion of the cataclysm as well as what followed afterward. Unfortunately, the observational data most helpful for reconstructing such a pre-Flood initial state with a reasonable degree of fidelity are simply not available. No Paleozoic or Precambrian ocean floor, for example, still resides at the earth's surface, and clues from the continental rocks are sparse. On the other hand, a moderately accurate guess for the initial state is absolutely essential in this type of numerical model if the final state is to bear any reasonable resemblance to today's earth. So I have chosen, for purposes of this illustrative calculation, to begin from a state for which we have at least a few reliable constraints in order to obtain at the end a result that somewhat resembles today's world. I believe this calculation, even though it does

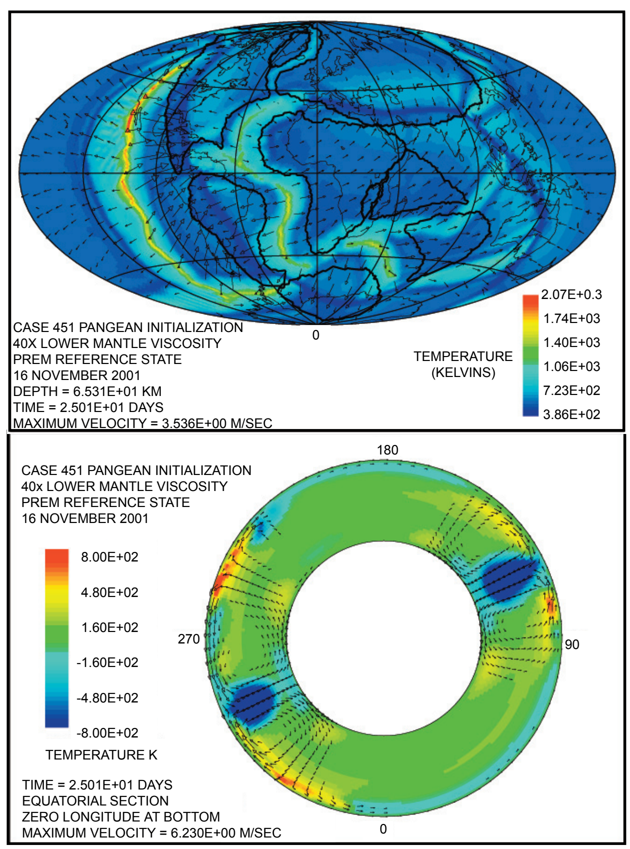

Figure 3(b). Snapshot of the solution after 25 days. Grayscale and arrows denote the same quantities as in Figure 3(a).

not reach back to the very beginning of the actual cataclysm, nevertheless provides useful insight into the dynamics involved and reveals many details that otherwise might not be apparent. Hopefully, with sufficient effort it will be possible in the future to realize a pre-Paleozoic initial state suitably reliable to model the entire catastrophe.

Observational Support for Catastrophic Plate Tectonics

If such a dramatic catastrophe has occurred in the recent past of our planet, surely there should be abundant observations to confirm it. Because of space restrictions I will limit my discussion to only a few lines of supporting evidence. First, there is the rock record itself. Briefly, the style and character of the Phanerozoic sedimentary record powerfully refutes the proposition that the present is the key to the past. Nowhere on earth do we observe contemporary continental sediment deposits with the huge lateral scale that typifies the Paleozoic, Mesozoic, and even much of the Cenozoic portions of the continental sedimentary record. Formations exposed in the Grand Canyon such as the Permian Coconino Sandstone, for example, extend laterally for hundreds to thousands of miles in both directions with amazingly uniform microscopic and macroscopic properties (Austin, 1994, p. 36). Beyond such impressive lateral continuity at the regional scale, Ager (1973) documents many examples of amazing persistence in physical properties of sedimentary units on a global scale. One example is the classic set of formations that comprise the German Triassic: the Keuper, Muschelkalk, and Bunter. These formations with near to identical coloration and physical properties are also found across Europe from England to Bulgaria and in North America on the eastern seaboard as well as across Texas, New Mexico, and Arizona (Ager, pp. 4–6). He points out that the high-energy basal Triassic conglomerate in England, with boulders of distinctive purple and white quartzites, is found "from one end of Europe to the other," with excellent examples in France, Spain, and Bulgaria. Indeed, the prominent occurrence of cross-bedding throughout the Phanerozoic record reveals that high-energy water transport was a ubiquitous phenomenon. Such cross-bedding is prominent in the Coconino Sandstone (Austin, pp. 29–36), but is even evident in portions of the fine grained Redwall Limestone (Austin, pp. 26–28). Further, the general absence of erosional channels at boundaries between these sedimentary units suggests a single continuous cataclysm (Austin, pp. 42–51).

Of course, one of the chief mental barriers to acceptance of the idea of a single cataclysm is the belief that radioisotope dating has proved beyond reasonable doubt that the Phanerozoic record spans many hundreds of millions of years. There is a startling inconsistency, however, between radiocarbon and long half-life radioisotope methods. Since the advent of the accelerator mass spectrometer (AMS) approach to measuring $^{14}C/C$ ratios about twenty years ago, AMS analyses of organic samples from throughout the Phanerozoic record consistently show reproducible amounts of ^{14}C that constrain their ages, instead of to 30 or 100 or 350 million years, to less than 70,000 years. This is true of essentially all samples tested since the early 1980s in dozens of AMS laboratories around the world as documented in the peer-reviewed radiocarbon literature (Baumgardner, Humphreys, Snelling, & Austin, 2003). Recent AMS analyses conducted by the RATE team on a set of ten coal samples solidly supports this conclusion (Baumgardner et al). The extreme conflict between ^{14}C age determinations and methods based on longer half-life isotopes is pointing to the likelihood that a foundational assumption of radioisotope dating, namely, that nuclear decay rates have always been time-invariant, is incorrect. A line of evidence strongly supporting this inference is the large amount of radiogenic helium still retained in zircons (Gentry, Glish, & McBay, 1982). Measured helium diffusion rates in zircon as well as in their common host minerals indicate such observed high levels of helium retention could persist for at most only a few thousand years (Humphreys, 2000; Humphreys, Baumgardner, Austin, & Snelling, 2003). Moreover, the observed small amount of helium in the earth's atmosphere is consistent with only a small amount of helium outgassing from the earth's mantle and crust, contrary to the higher levels expected if the conventional radiometric time scale were true (Cook, 1957).

Another indication that the uniformitarian time scale is faulty is the timing of the uplift of today's continental mountain ranges. Ollier & Pain (2000), have reviewed the considerable documentation in the geomorphology literature for a recent (Plio-Pleistocene) near-synchronous uplift of all the continental mountain belts. They point out that in most cases this uplift was preceded by widespread regional erosional planation of the land surface. They emphasize that both the planation and the rapid uplift were global phenomena. But they are utterly mystified as to what could have been the mechanism for the vertical uplift. Although they explain correctly the principle of isostasy (that the ground surface tends to adjust its height such that all columns of rock down to some compensation depth have the same total weight per unit area), they simply cannot take the obvious logical step of concluding the recent uplift reflects systematic and large-scale isostatic adjustment following massive recent changes in crustal thickness. They reject conventional plate tectonics as an adequate explanation because its timescale is too long and its rates are too small. Catastrophic plate tectonics, however, not only solves the timescale problem, but it also accounts for the widespread erosional planation, provides the mechanism for large local changes in crustal thickness, and explains why the uplifts occurred simultaneously.

Continental crust is roughly 20% less dense than the mantle rock beneath it. It is also typically much weaker, especially the warmer lower crust. Subduction, and particularly shallow subduction, therefore is able to alter the crustal thickness distribution beneath a continent. Shallow subduction of the Farallon plate beneath the western United States, dragging with it to the east ductile lower crustal rock before it plunged into the mantle below, for example, accounts for the dramatically increased crustal thickness beneath the Rocky Mountains and hence for the mountains themselves (Bird, 1988). When the Paleozoic, Mesozoic, and all but the latest Cenozoic portions of geologic history are compressed into the span of a year in the catastrophic plate tectonics framework, uplift naturally takes places afterward and, especially from a uniformitarian perspective, appears sudden and simultaneous. The earlier planation corresponds to large-scale erosional processes operating while most of the continental surfaces were still near sea level. Hence, the timing and simultaneity of the uplift of today's mountains represents powerful support for a recent catastrophic plate tectonics episode.

Yet another type of evidence for recent global tectonic catastrophe is the large magnitude of the temperature anomalies inferred for the rock near the bottom of the mantle. One of the most robust features of lateral mantle structure provided by the field of seismic tomography over the last 15 years is a ring of dense rock at the bottom of the mantle roughly below the perimeter of today's Pacific Ocean (Su, Woodard, & Dziewonski, 1994). The location of this ring correlates closely with the locations inferred for much of the subducted ocean floor since the early Mesozoic in the geological record. It is also consistent with location of the cold downwelling flow in the 3-D calculation of the previous section. Moreover, in the center of this ring of cold rock, on either side of the earth in the central Pacific and beneath Africa, are blobs of relatively warm rock, squeezed up as it were like toothpaste, as shown in Figure 4. The issue here is the large difference in density, and presumably temperature, between these cold and hot regions. The density difference is estimated to be on the order of 3–4% (Grand, 1997; Su et al.). This translates, assuming these regions have a similar chemical composition, to a temperature difference on the order of 3000–4000 K! Such a huge temperature contrast would not be expected if the cold upper boundary layer rock had taken 100 million years or more to reach the bottom of the mantle. On the other hand if this cold rock plunged through the mantle just a few thousand years ago, it should still be near the temperature it had when it was at the earth's surface, and such large temperature contrasts could indeed be real. Although accounting for such large density contrasts is currently a significant problem for the uniformitarian framework, it is readily explainable in the context of a recent episode of runaway subduction. In addition to the connection between past and current zones of subduction and the regions of cold dense material

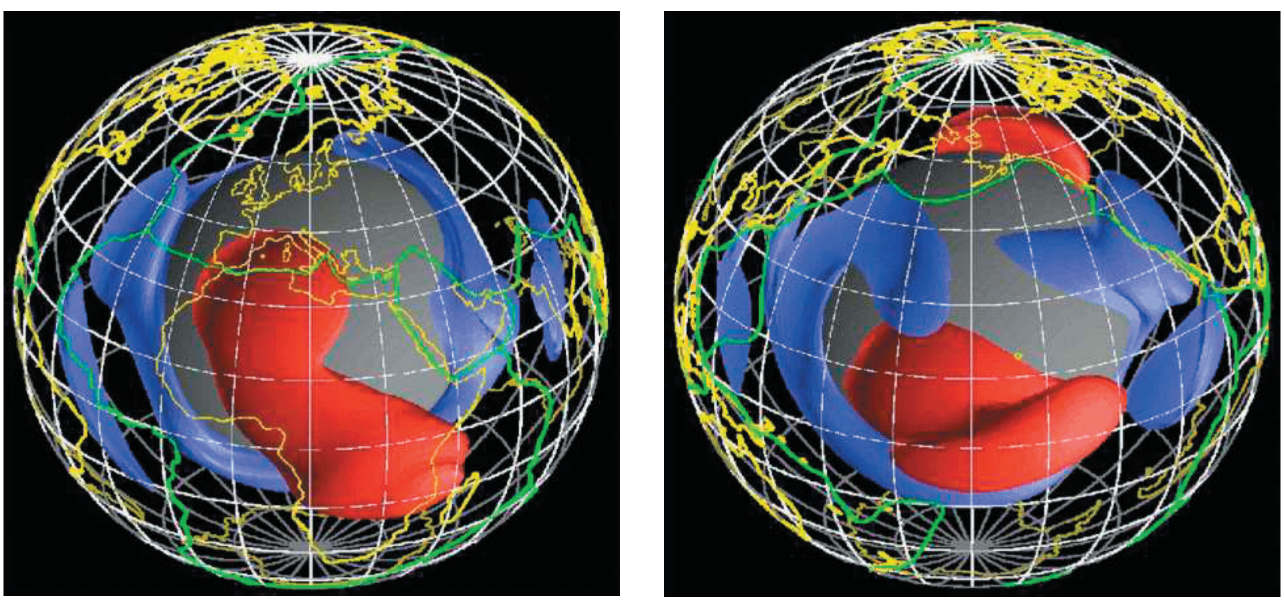

Figure 4. Distribution of hot (light shaded surfaces) and cold darker shaded surfaces) regions in today's lower mantle as determined observationally by seismic tomography as viewed from (a) 180° longitude and (b) 0° longitude. (Figure courtesy of Alexandra Forte.)

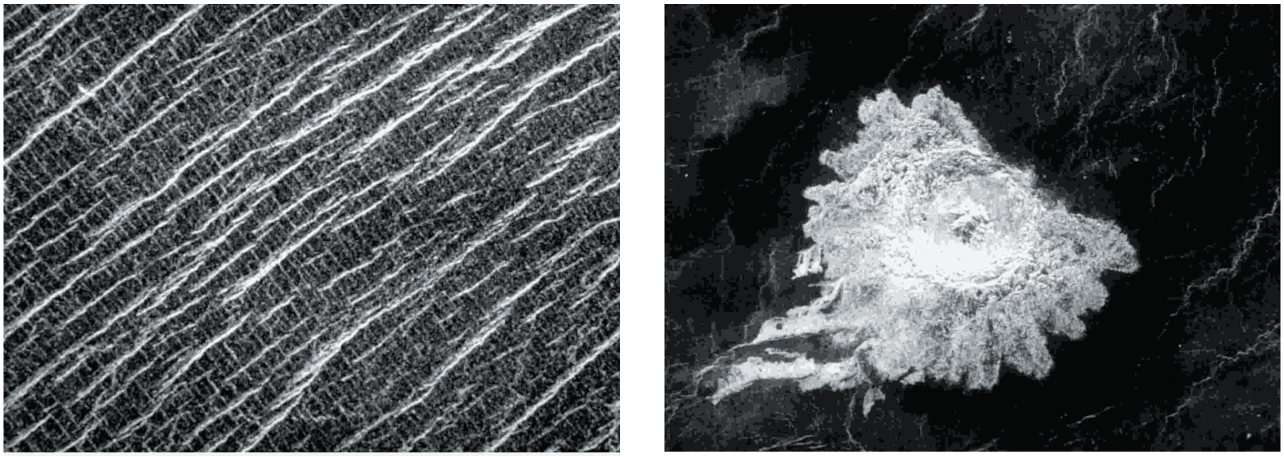

Figure 5. Synthetic aperture radar images of the Venus surface acquired by the NASA Magellan spacecraft. Left image displays the so-called "gridded plains" terrain associated with massive outpourings of basalt over the planet surface that subsequently cooled and fractured. Right image shows an impact crater about 30 km in diameter whose ejecta blanket is pristine and undisturbed. About 1,000 such craters were identified in the Magellan images. The freshness of these craters suggests the tectonism that generated the present Venus surface features was recent. (Images courtesy of NASA Jet Propulsion Laboratory.)

in the deeper mantle, there are readily apparent expressions of the hot buoyant regions (the features in Figure 4 resembling squeezed up toothpaste) also at the earth's surface. In the Pacific hemisphere, above one of these hot mantle features, are thousands of seamounts, or underwater volcanoes, dotting the Pacific Ocean floor. The ocean bottom itself displays an anomalous elevation of about 250 m in what is known as the South Pacific superswell (McNutt, 1998). In the opposite hemisphere, there is the East African Rift and its associated volcanism and a similar anomalous broad elevation of the topography, referred to as the African superswell (Lithgow-Bertelloni & Silver, 1998).

Still another line of evidence supporting the sort of mantle instability described in this paper comes from earth's sister planet, Venus. High-resolution radar images from the NASA Magellan mission in the early 1990s led to the amazing discovery that Venus had been globally resurfaced in the not so distant past via a catastrophic mechanism internal to the Venusian mantle (Strom, Schaber, & Dawson, 1994). More than half of the Venus surface had been flooded with basaltic lava to produce largely featureless plains except for linear fractures caused by cooling and contraction as indicated in Figure 5. The Magellan images also reveal evidence of extreme tectonic deformation that generated the northern highlands known as Ishtar Terra with mountains having slopes as high as 45° (Ford & Pettengill, 1992). Considering the high surface temperatures on Venus and the strength of silicate rock at those temperatures, it is next to impossible to sustain such high slopes for more than a few thousand years. Recent runaway sinking of much of the planet's cold upper thermal boundary layer into its mantle seems the most plausible mechanism to explain such a planetary resurfacing event (Strom et al.). Given this evidence for runaway in a planet so similar in size and composition as Venus, to me it is not unreasonable to consider this same mechanism as an explanation for the global scale correlations and the ubiquitous evidence for high velocity water transport and rapid deposition in the sedimentary record on earth.

Discussion

What are some of the most notable difficulties for the concept of catastrophic plate tectonics in accounting for the earth we observe today, including its record of past geological process? One of the most prominent problems I have mentioned in earlier papers is how the newly formed ocean lithosphere could cool to its present state within such a short span of time. Discussions in early 2001 with Nathaniel Morgan, a new graduate student at Los Alamos National Laboratory with a background in multiphase heat transfer, led us both to realize that supersonic steam jets were almost a certainty along the spreading boundary between diverging ocean plates during the runaway phase of the catastrophe. Further analysis showed that jet velocities exceeding the earth's escape velocity might be possible. In this case, the energy per kilogram of steam escaping to space is sufficient to accomplish the bulk of the lithospheric cooling while the plates are moving apart and do so without depleting the oceans of all their water. At a velocity of 14 km/s, for example, 1 kg of steam has about 108 J of kinetic energy. Removal of this amount of heat is enough to cool 140 kg of rock by 1000 K, for a representative specific heat of 710 J/kg-K. On the order of 1,000–1,500 m of water would then be needed to cool the present ocean lithosphere to its current state. Although this is a lot of seawater, it is not entirely beyond the realm of comprehension.

Another aspect of these jets is that seawater is converted to supercritical steam as the water penetrates downward through the fractured and porous newly formed seafloor, and then emerges almost explosively at the throat of the jet. Although there is some entrainment of water as the jets traverse the overlying layer of ocean water, mixing is minimal, and heating of the bulk ocean is therefore modest. Moreover, the seawater entrained in liquid form at the ocean-jet interface and lofted in widely dispersive trajectories provides a potent source of heavy rain so long as the jets are active. This mechanism solves a second fundamental problem that any credible model for the Genesis Flood must address, namely, the source of water for 40 days and nights of continuous rainfall. Explanations that involve the condensation of water vapor fail because, even assuming ideal black body conditions, radiation is incapable of removing the latent heat of condensation to space at a sufficient rate. With this entrainment mechanism, however, the water that falls as rain is not required to condense from the vapor state. To be sure, considerable additional analysis is required to demonstrate to a high level of confidence these supersonic jets can indeed cool the new ocean lithosphere to approximately its present state as it was being formed during the runaway episode. The initial analysis, however, looks promising.

What about the triggering mechanism for the runaway of the mantle's boundary layers? In my opinion the simplest possibility is that the initial state from which the runaway emerged was built into the earth as God originally formed it. In fact, I believe this almost certainly had to have been the case. It is also plausible that the earth's mantle had been grinding inexorably toward catastrophe during all the 1,650 or so years from when Adam disobeyed until "all the fountains of the great deep were broken up," such that no separate trigger immediately prior to the Flood event itself was even necessary (Horstemeyer & Baumgardner, 2003). For lack of any more specific information about how the cataclysm was triggered, I personally prefer this simple hypothesis.

Conclusions

As I drive and hike through the southwestern US where I live and observe on a frequent basis the magnificent exposures of the stratigraphical record, I can come to no conclusion other than the uniformitarian story, told over and over for the last 150 years or more—that present day processes operating at roughly present day rates correctly accounts for these strata—is just not true. The story simply does not agree with what can be casually observed in the field. Why then has generation after generation of geologists continued to pay it homage? Part of the answer no doubt is that much of geology focuses on the local detail and is not so directly concerned with big-picture issues. Another part of the answer, however, I believe is that a conceptual model that could account for the magnitude and character of the geological change implied by the observations was simply not available. But with the development of plate tectonics during the 1960s, this situation changed. For the first time in human history a conceptual framework existed that could account for large-scale tectonic change in a coherent manner. A piece of the framework still lacking at that point was a detailed understanding of the deformation properties of mantle rock. But methodical laboratory experiments over the last 35 years have largely removed this barrier. It is now clear that silicates, like metals, display a rich array of deformation behavior, including dramatic weakening at high temperature and moderate levels of stress. With numerical methods now available it is straightforward to show, upon including these deformation properties, that mantles of planets like the earth have the potential for catastrophic runaway of the material that form their thermal boundary layers. The evidence is compelling that Venus experienced such a global scale mantle runaway event in its relatively recent past. The evidence is even more compelling, in my assessment, such an event has also taken place on earth.

I therefore conclude that God has given His church crucial insight that allows us an opportunity to present to the world a framework for earth history with vastly more explanatory power that anything that uniformitarianism has been able to muster. This is a historic moment. We have the key that unlocks secrets to the history of the earth that no one has ever had before. I believe as creationists we should be laboring with every resource we have at our disposal to bring to fruition a comprehensive Flood geology model/framework that not only includes the large-scale tectonic phenomena but also details of dynamic topography during the catastrophe that influenced the erosion and sediment deposition patterns as well as of the isostatic adjustment following the cataclysm to form today's mountains, drainage patterns and other modern landscape features. It is a time to work together. It is a time for constructive action. It is a unique opportunity to honor God as we show in a loving manner how the physical world around us affirms so clearly what His written Word has declared for millennia.

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