Beyond Plate Tectonics: "Plate" Dynamics

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Preface

Plate tectonics dogma has resulted in a variety of theories that frequently violate first principles. In this article it is suggested that ridges are in compression, not tension from convection cells, triple junctions cause hot spots (not vice versa), mantle plumes do not cause hot spot tracks, chord push creates pressures well in excess of lithostatic load, the arch effect demonstrates that rifts form both in compression and tension, surging (*i.e.* the sudden and rapid motion of the plates) occurs episodically, the presence of a basal shear zone a few meters thick during surging, the preferred initiation of subduction zones at the ridge, revision of the Wilson Cycle, the conformance of "old" school geologists and plate tectonicians, earth-based non bolide impact mass extinctions, the loss of the earth's magnetic field and its subsequent reappearance, additional application of the least work (or maximum heat rejection) model. Collectively, they require a transition from a kinematic approach of plate tectonics to a realistic predictive model of domain dynamics.

Abstract

Revolutions transform themselves into fodder for the masses. Rebels in plate tectonics modeled themselves after Wegener and reached liftoff in the mid-1960s, mainstream status in the 1970s, and reactionary status by 2000. Plate tectonics—the geologic expression of major movements of vast slabs of rocks scores of kilometers thick—is 40 years old.

The creation of ridge crests and their mirror image, trenches, is a natural outgrowth of worldwide compression. The concept of chord push is introduced here as it relates to slow spreading centers and the idea of multiple causes for the creation of fast spreading lithosphere is based on the observation that accretion is of two end members: 1) During intersurge periods, roughly 90-99% of the timeframe, surface forces rule; 2) During surging, 1-10% of the time, tension, slab pull is the dominant influence and thus body forces are required to account for surging. The implications for surging are profound. Minor surges occur on a much greater recurrence level than devastating asteroid impact by a factor of 100-1000, yet, even a "small" surge could devastate California. The data from the Pacific seems to indicate that a surging event is reflected there in the past one million years. Large surges will lead to major transgressions, the collapse of mountain belts, climate change, mass extinctions, and the temporary loss of the earth's magnetic field, *e.g.* the Cretaceous in North America. Shortly after the surging event is over, much of the planet will go from worldwide tension at the surface to worldwide compression and the reassertion of relief, *i.e.* mountain belts worldwide.

Strong models corrupt the scientific method and should be questioned routinely. The anti-plate tectonics group make conceptual blunders as great as the "drifters," but their data suggesting surge tectonics is fully in keeping with this model. The data set from the Plate Tectonics Model is reconciled here with traditional data sets from "old" school geologists, *e.g.* surge geologists. The combination of these two data sets has resulted in a new school which combines the best elements of both ways of thinking.

The Wilson Cycle of oceans closing and then reopening is presented here in a fashion the author feels is consistent with the intent of the original paper, albeit in a somewhat different form. Due to the perceived need to add additional steps to the Wilson Cycle, the author has taken the liberty of presenting it in this new format.

The planet reorganizes itself to shed heat and, at the same time, to optimize the transferal of more dense material towards the core. This yields a predictable long-term assessment of the plate dynamics worldwide.

Introduction

Eighty years ago, we learned about the existence of the Mid-Atlantic Ridge from the Meteor expedition.[1] Then it became possible to determine that in the center of the Atlantic Ocean there was an elevated mountain belt with fresh basalts exposed at the surface. Mountains sloped downhill towards the continent. Eventually it became clear that new rock was being created at the mid-ocean ridges,[2,3] consumed at trenches,[4] and displaced along transforms.[5-8]

The attempt to model the earth as consisting of large convection cells is rendered improbable by the fact that convection cells have to migrate at the exact rate oceans open. Otherwise there wouldn't be a mirror image on either side of the ridge crest which we commonly observe. The Mid-Atlantic convection cell has somehow managed to migrate away from Africa at the same time that convection cells have stayed beneath Africa.[9,10] Paleomagnetics reveals bilateral symmetry, but the magnetics can range from excellent to imaginary. Simple technologies such as precision depth recorders, seismic reflection, heat flow, and seismology in general are of great value to the geologist, but the paleomagnetic data tend to average results and obscure the nuances of the planet (see below). Seamount loading studies have provided simplistic understanding of the viscosity of the asthenosphere. Is it the same viscosity 100% of the time or 1/100th the average viscosity for 1% of the time, *i.e.* the basal shear zone (BSZ: see below), and 100 times the average viscosity for 99% of the time? Where this becomes important is in assessing why guyots (a coral encrusted seamount) suddenly drop below the level where coral can grow. If we assume that the guyots drop 100-200 meters in 10,000-100,000 years, then this will allow subsidence to occur faster than the coral growth will be replenished (*i.e.* below the photic zone) and, as a result, the guyot "dies." This is consistent with dropping into the BSZ. The BSZ will tend to "even out" the topography for isostatic reasons.

Poles of Rotation

One of the poorly justified notions in geology today is that poles of rotation[11-14] have real physical significance, *i.e.* that they somehow represent a physical process. Poles of rotation are an idealized mathematical device which involves the Euler displacement of rigid bodies on a sphere about a suitably chosen "pole." But even this is doubtful.[15-20]

Initially, there were only six major plates and a dozen "minor" plates. Now, including micro "plates" we are up to about 100. At what point does the entire concept of a plate breakdown, *e.g.* what is the North American "Plate"? Is it one that includes the Appalachians, the New Madrid Zone, the Basin and Range Province and the Sierra Nevadas? The original concept of a plate as a rigid body has minimal meaning with respect to the continent of North America.

Neither is the oceanic part of the North American Plate "rigid," *e.g.* for the Atlantic[15-20] or the Indian Ocean.[21] In all probability, it will be accepted within the next few years that the only rigid plate is part of the Pacific Plate. Non-rigid behavior of "plates" applies to a higher percentage of the planet than rigid behavior of plates, *i.e.* rotations about a suitably chosen pole. Thus, some other term should be used to describe the behavior of contiguous large bodies of rock bounded by major high strain zones, such as domains or provinces.

Very early evidence in opposition to rigidity of the plates comes from the Oceanographer fracture zone.[18,19] The model of poles of rotation was tested. It didn't work. Normally, in view of this, the model would be abandoned, *i.e.* the idea of poles of rotation being used in the North Atlantic Ocean should have been abandoned because obviously they do not work.

If you are a persistent mathematician, the model has to be right, so the data must be wrong. Of course, there have been attempts to salvage the model by appealing to "error ellipses." This is not an error ellipse, it is a fudge factor.

Strong Models

One of the most insidious aspects of any strong model is that it tends to alter or suppress the collection and interpretation of data, *i.e.* facts. Graf: Strong models are like crude filters. They readily admit data consistent with the model and reject data inconsistent with the model. Another way to look at strong models is that they are like queen bees. Once the queen bee hatches, her first

Glossary of Terms

Andesite—Silicic island arc rock commonly believed to result by the introduction of water from the downgoing slab into the overlying asthenosphere

Arch effect—As the weight of the lithosphere is supported by compression, the confining pressure of the underlying mantle is reduced, and it melts

Asthenosphere—Believed to be the plastic boundary between rigid lithosphere above and less plastic mantle below

Basal shear zone—Hypothesized region at the bottom of the plate where deformation is extremely focused and hot

Basalt—Fine grained black (fresh) to green (metamorphosed) glassy magnesium and iron rich silicates commonly found on the sea floor along mid-ocean ridge systems

Catastrophism—The belief in the sudden and dramatic changes in the earth

Conduit—Region of the mantle providing partial melt to magma chambers

Crestal mountain province—In slow spreading ridges, the zone of elevated terrain bordering the ridge axis

Cretaceous—Time period 145-65 million years before present (dinosaurs)

Diabase—Coarser than iron and magnesium rich basaltic rocks commonly found exposed as sheeted dyke sequences in ophiolites

Diapirs—Large, balloon like, partially molten bodies of rock, displaced upwards due to density contrasts in the mantle

Gabbro—Coarse grained equivalent of basalt and diabase

Lithosphere—Rigid, large blocks of rock including the crust and mantle that make up the rocks above the plastic region of the earth known as the asthenosphere

Moho—The Mohorovicic Discontinuity allegedly separates the mantle and the crust

Obduction—Forcible emplacement of an ophiolite onto the continental margin

Ophiolites—Preserved sequences of oceanic sediments, crust and mantle on land

(Euler) Poles of rotation—Mathematical treatment of a rigid body on a sphere, used to predict and map trends of the ridge crest and transform faults

Reverse fault—High angle zone of displacement indicating a compressive regime

Rifts—Fault bounded depressions on either the land or in the ocean

Rift shoulders—Elevated land around a fault bounded depression

Sheeted dykes—Large, fine grained tabular bodies of diabasic rock believed to feed pillow basalts at the surface of the seafloor

Sills—Fairly thin flat lying bodies of solidified rock typically at shallow depths in the crust

Slab pull—As sea floor ages, it is more dense than the underlying mantle which predisposes it to subduct or descend back into the earth

Subduction—Plate motion leading to the under thrusting of one plate beneath another

Thrust fault—Low angle zone of rock displacement indicating compression official act is to kill off all other potential queens. This is the way strong models operate, whether it is plate tectonics or opposition to cold fusion.

To some plate tectonicians, the Meyerhoffs were viewed as crackpots. It is one thing to throw out the interpretation of the facts; it is an entirely different situation when the facts are thrown out just because they conflict with an existing paradigm. This has been the situation with respect to the Meyerhoffs and, in general, with any opponent of plate tectonics.

The opponents of plate tectonics, it can be argued, are just as dogmatic and sweep data in support of plate tectonics under the rug. They even offer ridiculous alternatives, *e.g.* an expanding earth. ". . .the entire surface of a smaller earth with about 55% of it current radius. . ."[22] Let's see about this and convert this value into volume, *i.e.* 55% x 55% x 55% = about 1/6 of the volume of the earth today. Unless there is some monumental addition to the earth from extraterrestrial sources that would have destroyed all extremely old rocks, the mass of the earth has presumably remained relatively constant. That means that the density of the earth was six times its present value. This means that the crust had to have a density greater than gold and the core was denser than any substance known to man. Appealing to an expanding earth, without understanding the ramifications, is every bit as irresponsible as anything done by plate tectonicians.

This paper merges "old" style geology with plate tectonics theory and data. It encompasses at least 90-99% of the data compared to perhaps 80% for plate tectonics data and 50% of the old school data. This paper should lay the foundation for a strong model.

Once plate tectonics became the accepted paradigm, the collective desire for geologists to conform to the new model has corrupted the data (mea culpa), *i.e.* the very facts upon which the model is based. This feedback loop between the strong model and the corrupted data is very bad for science. This is why such things as poles of rotation are so dangerous. It is assumed that the "data" have not been corrupted by the desire of the participants to conform. Are they looking over their shoulders to see what their data should say or are they collecting data objectively?

RRR Triple Junctions

Ridges are in compression (Jon Scott, pers. comm., 1973), not tension, as those who claim mantle convection cells pull the plates apart. Where the compression is most pronounced, we will see ridges of rock standing above the surrounding seafloor. Even taller standing ridges will occur at ridge-ridge-ridge (RRR) triple junctions partially because this is the region of a misfit in the lithosphere, *i.e.* there is a "hole" where the three plates meet and they cannot come together because of the viscous nature of the asthenosphere. In contrast to a two limbed ridge, where two planes abut one another, in a RRR triple junction it forms three bulbous surfaces that cannot meet at a point; hence a great drop in confining pressure occurs within this narrow tube perhaps only a few meters wide. The need for fluid to fill the gap creates a hot spot.

At this point we would like to introduce a new concept relating to stress at a point (at least it is not in Means[23]). When the three axes of a RRR triple junction meet at a point, we no longer have an x-y plane, we have a w-x-y coordinate plane. The three axes of maximum stress meet at a point at an angle of 120°. Minimum stress at an angle of 60° occurs between each axis of maximum compression. It is along the axes of maximum compressive stress where the ridge crests are formed. Directly opposite the point where the three axes meet, along an extension of each coordinate axis, one will find an axis of minimum compressive stress. Thus stress goes instantly from maximum compression to minimum compression stress as you pass through this point; this is a stable system.

In compression, the lithosphere will assume the characteristics of an arch which will reduce the weight of the lithosphere on the underlying mantle. This mantle, in response to a reduction in compressive stress, will melt beneath the arch; thus, it is possible to get the creation of molten rock in either tension, or more surprisingly, in compression.

Triple junctions will experience the greatest reduction in confining pressure, hence the greatest outpourings of volcanic material. Mantle plumes do not necessarily cause triple junctions; triple junctions may cause mantle plumes. If so, we would predict that this will place that part of the mantle in compression, thereby leading to the arch effect.

Basal Shear Zone

One concept that will surely cause some geologists to doubt this model is the manner in which magma gets to the magma chamber from a distance as great as 500+ km towards the interior of the plate. The answer is remarkably simple. When surging occurs (see below), the boundary between the surging plate and the underlying asthenosphere is a basal shear zone (BSZ) a few meters wide that lies beneath the entire plate. This BSZ can be inferred.[24] A shear zone slipping at 10 cm/year ". . .would lead to temperature increases close to 590° at the Moho, and 475° at 20 kilometer depth."[24] Thus the suggestion of a BSZ, where temperature increases of 200-300 degrees for a plate slipping at the rate of 1m/year, seems likely. The significance of the BSZ and how it relates to magma chamber dynamics will be dealt with elsewhere, but for now it seems likely that the heat of the BSZ will wind up in the magma chamber with a plethora of impacts.

Imagine the initiation of shear at the base of the plate as it begins to accelerate. First it breaks free along diffuse high strain zones that progressively focus deformation. When stasis occurs as the result of surging taking place for over 10,000 years at the rate of 1m/yr, here is how the author believes the BSZ will be expressed. At the periphery of the BSZ we would expect crushed tiny grains of hot, low-density fosterite (magnesium rich olivine) abutting cold country rock. Crushing generates heat even if the medium is ductile, not crystalline, although it seems likely that tiny fosterite grains may freeze at the boundary between the plates above and below. The entire plate can contribute to that heat as friction and shed the lower melting fractions, *e.g.* iron rich olivine which may form a Teflon-like character to the plate boundary a few centimeters thick. Within the BSZ, rolls of fosterite of relatively low density will work their way up the BSZ. The entire BSZ feeds tremendous heat into the magma chamber, perhaps preserving some of the fabric of the BSZ in the process. One expression of the BSZ will be olivine squirted into the base of the ophiolite that could form along a stretching fault.[25]

Mantle Plumes?

The idea of deep mantle plumes has been known for over forty years;[26] this caught on like wildfire[27-29] and became the reigning paradigm, temporarily replacing the more realistic alternative of a fault-based origin. Plumes fail on the basis of the geology and on the basis of first principles.

In terms of first principles: "Mantle plumes" don't burn through the plate:[30] "An experiment with a moving lithosphere was run and shows that thermal erosion does not affect significantly a moving lithosphere even for slow drifting velocities (few centimeters/year). Indeed, the thermal structure of the lithosphere is not modified above the 800° C isotherm except for a motionless plate."[30] The Pacific plate is moving much faster than that, so it is impossible that the plume burned its way through the plate.

Faulting provides a means of egress for the volcanic fluid. Also, to the best of the author's knowledge, there are no active faults going through Hawaii that continue on the other side. This is similar to the way cracks on a windshield can by stopped, *i.e.* by drilling a hole ahead of the crack tip. Hawaii may be a larger example of this phenomenon with the "hole" being filled with magma.

The Hawaiian Islands are an example of maximum shear. Clearly, the presence of magnitude 7 earthquakes near the Hawaiian Island is consistent with intraplate tectonism.[31,32] These through going faults serve as the basis of massive volcanism. This has been confirmed.[33]

Several authors offer alternatives to mantle plumes,[34-37] the most likely being the behavior of the plate in response to the down going slab. This sets up stress within the plate where faulting occurs and this causes the reduction in compressive stress within the mantle beneath the plate; out pops volcanoes and a "hot spot" is borne.

Where the plume hypothesis fails on first principles in the Pacific is with respect to the mid Pacific mountains.[38] They appeal to a "broad ENE trending double chain of mid plate island seamounts over a mantle hot spot. . ." This seems improbable to the author.

Why would two hot spots be shed by the same plume? Wouldn't feedback between the amphitheaters of two hot spots result in one becoming dominant and the other submissive, *i.e.* wouldn't one expect one "hot spot" to die off almost immediately?

Origins of Subduction

One of the mysteries of plate tectonics is how to initiate subduction zones, *i.e.* places where one plate dives beneath another. Using the standard cartoon to depict convection, it is clear that many geologists believe that the old, cold plate somehow gets its edge over the top of another older lithosphere plate. This is required to make the convection cartoons work. In other words, if cold, dense lithosphere is required to subduct to obey convection, it requires an impossible mechanical model. Convection alone cannot possibly cause one piece of lithosphere 100 km thick to override another piece of lithosphere 100 km thick. However, we may get subduction along an old boundary if transforms allow the steady slivering of the seafloor shedding thrust faults and loading the edge of the plate (Figure 1: 4, 5). In contrast to a head on collision where the rock must break in compression, the rock along a compressive transform will break in shear. Slowly but steadily, thrust sheets will stack up, load the edge of the plate, and eventually cause the leading edge to subduct.

In this model, ridges are very similar to subduction zones. Thus, if compression cannot be accommodated by seafloor spreading, *i.e.* chord push (see below), one side of the plate will be forced over the other (Figure 1: 4, 5). Very likely, just

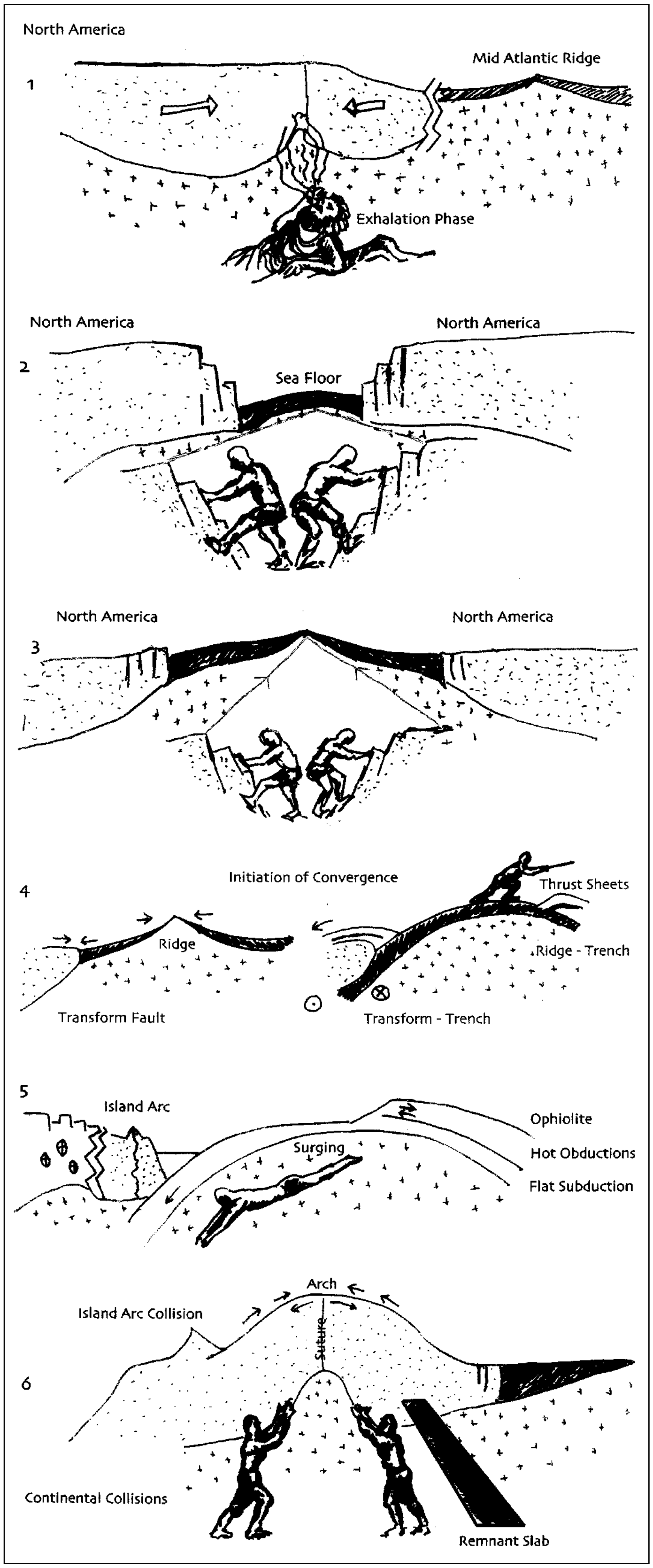

Figure 1. The Wilson Cycle.

before the ridge subducts, a massive magma chamber will occur as first seafloor spreading ceases and the ridge experiences negative accretion. The initial stage of subduction may be nothing more difficult than having a large, unstable lid founder into the magma chamber which heralds the onset of subduction. Subduction zones most commonly start at the ridge where the plate is thinnest and mechanically it requires the least energy to initiate them, *e.g.* into a large magma chamber. It seems especially likely that due to buoyancy considerations that hot obduction is most likely to occur when the lid spontaneously founders.

What should be clear is this: Random heterogeneities will result in the plate mosaic "shaking out" of the compression, *i.e.* we would expect ridges, trenches, and transforms to occur. This is what we observe. Ridges, in particular, will be self-perpetuating because the fluid involved in eruption will cause fluid anywhere within 500 km of the ridge to flow towards the ridge axis in response to tension and a surging episode (see below). The drop in pressure below the ridge crest will also cause additional partial melting, which, in turn, leads to more intrusives.

Chord Push

There are two basic sources of compression at the ridge, one known, another new. Ridge push, the process by which mantle from depth flows between the diverging plates and pushes the plates apart, is known. Chord push is new and can be viewed as a unique kind of ridge push primarily because it can exceed lithostatic load; it can cause the plate to accelerate beyond its average rate of displacement, *i.e.* faulting along the Moho.

At this point, the proposed paradigm of chord push is introduced (Figure 1: 3). As far as chord push is concerned, the ridge rises in compression; extensional cracks develop at the surface. These permit the egress of fluid from the process of magma fracturing at depth.

This doming and uplift followed by intrusion creates a greater amount of seafloor compared to the pre-uplift phase. Now there is a space problem. If the ridge cools or subsides for any reason the excess gets in the way of subsidence. (Try putting your arms on the table with your fingertips touching just four inches above the table. Now bring your fingers down to the table without moving your elbows. You will notice how hard it is to force your fingers onto the table.) This is chord push (Figure 1: 3). In ridges, the driving mechanism of chord push is gravity (Figure 1: 3). Imagine a ridge rising 100 meters in 100 years. Now imagine dyke injection taking place at the ridge crest. Cooling and subsidence set in. Suddenly, as the lid subsides, it goes into compression. If a vertical drop of 100 meters permitted horizontal displacement of 2 meters, then that is 2 meters/100yrs. In fast spreading centers, the rise and fall of the ridge crest may be much more rapid but of much lower magnitude (Figure 1: 3). When uplift reaches a critical value, dyke swarms may be injected and new seafloor 1 to 10 meters wide may be created. The uplift of the seafloor, and concurrent with that, magma fracturing, will also allow the development of hydrothermal circulation which will further the rate of subsidence and the stress imposed on the seafloor. The magma fracturing tends to absorb all available strain and places the lid in compression. When chord push occurs, there is no way to provide additional strain without thickening, breaking, or folding the rocks.

One possible site for the layer of decoupling between the upper and lower plate required by chord push may be along the Moho. The Moho is a seismic discontinuity which allegedly separates the crust and mantle. However, if chord push is correct, then we would predict that shear zones would piggyback on existing zones of weakness. Clearly, the boundary between the crust and mantle would be a favored region for faulting.

What should be evident is that gravity can cause the lid to experience considerably more force than the weight of the lithosphere. Chord push may be powerful enough to break rocks in shear. The result: We probably get thrust faulting and reverse faulting in the crestal mountain province of slow spreading centers (Figure 1: 3). Decay of the topography landward of the crestal mountain province is suggestive of chord push along reverse faults.

Chord push complements ridge push in the sense that the surficial effects of chord push can be meshed with ridge push. The ultimate combination of these two processes is particularly important when assessing the evolution of slow spreading centers.

If fast spreading centers caused minor chord push forcing the ridge apart, we would expect these properties to show up in ophiolites. Bruce Idleman (pers. comm., 1979) mentioned that the dyke margins in the Betts Cove ophilote appeared to be sheared. This is consistent with placing the lid in compression shortly after it is formed. However, compression may not be observed during a surging episode (see below).

If the lid of the magma chamber is in compression shortly after it is formed, chord push could conceivably result in pressure several times lithostatic load. Accelerated spilitization (low grade metamorphism) should occur at shallower levels than those predicted on the basis of lithostatic load and the temperature and pressure fields of the spilite. Low grade metamorphism due to hydrothermal alteration of the seafloor had to have occurred at the ridge crest in a manner inconsistent with regional metamorphism.[39] The only addition to this concept the author offers is that initially during doming and uplift and the creation of cracks, large amounts of water are introduced deep into the crust and mantle. Then chord push closes the cracks and the rock "cooks." This drives spilitization (the hydrothermal alteration of shallow level rocks) due to the "desire" of the rocks to release the pressure by a volume decrease within the impacted rocks. Serpentinization (the hydrothermal alteration of ultramafic rocks), on the other hand, may lead to a volume increase and result in a process similar to chord push.

Chord push may be a very important part of the generation of oceanic lithosphere along fast spreading centers. Delamination of much of the lithosphere from the Pacific Plates has been suggested.[40] Whether this is an error of interpretation of the seismic data, chord push, or some other phenomenon is unclear. Chord push quite clearly can account for delamination along the Moho.

In slow spreading centers, to create the tall standing crestal mountain province requires forces vastly greater than can created by slow moving convection cells favored by geophysicists. It is also difficult to understand *at the ridge crest* how it is possible with convection alone to create the chopped up Australia-Antarctic Discordance Zone (AADZ).[41,42] Perhaps with the AADZ we are looking at the nascent stage of trench development.

What has confused marine geologists is the presence of extensional tectonism, *i.e.* gravity faults along slow spreading centers. This is due to the cooling and subsidence of the ridge and has nothing to do with tension. Gravity causes the steep walls of the rift valley to collapse as gravity faults. Also, cooling and subsidence in active volcanoes may impact on the walls of the volcano due to chord push. It is possible that some sort of mechanism related to chord push can cause the walls of volcanoes to collapse, *e.g.* Mt. St. Helens.

Accretion consists of: 1) Uplift of the seafloor over 100-10,000 years with hydrothermal circulation, 2) Dyke injection, 3) Chord push, the creation of the crestal mountain province in slow spreading centers and low grade metamorphism as cracks close in fast spreading centers, 4) Gravity faulting, *i.e.* normal faulting at the edges of the slow spreading ridge axes in response to subsidence of the ridge crest during the cooling phase. Gravity faulting in slow spreading centers will give the illusion of the ridge crest being in tension and being pulled apart, when, in fact, the ridge is in compression and is being forced apart.

The dynamics of the lid change dramatically during chord push. First of all, cracks at the surface close as the lid goes into compression. If fluid evacuates from beneath the lid due to the arch effect, then a massive drop in confining pressure will occur just below the bottom of the lid. This will cause volatiles to be expelled upward as the magma boils. This sudden influx of volatiles will create a great climate for the creation of gabbroic pegmatites and, if hydrous blocks of diabase or gabbros stope into the chamber, the creation of silicic pegmatites.

One consequence of chord push will be the appearance of gabbroic sills high up in the section at the boundary of the diabase dyke and the underlying gabbros, possibly within the pillow basalt sequence, *e.g.* diabase may be emplaced within the pillow sequence.[39,Fig.68] Basaltic pillows may be ideal for sill emplacement.[39] Sills will “misread” their depth below the surface; they will “think” that they are being injected at a much deeper level than they really are. The compressive stress at the ridge, effectively, will prohibit fluid from rising to the surface. Thus the ratio of the length of the dyke L and its depth below the surface, H, is no longer true, *i.e.* it no longer must obey the relationship L/H is greater than one. If the sill extends beyond the critical distance, it may curve up towards the seafloor and, if it punches through the lid, which is still in compression, will almost reach the surface where it will be recovered by dredging.

If the pressure drop lasts for long enough, then ultramafics may intrude the layered gabbros within the magma chamber. If there is no magma chamber, or if the magma chamber freezes, within the dyke sequence and pillow basalt, peridotite (deep seated rocks) may be emplaced. This may be the cause of the Mt. Olympus peridotite that is interpreted as a diapir[39] due to its distinctive gravity anomaly. Perhaps it represents proximity to a transform/ridge intersection of a fast spreading center. This may be the archetypal example of how ultramafics can be sampled at the surface of the seafloor. These diapirs may even lead to vast tracks of seafloor without any crust.[43]

As the arch takes place, below the neutral surface, cracks may develop at the underside of the arch below the neutral surface where compression at the top of the arch gives way to tension at the bottom of the arch. This is ideal for magma fracturing and the injection of gabbroic pegmatites to microgabbros that may climb almost to the surface. Crack closure prohibits the introduction of additional water near the surface, hence hydrothermal circulation is shut down during chord push. These gabbroic pegmatites, gabbros, and microgabbros may be sampled during routine dredging at transforms, along large throw faults.[44] If there is no magma chamber when the arch effect takes place, then ultramafics may be forced into the lid by hydraulic effects, partially through serpentinization.

One of the problems recognizing compressional features along a Mid-Ocean Ridge (MOR) segment is that we have a classic problem of the strong model of plate tectonics which requires the absence of significant compression along the ridge. Thus, like any strong model, researchers are apt to suppress or ignore evidence of compression because it is the “wrong” kind of deformation for the MOR. Sometimes instrumentation limitations preclude the recognition of reverse faults;[45] they state, “. . .while decelerations produced subsidence with modest contraction, reflected in reverse faulting and folding. . .reflection seismic records. . .(are) not well suited to detect reverse faulting.” Also, calcite twinning along the Mid-Atlantic Ridge has been observed near Iceland, “. . .preserve a subhorizontal shortening strain normal to the Mid-Atlantic Ridge on both sides of the plate boundary.”[46] This is consistent with chord push.

Two other authors doubt what they see, “Removal of the axial valley can only be accomplished by reversal of the regional extensional strains immediately upon cessation of active spreading. However, such a process does not seem likely.”[47] “. . .(R)elief. . .decreases systematically to 40 km off-axis (1.5 Ma seafloor). Since reversal of fault offsets is unlikely in this tectonic setting. . .”[48] Focal mechanism data is consistent with compression at the ridge.[49]

Because plate tectonics predicts only extension at the ridge as the preferred paradigm, we can only speculate how often, as a strong model, it corrupts the data. How many scientists have seen evidence of compression at the ridge and either ignored it or suppressed it?

Vogt’s V’s and Propogating Rifts

Vogt’s V’s are lines of seamounts and high spots on the ridge that form V-shaped lineations along the ridge like a flock of geese. They probably result from the migration of a stress spot along the ridge. At each step of the way, maximum compressive stress is created along the ridge, maximum reduction in confining pressure occurs, and then a volcano forms. As the stress spot migrates along the ridge it will leave a wake of V-shaped lineations. Does it represent rotation of the stress spot (instantaneous pole of rotation) about the pole of rotation for the entire plate? This is why poles of rotation are no substitute for process.

Propogating rifts[50] are rifts that appear to grow by the widening of a crack that becomes a V-shaped rift. What should be pointed out is this: The only way a crack can open in this fashion, *i.e.* have a crack tip, is if the rock immediately ahead of the tip is in compression. What we have in that situation is “an instantaneous pole of rotation.” Because the rock is much stronger in compression than tension, the ridge always migrates through the “pole of rotation.” This will tend to leave V-shaped lineations.

Catastrophism

If catastrophism happens 1-10% of the time, and steady-state processes happen 90-99% of the time, it will be difficult to say which is more important. The amount of geology that can happen in the 1-10% of time is staggering. It is proposed here that 10-50% of plate motion occurs in 1-10% of the time for fast spreading centers and that 5-10% of plate motion occurs in 1-10% of the time for slow spreading centers. If we are not in that 1-10% of the time right now, then the present is not the key to the past. We must, instead, look to the rock record.

Catastrophism associated with non-impact causes has modern adherents.[51-55] The magnetics are very confusing when it comes to surging. Most surging episodes will occur within one or two anomalies and they will be invisible. (This is why geophysical models are so dangerous. The tendency to average the magnetic anomalies disguises the surging episodes.)

Glaciers surge, *i.e.* experience rapid displacement (glaciers surge up to 100 meters/day), for short periods of time.[56] By analogy, for brief periods of time, plates might achieve velocities 10-100 times their steady-state displacement.

One of the debates in geology is over body forces (gravity) versus surface forces (*e.g.* traction (friction) at the base of the plate). If the viscosity of the mantle beneath and to the sides of the plate is very high, then the plate must be forced into the trench, *i.e.* slab pull doesn't apply. At some critical value which may be exceeded by the gentle rise of the ridge crest from addition of mantle beneath it, the tendency will be for the plate to slide downhill at the exact rate of accretion. 1) For every viscosity of the mantle, there has to be an exact value where the slope of the underlying mantle exactly matches the rate of slip. 2) If the mantle is more viscous than 1 above, the mantle retards slippage and surface forces drive accretion. 3) If the mantle is less viscous than 1, the plate accelerates due to body forces.

Think of a plate at the tipping point. Over the span of 100,000-100,000,000 years (minus surge versus major surge), if the plate is in an inter-surge phase, the ridge crest and flanks may acquire elevation and the slab, as a whole, acquires gravitational potential energy. Now "1" goes to "3". Once the plate begins to accelerate, it is a self-exciting process.

Energy dams within the plate probably regulate the timing of surges. In other words, it is entirely possible that the plate may break free in the interior of the plate without actually causing a surging episode. If, for example, we assume that rock can absorb .1% of compressive stress without breaking free from the mantle, *i.e.* surge, then for a plate 3,000 km wide it should be clear that the plate can absorb some 3 km of strain without surging. This brings up the concept of energy dams. During proto surging events, energy dams flow down the plate like a caterpillar each time fetching up before they get to the trench. Eventually, they start climbing down the trench into the asthenosphere. Here the plate encounters resistance to subduction; the mantle may prohibit surging because the plate cannot overcome the resistance to subduction. In this situation, a small surge or no surge may occur, *i.e.* 1-10 km. If a surge of this magnitude were to occur tomorrow opposite California, the fault systems would respond in predictable ways. Specifically, we would expect much more energy to be shed along the San Andreas Fault and its subsidiary faults.

Eventually, though, shear planes may be set up within the slab, or, the snout of the downgoing slab may be abraded by flow across the snout leading to extremely high tensile stress at the snout. If the shear planes set up low angle thrust faults within the slab, this will permit the gravity forces to act along the fault as a wedge. In other words, it is possible for the wedge to displace asthenosphere along fault planes that eventually double up, imbricate the slab. By this method, it becomes possible to displace asthenosphere away from the plate along a zone that may be several hundred kilometers long. This facilitates subduction. However, if the wedging effect stops for any reason, *e.g.* the asthenosphere resists displacement, the surging stops. Surging may be associated with subduction at an intermediate rate, *i.e.* 10-100 km. The Columbia River Flood Basalts may be an example of an intermediate surging event. To put into perspective the significance of the Columbia River flood basalts, as it relates to the heat rejection model, see below.

Now the massive subducted slab takes off. Slab pull becomes enormous and the only limiting variable as far as the rapidity of subduction is how the down going slab gets rid of all the subducted material. It may fold, imbricate, thicken, or plug flow may punch a hole through the 670 kilometer discontinuity. The subducted slab may snap, most likely at the hinge where the plate goes through a 45° bend. When it necks and then snaps, elastic rebound will cause trench sediments to be yanked out of the trench leading to eduction. As the plate necks, hydraulics, piston effects, favor emplacement of ultramafic diapirs into the necked region.

The basal shear zone between the down going slab below and the hydrous sediments above will shed boninites (hydrous, magnesium rich basalts[57]); extreme friction during a surging episode will create highly refractory mantle that may result in the tendency to drive away the lower temperature melting iron minerals. As the plate necks, the boninites might get pulled to the surface within diapirs that shed partial melt into convergent boundaries.[57] Without slab pull, the surging episode will end.

Periodically, during surging, the plate may "fetch up" and stop surging for hundreds of thousands if not millions of years due to the fact that it may take hundreds of thousands of years to build up sufficient stress in the down going slab to create a climate for imbrication, the doubling up of the down going slab, or other factors favoring rapid subduction. Once imbrication starts, surging may resume.

Surging episodes are not going to impact worldwide except under extreme conditions. In other words localized surging events will cause local transgressions where, somewhere else in the world, might well be experiencing a regression. Almost all major geology, planet wide, is being driven by the behavior of the down going slab.

In theory and in terms of observation, it appears that surging is real. Just by looking at theoretical considerations, it becomes clear that almost any level of surging is possible, particularly as it relates to the behavior of the down going slab.

Large amounts of cold lithosphere sitting at relatively shallow levels in the mantle are gravitationally unstable, *i.e.* more dense mantle resides above less dense mantle. This promotes overturn, or convection, with dense mantle descending rapidly as large diapirs to lower levels in the mantle which is replaced by less dense, hotter mantle rising towards the surface. This is what may have happened to the mantle underlying the site of the Columbia River flood basalts which would look like a hot spot. This in turn makes subduction into the mantle more likely and the predictable response of the lithosphere, surging.

Due to the necessity to densify the plate and, at the same time, to reduce the amount of material that is subducted, very often the upper part of the seafloor which is less dense will be scabbed off and wind up on land as an ophiolite. The ophiolites may well be emplaced shortly after the ridge becomes a trench. This is also why ridges can be subducted.

Should massive surging occur, a rise in sea level will cover the continents, *e.g.* the Cretaceous in North America. This is the result of three factors. 1) Shoaling of the average seafloor caused the average age of the seafloor to decrease, displacing water upwards; 2) Relaxation of compressive stresses caused the continent of North America to sag, spread laterally and witness the collapse of mountain belts. (The relaxation of compressive stresses is due to the rollback of the hinge line once slab pull takes over as the primary cause of subduction); 3) Warming of the oceans due to global warming, in general, will cause sea level to rise.

Other characteristics of a major surging episode are mass extinctions due to the appearance of large amounts of poisonous sulfur and other compounds impacting negatively on the terrestrial animals.[51] In the sea, the breakdown of plagioclase and pyroxenes would release vast amounts of aluminum which could poison phytoplankton.[58,59] Chop a hole in the food chain and everything upstream at the surface dies off. Other major changes, such as pH, temperature, and other changes in the chemistry of the water could easily lead to mass extinctions that have nothing to do with asteroid impact. Anoxic conditions will also develop due to the loss of the North Atlantic Deep Water and the Antarctic Bottom Water because of the absence of polar ice sheets. This will turn the ocean basins into sewage (no overturn due to severe density contrasts both at the surface—brackish water and the saline waters at depth; the only animals that can survive must be able to consume sewage or rely on chemosynthesis near black smokers). Another unknown is what happens to the earth once the magnetic field is lost. High energy particles from the sun will bathe the entire planet with deadly radiation.

The final expression of a major surge is the illusion of a great many "mantle plumes." A pseudo plume can occur whenever a ridge spreading at 1m/yr for hundreds of thousands of years, creates instability in the mantle to great depths for two reasons: 1) A bulb of low density asthenosphere will "pull" mantle up from great depth clearly in the neighborhood of several hundred kilometers; 2) Massive overturn of the mantle is predictable based on the instability of the cold slabs at shallow depths. This overturn may look like a mantle plume, *e.g.* the Yellowstone "hot spot," the Columbia River flood basalts, and the Basin and Range Province.

If the subducted slab fetches up at the same time as the seafloor continues to surge, compressive stresses will ripple up the slab from depth and cause the outer bulge to rear up and become sub aerial. Streams may down cut all the way to the mantle, shed detritus into the trench adjacent to the outer bulge, and, if surging continues, may over thrust the trench as the plate rips through the outer bulge.

At the end of the surging episode, worldwide compression would assert itself quickly. The transgression into the interior of North America would end quickly as the continental lithosphere thickened by shortening, the average age of the seafloor increased and the oceans cooled in the Tertiary. The continent, as a whole, went into compression. During the phase of collapse of the mountain belts and the tendency of North America to spread laterally, isotherms rose into the continental crust as the thinned continental crust was exposed to the heat of the mantle caused by the induced convection of the surging phase.

This is how heat is shed more efficiently. First flow laterally, then heat up, and, finally, undergo partial melting, with the ascension of partial melt into shallow levels of the crust; as the continental lithosphere thickens, it resists displacement, and the arch effect takes over. This converts conductive heat loss to convective heat loss.

Regressions, or the tendency for the continents to stand out of the water, will occur when the continents are in compression, mountain belts will grow, and the seafloor will begin to store gravitational potential energy in anticipation of the next surging episode. When the mountain belts begin to grow during a regression, they probably acquire great relief rapidly.

The Wilson Cycle

This model requires and permits the exposition of a new way of presenting the Wilson Cycle of oceans closing and then reopening. Since the author believes that the Wilson Cycle is incomplete, he has taken the liberty of reorganizing the Wilson Cycle to incorporate these new steps. This is not a "new" Wilson Cycle; it is a new way to present the existing cycle in a format that is arguably more consistent with the model. In other words, first there had to be oceans that were created; only after they were created could they close.

At the earliest stage, say the Appalachians today, a proto ocean, we would predict that the arch effect would place the entire Appalachian Mountain belt in compression at the suture (Figure 1: 1).[61,62] One facet of the Wilson Cycle that seems clear is that seafloor spreading often starts at the suture. The reason for this is that the suture represents a site of maximum thickness of the lithosphere. It is a thick wad of buoyant material that resists displacement. The arch effect will decrease the confining pressure below and, as a result, we would expect the exhalation of volatiles from the mantle (Figure 1: 1). Thus, in the earliest phases of ocean opening, it can be predicted that massive sulfides will be emplaced at depth due to the drop in pressure in the mantle below the root of the mountain. These sulfur bearing volatiles (*e.g.* Sharon Springs, New York), along with CO_2 (*e.g.* Saratoga Springs, New York) and methane (East African Rift Valley[63]) will degas from the mantle.

The second phase (Figure 1: 2) may involve the arch effect and/or it may evolve into the stretching of the lithosphere, during a surging episode. Surging may have caused the opening of the South Atlantic. Evidence for continental drift occurs here where the displaced areas of Africa with respect to South America indicate an overlap during reconstructions which could be due to stretching of the lithosphere during the initial stages of rifting.

The next phase of ocean opening is well known, *i.e.* the creation of a large expanse of progressively aging seafloor that becomes gravitationally unstable (Figure 1: 3). The part of the Wilson Cycle that has been missed at this stage is the surging episode, when the worldwide compressive stress gives way to tensile stress for perhaps as little as 100,000 years to a few million years (Figure 1: 4,5). This entails the collapse of mountain belts, the transgression of the oceans onto the continent, mass extinctions, the loss of the earth's magnetic field, and, in the Cretaceous, perhaps the opening of the South Atlantic. Its appearance is that of a fast spreading center even though the South Atlantic is a slow spreading center (pers. obser. of seismic reflection records in the Atlantic).

The next phase of the Wilson Cycle will be the collision of one or more island arcs prior to continental collision (Figure 1: 6). The final stage of the Wilson Cycle will be continent-continent collision (Figure 1: 6).

Fast Spreading Centers

Ridges and transforms will be beautifully orthogonal along fast spreading centers because viscous drag of the upwelling asthenosphere in the conduit will be several orders of magnitude greater than resistance to shear along transforms, *i.e.* maximum transform length and minimum ridge length will be favored.[64] This is observed. It is also true that viscous drag will be at a maximum at ridge/transform intersections, thus the ridge will reorient to minimize intersections. That is why we have long ridge/long transforms in the Pacific (Dave Gallo, pers. comm., 1980).

In this scenario, the Easter Island chip occurred because the plate tore in response to being pulled into the trench and a small fragment of the plate was left behind. Horst blocks may drag beneath the basal shear zone, causing the plate to tear on the landward side of the horst causing the Easter Island chip to form. The Nazca Plate occurred because the trench encountered more buoyant seafloor and this caused the Farallon plate to twist or torque, creating the Nazca plate (Dave Gallo, pers. comm., 1980). Twisting of the plate at the subduction zone may result in the plate pivoting about the zone of resistance to spreading. This could conceivably lead to another kind of eduction, one driven more by geometry than process, *i.e.* as the plate pivots (pole of rotation) at the subduction zone, part of the plate may be pulled out of the trench.

Surges may have a recurrence level somewhere between 100,000 years for small surges to millions of years for major surges. If the latter is the case, it might be possible to create 1,000 km of seafloor in as little as one million years with subduction at the rate of 1 meter/year. The tendency of this surging episode will be "to stir the pot." In other words, due to surging we would predict a dramatic up tick in induced convection that might tend to reheat the older lithosphere both in the ocean[65,66] with regard to South Pacific less than 3.0 cm/yr[65,66] and beneath continental lithosphere, *e.g.* Columbia River Flood Basalts, Yellowstone, and the Basin and Range Province.

Surges have a greater probability of occurring by a factor of 100-1,000 times than that of devastating asteroid impact and should be of more immediate concern. It is imperative that the model be tested against known data sets. A child born today has a .1% chance of seeing a surging episode.

The most obvious expression of a large scale surging episode will be the appearance of high levels of CO_2 created by the wholesale runaway subduction over large areas of the trench complex. As massive subduction occurs, this will lead to the appearance of vast quantities of andesitic stratovolcanos and additional seafloor spreading at an elevated rate. Marginal basins[67] and multiple island arcs may form and split due to chord push when the plate "fetches up," or, as the result of extension.

The simplest explanation for the elevated CO_2 levels in the Cretaceous is that conditions were favorable for slab pull most likely as the result of some mechanism that permitted large amounts of subducted material to be displaced ahead of the down going slab. It is very likely that this might have been some kind of plug flow phenomenon in which hundreds of miles ahead of the down going slab material was being displaced as part of a plug, *i.e.* this is not part of the down going slab *in sensu strictu*. In other words, it is suggested here that country rock ahead of the down going slab will "feel" the runaway event long before the slab physically gets to that elevation.

Another characteristic of major surging episodes is that they may result in mass extinctions, *e.g.* the boundary between the Permian-Triassic, 250 million years ago, one between the Triassic-Jurassic boundary about 200 million years ago, and the Cretaceous/Tertiary boundary at 65 million years ago. This was a hot debate over extinctions with the impact people[68] leading the charge. However, *Science* may be far too biased in its coverage of extinctions, which may steer the results towards impact craters and away from a volcanic origin.[51]

One predictable consequence of a surging episode is that within 1,000 years of the start of the surging episode, great amounts of wet seafloor will be subducted well below its zone of stability. The result: Massive andesitic stratovolcanoes will be observed inland of the trench. These may well be followed by flood basalts because the country rock will be exposed to a great drop in confining pressure caused by evacuation of andesites which will lead to flood basalt activity. This scenario seems to have happened with regard to the Columbia River Flood basalts, where over 234,000 times the volume of volcanics from Mount St. Helen was erupted over 1.6 m.y.[69]

One puzzling aspect of the Cretaceous seafloor is the absence of well-defined magnetic anomalies. This is consistent with this model, which predicts that massive surging created seafloor so rapidly that the magnetic anomalies couldn't keep pace with the accelerated rates of seafloor spreading.

One of the characteristics of surging episodes will be the creation of large shield volcanoes. In other words, if magma has to be supplied to the conduit at a rate 100 times the average amount, it must involve the mantle to a much greater degree than normal accretion. As a result, there will be a much greater partial melting because of a sharp pressure drop in the mantle.

A telltale sign of the end of a surging episode will be the creation of a string of shield volcanoes parallel to the ridge. These shield volcanoes should happen at the end of even a minor surging episode. The ridge seaward of California is very encouraging for California.[70] They see the development of the Roca Redonda shield volcano in the Galapagos. This information and related work[71] are consistent with a mature surging episode that may be dying off. It is hard to say with any certainty where we are in the surging episode, assuming it is a surging episode.

Surging episodes may leave a telltale stair step appearance to the seafloor, *i.e.* during the surging episode, the seafloor will be fairly flat and during the inter-surge phase the seafloor will "step" down to the next level. It is difficult to know how the surging episodes will be impacted by differences in the calcium carbonate compensation depth, but it is possible some of the saw tooth appearance may be associated with surging; it is unclear just what the expression would be.

The sudden descent of the mantle below the slab may cause a massive lopsided earth at depth. This may lead to an avalanche towards the core,[72] considerable wobbling, and, potentially, the loss of the earth's magnetic field due to the instabilities of the core caused by the wobbling. As mass flow created by density smoothes out the mantle at depth, wobbling diminishes and the earth's interior becomes more homogenous; we would expect the dynamo to reassert itself and the reappearance of the earth's magnetic field in the Tertiary.

Another implication of the model is that mass flow from the imbricated slabs during surging will not descend into the mantle uniformly. We would predict that a "funneling" effect will cause a depression in the earth's geoid. Random heterogeneities in the mantle will favor descent of some diapirs over others. This will result in a kind of siphon in which diapirs are drawn to the zone of rapid down welling. This is a self-exciting process, sort of a massive diapir in reverse. That is, the diapirs will entrain the surrounding mantle and cool it off, causing it to descend towards the core/mantle boundary. This funneling effect will result in a massive zone of down welling perhaps as much as 1,000 km across. This will be expressed at the surface as a large depression in the earth's geoid, which is what we observe in the Indian Ocean.

Discussion

Policy planners must be prepared for surging episodes. Decision makers might listen to a seismologist who tells them that because a magnitude 8 earthquake has struck the region, that stress has been relieved on that fault for 100 years. Then a second magnitude 8 earthquake strikes the same area 25 years later. What do you do? Shoot the seismologist? Without the correct model for guidance, policy makers will opt to rebuild, because it, "Can't happen again." When the loss of life after three magnitude 8 earthquakes in 50 years surpasses 100,000, a decision may be made to evacuate the islands of Japan or the West Coast of the U.S. The critical choice when faced with a potential surging episode will be whether to stay and put millions of lives at risk, or leave and abandon a multi-trillion dollar infrastructure. Surging and its aftermath—andesitic volcanism eventually and flood basalts—could result in global cooling, another ice age, or, perhaps, mass extinctions. This may be followed by global warming due to the buildup in CO_2 from all the volcanoes impacting on the region. This is what happened during the Cretaceous. Contemporaneous with this, aggressive reef development sequestered more carbon by a factor of ten than was pulled out during the great coal generating eras earlier (Kevin Burke, pers. comm., 1979). This eventually caused the global cooling of the Tertiary.

Can we determine through independent means whether surging is likely to occur? A great deal of information can be learned from ophiolites. If it turns out that it is possible to identify 100 meters of extension within the sheeted dyke sequence over a very short period of time, this would be evidence of a small surging episode. Since dykes intruding dykes and one way chill margins are often observed, it clearly proves mini surges have occurred. Dykes acquire strength so rapidly that the only way dykes can intrude dykes or exhibit one way chill margins is if the subsequent intrusion, at most, took place in a matter of a few hours to a few days (Norm Sleep, pers. comm., 2004). If the plate is pulled into the trench, by slab pull, then the trailing edge might tear in small jerks, resulting in the observed dyke relationships. Once the plate begins to surge, ridge push is converted to ridge suction. Once small surges can be proven, it seems reasonable to assume that larger scale surging may occur.

Least Work Configuration

Very few data sets fall outside the umbrella of this model. It appears highly inclusive. At very high strain rates transforms disappear.[71] That may be true of a very hot mantle where there is no mechanical advantage of slipping along a transform as opposed to energy tied up in the conduit. It also may happen along a relatively cold conduit if the offsets are very small.[20]

With a hot mantle we would predict such things as oblique spreading,[73] microplates,[71,74] propogating rifts,[50] and overlapping spreading centers.[75] The least work configuration, in order to maximize ridge length of a recent surging episode, depends on the hot thermal regime of the asthenosphere which has been altered radically.[76] In any event it seems unlikely that the great transforms of the Pacific will be impacted by surging events unless they achieve dimensions above some critical unknown value.

The least work configuration depends a great deal on the viscosity of the conduit. If the conduit is very fluid, there is no advantage to having transforms. Think of the ridge crest as a radiator; it will always reorganize to the most efficient means to expel heat (Dave Gallo, pers. comm., 1980). In the case of long ridge/long transform lithosphere, what we are looking at is the fact that old lithosphere abutting young lithosphere absorbs heat, *i.e.* it cools off the younger plate. There has to be a relationship between the age offset of the transform and the viscosity of the conduit. For very low viscosity conduits, the age offset of the transform has to increase for the transform to be stable. As the viscosity of the conduit increases due to a temperature drop, the age offset across the transform will decrease yet the transform will be stable.

During the start of a surging episode (see Hacker[77] for an ancient analog), we would expect to see the reorientation of the ridge due to an increase in resistance of deformation in the conduit. In other words, if the conduit is "happy" at a spreading rate of 5 cm/yr, it is "unhappy" if the ridge suddenly jumps to a spreading rate of 20 cm/yr. For a period of a few hundred to a few thousand years, the time it takes to wake up the diapirs at depth, the ridge will drop desperately, try to reorient itself to cut down on the energy tied up in the conduit, and make sure that the ridges and transforms are orthogonal. Minimizing the number of intersections is also desirable. We would expect that at the start of a surging episode that propagating rifts will attempt to connect short offset transforms and convert them to long ridge, long offset transforms. Shortly after this, the conduit will "catch up," *i.e.* the viscosity of the conduit will diminish rapidly as heat from the basal shear zone and additional diapirs at depth are added to the conduit. Based on this scenario, it is suggested that due to mechanical reasons, several short offset transforms will have already been converted into long offset transforms, and they will survive the drop in the viscosity of the highly fluid conduit. The short offset transforms will not survive.

There are two basic kinds of propogating rifts: 1) Propogating rifts that are radiators, *i.e.* they are designed to reject the maximum amount of heat directly, and, 2) Propogating rifts that connect short offset transforms at the start of a surging episode. The former is harmless, the second, potentially devastating.

As the thermal burden goes up, the need to expel heat in some scenarios with short offset transforms is no longer efficient and first, the ridge switches over to oblique spreading, *e.g.* the Reykjanes Ridge.[73,78] With the Reykjanes Ridge we see two radiators in action, the Ridge and, abutting the ridge, the Charlie-Gibbs transform,[73] a long-offset transform, a second radiator. Thus the Iceland hot spot has managed to reorganize the seafloor in such a fashion that it achieves the maximum heat rejection.

One question that needs to be answered is what the maximum heat rejection configuration for the planet is as a whole. In other words, "Are steady state processes favored, or is episodicity favored as the preferred means to shed heat?" Conceptually, it is clear that with regard to trenches, episodicity is preferred. The sudden introduction of large amounts of the hydrous lid and mantle into the asthenosphere will result in the evacuation of large amounts of andesites as stratovolcanoes. These individual volcanoes serve as radiators. More importantly, the involvement of the asthenosphere in massive partial melting during a surging episode is a way to improve heat rejection over a steady state process because, in the latter, the mantle is not involved as much and no flood basalts are erupted. Flood basalts can expel heat in ways that continental lithosphere does poorly: convect. It is evident in this situation that surging is more efficient at rejecting heat than steady state processes.

For the Columbia River flood basalts, if we assume the lid above a magma chamber is 6 km thick, then a rectangular solid 1 km (ridge length) x 1 km (ridge width) x 6 km (ridge depth) would, if extended along a single ridge, be a ridge 40,000 km long (240,000/6=40,000). Alternatively, it could be a ridge 4,000 km long and 10 km wide. At a spreading rate of 10 cm/yr, this represents 100,000 years of seafloor spreading along a ridge crest 4,000 km long.

It is entirely possible during a surging episode that the cold plate may penetrate to deeper levels during a surging episode than a steady state situation. This facilitates the transfer of heat more efficiently. During surging episodes, resistance to subduction is decreased, thus insuring that the maximum amount of cold plate gets subducted in response to the recovery of gravitational potential energy. Just as energy gets tied up in the conduit during steady state ridge accretion, the plate resists subduction during steady state processes because slab pull is ineffective.

Another characteristic of surging that favors heat rejection is the disaggregation of old slabs by tearing during the surging phase. This exposes old, cold lithosphere to hot magma, a great way to reject heat.

During surging, hot, magnesium rich olivine (fosterite) may be incorporated in the magma several hundred degrees above the average temperature of the asthenosphere. It mixes with and decreases the viscosity of the conduit. Acting together, the energy tied up in the conduit during a surging event may be less than the energy tied up in the conduit during steady state accretion. This just means that it requires more effort for magma to create a swath of seafloor 1 cm wide for a slowly accreting ridge crest than one 1 m wide for a ridge crest that is surging.

There is a very good possibility that the diapirs created by the remnants of lithosphere slabs underthrust during surging events are larger and persist longer than diapirs shed by steady state subduction. As a result, the larger diapirs are more effective at displacing mass, *i.e.* heat to a much greater degree than smaller diapirs shed from a slower downgoing slab (see previous section).

Another consequence of surging is that it removes all the old oceanic conductive layer. After a surging episode, all the continents will be placed in a large clump so that the oceans have maximum freedom to subduct and get rid of as much seafloor as quickly as possible. The ultimate result: The average age of the seafloor at the end of a surging episode lasting 10 million years at the rate of 1 meter/year might be as low as 20 million years. In other words, sweeping the continents together in one place is the least work configuration. Specifically, pushing continents around because they are so uneven (mountain belts) is hard work, so the ocean reorganizes them into large, compact land masses. While the oceans get rid of old lithosphere, induced convection heats up the super continent at depth. Once the seafloor reaches an average age of about 20 million years, 10 million years into a surging episode, the oceanic lithosphere is too buoyant to subduct and the surging episode is over.

Suddenly, a crossover point occurs when it is more advantageous, in terms of the least work configuration, to break up the boundary conduction layer, *e.g.* Pangaea was being compressed by the oceans which could no longer subduct the seafloor because it was young and positively buoyant. This yields the arch effect and now it is advantageous from the standpoint of the least work configuration to break up continents so that the cold continent is exposed to hot rock, *i.e.* convection beneath the continent places hot rock next to cold rock hence the need to break up all super continents once all the old seafloor is subducted.

It can be predicted from this model that as old seafloor disappears, marine transgressions will be punctuated by regressions. Convection reorganizes the trailing edge of the plate and the descending slab.

The least work configuration has many expressions and each has certain diagnostic characteristics. The entire range of seafloor expression at the ridge can be accommodated by a model of the least work configuration or, more correctly, the maximum heat rejection configuration. This heat rejection model does not apply just to the ridge crest; it applies to the planet as a whole.

In several separate and distinct ways, it can be argued that episodic events in the planet are more effective at rejecting heat than steady state features. With this caveat in mind the processes driving the planet are much easier to understand.

Summary and Conclusions

In plate tectonics, conceptual rigor was replaced by bogus mathematical rigor. Geologists were content to allow physicists to dictate geology to them. What was once a discipline founded on the basis of real world examples, *e.g.* basic mapping on land and in the oceans, became secondary to the broad brushed approach of the geophysicists and mathematicians who were content to develop models divorced from real world examples. Plate tectonics developed into a grandiose castle in the sky with no foundation. This trend can only be reversed if we develop sound models based on the best conceptual basis that is divorced from the highly restrictive paradigm that has become plate tectonics.

Strong models corrupt weak men and women. The desire to conform is almost as strong as the desire to create. Thus the systematic corruption of the foundation of any theory, the data, is predictable due to the desire to conform, or to promote a specific agenda. An honest appraisal of the data sets collected, post-acceptance of plate tectonics as a strong model, would reveal thousands of incidents where scientists have twisted the data to make it fit the plate tectonics paradigm. Data should be collected in the absence of knowledge of any model. What is often overlooked by the public is that scientists are driven by the same motivations as the non-scientist. The ivory tower is a myth.

Worldwide compression, coupled with the natural process of chord push, drives the plates except during surges when there is a switch from compression to tension as the plate goes from being forced into the trench as opposed to being pulled into the trench. The implications of this model are profound as it relates to national security. The entire West Coast of the U.S. may have to be evacuated in as little as a few hundred years if we are at the start of a surge and after a few hundred thousand years if we are not. It is predictable that during a minor surge, California will experience magnitude 7 earthquakes every year, magnitude 8 earthquakes every decade, and magnitude 9 earthquakes every century. Within 100 years of the start of a surging episode, not one masonry building will be left standing in California.

The earth is an engine designed to reject heat by virtue of rearranging the density of the planet. It adopts the most efficient long-term heat rejection that runs in cycles. One cycle is the time it takes between surging episodes. Other cycles in the earth might take 500 million years to occur, *e.g.* massive overturn of the lower mantle.

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