# Electronic Tectonics



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The Earth's crust is sub-divided into plates, whose relative motions are well known. But the energy driving those motions remains enigmatic. Convective potential (as gauged by radiative heat loss) is insufficient, amounting to merely 4% of the total crustal energy expenditure. Furthermore, it is going in the wrong direction, since temperatures in subduction zones are higher than in the mid-ocean ridges, and therefore the buoyancy should send the oceanic plates upward and outward from the "subduction" zones, and downward at the mid-oceanic ridges, if convective potential was powerful enough to be the driving force anyway. Deformation from tidal forces is another source of energy, but it supplies only 0.01% of the energy consumed in tectonic friction. Recent research has found a wide variety of evidence of electric and magnetic fields associated with tidal and seismic deformation, though the origin of those fields is unknown. The present work explores the possibility that the mantle below the Mohorovičić discontinuity is positively charged by electron degeneracy pressure. If so, there is an electric field between the positive ions below the Moho, and the expelled electrons above it. If the pressure remained constant, the charge separation would be static, establishing current-free double-layers. But tidal and seismic deformation alters the pressure at depth, meaning that the threshold for ionization is constantly shifting. The significance is that a shifting boundary will drive telluric currents, with electrons flowing upward (or downward) when the pressure is increased (or decreased). Thus the energy generated by crustal deformation has been underestimated, since only plastic and inelastic thermalization was considered, and not ohmic heating from telluric currents. The general form of the EM data matches the expectations of this hypothesis.

The plate tectonics theory has become widely accepted, but the driving force has not been identified. An early hypothesis was that some sort of volcanism in the mid-ocean ridges was forcing magma to the surface, which then exerted pressure, pushing the plates apart. But the ocean floors lack the pressure ridges that would certainly develop under such enormous forces, and instead, are characterized by transform faults, indicative of sheared tensile strain. So the plates are actually being pulled apart. The mid-ocean ridges are just the consequence of magma that solidified on its way up, and then got pulled horizontally, not accomplishing a sharp 90° turn in the process. (See Figure 1.)

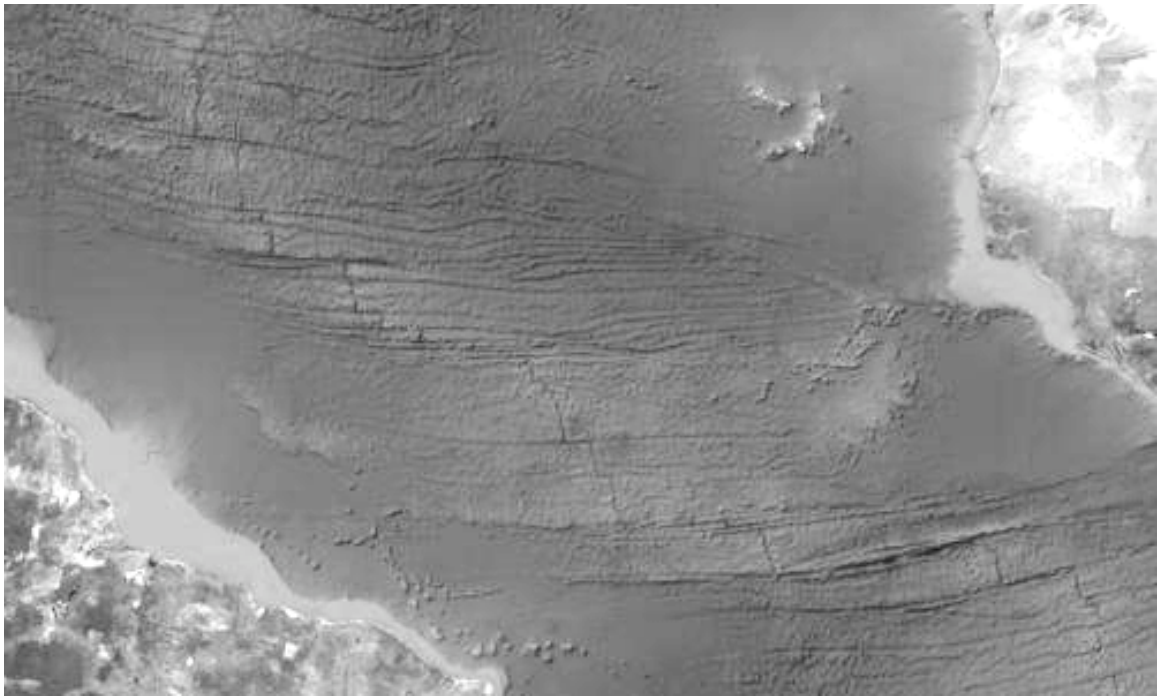

Figure 1. The Mid-Atlantic Ridge and its transform faults.

The following is the accepted hypothesis concerning the force that is pulling the plates apart, as described by Wikipedians.

> When the new crust forms at mid-ocean ridges, this oceanic lithosphere is initially less dense than the underlying asthenosphere, but it becomes denser with age, as it conductively cools and thickens. The greater density of old lithosphere relative to the underlying asthenosphere allows it to sink into the deep mantle at subduction zones, providing most of the driving force for plate motions.

But this still isn't correct, as the following facts demonstrate.[1:45]

> In the plate tectonics context, heat loss should have its highest values in mid-ocean ridges, and it will be gradually reduced moving away from the central ridges, reaching its lowest values in trench and trench-arc gap regions, i.e., at depths of the Benioff zone, shallower than ~100 km. But the data[2] indicate that the mean heat flow value is about 60~80 $mW/m^2$ in oceanic or continental sites, independent of and despite idealized plate tectonics expectations. Also, heat flow values below 30 $mW/m^2$ are actually common in and near mid-ocean ridges, and values above 150 $mW/m^2$ are paradoxically common in trenches and back-arcs. The most characteristically contrary examples to standard expectations are those of Japan and Fiji-Tonga,[3] where most of the deepest earthquakes actually

occur, and alleged subduction of cold "lithospheric" oceanic slab is thought to occur.

With the coolest, heaviest rock rising in the mid-ocean ridges, and the hottest, most buoyant rock sinking back into the mantle, this is clearly not a simple convective system. Further to the point, it takes a running average of $10^{15}$ watts of power to grind tectonic plates past each other, which is 95% of the total near-surface power, while radiative heat loss is only 4%. (See Table 1.) If hot magma from the Earth's interior was driving plate motions, radiative heat loss would be far greater, and tectonic friction would be a smaller percentage of the total.

Table 1. Crustal powers, from Tassos & Ford (2005, pg. 46).

| Energy Type | % |
|---|---|
| tectonic friction | 95.789 |
| radiative heat loss | 4.122 |
| lava production | 0.084 |
| elastic wave energy | 0.005 |
| total seismic moment | 100.000 |

So what does provide the power to move the plates, if not internal heat?

There is an external heat source that can be considered. The Moon's gravity elevates the crust ~11 cm at high tide, and the deformation generates heat. But inelastic and plastic deformation combined only account for about $10^{12}$ watts, which is 4 orders of magnitude less than the power consumed by tectonic friction.[1:46] Furthermore, tidal deformation operates on the entire crust, begging the question of what concentrates the heat in the subduction zones.

This leaves us without any energy sources at all that could be up to the task, so we need to review what we have, to see if we can find one that we're missing. And indeed, there is a force, other than gravity, internal heat, and tidal deformation. It's electromagnetism.

At sufficient pressure deep inside the Earth, rocks get ionized.[4] At the atomic level, electrons can only exist as free particles or in specific shells, and if the atoms are pushed too close together, the shells fail, thus releasing the electrons as free particles. If the pressure is relaxed, the electrons will be drawn back to the +ions by the electric force. If the pressure is static, the charge separation is stable, with +ions deeper than the threshold for compressive ionization, and -ions above it. But if the pressure changes, electrons will flow, either out of the matter as the pressure increases, or back into it as the pressure relaxes.

So what would cause the pressure to change? For one case, we can consider the effects of tidal forces. As the crust is raised and lowered ~11 cm twice a day, the pressure on the underlying rock is altered, varying the degree of ionization. Therefore, at high tide electrons are flowing deeper into the Earth, to recombine with +ions that no longer have a reason to be ionized, and at low tide, electrons are being expelled upward by the pressure.

At what depth does the pressure become sufficient for ionization? There isn't an absolute answer to this, since ionization isn't all-or-nothing. Elements heavier than hydrogen have

degrees of ionization. The greater the pressure, the greater the number of electrons that are expelled. Iron, with 26 protons, has 26 degrees of ionization, 1 for each electron it can lose. Hence with increasing depth, the pressure increases, and thus the degree of ionization, at a more-or-less steady rate. But we know that in the transition from the rigid lithosphere to the plastic asthenosphere, ionization has already begun, since the removal of valence electrons weakens the crystal lattice, allowing the rock to flow instead of fracturing. In the lower lithosphere, we can expect the rock to be partially ionized, but with enough valence electrons to support some rigidity.

What observable effects would tidal ionization produce?

At high tide, the crust is elevated, reducing the pressure on the mantle. With less pressure, there is less ionization, so electrons flow back in. Telluric currents associated with tides are well known. Of course, such currents are typically attributed just to the flow of water in the oceans, and no explicit study of inland tidal ionization has been located thus far. But an indirect measure might have been found by a study of lightning in North Dakota, USA (which is definitely inland). In 10 years of data, the cloud-to-ground strike rate averaged 22% greater at high tide, which was statistically more significant than the other factors normally associated with lightning induction, such as topography, vegetation, and infrastructure.[5] Since 85% of all CG strikes are from a negative charge in the cloud to a positive charge in the ground, this suggests that the ground had a stronger positive charge at high tide. And indeed, if the surface is elevated, the pressure underneath is relaxed, allowing charge recombination, and thus a downward flow of electrons, leaving the surface positively charged.

For another case, we can ask whether crustal deformation in a subduction zone is also accompanied by electric currents. And this is precisely what we find.[6,7,8] Figure 2 shows a typical subduction fault.[9] A description of the fault process follows.

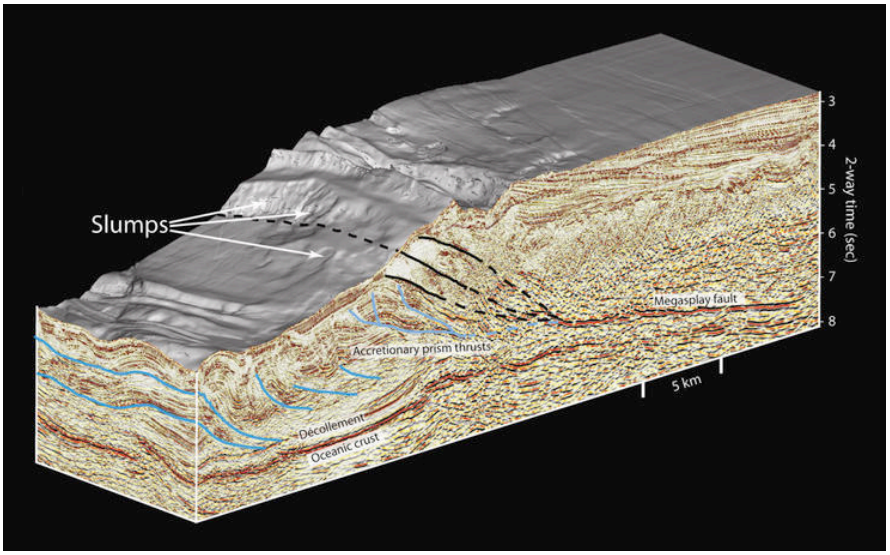


Figure 2. Subduction in the Nankai trench off the Izu Peninsula, Japan, courtesy of the University of Texas Jackson School of Geosciences.

The rupture of a subduction fault starts with the slippage of the lithosphere with respect to the underlying asthenosphere, without loss of traction along the fault.[10] This increases the pressure at the fault. The pressure is felt throughout the plates, and all other factors being the same, the plates could buckle anywhere to absorb the stress. But as we see in Figure 2, the plates are thinnest where they have been ground down by previous tectonic friction, so buckling is more likely to occur near the fault. The lower (oceanic) plate has forces on both sides of it, but the upper (continental) plate has nothing above it, so it buckles upward. (This is what causes ground water levels to change in the days before a quake.) When the fault ruptures, the buckle flattens back out again, with the leading edge of the continental plate advancing over the oceanic plate, like an inchworm moving forward as it straightens out.

Before and during the earthquake, there are distinctive signs of electromagnetism, including changes in electric fields, "earthquake lights" (which are corona discharges from tall, pointed objects),[11] and perturbations in the Earth's magnetic field. All of these are typically attributed to the piezo effect,[12] but that isn't correct. Certain types of crystals, including quartz, become electric dipoles under pressure. So mechanical forces can create electrostatic potentials. The converse is that such crystals can be made to do mechanical work when exposed to an electric field. (This is how piezo tweeters work.) But the dipolar field created under pressure doesn't extend much beyond the crystal itself. Furthermore, the quartz grains in the Earth are randomly oriented, meaning that the effects from individual crystals should cancel each other out, leaving no net piezo effect.[13:42] Yet compressive ionization can occur in all matter, regardless of the crystal lattice (or lack thereof, if the rock is molten), so this is the more plausible mechanism responsible for the observed EM effects. In the present model, the buckling of the crust reduces the pressure exerted on the underlying rock, enabling de-ionization, and thus an electric current. The effect is far more dramatic than tidal deformation, which elevates the crust ~11 cm at high tide, while pre-quake buckling can raise the surface several meters in just a couple of days.

Note that it seems odd to be talking about electric currents in rocks. Solid granite has a resistance of 2.4 MΩ, and the electric field necessary to get a powerful current flowing against such resistance just isn't present. But the fracturing in the buckled crust makes it a much better conductor. A crack only 1 nm wide is enough to allow the passage of electrons, and the resistance drops to roughly 377 ohms, enabling currents at much lower voltages.[1:71,14,15]

So what ultimately causes the earthquake?

It is commonly believed that the buckled crust is elastic. If that were true, it would be able to store energy that could be released catastrophically when the traction failed along the fault. But that isn't correct — under stresses sufficient to cause buckling, the rigid crust fractures, which is an irreversible deformation that stores no energy.[13:39] Without elasticity, a buckled crust shouldn't produce an earthquake — the buckle should just become a permanent geologic feature, possibly growing over a long period of time into something resembling the Appalachian Mountains. Some have argued that the uplifted

rock has converted pressure into gravitational potential that gets released catastrophically. But if gravity was powerful enough to generate a megathrust fault just because the crust was elevated a few meters, mountain ranges 5,000 meters high, within 250 km of a trench (and fully inside the Benioff zone[16]), would be quite impossible. (See Figure 3.)

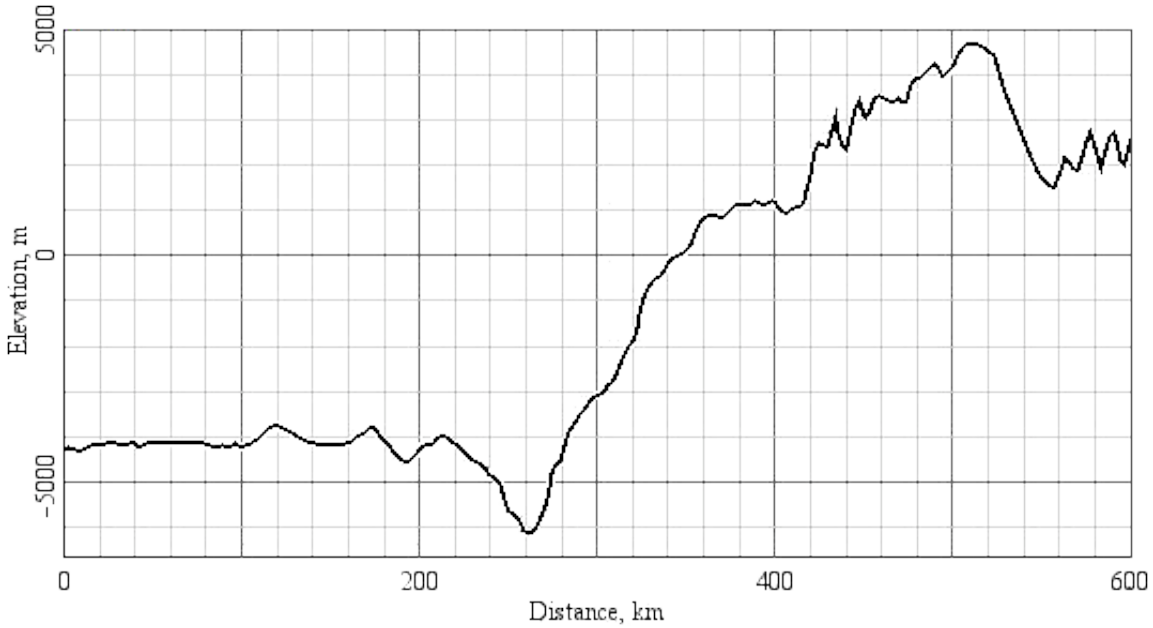


Figure 3. Topographic profile through the Peru-Chile trench and Andes Mountains.

Since earthquakes definitely happen, and mountain ranges certainly exist, we can only conclude that the kinetic energy of colliding plates isn't stored and then released catastrophically, since there is no suitable storage mechanism. Rather, the plate collision can only be releasing some other form of potential.

And what other potentials are there? We know that electrostatic potentials are present, as a consequence of compressive ionization, and that there are distinctive changes in electric fields associated with earthquakes. So we should consider the possibility that the kinetic energy of the plates is somehow triggering the release of electrostatic potentials, by somehow altering the degree of compressive ionization.

If we step through the whole process, we can easily see where this is happening.

1. Tectonic motion builds up pressure at the fault.
2. The rigid crust buckles under the pressure.
3. The elevation of the crust reduces the pressure underneath it.
4. The reduction in pressure reduces the degree of ionization.

5. De-ionization motivates an electric current through the fractured crust.
6. The electric current causes ohmic heating in the crust.
7. The ohmic heating causes the crust to expand.
8. The expansion increases the buckle.

Note that steps 3~8 constitute a force feedback loop. The more the crust buckles, the more ohmic heating it gets, which causes it to expand, increasing the buckle. Also note that the buckle reduces the mating surface of the two plates, meaning less traction. (See in Figure 4.) A runaway expansion of the crust, coupled with a loss of traction, guarantees a rupture.

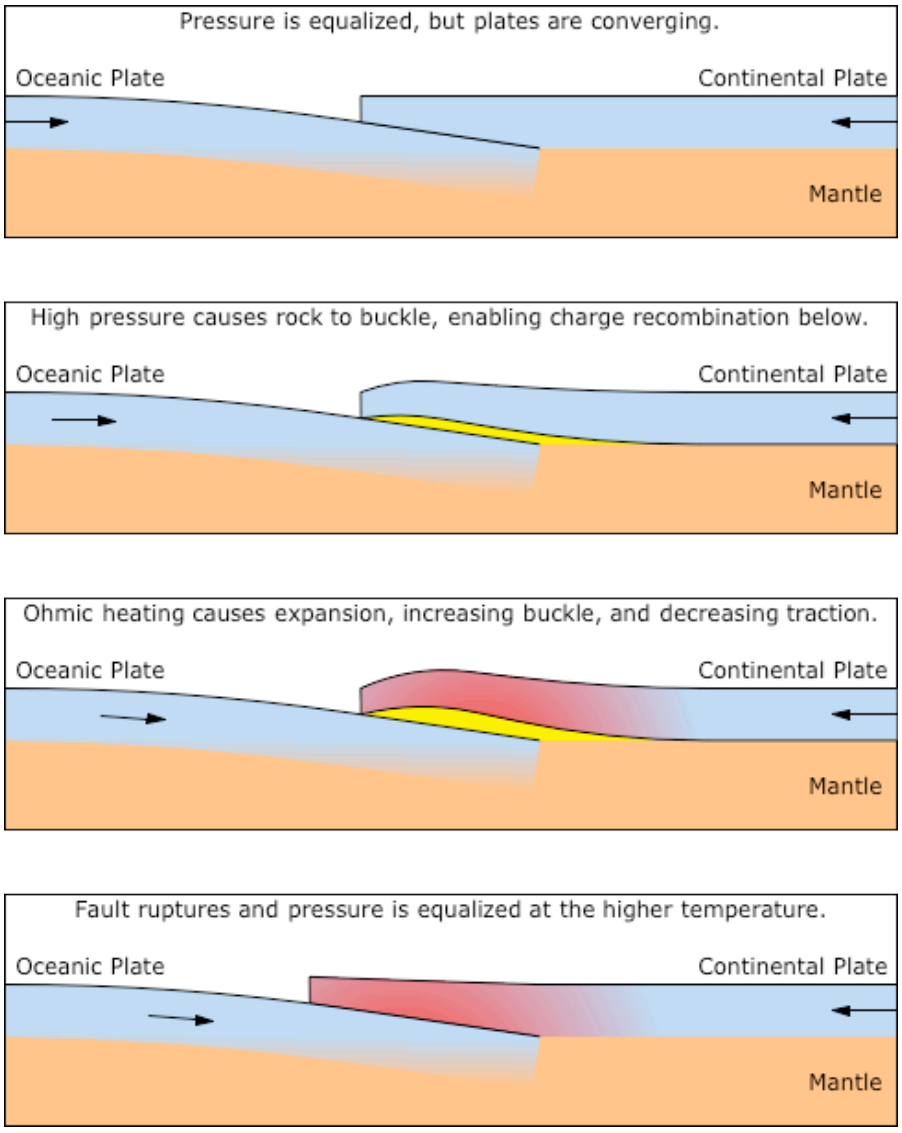

Figure 4. Subduction fault.

The one other factor that increases the chance of an earthquake is a new moon, when the tidal forces are the greatest.[17] In the standard model, this doesn't make sense, as the gravitational potential causing stress at the fault is reduced by tidal forces, and the quake should wait for low tide and a moon in its 1st or 3rd quarter. But if tidal forces increase the crustal deformation, they are contributing to the force feedback loop that causes the runaway expansion of the crust.

This model passes the next test as well. One of the major mysteries about earthquakes is that they produce a series of waves, sometimes lasting for minutes. The inelastic rock shouldn't oscillate like this. As proof, an experiment was once conducted, involving the detonation of a 1 megaton nuclear bomb, 1 km below the surface. This successfully caused a surface fault about 1.2 km long. But it did not create a series of seismic waves. The second wave had only a small fraction of the energy of the initial shock front, and the elastic reverberations died out quite quickly.[18] Without elasticity, what causes sustained seismic waves?

In an EM context, we'd call this a form of sputtering. The electric currents flowing through microfractures turn them into plasma discharge channels. These can get very hot, very fast, and the pressure can quickly become enormous, and this is the force that ultimately causes the rupture. (In other words, with its low thermal conductivity, the crust is not subjected to general ohmic heating, resulting in expansion. Rather, extreme heat in micro-channels generates the hydrostatic pressure.) The amount of force that this can generate should not be underestimated. Consider the following report of what one lightning strike did to a large chunk of rock.[19:150,20:72]

> In Fetlar, one of the Shetland Islands, a solid mass of rock 32 m long, 3.05 m broad, and in some places more than 1.22 m high, was in an instant torn from its bed by lightning and broken into three large and several small fragments... [One fragment], 8.53 m long, 5.18 m broad, and 1.52 m in thickness, was hurled across a high point of rock to a distance of 45.72 m. Another broken mass, about 12.19 m long, was thrown still farther, but in the same direction, and quite into the sea...."

This is an unusual occurrence, and understandably so, considering the normal resistance of granite. Clearly the discharge found its way through the rock by following fractures. And though there is no theoretical limit to the amount of ohmic heating that can be applied to matter, there is no back-pressure on the current — conductivity increases with temperature. Once the current found a way through the rock, the current and the pressure on the surrounding rock increased together, eventually exceeding the tensile strength of the rock.

The conditions are different deep inside the Earth, where the discharges are self-defeating, because the expansion of the heated rock closes the channels, raising the resistance back up to 2.4 MΩ. Yet slippage at the fault sends a negative pressure wave back through the rock, re-opening the discharge channels. So the current flows again, quickly restoring the temperatures and pressures necessary for another rupture. The result

is a series of shock waves that can sometimes last for minutes. But these are not elastic reverberations. Rather, each shock front has its own electro-mechanical source. Successive sputtering then eventually relieves all of the pressure. When we inspect the fault, we see that the subduction has advanced another couple of meters. But there was actually a series of ruptures only centimeters apiece, from each individual wave.

Now we should consider the behaviors of this model after the quake. All of the pressure at the fault has been relieved, and the continental plate lies back down on the oceanic plate, re-establishing traction. Then the hot rock begins to cool. As it does, it shrinks. There are two possible consequences of the shrinkage.

First, if the traction fails, there will be an aftershock. Note that a number of laws have been empirically derived from the regularity of aftershock swarms.

- Omori's law: aftershock frequency varies with the inverse of the time after the main shock.[21]
- Båth's law: the difference in magnitude between a main shock and its largest aftershock is approximately 1.1~1.2 MMS, regardless of the main shock magnitude.[22] So if the main shock is M7.5, the largest aftershock will be M6.3~6.4.
- Gutenberg-Richter law: there are fewer large aftershocks, and more small ones.[23:69]

Other models seem to be consistent with these laws, but they assume elasticity that granites and basalts don't have. In the present model, these laws are predictable consequences of post-rupture shrinkage in an inelastic medium. Heat dissipation is fast at first, and asymptotically approaches zero with time. Hence aftershocks will be frequent right after the main quake, and the rate will slow asymptotically (i.e., Omori's law). The energy of the largest aftershock will be a fixed amount less than the main shock, because quake magnitudes are measured on a log scale, and cooling per degree of difference also follows a log scale. Hence a large rupture will be hot, and will cool rapidly, with massive shrinkage, while a small rupture is produced by a smaller temperature difference, and the shrinkage will be consistently less (i.e., Båth's law). And shrinkage of a large block can easily produce many more small ruptures than large ones (i.e., Gutenberg-Richter law). In the conventional model, only considering tectonic pressure and the release thereof, and acknowledging the inelasticity of the granite/basalt, both plates should move as rigid units, and ruptures should only occur when the traction fails along the entire fault. But stresses vary in a shrinking plate, being the product of local and compounded distant shrinkage, and there are many more opportunities for small ruptures than for large ones.

Second, if the traction holds, the shrinkage will produce a tensile force on both plates, pulling them together. (See Figure 5.) Now if we just acknowledge that the force feedback loop that causes the rupture happens fast, while the cooling happens slowly, we see that the plates are subjected to tensile force longer than they are under pressure. For this reason, more of the tensile force gets converted to momenta than the collisional

pressure detracts from it. In short, the net force is a pull, and the entire process is a form of ratcheting.

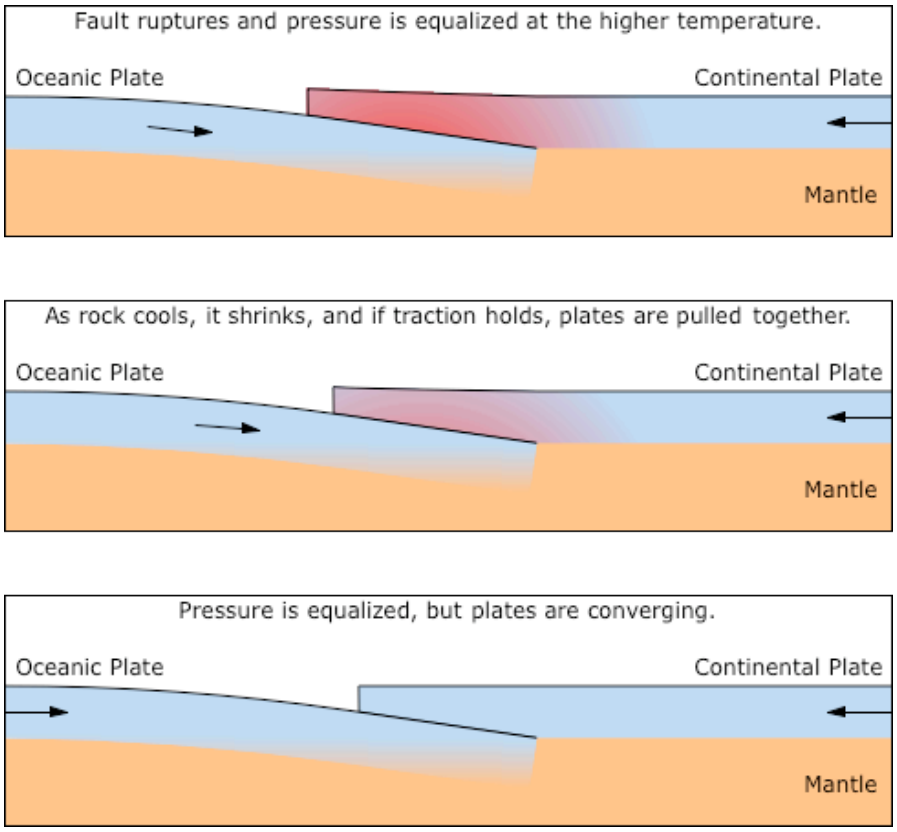


Figure 5. Post-rupture shrinkage pulls the plates together.

As such, we might now have an answer to the original question concerning what causes tectonic motion in the first place. It isn't pressure at the mid-ocean ridges, and it isn't the negative buoyancy of the oceanic crust that gets subducted. Nor is tidal deformation powerful enough to shift tectonic plates, given that the force was focused in just the right place, which it isn't. So the tensile force from post-rupture shrinkage is the first legitimate candidate.

Now that we're talking explicitly about tensile tectonics in mechanistic terms, a couple of questions need to be answered.

First, granite/basalt is high in compression strength, but low in tensile strength. Could a tensile force at a plate boundary actually drag the entire continent?

This is a problem for any theory that states that the continents are being pulled apart, instead of pushed together (including lithospheric convection). Either way, it's an excellent question. And there is certainly evidence of the crustal tensile strength failing. Rifts such as in Death Valley USA, and possibly in back-arc basins, result from stretching near subduction zones. (See Figure 6.)

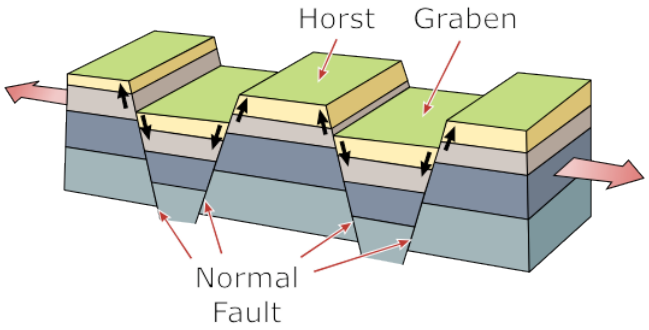


Figure 6. Rifts form due to crustal stretching.

Nevertheless, the mid-ocean ridges are proof that continental spreading begins there. The most likely overall explanation is that it isn't a tensile force per se, and it's not just the crust that's involved. Rather, high pressure in the lower lithosphere, due to vertical loading, is relieved at one end by subduction, and the rest of the lithosphere flows in that direction, dragging the crust along with it. So it's really just an absence of a compression force, combined with the plasticity below the crust, that moves the plates.

Second, a question specific to tectonic ratcheting concerns how the process was initiated. If the plates have collisional momentum, there will be a rupture, and when the plates fuse back together, shrinkage will supply the tensile force (or the absence of compression at depth) that replenishes the momentum, eventually leading to the next rupture. But how did the plates develop collisional momentum before the first post-rupture shrinkage? Here there are a variety of possibilities, but one candidate is the "shock dynamics" model, which asserts that an impact event at the northern tip of Madagascar set the plates in motion.[24] This model explains so many details about tectonics that it's an excellent place to start. But an instantaneous event would not create the features that could have only emerged only a long period of time, such as magnetic striping in the mid-ocean ridges. So it's more likely that an impact event initiated plate motions, but thereafter, tectonic ratcheting perpetuates the process.

Another large-scale issue that needs to be addressed is deep-focus quakes (i.e., with hypocenters as deep as 700 km). This "should" be impossible, as the rock below ~40 km is under sufficient pressure to flow. (In the present model, it's not just pressure all by itself that enables the plasticity, but more importantly, the ionization, which weakens the crystal lattice.) The significance is that such rock shouldn't be capable of rupturing.[25] For

this reason, the consensus is that a subducted plate is sent diving down into the mantle, and because it is brittle, it is still capable of rupturing, until it is heated up to the same temperature as the rest of the mantle. (See Figure 7.)

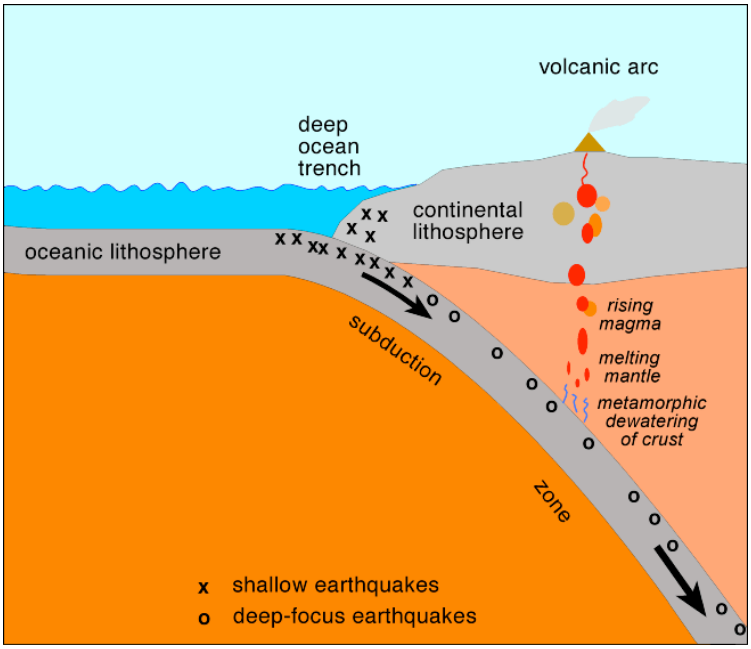


Figure 7. The conventional model of deep-focus quakes, assuming the persistence of the subducted crust deep into the mantle.

The thermal conductivity of granite might be poor, but subduction at a rate of less than 10 cm/yr means that it takes more than 7,000,000 years to get to a depth of 700 km. Granite isn't that poor of a thermal conductor. It's also hard to believe that the subducted plate would encounter enough friction for a rupture.

The present model offers another suggestion. Buckling of the crust can affect the pressure theoretically all of the way to the core (though the difference will relax with the square of the distance from the buckle). The reduction in pressure allows electron uptake, motivating electric currents through micro-cracks in the rocks. Hence rock at a depth of 700 km might be too plastic for a rupture, but it might still be vulnerable to the explosive effects of electric currents.

Note that not all geologists believe that the lithosphere drifts across the asthenosphere, since mountain ranges near subduction zones appear to have "roots" as deep as 600 km.[1:50,26] Such "roots" are detected as wave transmission speed anomalies, which imply some sort of continuous structure. But if this is true, both the lithosphere and

asthenosphere are getting subducted, and the amount of energy to accomplish that amount of deformation simply isn't present. It seems more reasonable to think that the mountain "roots" are not physical structures, but rather, some sort of transient condition that occurs under the weight of the mountains, and which moves with the mountains. For example, the transmission speed anomalies might define the limits of an extra degree of compressive ionization due to the weight of the mountains. Deep-focus earthquakes are then occurring along an ionization boundary, not a fault. The oceanic crust might then simply slip under the continental crust with a lot less energy, and never extend far into the lithosphere before melting and merging with the existing magma there.

So far, we have developed a nice list of anomalies that can be explained by the present model. But just to make sure that we're not cherry-picking anomalies that lend themselves to this new treatment, we should review a more comprehensive list of acknowledged anomalies, which many researchers consider to be too diverse to come from the same mechanism.[13:38]

- changing well water levels
    - The Earth is buckling under tectonic pressure (plus tidal forces).
- ground-hugging fog
    - The buckling creates a low pressure under it, which cancels compressive ionization. So electrons flow downward. This produces a temporary electron deficit in the overlying rock. Hence the Earth, at its surface, becomes positively charged.[13:38,27:402] A negative space charge develops in the air above the ground. Electric fields encourage the condensation of water molecules (by polarizing them). The fields also cool the air, because the electric force removes degrees of freedom.[28] So the conditions favor the production of water aerosols, which will be negatively charged, and which will cling tightly to the positive charge in the ground.
- earthquake lights from ridges and mountain tops[29]
    - The electric field exceeds the potential for corona discharges from pointy objects (or even large geologic features).
- low frequency electromagnetic emission
    - Ohmic heating generates infrared radiation.
- local magnetic field anomalies up to 0.5% of the Earth's dipole field
    - Electric currents generate magnetic fields. The piezo effect does not.
- temperature anomalies by several degrees over wide areas as seen in satellite images
    - Ohmic heating again.
- changes in the elevation of the Earth's surface
    - The crust is buckling.
- changes in the plasma density of the ionosphere
    - If the Earth is positively charged, that's a polarity reversal from the fair weather field, which will affect the ionosphere.

In conclusion, the present model appears to explain the full range of tectonic behaviors, which to date no other model has accomplished.

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