GY 111 Lecture Note Series
Intro to Plate Tectonics

Lecture Goals:
A) Alfred Wegener and Drifting Continents
B) The Plate Tectonic Revolution
C) The Earth's Interior (Seismic waves)
D) Plate Tectonics Mechanisms

Reference: Press et al. (2004), Chapters 2, 4, 20 and 21; Grotzinger et al. (2007) Chapters 2, 12 and 14

A) Alfred Wegener and Drifting Continents
In the early 1890’s, a rather perceptive German meteorologist by the name of Alfred Wegener began to look at the world in an unorthodox manner. This was a time when scientists of all disciplines were analyzing every aspect of the Earth and the beasties¹ that inhabited the Earth. They followed standard scientific procedures (or at least they should have). They observed, they hypothesized, they tested, they refined their hypotheses and lastly, they formulated theories. It was not that long before that Darwin came up with the theory of evolution. Geologists, always a careful bunch, were still coming to grips with geological processes. They knew about volcanoes and earthquakes, they knew what mountains were composed of and that fossils were important components of a lot of rocks, they just couldn’t come up with the methods by which all these observations could be united. They were looking for a geological theory of everything. (note: the geologists eventually found it. Physicists are still looking for their Grand Unification Theory – this will unite all known physical forces).

Back to Wegener. He observed that the shorelines of some continents looked like they could fit into the shorelines of others almost like a jigsaw puzzle. Take for example the coastlines of Africa and South America:

Wegener also realized that there were geological elements common to both shorelines. Rocks of around 250-300 millions year of age (250-300 Ma) were similar on both sides and they contained identical land-based beasties (e.g. dinosaurs). Wegener hypothesized that in the past, Africa and South America were united together. Not only that, he was able to put most of the continents together into a supercontinent he called Pangaea. He published a map very much like this one in 1912 and his idea soon became known as Continental Drift:

¹ Dr. Haywick refers to all living creatures as “beasties”. There are big beasties (elephants and whales), small beasties (dogs and cats) and micro beasties (plankton etc).
To put it bluntly, the geological world did not take kindly to Wegener’s “radical” idea. Remember, by this time, scientists expected hard evidence and testing of hypotheses rather than simple ideas. Moreover, a very famous geologist at the time (Dana) had recently argued very convincingly that the oceans and continents were “firmly” rooted in place (e.g., no drifting was permitted). So if you were a geologist at the time, who would you believe? A well established geo-God (Dana) or a non-geologist newbie (Wegener). True, there was some evidence for continental separation (e.g., the fossils), but argued the scientists, maybe the animals just rafted across the sea on top of a tree. Today, the terrestrial fossil content of rocks on both sides of the south Atlantic Ocean when taken in conjunction with lots of other data is considered vital evidence of the earlier existence of super continents; however, 90+ years ago, the fossils alone could not do it. Continental Drift was delegated to the “quasi-science” shelf of libraries because it did not have enough supporting evidence. I collect old geology books and it is interesting how some researchers ridiculed Wegener’s idea. I wonder what they thought when Wegener was proven almost right.

Are you interested about what geologists of the time believed in? Are you curious about what the accepted “theory” of mountain building was in 1912? The check out the link below (it’s to a GY 112 lecture).


Wegener’s ideas remained purely speculative for about 40 years. In the interim, the world went to war twice. Most people remember these World Wars as a time of death, destruction and overall nastiness. They did do one thing that would prove invaluable to science in general (and geology in particular): they produced new technology. Wegener’s ideas were born again following World War II.

B) The Plate Tectonic Revolution
Did you see the movie U571? Remember that scene when the submarine is diving beneath the German destroyer and they almost hit the bottom of the boat? Scary stuff huh? That was fiction. In World Wars I and II, it was more likely that a sub would run into a submarine mountain than
another boat. The surface of the ocean may appear to be flat, but the bottom of the ocean is NOT. The earliest mariners suspected this and WWI/WWII submariners knew this (thank God for sonar!), but until the end of WWII, no one made any attempt to map out the ocean floors. The technology was not available yet. Once the war ended, a number of surveys were initiated and the submarine highs and lows were finally mapped out. Surprise, surprise; instead of a random distribution, **topographic highs** and **lows** were arranged in linear fashion. There were underwater mountain ranges (called **mid oceanic ridges**) and deep valleys (called **trenches** or **troughs**). Most mid oceanic ridges were dominated by volcanoes, thermal vents and active lava flows. One in particular (the **Mid Atlantic Ridge**) ran right down the middle of the Atlantic

This was pretty neat stuff. A few years later, a new discipline of geology was initiated that would forever change the way geologists looked at the world. Researchers learned that some iron-bearing minerals and rocks preserved the Earth’s magnetic orientation *at the time of their formation*. Igneous rocks formed 100 million years ago (100 Ma) were like compasses. Provided that you could read the **paleomagnetic signature**, you could determine the orientation of the rocks relative to the north-south poles at that time. Well it is pretty easy to read the paleomagnetic signature of rocks. The interesting thing is that the poles were not consistent over time. In the past (and presumably this will also occur in the future), the north and south poles reversed themselves every few 10’s of thousands of year (10’s of Ka). Successive lava flows recorded these reversals:
When marine geologists started to sample across the Mid Atlantic and other oceanic ridges, they made an amazing discovery. The paleomagnetic signatures of the rocks recorded numerous reversals, but in a striped pattern (see image to right from http://www.calstatela.edu)

The youngest rocks occurred down the middle of the oceanic ridges (remember the middle of the oceanic ridges were characterized by active volcanoes) and the oldest rocks occurred along the continental margins. Most importantly, the age pattern was symmetrical around the ridges. The explanation for these data is pretty clear. The volcanically active mid-oceanic ridges must be areas were new oceanic crust is being formed and from here, the crust spreads out laterally. Wegener was kind of right. The continents are drifting apart, but it is not just the continents that are moving. The continents and large parts of the oceans are moving relative to one another. We now envision the Earth’s surface as being broken up into a series of plates (officially tectonic plates) and refer to the motion of continents/oceans plate tectonics. It wasn’t until the middle to late 1960’s that plate tectonic theory was generally accepted by the majority of the planets geologists. Plate tectonics, which is as important to geologists as evolution is to biologists is less than 50 years old. We are still refining it. These are interesting times to be a geoscientist.
Once the idea of plate tectonics was widely accepted, geologists sat down and really looked at the Earth. The evidence of plate tectonics started to jump out at people:

1) Fossil and rock suites that match up on opposite sides of continental shorelines (Wegener was right!)

2) Localization of mountains, volcanoes, earthquakes and trenches along lines on the Earth’s surface (they show the location of plate boundaries)

We’ll be spending a good chunk of an upcoming lecture or two discussing volcanoes and earthquakes. For now, consider just where most of them take place. The map to the right comes from http://pubs.usgs.gov and shows the distribution of earthquakes from 1978-1987:

And this one shows the distribution of volcanoes (from http://www.intute.ac.uk):

There is nothing random about where most of the volcanoes and earthquakes occur; they are on plate boundaries. If Wegener had this information when he proposed continental drift, it likely would have been accepted a lot earlier that it was.
There is more morphological evidence for plate tectonics. Mountain belts and their inverted counterparts trenches are also mostly located along plate boundaries. Trenches are deep canyons in the ocean floor and they occur where the subducting plate is dragged under the overriding plate at convergent plate boundaries (see image to the right showing the trench between the South American and Nazca Plates from: http://www.platetectonics.com/). More on this shortly when we get to plate tectonic mechanisms.

There is still more evidence supporting plate tectonics:

3) **Hot spots** and chains of volcanic islands within ocean basins etc. Hawaii is the classic hot spot (see image to left from http://visearth.ucsd.edu)

There is lots of other evidence (e.g., accurately measured spreading rates through the use of laser), but you should appreciate the strong case for plate tectonics. Text books usually go into more detail about the evidence supporting plate tectonics and you are HIGHLY encouraged to read the relevant chapters pertaining to this topic. As I have tried to convey to in this lecture, the story of the evolution of plate tectonics is at least as fascinating as the theory itself.

**C) The Earth's interior & seismic waves** (very detailed notes; more on this topic later in the semester)

If we all lived in a Star Trek universe, exploring the interior of the Earth would be comparatively easy. All you'd have to do is use scanners or beam a chunk of it up to the Enterprise and let Data or Spock examine it with a tricorder. Unfortunately, we are a long way from that type of exploration.

Today, there are really only a few ways that we can explore the interior of the Earth. I can think of 3 ways:

1) **Drill a hole**: Geologists have been drilling holes into the Earth since the late 1800's. This is easy. All you need is a drilling rig, some drilling pipe and a drill bit. If I have the time (and remember to bring them in), will see some examples of drill bits in the lecture. They look pretty impressive (especially the big ones!), but they really are simple devices. They have rotating tungsten-carbide cutters that grind away the rock as they turn. A bit is attached to a length of drill pipe and the whole thing is turned in the rig complex. As the bit descends deeper into the Earth, pipes are added to the assemblage extending its penetration. Today, petroleum geologists regularly drill holes that exceed 20,000 feet.
(almost 4 miles) to obtain natural gas (e.g., Mobile Bay). They can go deeper, but there would have be pretty good economic reasons to do so because of the cost involved in drilling. There are a few “academic holes” out there and I had the opportunity to visit one of them in the fall of 2006. I was at a conference in Bavaria, Germany and the intra-conference field trip was to the German Deep Borehole project (see image at bottom of this page). In the 1980’s, the Germans began a project to drill the world’s deepest well in order to study high temperature geochemical/geophysical processes. They planned on going down to 12 km (almost 7 miles), but stopped at 9 km (5 miles) when they hit temperatures around 325°C (their target). Apparently they miscalculated the geothermal gradient in this area. So their hole is NOT the world’s deepest (that record is held by a well in California), but it is still the deepest currently open borehole. Indeed, the project is still active and geologists from around the world come here to study subsurface conditions not otherwise possible. They kept the drilling complex up (see photo to right) and added a nice visitors center to the site where you can buy all manner of crap, including rock cuttings (the remnants of the rock drilled through to make the hole).

If you are wondering how far down can we go, well at the present time, it really is not possible to exceed more than 10 miles by conventional drilling. The metal drill bits simply start to melt if you go too deep. So until we develop “new technology (where's Captain Kirk when you need him!), we will have to rely on other sources of deep Earth information.

2) Get physical samples from volcano: Volcanoes are simply holes at the Earth's surface where molten rock escapes from the interior. It follows that the stuff erupting from a volcano tells you about the nature of rocks, fluids and gases below the surface (there is more erupted from a volcano than just lava; there are horrendous amounts of gases including water vapor). Each active volcano is underlain by one or more magma chambers 5 to 20 km or so below the surface. In some cases (e.g., above hot spots), the magma may be derived from much deeper. But as useful as these samples are, they are isolated to specific points on the Earth. What's really needed to sort out the Earth's interior is some sort of technique that allows us to build up a coherent picture of the whole darn planet. What we need is rock version of radar or medical X-rays. Luckily for us, such a technique exists. It's called geophysics.

Geophysics, as the name implies, is a combination of geology and physics. Specifically, it is the study of how shock waves (officially called seismic waves) travel through the Earth. To explain how this works, it is best to once again turn to petroleum geology (see cartoon to right from http://www.naturalgas.org). Since the early 1900's geologists have used seismic waves to look for petroleum reservoirs. What they do is install a series of microphones (called geophones) and listen to how seismic waves travel through the rock over time. The seismic waves used to be generated through explosions, but now we simply use thumpers, devices that repeatedly lift and drop heavy metal plates on the ground. The result is similar to the effect of smashing a hammer on a cement floor. Seismic waves can also be generated at sea through the use of "pingers" (these
devices generate sound waves of a specific frequency that are capable of traveling through rock layers). My favorite type of seismic survey are the “convoy” type systems whereby large truck like components simply drive across the countryside recording the seismic stratigraphy below the surface as they go. The Lithoprobe project (see image to left from http://www.geop.ubc.ca/ Lithoprobe/transect/SOSS) is an example of this type of survey. Five or six vehicles that each do something (one “pings”, one records, the others “listen”) can quickly do a seismic line many hundreds of km long. Hey; this is almost Star Trek-scale science!

No matter how the seismic waves are generated, they all travel through the earth following specific physical rules. As they travel from one medium to another (one rock type to another), they can speed up or slow down, bounce back toward the surface, or even stop entirely. Before we focus on the behavior of seismic waves, it is perhaps best to first consider something that you are more familiar with through high school physics classes; light waves.

When light passes from one medium (e.g., air) to another (e.g., water), it changes speed. From air to water, the light rays slow down. To your eye which requires reflected light to see things, the change in speed is perceived as a change in the orientation of objects that pass from air into water. This is what causes the “broken arm” appearance when you stick your arm into a pool of water or the displaced fish perception (see image to right from http://www.iop.org), when you go to clean your aquarium. This property is called refraction. Light waves can also bounce or reflect off of surfaces which is the reason why we can perceive them with our eyes in the first place. Seismic waves do exactly the same thing and if you are a clever petroleum geologist, you can use the pattern of reflections combined with refractions to build up a coherent picture of the rock layers below the surface (see nasty image to left from http://www.geo.uu.nl). Of course you do need a computer to time the arrival of all of the reflected seismic waves and to sort these data into a picture of the rock layers. Even still, there is a significant amount of skill that is required to "read" these images. Like all scientific techniques, becoming an expert in seismic stratigraphy (this is the science of resolving rock layers via geophysical techniques; see image at the top left of the next page from http://www.cpfieldinstitute.org) requires practice, practice, practice.

Now let's turn back to the Earth's interior. A thumper or small explosion is sufficient to generate a seismic pulse that can be recorded by geophones in the vicinity of the source of the waves, but there is only so far that these waves can travel before they diminish to nothing. In order to resolve structures near the center of the Earth, we need either really large explosions (which are fun, but difficult to obtain licenses for), or
Another recurring source of powerful seismic waves. Depending upon your point of view, we are lucky (or unlucky) to have just a source of these waves. They are called earthquakes.

Earthquakes occur when stresses build up beyond the ability of rock layers to resist them. There is a sudden break, a release of built up energy and formation of seismic waves. Earthquakes will be discussed shortly, but right now, we need to discuss what happens when an earthquake occurs in order to better understand geophysics and the Earth's interior.

Earthquakes are capable of generating 2 major Earth-penetrating types of seismic waves (also called body waves; see image at the bottom of this page):

1) P-Waves and 2) S-Waves

Once generated, these seismic waves can travel throughout much of the Earth's interior. We record their passing through the use of a seismograph. Seismographs and the technique of locating earthquake epicenters, will also be discussed in depth later.

P-Waves (or primary waves) are associated with compressive deformation (compression). They travel through all states of matter (liquid, solid), are the fastest of the three seismic waves and range in speed from 6 km/sec (granite) to 7 km/sec (gabbro) in crustal rocks. P-waves dramatically increase in velocity the deeper they penetrate into the Earth. The reason is that seismic waves travel faster through more dense materials.

S waves (or secondary waves) are associated with shear. They are significantly slower than P-waves (commonly 4-5 km/sec) and can only pass through solid materials. Should they encounter rock with liquid properties (e.g., magma), they simply die out. This is an important thing to remember because it will be one of the facts that allow us to resolve the Earth's interior.

First let's talk reflection and refraction on a grand scale. P- and S-waves literally bounce all through the Earth following a major earthquake. In fact, the Earth literally "rings" like a bell due to the almost constant vibrations caused by earthquakes. The figure at the top of the next page is from http://www.bbc.co.uk and illustrates the trajectories of P and S-waves from an earthquake near the
As the seismic waves penetrate into the Earth, they pick up speed or slow down depending upon the density and physical state of the rock layers that they are passing through. It is that reason for the bending that takes place in the cartoon. The waves also bounce off of specific layers in the interior (not shown on the simplified cartoon) and it is these major levels of seismic reflection that geologists use to divide up the Earth's interior. If you get the feeling that keeping track of all of the reflected, refracted and primary seismic waves is a difficult task you are correct and that is why seismologists came up with the strict nomenclature that is used to label the waves in the sketch above.

Another more detailed diagram that illustrates the changes in wave transit speed versus depth is necessary at this point in our lecture (see image to the right). It comes from http://geoweb.tamu.edu. In it you will see several sudden changes in wave velocity. The first is hard to see on the scale of this diagram as it occurs a mere 5 to 35 km below the Earth's surface. It was first identified by a Istrian (part of Croatia) seismologist named Andriji Mohorovicic in 1909 which explains why the transition goes by the official name of Mohorovicic discontinuity. However, since most of us can’t pronounce it, it is usually just called the Moho. At the Moho, the velocity of S-waves suddenly decreases from about 5 km/s to just over 4 km/s and across the Moho, the velocity of P-waves suddenly increases by about 15 to 30 %. Clearly something weird is going on at this level. Mohorovicic's interpretation was that there was a sharp transition from rocks of lower density to rocks of higher density. Experiments established the travel time of seismic waves through different types of rocks and through these data, geologists confirmed his conclusion. Rocks above the Moho are primarily granite (6 km/s) and gabbro (7 km/s), and rocks below the Moho are primarily peridotite (8 km/s). These are rock terms that we haven’t heard for a while in GY 111 which just goes to show you that you can’t afford to forget anything while at University (especially geology stuff!). For now, it is sufficient just to recognize that there is a transition in rock types at shallow depths below the Earth's surface, that it is resolved on geophysical grounds, and that it is the first division of the Earth's interior; the crust.

We have already discussed the Earth’s interior, so there is no need to do it again. However, there are a couple of new aspects of seismic waves that we need to deal with given the remaining parts of this lecture. The first are seismic shadow zones. If you look at the bottom diagram on the previous page (the one from the BBC) you will see that on the opposite side of the Earth from where an earthquake occurred, there is a region where seismic waves do not occur (hence the term “shadow” zone). The one for S-waves (S-wave shadow zone) is particularly obvious because it is so wide. It was this very fact that led geologists to conclude that the outer core of the
Earth was liquid in the first place. There is also a **P-wave shadow zone**, but it is much less obvious on the BBC figure.

I am going to leave you hanging at this point with respect to the consequences of seismic wave and earthquakes. We need to return to plate tectonics. However, later in the course, we will return to earthquakes when we go into detail about structural geology and faulting. We will also talk about the damage caused by seismic waves in a lecture I call Death and Destruction 101.

So back to plate tectonics. Seismic waves allowed geologists back in the 1930's to resolve several layers inside of the Earth. The discoverer of the core (a female seismologist named Inge Lehmann) observed wave refractions that she deduced had to be coming off a more dense layer below the surface. We now recognize 4 major layers\(^2\). From top to bottom, these are:

1. **inner core**, 
2. **outer core** 
3. **mantle** 
4. **crust**

The thickness and properties of each of these layers are summarized in the table and figure below:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Name</th>
<th>Depth (Thickness)</th>
<th>Composition</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Crust</td>
<td>0-35 km (5 - 35 km)</td>
<td>Rock</td>
<td>Solid</td>
</tr>
<tr>
<td>3</td>
<td>Mantle</td>
<td>35-2900 km (2865 km)</td>
<td>&quot;Rock&quot;</td>
<td>Solid-Ductile</td>
</tr>
<tr>
<td>2</td>
<td>Outer Core</td>
<td>2900-5100 km (2200 km)</td>
<td>Iron/nickel</td>
<td>Liquid</td>
</tr>
<tr>
<td>1</td>
<td>Inner Core</td>
<td>5100-6370 km (1270 km)</td>
<td>Iron/nickel</td>
<td>Solid</td>
</tr>
</tbody>
</table>

The most important thing to note about these layers is that they are distinguished on the basis of geophysical properties. We now know that there are many more finer scaled layers in the Earth’s interior (the Earth is more like a CD than an onion in terms of the scale of the layering), but the four principle layers identified through geophysics are though to be at least partly responsible for plate tectonics. The core is hot. The outer mantle and the crust are relatively cool. Heat exchange is known to produce **convection currents** from deep

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\(^2\) New studies (post 2010) are starting to resolve even more subtle layering within the Earth's core. Some are suggesting a possible sulfur-rich inner-inner core. Others imply an inner-inner core enriched in other metals like potassium or even uranium. Both of these metals have radioactive isotopes which might also explain the continued high temperatures of the inner Earth.
portion of the Earth’s mantle that flow up toward the crust and then down again as the currents cool. There is still considerable discussion about how convection actually occurs. Some studies suggest that convection currents originate at the mantle-core interface. Others suggest a stratified mantle where convection occurs at different levels. A new study (2002) has questioned the ultimate source of the heat from the core. It can’t be left over heat from the origin of the solar system. The Earth is over 4.5 billion years old (4.6 Ga) and would have cooled to a solid if there was not an additional source of heat. We now know what that source is; radioactivity. As mentioned in the footnote on the previous pages, new research has suggested that the Earth may contain an inner-inner core composed of an iron-uranium or potassium alloy rather than iron/nickel as previously concluded. Alternatively the radioactivity might just be spread throughout the Earth's interior. I personally don’t go for the uranium core idea because we do not find evidence of this in the solar system (e.g., some iron/nickel meteorites would be highly enriched in uranium were uranium a common element in planetary cores). But then again, who knows. It will be a long time before we ever get to directly sample the core of the Earth (or any other planet for that matter).

What ever the ultimate source of the heat, convection currents rise toward the surface of the Earth and when it gets near the surface, it spreads out:

The upper 100 km of the Earth (this contains the crust and the uppermost mantle) behaves relatively rigidly because it is cool. The mantle that lies below this rigid interval is much hotter and behaves in a more ductile fashion. The gist of all this is that the rigid interval (known as the lithosphere) tends to break when subjected to forces produced by convection. The ductile layer (called the asthenosphere) tends to stretch and flow.

Wegener proposed that the continents were moving relative to one another. He was right, but he did not realize that the movement involved 100 km thick plates of lithosphere rather than just the continental masses. There are many large and small lithospheric plates (see the colour diagram below) and in typical scientific fashion, most of them are named. North America for example, is riding on the North American plate as is the western portion of the northern Atlantic ocean. Everything from Oakland, CA to western Iceland is moving slowly westward at 2.5 cm/year relative to the other side of the Mid-Atlantic Ridge. Every year London and New York move about an inch further apart. The distance between Mobile and London is also increasing, but the distance between Mobile and New York stays the same (we are on the same plate).
Most geological "action" is concentrated along the edges where the plates rub past one another. These are the so-called **plate boundaries** and 3 distinct types are recognized:

1) **Divergent plate boundaries** are ridges where new oceanic crust is generated (e.g., mid oceanic ridges like the Mid Atlantic Ridge and the East Pacific Rise). These are areas where the dominant force between the plates is **tension**.

2) **Convergent plate boundaries** are linear belts where plates are pushed together (e.g., western South America, India-Asia etc.). Here the dominant force is **compression** and the ultimate result is major uplift resulting in mountain belts. As will be discussed in an upcoming lecture, oceanic crust is destroyed through a process called **subduction** along these plate boundaries. Subduction also results in deep marine trenches.
3) **Transform plate boundaries** are areas where plates slide past one another. Here, oceanic crust is neither produced nor destroyed. An excellent example of this type of plate boundary is the San Andreas fault in Southern California. Another is the even more impressive Alpine Fault of New Zealand as shown on the diagram at the top of the next page.

Source: [http://www2.nature.nps.gov](http://www2.nature.nps.gov)

It should be noted that each boundary has subdivisions. For example, convergent plate boundaries may involve the collision of two plates that both contain oceanic crust (*ocean plate-ocean plate convergence*; example- Kermandec Subduction Zone north of New Zealand; see image from www.geosci.usyd.edu.au to right), or that both contain continental crust (*continental plate-continental plate convergence*; example- Africa colliding with Europe), or where one contains oceanic crust and the other continental crust (you should be able to figure the name out for this one by know; example- South America colliding with the Pacific Plate).

As previously mentioned, each of the major tectonic plates has an official name, usually consisting of the major physiographic feature that is “riding” on the plate (e.g., we live on the **North American Plate**). You probably noticed on the last figure that residents of New Zealand live on two separate plates (the **Australian Plate** and the **Pacific Plate**). This is because a major plate boundary runs right through the middle of the country. It’s actually a transform fault boundary and is dragging New Zealand into (as the Australians love to say), “the largest semicolon in the South Pacific.”

If you look at the named plates, you might initially be surprised to learn that there is no Atlantic Plate. The boundary of the North American Plate is in the middle of the Atlantic Ocean along the Mid-Atlantic Ridge. As mentioned previously, everything west of this mountain range (including the west half of Iceland), is moving in the same direction as the rest of North America whereas everything to the east, is moving east with Eurasia. Since there is no independent movement of the Atlantic, it is not considered a separate plate. By the way, Iceland, which lies directly on the divergent plate boundary that

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3 The actual name for the Australian Plate is the **Australian-Indian Plate** as both of these continent bearing sections (as well as the ocean between them) are moving as a single body. At least for now. Your humble instructor has some ideas about what might happen in the future about this tectonic plate. Why not ask him in an upcoming class?
comprises the Mid-Atlantic Ridge, is getting wider every year in the same way that New Zealand is getting “thinner.” There is good marketing potential for a weight loss product using plate tectonics if any of you are majoring in advertising.

**Important terms/concepts from today’s lecture**

*Google any terms that you are not familiar with*

- Alfred Wegener
- continental drift
- hypothesis versus theory
- super continent(s)
- trenches and troughs
- mid oceanic ridges (incl. Mid Atlantic Ridge, East Pacific Rise)
- Paleomagnetism
- plates (tectonic)
- plate tectonics
- Crust, mantle, inner and outer core
- geophysics
- convection (currents)
- lithosphere
- asthenosphere
- divergent, convergent and transform plate boundaries
- subduction
- various tectonic plates (e.g., North American, Australia-Indian, Pacific etc.)
- Island Arc
- Magma
- Country rock
- Hot Spots