Plate Tectonics

It touches on almost all areas of geology.

We have already noted its relation to many of the topics we have discussed:

Location of earthquakes.

Location and types of volcanism.

Mountain building.

Metamorphism.

Basic idea behind the theory:

The theory states that roughly a dozen rigid lithospheric plates move with respect to each other on the surface of the planet.

Oceanic lithosphere is created at divergent plate boundaries.

At other boundaries plates are either moving into each other (convergent) or sliding by each other (transform) boundaries.

Here we will study plate tectonics in more detail:

How does the oceanic crust form?

Structure of the ocean bottom.

Structure of plate boundaries.

How do the plates move?

What drives the plate motions?

Formation and Origin of the Oceanic Crust

As we have seen, oceanic crust is created at divergent plate boundaries.

These start as one or more hot spots impinge on the underside of the lithospheric plate.

This weakens the overlying plate causing rifting.

Fractures plate along three branches.

Usually, plates move apart along two branches while the third fails.

Rifting results in very distinctive geologic features.

Can be very large features (deeper than the Grand Canyon).

Different than mountain ranges seen on land.

Failed branch of the rift zone yields a rift valley.

A good present example is the East-African rift system.

Divergent Plate Boundaries

Sea floor spreading centers.

Would you expect volcanism at such boundaries?

Tensional geologic features. (Normal faults).

Numerous earthquakes but typically not large and generally quite shallow.

Convergent Plate Boundaries

As we have seen, new lithosphere is continually being created at divergent plate boundaries.

The Earth is not getting bigger—thus if surface area is being created at some places what must be occurring elsewhere?

Oceanic crust is denser than continental crust, thus where oceanic crust meets continental crust the oceanic plate dives under the continent.

Where two oceanic plates collide, one usually dives under the other.

Associated with substantial volcanism and earthquakes.

Continent-continent collision

Continental crust is low density.

Thus it cannot be subducted very far.

Thus when two continents collide neither plate dives into the mantle.

Instead, the plates smash into each other greatly deforming and folding up the rocks near the plate boundary.

This increases the thickness of the material leading to a new mountain range.

Examples:

Transform Plate Boundaries

Regions where plates are sliding by each other.

Examples?

Associated geologic activity?

Age of the Oceanic Crust

The oceanic crust is continually being recycled.

Crust is generated at midoceanic ridge.

Moves away from ridge.

Eventually oceanic crust is consumed at a subduction zone boundary.

Because of this, oceanic crust is young.

Oldest oceanic crust is ~200 million years old.

In contrast, continents do not subduct, basically floating around on the asthenosphere.

Continental rocks can be much older.

Measuring Plate Motion

The theory of plate tectonics gained acceptance in the 1960s even before we could actually measure the motion of the plates.

However, since that time it has become possible to directly measure the actual plate motions.

With the use of GPS one can determine ones location on the surface of the planet to within feet.

With GPS the motion of the continents has been directly measured.

Rather direct proof that plate motion does actually take place!

Hot Spots

Hot spots appear to be regions where thermal plumes from deep within the Earth's interior impinge on the base of a lithospheric plate.

Sometimes these plumes can "burn through" the overriding plate creating volcanoes.

If they reach the surface they can become islands.

The hawaiian islands are the classic example.

If we look at the hawaiian islands we see that their ages increase to the northwest.

Only the big island currently has active volcanism.

A new island is currently forming to the southeast of Hawaii.

In fact, the hawaiian islands are but part of a larger chain of islands, seamounts and guyots running to the northwest and north to the Aleutian trench.

(Midway, the site of a decisive WWII sea battle is part of this chain).

These have been dated and found to become older to the northwest.

Islands created as the Pacific plate moved over the hot spot which periodically burned through the plate.

Given this information, which direction is the Pacific plate currently moving?

Distance and age difference between the islands can be used to determine the speed of motion.

For example:

If we can directly measure the motion of plates, why measure the speed from hot spots?

What Causes Plate Motions?

The mechanism responsible for the motion of the lithospheric plates is currently an unresolved issue.

Several mechanisms have been proposed:

1. Mantle Convection

   —Hess's original proposed mechanism for sea floor spreading.

2. Ridge-Push

3. Plate Sliding

4. Slab-Pull

2. Ridge-Push

If plates are moved by magma forcing the plates apart what kind of stresses would the rocks in the plates be put under?

If this is the case what kind of features would we expect to see?

3. Plate-Sliding

Because it is warm and thus less dense the oceanic crust is raised at the midoceanic ridge.

Away from the ridge it cools off and sinks.

Further, cooling away from the ridge results in a thickening of the lithospheric plate.

For both these reasons the plate at the ridge is significantly higher than nearer the edge of the continents.

Plate can thus slide downhill much like a child sliding down a slide.

4. Slab-Pull

At subduction zones oceanic plate dives down into the mantle.

Plate is cold relative to surrounding mantle --> more dense.

Gravity thus pulls the descending slab downwards.

Pulls the rest of the plate with it.

Thought to be more powerful than plate-sliding.

May explain why plate motions into subduction zones tends to be faster than at divergent boundaries.

Geologic Landforms

The Earth is a geologically active planet.

Leads to a variety of interesting landforms.

What drives this activity?

Two major heat engines are operative:

Internal energy within the Earth.

External energy (solar energy).

Each of these sources drive different aspects of the geologic activity we see.

Landforms can be split into two major categories:

1. Constructive Landforms (Part II in the textbook)

Regions which are currently being built up.

Examples?

Most of these processes are driven by internal energy within the Earth.

2. Destructional Landforms (Part III in the textbook)

Regions which are currently being eroded away.

Examples?

Most of these processes are driven by energy from the sun.

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Destructional Processes

Weathering

Mechanical

Chemical

Wind

Coastal Processes

Mass Wasting

Mass wasting is the motion of material under the influence of gravity alone.

Glaciers

Glaciers are the 2nd most important transport agent after rivers (transport ~7–8%).

Glaciers form distinctive “U”-shaped valleys.

Rivers

Rivers transport most of the material eroded off of the continents (~85%).

Rivers often fed by mass wasting off its valley.

However, they can also erode material themselves.

Rivers usually form distinctive “V”-shaped valleys