University of Anbar

College of Science

Department of Applied Geology

Tectonics

Title of the lecture

What drives plate motion and its velocity

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What drives plate motion and its velocity

When geologists first proposed plate tectonic, they thought the process occurred simply because convective flow in the asthenosphere actively dragged plates. Thus, early images depicting plate motion showed simple convection cells beneath mid-oceanic ridge. Generally, geologists came to the conclusion that convective flow within the asthenosphere does not drive all plate motion, though, it may play a role. Today, geologists favor the hypothesis that plates move primarily in response to two force, ridge-push force and slab-pull force.

Ridge-push force:

This force develops because mid-oceanic ridges lie at a higher elevation than the adjacent abyssal plain of the ocean Fig 1. To understand ridge-push force, imagine you have a glass containing a layer of water over a layer of honey. By tilting the glass momentarily and then returning it to its upright position, you can create a temporary slope in the boundary between these substances. While the boundary has this slope, gravity causes the elevated honey at the lower elevation. The geometry of a mid-oceanic ridge resembles this situation. The surface of the sea floor is higher along a mid-oceanic ridge axis than in adjacent abyssal plain, because the lithosphere underlying the ridge is thin and warm, and thus less dense and more buoyant than the lithosphere beneath the abyssal plains.

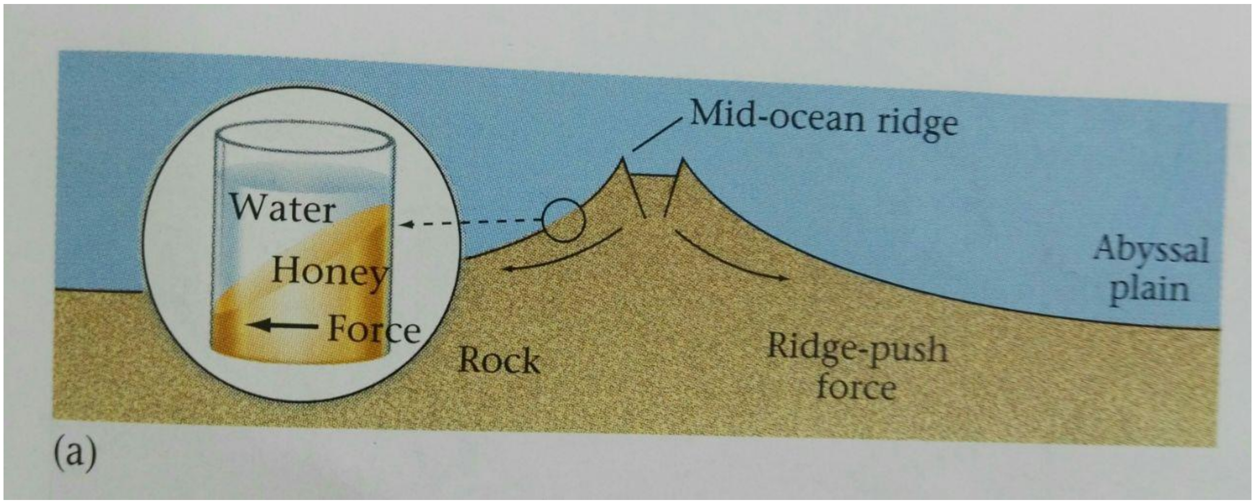

Fig. 1. The elevation of the ridge causes an outward ridge-push force that derive the lithosphere plate away from the ridge

The surface of the sea floor overall slopes away from the ridge axis. Gravity causes the elevated lithosphere at the ridge axis to push on the lithosphere that lies farther from the axis making it move away. As lithosphere moves away from the ridge axis, new hot asthenosphere rises to fill the gap; it then moves away, cools, and itself becomes lithosphere. During this process, some of the rising asthenosphere melts, generating magma that then rises, solidifies, and forms the rock of the oceanic crust.

Slab-pull force:

The force that downgoing plates (also called downgoing slab) apply to oceanic lithosphere at a convergent margin, arises simply because lithosphere that was created more than 10 million years ago is denser than asthenosphere, so it can sink into the asthenosphere Fig. 2. Thus, once an oceanic plate starts to sink, it gradually pulls the rest of the plate behind it, this pull is the slab-pull force.

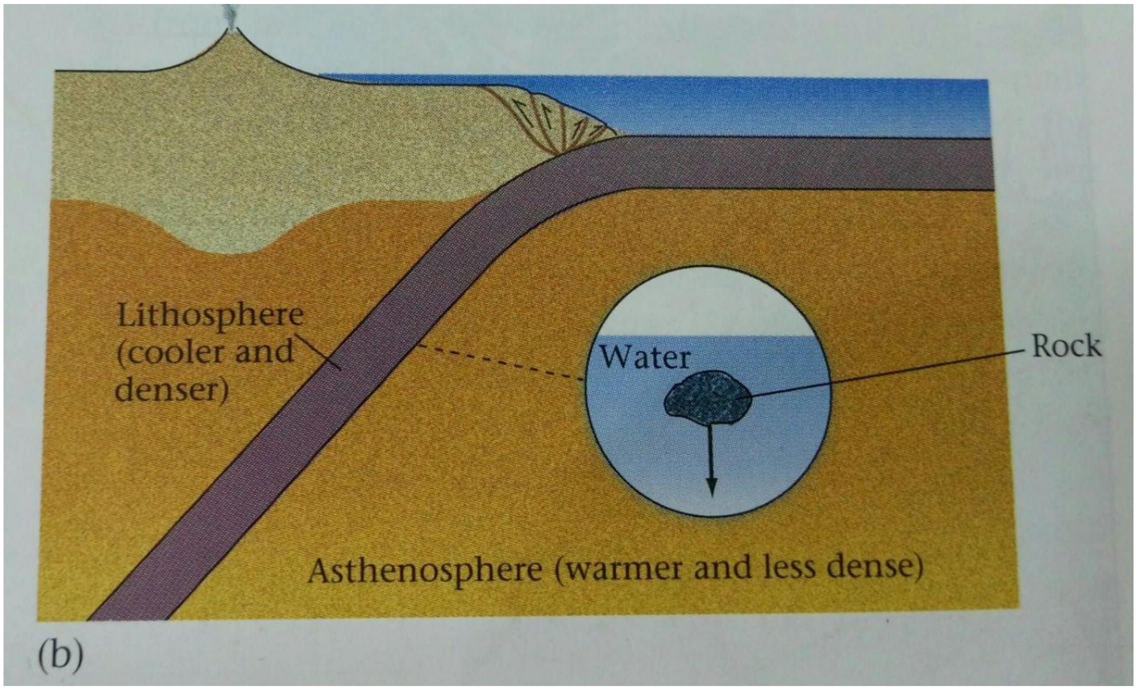

Fig 2. In this cross section illustrating slab-pull force, the oceanic plate is denser than the lithosphere, so it sinks into the asthenosphere

Now let´s summarize our discussion of force that derive plate motion. Plates move away from ridge, in other words sea floor spreading occurs, in response to the ridge push force. Old and cool oceanic lithosphere, bring denser than asthenosphere, sink down into the asthenosphere, creating slab-pull force that tows the rest of the plate along with it. But ridge push and slab pull are not the only force acting on the plate-movement of asthenosphere probably exerts a force on the base of the plate. If this force happens to be in the same direction the plate is already moving, it can speed up the motion, but if the force is in opposite direction, it might slow the plate down. Also, where one plate grinds against another, as occurs along a transform fault or at the base of an overriding plate at a convergent margin, friction may slow the p0late down Fig. 3. Since plate motion does occur, ride-push and slab-pull forces must be greater than all the resistance forces combined.

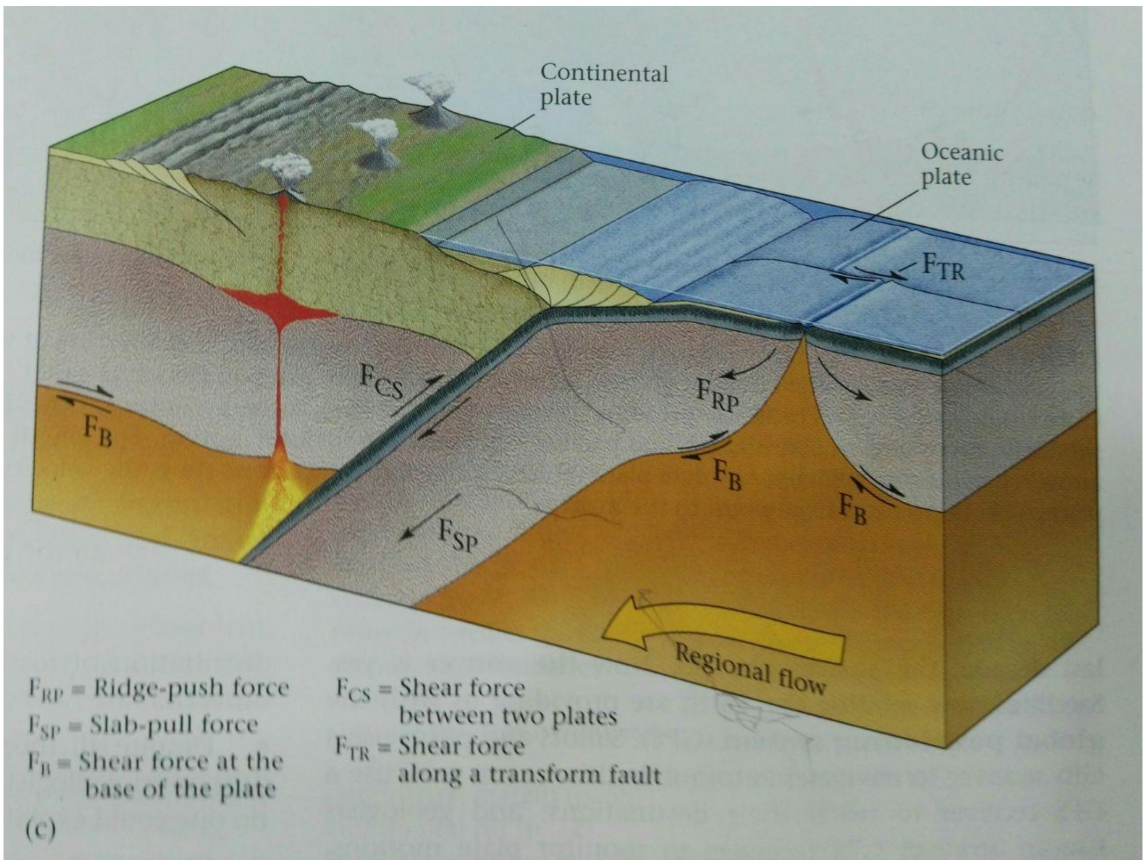

Fig. 3. In addition to ridge-push and slab-pull, the plates feel shear force along their base as they move into asthenosphere.

The velocity of plate motions

The geologists use two different frames of reference for describing plate velocity (velocity = distance/time). If we describe the movement of plate A with respect to plate B, then we are talking about relative plate velocity, but if we describe the movement of both plates relative to fixed point in the mantle, such as a mantle plume, then we are speaking of absolute plate velocity.

Geologists measure the distance of a known magnetic anomaly from the axis of a mid-oceanic ridge, and calculate the velocity of a plate relative to the ridge axis by applying the equation: plate velocity = distance from the anomaly to the ridge axis / age of anomaly. The velocity of the plate on one side of the ridge relative to the plate on the other is twice this value. The track of hot-spot volcanoes on the plate movement over the plume provides a record of the plate absolute velocity and indicates the direction of movement Fig. 4.

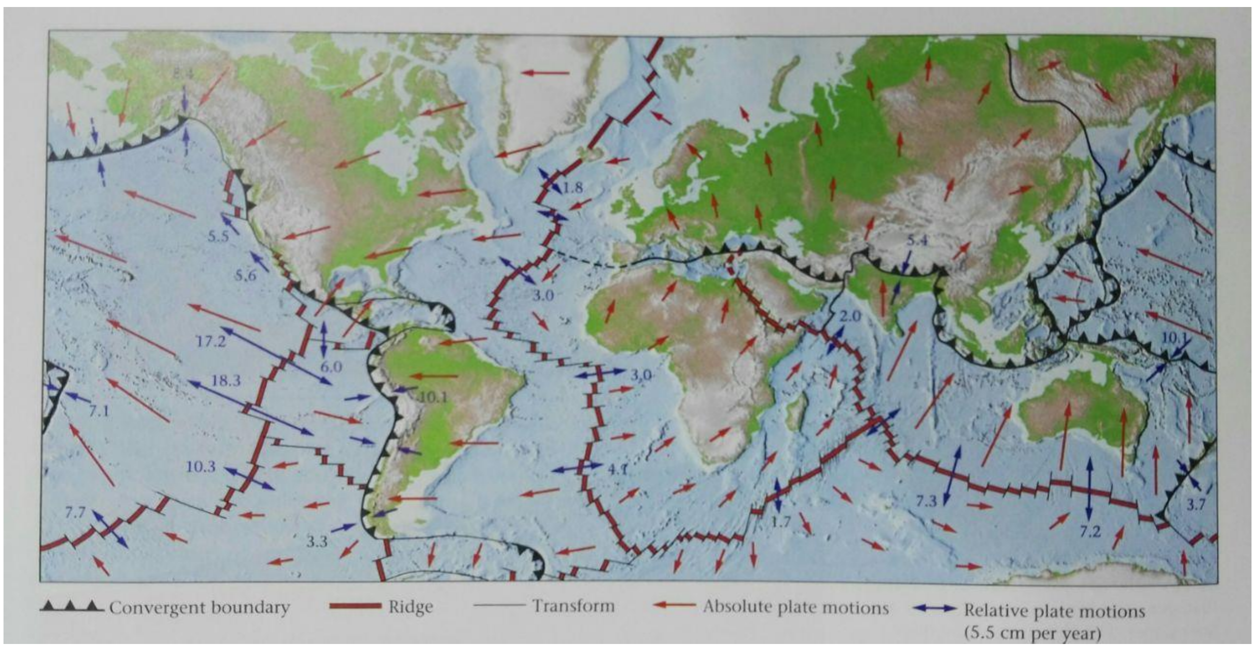

Fig. 4. Relative plate velocities: the purple arrows show the rate and direction at which the plate on one side of the boundary is moving with respect to the plate on the other side. Outward-pointing arrows indicate spreading (divergent boundaries), inward-pointing arrows indicate subduction (convergent boundaries), and parallel arrows show transform motion. The length of an arrow represents the velocity. Absolute plate velocities: the red arrows show the velocity of the plate with respect to a fixed point in the mantle.

The Hawaiian-emperor seamount chain, for example, defines the absolute velocity of the Pacific Plate. Note that the Hawaiian chain runs northwest, while the Emperor chain curves north-northwest (the bend occurs at Midway Island) Fig. 5. Radiometric dates of velocity rocks from Midway indicate that they formed about 40 million years ago. Based on the calculations such as those describe above, geologists have determined that relative plate motions on earth today occur at rates of about 1-15 cm per year. But these rates, while small, can yield large displacements given the immensity of geologic time; in a million years, a plate can move 100 km. now the geologists use an array of GPS receiver to monitor plate motions.

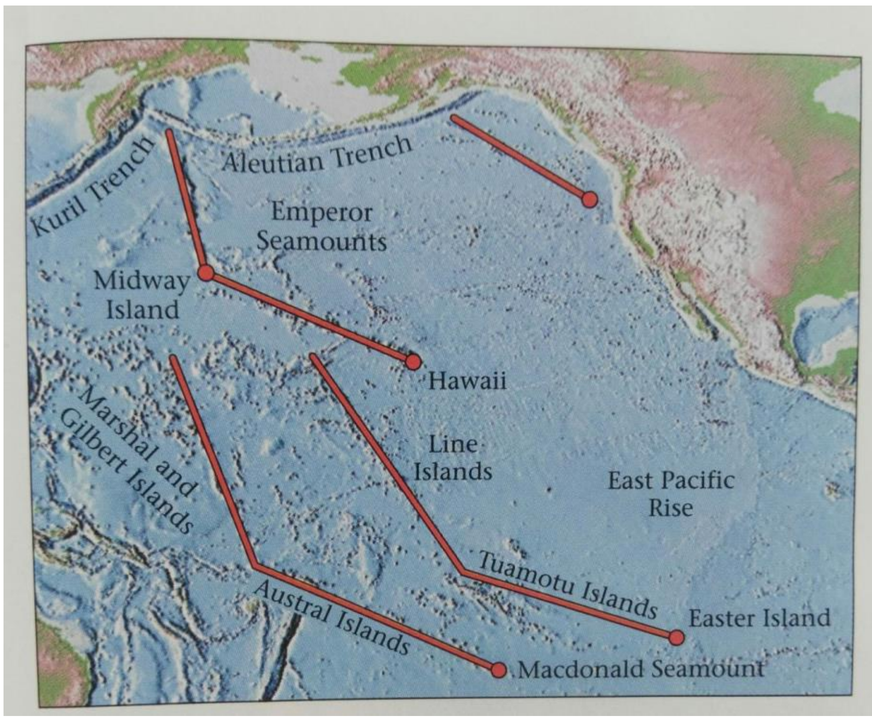

Fig. 5. Hot-spot tracks in the Pacific Ocean. The small dotes represent islands or seamounts. The straight lines indicate the geometry of the tracks. Note that the chains have a 40° bend in them, resulting from a change in the direction of motion of the Pacific plate about 40 million years ago.

The reference

Stephen, M., (2004) Essentials of geology, first edition, printed in United State of America, P 536.