GY 111 Lecture Note Series
Faults

Lecture Goals
A) Fault terminology (recap of brittle deformation)
B) Types of faults
C) Faults on maps

Reference: Press et al., 2004, Chapter 11; Grotzinger et al., 2007, Chapter 7: p 158-160
GY 111 Lab manual Chapter 7

A) Fault Terminology
Last time we were discussing ductile deformation. Recall that this form of rock alteration results in folds. This time, we concentrate on the other type of permanent alteration; brittle deformation. Brittle deformation results in the breaking of rocks. It normally occurs in rocks that are near the surface of the Earth (and therefore in an environment of low confining pressure), or in rocks that are naturally strong and which therefore are less likely to "bend" (e.g., thick beds of quartz arenite sandstone, limestone or dolostone). Rocks that are prone to brittle deformation break when subjected to stress. When rocks break, one of 3 things can occur:

1) cracking/fracturing
2) jointing
3) faulting

We've already discussed cracking/fracturing and jointing (at least as much as I think we need to in GY 111), but we really need to spend this lecture discussing faulting. Faulting occurs when there is movement along the plane of breakage induced by brittle deformation. This is an extremely important aspect of geology because the slippage is usually accompanied by the sudden release of "energy" which we call an earthquake. Earthquakes are one of the Earth's most destructive events with annual damage costs in the hundred of millions to billions of dollars. Even worse, hundreds to thousands of deaths per year can be directly linked to "slippage" along faults. We will devote an entire lecture to earthquakes very soon, but for today, I'd like to stick with just the geological "facts" about faults. Let's start with basic fault terminology. Consider the following block diagram cartoon:
The first of the block diagrams shows a tranquil scene near a farmhouse in the middle of nowhere. The only excitement here is when the 9:15 express train passes by the farmhouse. But there is something stirring beneath the surface of the Earth. A crack (actually a plane of fracture) lies close to the farmhouse and underlies the railroad. Here, tensional stress is building up. All rocks have a certain amount of elasticity to them. Moreover, they are rather resistant to stress. You have to overcome inertia and friction along the plane of fracture before there is movement. This is true for all earthquakes; they only occur when the force of stress overcomes the forces of elasticity, friction and inertia. When it occurs (and eventually it will), there will be a sudden release of all the built up "energy" and movement will occur along the plane of fracture (now called the fault plane). The point on the fault plane where the initial movement occurred is where most of the "energy" appears to radiate from. This is called the earthquake focus. The "energy" is emitted in a series of pulses that radiate away from the focus in all directions. The "energy" that moves upward hits the point on the surface of the Earth directly above the focus first. This point is called the epicenter and it is usually the place where most of the damage in an earthquake occurs.\footnote{But not always. In some earthquakes, there is less damage nearer the epicenter than away from it. This is usually a result of bedrock or sediment composition. Stay tuned for details in a later lecture.} The "energy" that is released in an earthquake travels as shock waves that geologists refer to as seismic waves. There are several different types of seismic waves that we will discuss in more detail than you would ever imagine in a future lecture. For now, back to the previous cartoon.

There are several key morphological components to the post earthquake block diagram on the previous page. They are identified on the next block diagram (as is the focus and epicenter of an earthquake). Each side of the fault plane (labeled 2) represents a separate fault block (labeled 1a and 1b). If you know the orientation of the fault plane, you can add a compass direction to the fault blocks (e.g., eastern fault block, southern fault block etc.). The diagram also shows the fault line\footnote{The fault line is the line of intersection between the fault plane and the earth's surface, which is more or less a horizontal plane. If you have understood the last several lectures, you would have been able to predict that the intersection of an inclined plane (fault plane) with a horizontal plane (Earth's surface) would result in a horizontal line (Fault line). If none of this makes sense, it's because you (1) have not been coming to class, or (2) you have been sleeping in class, or (3) you really don't understand anything about basic geometry.} (labeled 3) and the fault scarp (labeled 4).
4). The fault scarp is the cliff that represents the portion of the fault plane exposed above the surface of the Earth. Hey, want a piece of good advice? If anyone ever tries to sell you a chunk of real estate adjacent to a fault scarp or a fault line, DON'T buy it. Believe it or not, lots of people have and some have even built houses near them. In California, a bunch of not-so-insightful engineers even built a nuclear power plant on top of the San Andreas Fault line (see image at the top of the previous page from pubs.usgs.gov). Fortunately, they couldn't get a permit to power up the plant.

There are another couple of terms that you need to hear about even though they are largely archaic. They come from the golden days of mining (1800's) when geologists had to explain to miners where to blast/dig for valuable ores. Faults are frequent targets for economic geologists because they act as pathways for hydrothermal fluids. The problem is that underground, it's hard to keep track of directions. So mining geologists came up with the concept of footwall (the fault block that your feet are standing on) and the hanging wall (the fault block that you would hang a lantern on). The nice thing about these two annoying terms is that they are independent from the orientation of the fault plane. The diagram below attempts to show how orientation and footwall/hanging wall terminology works.

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**B) Types of faults**

The type of fault you get when rock breaks depends upon the type of stress they were experiencing and the direction of movement along the fault plane. Geologists recognize two distinct classes of faults, (1) **dip slip faults**, where movement is in the dip direction of the fault plane, and (2) **strike slip faults**, where movement is in the strike direction of the fold. You will (hopefully!) recall the terms strike and dip from earlier lectures about inclined bedding and folds. If you think about it, a fault plane is just an inclined plane.

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3 These are geologists that search for economic minerals like gold, silver, mercury, diamonds, copper etc. Economic minerals are largely mineral ores that are important to the economies of nations. The difference between economic geologists (those that make a lot of money for the mining industry) and petroleum geologists (those that make a lot of money for the petroleum industry) is how you are likely to die. Economic geologists commonly die in mining accidents, helicopter crashes and bear attacks. Petroleum geologists die from heart attacks and cholesterol (too much rich food), and road rage incidents while trying to drive home from Houston during rush hour.

4 Or from which to hang a bad geologist.
so it is obvious that you can provide strike and dip orientation of a fault plane. In the cartoon above, movement was down the dip direction of the fault plane. This is the only way that fault blocks will shift when tension is the operating stress. Once again, if you think about it, this should make sense. The act of tension stretches the rocks, and even though the rocks have broken (brittle deformation), the rocks have still stretched from their original length (see part A of the next diagram). This type of dip slip fault is called a normal dip slip fault (or a normal fault for short). Had the operating force been compression, the direction of movement along the fault plane would have been the exact opposite. The rocks would have been shortened and the sense of motion would have been up the dip direction of the fault plane (see part b of the next diagram). This type of dip slip fault is called a reverse dip slip fault (or a reverse fault for short) and they are common components of mountain belts around the planet.

![Diagram of normal and reverse dip slip faults](image)

Structural geologists keep track of the type of dip slip fault by the relationship of movement between the footwall and the hanging wall. To them, a normal fault is one where the hanging wall has moved downward relative to the footwall. A reverse fault is one where the hanging wall has moved upward relative to the footwall (see previous cartoon).

Strike slip faults occur as a result of shear stress and like dip slip faults, there are two types. It is called a left lateral strike slip fault if the movement results in a leftward displacement or a right lateral strike slip fault if the movement is rightward. This is more difficult to explain than to draw, so check out the diagram to the right to see how the nomenclature works. You imagine yourself looking across the fault line to see how objects appear to have shifted. In the cartoon example
above, the railroad tracks look like they have moved to the right\(^5\) so that makes the fault a right lateral strike slip fault. I should point out now that this method of naming faults doesn't really give you an absolute sense of motion. You can't tell if the fault block to the right of the fault plane has moved or the one to the left has move. Both could have moved. We speak of \textit{relative} motion when we talk about fault slippage. Case in point; the San Andreas Fault in southern California (see graphic to left from www.berkley.edu) is a right lateral strike slip fault. To the residents of La La Land\(^6\), the rest of North America\(^7\) appears to be moving to the right. As it turns out, North America and Los Angeles are both moving to the north-northwest, but at a slightly skewed angle to one another. The San Andreas Fault is the plane where the shear stress between the two plates is released.

I almost forgot to mention that there is also a fault that has movement in both the strike and dip direction of the fault plane. These faults are called \textit{oblique faults} for reasons that are so obvious I won't even mention them.

\section*{C) Faults on maps}
I think it's safe to say that interpreting faults on geological maps is one of the least favorite activities for students in a GY 111 class (right up there with interpreting folds on maps). The problem is simply one of perspective. You have to be able to imagine things in 3 dimensions. If time permits this year, you will have a chance to try this during the last lab session. If not, the following diagrams should help you to appreciate how faults affect geology and how they are labeled on geological maps. These diagrams come directly from your GY 111 lab manual.

\subsection*{1) Normal Fault}

\footnote{\(^5\) It doesn't matter which side of the fault you are on. The relative sense of movement is the same.}
\footnote{\(^6\) AKA Los Angeles.}
\footnote{\(^7\) AKA the good part.}
2) Reverse Fault

3) Right Lateral Strike Slip Fault

4) Oblique Slip Fault
Important terms/concepts from today’s lecture

(Google any terms that you are not familiar with)

brittle deformation (again!)
earthquake
seismic waves
fault
fault line
fault plane
fault blocks
fault scarp
hanging wall
footwall
San Andreas Fault
epicenter
focus
dip slip faults (normal and reverse)
strike slip faults (left lateral and right lateral)
oblique slip fault