19. Crustal Deformation I

Introduction

Although the Earth is 4.6 billion years old, most of the oldest rocks on Earth have long since vanished, so we see more younger rocks than older rocks. So the older rocks must have been removed by processes like weathering, erosion, and the effects of plate tectonics. Some rocks were deeply buried and turned into metamorphic rocks.

Where do we see deeply formed metamorphic rocks that now form mountain ranges?

All over the world, rocks that were once perfectly flat lying are often inclined at a range of angles or are warped. They are also often intensely fractured and may contain abrupt breaks called ______________ across which one block of rock slides past another block.

These different types of features are called deformation features. We need to know how to describe them, how they formed, and what they can tell us about the geologic history of a region.

The field of geology that considers deformation of rocks is called ___________________. It is vital for understanding what happens to rocks in response to the huge forces that occur inside the Earth's crust as a result of plate tectonics.

Rock Deformation

When we looked at metamorphic rocks, we learned why a foliation develops in a rock.

Foliation is produced by forces pushing against rocks, but the force cannot be the same from all directions. To produce a foliation, we need to have forces being different from different directions- this is called a ____________________.

This gets produced by the interactions and motions of the tectonic plates. These motions produce stresses that we call tectonic stresses, which are different from different directions, resulting in differential stress. As a result, rocks get deformed.

Rock deformation refers to all the different ways that rocks respond to squeezing, stretching, or any other kind of tectonic force.

This deformation may involve:

1. Buckling and bending of rocks, which we call ________________; or
2. Cracking and breaking of rocks, which we call ____________________.

Examples: ________________ and ________________.

Rocks may also change their shape or volume in response to differential stresses.
Pressure, Stress, and Strain

Stress and pressure are both a measure of forces being applied to rocks inside the Earth. So how are stress and pressure different from each other?

Pressure: ________________________________ (also called ______________)  
Stress: ________________________________

How is stress defined in terms of force? ________________________________

Whenever a stress is applied to a rock, something happens inside the rock. It starts to deform, and the rock is said to have undergone ________________.

Definition of strain: ________________________________

The reason for this is that rocks are not infinitely strong. If you push on it hard enough, something happens inside the rock, either at the grain scale or the atomic level, to produce strain. So rocks have a limit to their strength.

Definition of rock strength: ________________________________

The tectonic stresses produced inside the crust are big enough to deform rocks. But they are applied to rocks over such a long period of time that we rarely see deformation happening in rocks. What we see today happened a long time ago.

If a uniform pressure is applied to a rock (in other words one that is the same from all directions), the only strain that the rock can undergo is a decrease in volume, but no change in shape.

Example of a typical source of uniform pressure in the Earth: ________________________________

What would happen to a cube of rock under the influence of a uniform pressure?

______________________________

In order for a rock to change its shape as it deforms, a differential stress must be applied to the rock. The three types of differential stress are:

• _______________________ - pushes on rock and causes it to shorten or compress.

• _______________________ - pulls on rock and causes it to stretch or extend.

• _______________________ - slides the rock in opposite directions from each side and causes it to change its shape (like shearing a deck of playing cards).

Types of Deformation

The way in which a rock responds to stress is not always the same. Some rocks deform by bending whereas others responded by breaking. What was different about these rocks that caused the deformational style to be so different?
First, let us define what the different types of deformation behavior are. There are essentially three:

1. ______________ deformation - if you apply force to a rubber ball and then remove it again, it deforms while the force is applied, but goes back to its original shape after the force is removed. This is called elastic deformation. Rocks can also behave elastically. They start to deform as stresses are applied, but return to their original shape if the stress is removed.

So is elastic deformation PERMANENT or RECOVERABLE?

2. ______________ deformation - this is what happens to rocks when they can no longer behave elastically. They fracture.

Examples of fractures: ______________ and ______________

3. ______________ deformation - some rocks deform by flowing or bending instead of fracturing. This is called ductile deformation, or ________________, which is how ______________ develop.

Controls on Deformation

Whether a rock is brittle or ductile depends on the conditions under which deformation occurs. A certain type of rock may be brittle under one set of conditions but ductile under another set of conditions (i.e., temperature, pressure, rock type, and strain rate).

• Temperature - as temperature increases, do rocks become:

LESS BRITTLE or MORE BRITTLE?

So they stop fracturing and instead start to flow. They become ductile.

Where in the Earth are rocks the most brittle? ______________

Rocks get more ductile with depth due to the _________________.

• Pressure - greater pressures cause rocks to be more ________________, which adds to the temperature effect deeper and deeper into the Earth.

• Rock type - the composition of the rock is important because different materials behave differently at a particular temperature and pressure. For example, feldspar behaves in a ductile manner at higher pressures and temperatures than is needed for quartz. So is feldspar more ductile than quartz deeper down in the Earth or higher up?

DEEPER or SHALLOWER?

• Strain rate - the rate of deformation has a great impact on the type of deformation that occurs in rocks.

Does brittle deformation occur for fast or slow strain rates?

FAST or SLOW?
The same material will deform differently depending on strain rate. In the Earth's crust, high strain rates, like __________________ and blasting with explosives causes brittle deformation, or fracturing. Low strain rates, such as are produced by tectonic forces, are more likely to cause ductile deformation.

**Brittle Structures**

Brittle structures are fractures, such as **joints** and **faults**, which are produced because of tectonic stresses. The intrusion of magma into rocks can also create brittle fractures such as **dikes** and **sills**.

**Joints**

Joints are fractures that form very close to the Earth's surface, and indicate that the rock has been stretched by tensional stresses. When the rocks are stretched far enough, the elastic limit is exceeded and the rocks fracture. The two sides of the joint simply pull apart from each other.

Joints can be found in most rocks. They generally open by no more than ___________________. They often form dense networks that leave rocks intensely fractured. Joints are useful because they can tell us about the stresses that produced them.

Joints form ___________________ to the direction of maximum tensional stresses.

When a number of joints form parallel to each other, they produce a ____________.

A special type of joint called a ___________________ forms as lava cools and contracts to form an igneous rock. These joints arrange themselves into polygonal shapes, forming long columns of rock.

**FINAL QUESTION:**

What rock type commonly forms these joints as lava cools?

____________________