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Silly Putty™—Brittle, Ductile, *AND* Elastic

http://www.iris.edu/hq/inclass/lesson/565

Version 0.2 (2012)

Incorporated Research Institutions for Seismology

OVERVIEW

This activity extends student understanding of the deformation a rock undergoes as a result of stress, plus several factors that contribute to the behavior. Students work in pairs to explore deformation using Silly Putty™. The student worksheet ties the deformation to the concepts of faulting (earthquakes) and folding, and ultimately concludes with an opportunity for students to design their own deformation experiment. Inclusion of the "Marble Tongs" activity is not required, but reinforces the concept that rock can be elastic.

This activity is designed to take 15 minutes as a demonstrated inquiry, or 45 minutes as a structured inquiry.

Beginner

15 min → 45 min

Materials

Whole Class | Demo

Figure 1: *Dr. Robert Butler demonstrating the ductile quality of Silly Putty™.*

LEARNING OBJECTIVES:

Students will be able to:

- Demonstrate the three types of stress using Silly Putty™.
- Define strain in a written paragraph.
- Demonstrate brittle, ductile and elastic deformation using common objects.
- Demonstrate that rocks can be elastic with Marble Tongs.
- Describe the cause of an earthquake using the terms stress, strain, elastic rebound, fracture, potential energy, kinetic energy.

TABLE OF CONTENTS

Materials

- Silly Putty™ for each pair of students
- Class set of worksheets
- Mable Tongs. Refer to previous "Rocks are Elastic" activity: www.iris.edu/hq/inclass/lesson/28)

Video resources for Brittle, Ductile, Elastic

Video Lecture on Silly Putty™ analogy
http://www.iris.edu/hq/inclass/video/102

Big Hunk© models brittle vs. ductile (related demo and video lecture.)
www.iris.edu/hq/inclass/video/65

Elastic Rebound Demonstration using a Yardstick (brittle and elastic behavior)
http://www.iris.edu/hq/inclass/video/64

Can Rock Bend? Marble Tongs elastic rebound demonstration (Figure 2)
www.iris.edu/hq/inclass/video/67

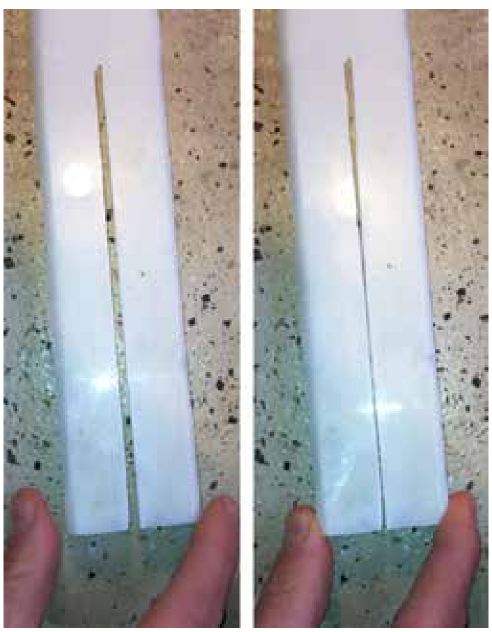


***Figure 2**: Squeezing the Marble Tongs to show how rock can bend. Although not required for this activity, the Marble Tongs provide a good linking activity to show the elastic behavior of rock. In this case, when the rock is pinched it stores elastic energy until the pinch is removed and it rebounds to its original position.*
Question #5 on the Student Worksheet asks to students to compare and contrast the rock with the Silly Putty. This is meant to avoid generating misconceptions when working with models, by creating a list to emphasize BOTH like and unlike features, as well as strengths and limitations, of the model and reality.

VOCABULARY

Brittle deformation— Irreversible strain where the material fractures/ breaks in response to stress.

Compression stress— the stress component perpendicular to a given surface, such as a fault plane, that results from forces applied perpendicular to the surface.

Ductile deformation— When rocks deform in a ductile manner, they may bend or fold, and the resulting structures are called folds.

Elastic strain— a form of strain that, when the deforming force is removed, the distorted body returns to its original shape and size. Earthquakes are caused by the sudden release of energy as strain is overcome and the sides of the fault move past each other. This form of energy release is the only kind that can be stored in sufficient quantity to be regionally damaging.

Fault— a fracture or zone of fractures in rock along which the two sides have been displaced relative to each other.

Fold—A bend or flexure in a rock that is a result of permanent deformation.

Shear stress — the external force acting on an object or surface parallel to the slope or plane in which it lies; the stress tending to produce shear.

Strain— Strain is defined as the amount of deformation an object experiences compared to its original size and shape.

Stress— Stress is defined as force per unit area. It has the same units as pressure, and in fact pressure is one special variety of stress.

Tension—refers to a stress which stretches rocks in opposite directions. The rocks become longer in a lateral direction and thinner in a vertical direction. One important result of tensile stress is jointing in rocks.

LESSON DEVELOPMENT

This activity is structured using the "**OPERA**" system (Appendix B) and additionally offers leveled questions that will move your students from evaluating their knowledge to synthesizing new information.

TIP

Time saving option: If your instructional time is tight, the instructor can also complete this activity as a demonstrated inquiry in the front of the class.

Open

A. Allow students to "play" freely with the Silly Putty™ for a few minutes to get a "sense" of the material they will be working with.

B. Once explored, they should focus on performing the various tasks assigned later in the lesson.

Prior Knowledge

Ask students to respond to Questions #1 & #2 on their worksheets in small groups.

ANSWER: Discuss the groups' responses. Answers will vary but emphasize that stress is the force acting on an object while the strain is the change in the size, shape or volume of an object as a result of stress (e.g. my fingers put stress on the putty; the putty responds with visible strain.)

Explore/Explain

1) Ask students to list different ways they could apply stress to the Silly Putty™?

ANSWER: There are no right or wrong answers. As you collect answers on the board, begin to lead students to see that all their suggestions generally fall into the three categories of Compression Tension, and Shear stresses (see Teacher Background). Use this as an opportunity to define these terms. Students should complete question 1 on their worksheet.

2) Next, instruct students to complete Question #4 on their worksheets.

3) Record the results of the structured inquiry in a table on the board. Discuss. During the discussion introduce the following vocabulary (see also Vocabulary on previous page):

Ductile deformation is irreversible strain seen in bent or folded rock strata.

Brittle deformation occurs when the material fractures or experiences irreversible strain where the material is separated into two or more pieces. Also, remind them of the reversible strain or Elastic deformation they saw in the marble tongs demonstration (repeat the demo if necessary). Here, the material will return to its original position when the stress is removed.

MODEL FOR THE ASTHENOSPHERE?

There are many misconceptions about the asthenosphere.
The Silly Putty demonstration addresses the viscoelastic properties of the asthenophere, the region of Earth's mantle below the lithospheric plates that is hot and ductile, not brittle like the lithosphere. Silly Putty is used as a model to show how the asthenosphere is elastic when exposed to short-duration forces (like seismic waves) but plastic when exposed to long-duration forces (like the load of the Hawaiian Islands on the Pacific Plate)

Reflect

1. Instruct students to reflect on the strain they saw in the Silly Putty™ and the strain they saw in the marble tongs (figure 2) and then complete Question #5.
2. Discuss how some things tend to be more brittle and some things tend to be more ductile in their behavior. This is a good place to ask students for other common examples of brittle (e.g. soda crackers), ductile (e.g caramel candies) and elastic (e.g. chewed gum) materials.

Apply/Assess

Instruct students to complete Questions #6, #7, and #8.

APPENDIX A

Teacher Background

The rocks that make up Earth's outer shell are continually subjected to stresses. Stress is the amount of force applied across the area of an object. There are three types of stress affecting rocks: they can be squeezed by compressional stress, stretched by tensional stress, or sheared by shear stress (Figure 3). In response to the ongoing stress, rocks show strain, reflected in changes in size, shape, or volume.

The graph below illustrates the concept that as stress increases, rocks respond by passing through three successive stages of deformation.

1. Initially rocks respond elastically. Elastic deformation is reversible. This means that when the stress is removed the material will return to its original position or shape. A common example of elastic deformation is the change in shape a rubber band experiences when you pull on it. Once this stress is removed, the rubber band returns to its original shape.
2. As rocks pass their elastic limits they experience ductile deformation. Ductile deformation is irreversible. This means that when the stress is removed the deformation remains. A common example of this is applying stress to a copper wire. As stress is applied, the wire's shape is changed as it bends. When the stress is removed, the wire remains bent.
3. Finally, when a rock undergoes irreversible strain it fractures, and the material is separated into two or more pieces. A common example is a piece of uncooked spaghetti. When enough stress is applied, the strain becomes so great that the spaghetti breaks into two or more pieces.

Evidence that deformation has occurred in the past can be found in places where rock layers are exposed at the surface, such as in road cuts. For example, Figure 5A shows a person standing in front of a fault. A fault is a fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture. This fracturing of the rock produces an earthquake, or the sudden release of energy that has accumulated elastically in the rock over a long period of time. Figure 5B shows a fold in the rock layers. Folds form when rocks bend or undergo ductile deformation over a prolonged period.

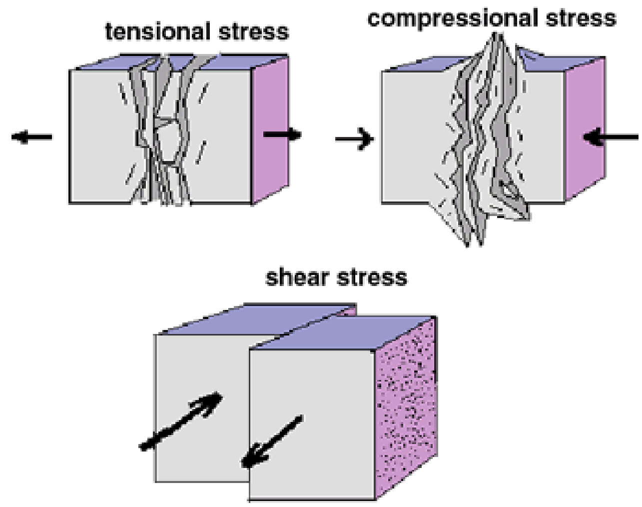


Figure 3. Rocks are subjected to three types of stress. (Image courtesy of Michael Kimberly, North Carolina State Univ.)

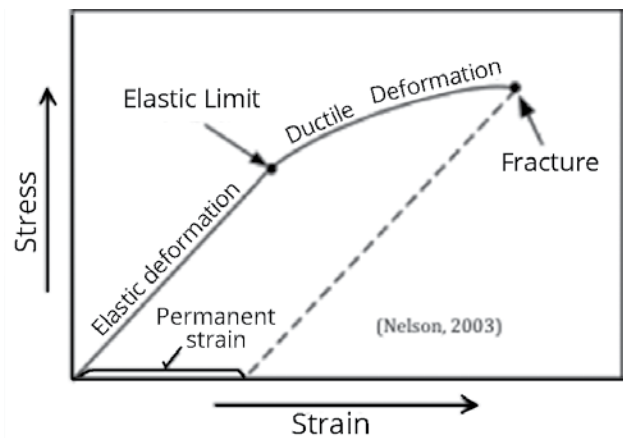


Figure 4. Rock passes through three successive stages of deformation as it is subjected to increasing stress.

***Figure 5**. Figures from page 4 of the Student Worksheets.*
A. Road cut revealing a normal fault, down on the left.
B. Folds in layered metamorphic rock outcrop.

APPENDIX B

OPERA Learning Cycle

A learning cycle is a model of instruction based on scientific inquiry or learning from experience. Learning cycles have been shown to be effective at enhancing learning because by providing students with opportunities to develop their own understanding of a scientific concept, explore and deepen that understanding, and then apply the concept to new situations. A number of different learning cycles have been developed. However, all are closely related to one another conceptually, and differ primarily in how many steps the cycle is broken into. The "flavor" of learning cycle that you choose is primarily up to what works best for you, just pick one or two and use it as the basic formula for all your instruction.

This lesson is designed around a learning cycle that can be remembered as O-P-E-R-A. OPERA is convenient when designing lesson-level instruction because one can generally incorporate all the major components into the single experience. Each phase of the OPERA cycle is briefly outlined below.

	Instructional Stage
Open	**Open** the lesson with something that captures students' attention. This could be through demonstrations, videos, or thought-provoking ideas. In this case you will tell them that you have the power to bend rock.
Prior knowledge	Assess students' **Prior Knowledge** and employ strategies that make this prior knowledge explicit to both the instructor and the learner
Explore	Plan and implement a minds-on experience for students to **Explor**e the content
Reflect	**Reflect** on the concepts the students have been exploring. Students verbalize their conceptual understanding or demonstrate new skills and behaviors. Teachers introduce formal terms, definitions, and explanations for concepts, processes, skills, or behaviors.
Apply	Practice concepts, skills and behaviors by **Applying** the knowledge gained in a novel situation to extend students' conceptual understanding.

APPENDIX C—NGSS SCIENCE STANDARDS & 3 DIMENSIONAL LEARNING

Earth's Systems

MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=224

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.	**ESS2.A:: Earth Materials and Systems** The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.	**Patterns** Patterns in rates of change and other numerical relationships can provide information about natural systems.

Name:

Period:

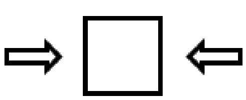
Date:

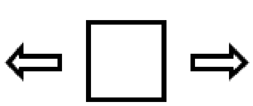
SILLY PUTTY™: BRITTLE, DUCTILE, AND ELASTIC

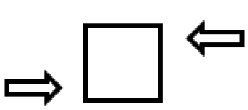
1) What is stress?

2) What do you already know about how rocks, and other materials, respond to stress?

3) Types of stress. Draw a line to match the terms on the right to the diagrams on the left.







Tension

Compression

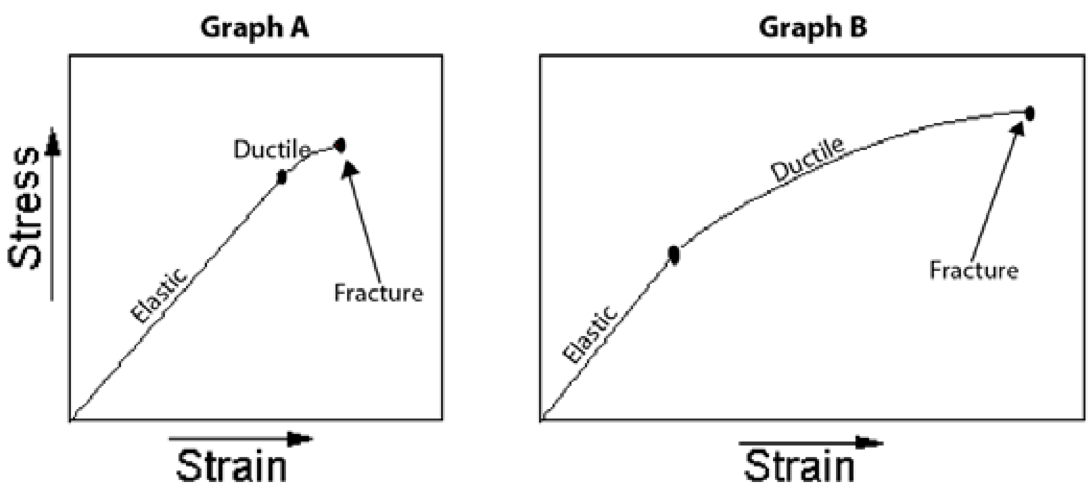
Shear

4) Complete the following experiments with the Silly Putty™ and record the result below.

Action	**Stress**	**Strain** *(Sketch and/or describe)*
Hold Silly Putty in both hands and push hands together.	Compression	
Action	**Stress**	**Strain** *(Sketch and/or describe)*
Hold Silly Putty in both hands and pull in opposite directions	Tension *(slow pull)*	
	Tension *(quick pull)*	
Hold Silly Putty in both hands and push each hand *past* the other	Shear	
Roll Silly Putty into a ball and drop on desk.	Compression	

5) How does Silly Putty compare to the way the marble tongs responded to stress?

Like the tongs	Unlike the tongs



(Adapted from Nelson, 2003)

6) Examine each of the graphs above. Based on your experimentation, which graph would be the most representative of the Silly Putty's deformation?

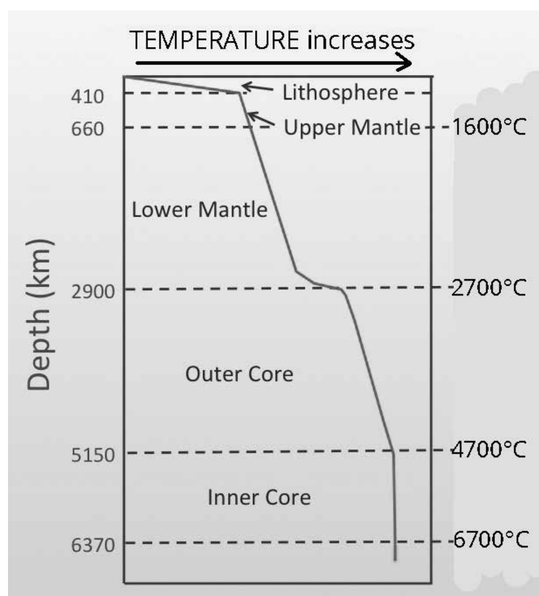
Explain your answer.

7) Picture **A** (left) shows a person standing in front of a fault. A **fault** is a fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.
Picture **B** (right) shows a fold in rocks. **Folds** form when rocks bend or experience ductile deformation.

Which of these two rock features would you associate with earthquakes and brittle deformation?

Why?

8) As illustrated at the right, temperature increases with depth in Earth.



As a rock mass gets warm at depth what type of deformation would you expect?

Design an experiment to test the effects of temperature on Silly Putty's deformation.

INSTRUCTOR ANSWER SHEETS

Name:

Period:

Date:

STUDENT WORKSHEET—SILLY PUTTY: BRITTLE, DUCTILE, AND ELASTIC

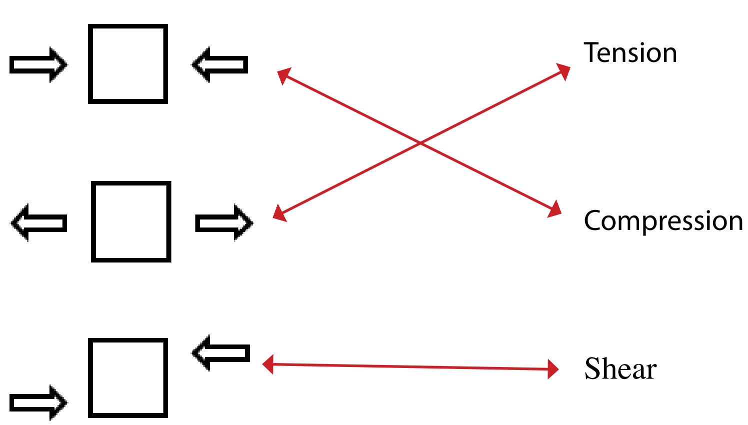
1) What is stress?

Stress *is the amount of force applied across the area of an object.*

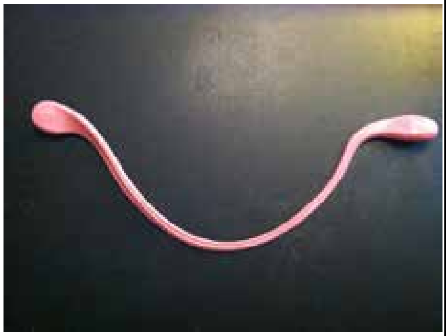
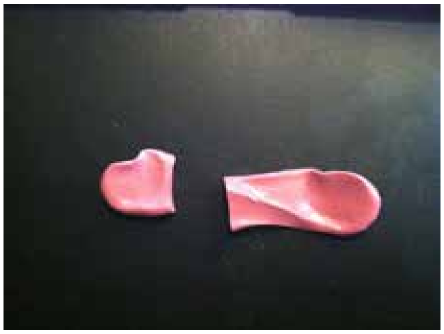
2) What do you already know about how rocks, and other materials, respond to stress?

Answers will vary but emphasize that stress is the force acting on an object while the strain is the change in the size, shape or volume of an object as a result of stress. From the previous activity (NEED REFERENCE TO MARBLE TONGS ACTIVITY) students should be aware that rocks can deform elastically and can fracture from brittle deformation.

3) Types of stress. Draw a line to match the terms on the right to the sketches on the left.



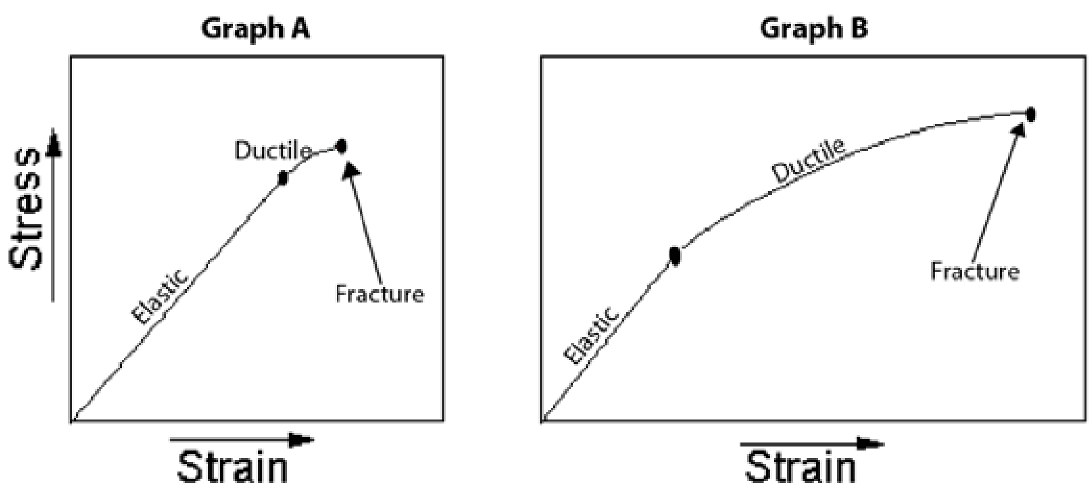
4) Complete the following experiments with the Silly Putty and record the result below.

Action	Stress	ANSWER	Photo
Hold Silly Putty in both hands and push hands together.	Compression	*Ductile deformation* *The Silly Putty squishes out in the middle and does not return to its original position.*	
Hold Silly Putty in both hands and pull in opposite directions	Tension *(slow pull)*	*Ductile deformation* *The Silly Putty is stretched, thinning in the middle and does not return to its original position.*	
	Tension *(quick pull)*	*Some ductile deformation and then fracture (brittle deformation)* *The Silly Putty stretches slightly and then breaks cleanly.*	
Hold Silly Putty in both hands and push each hand *past* the other	Shear	*Ductile deformation* *The Silly Putty stretches in the directions of the force and does not return to its original postion.*	
Roll into ball and drop	Compression	*Some ductile deformation and elastic deformation. The Silly Putty compresses as it lands on the tabletop. As it does, kinetic energy is converted to potential energy as the Silly Putty ball flattens out. When the Silly Putty returns to its original shape, the potential energy is converted back into kinetic energy and pushes against the tabletop. As a result it bounces up into the air. Some minor ductile deformation does occur as indicated by the flat spot on the ball.*	

5) How does the Silly Putty's compare to the way the marble tongs responded to stress?

Like the tongs	Unlike the tongs

To avoid generating misconceptions when working with models, create a list such as this to emphasize BOTH like and unlike features, as well as strengths and limitations, of the model and reality.



(Adapted from Nelson, 2003)

6) Examine each of the graphs above. Based on your experimentation, which graph would be the most representative of the Silly Putty's deformation?

Explain your answer.

Silly Putty's deformation is most like Graph B. Silly Putty has a short window of elastic deformation and a long window of ductile deformation before it finally fractures (except when the silly putty is pulled quickly, the ductile phase quickly moves to the point of fracture).

In contrast, Graph A has a much longer window of elastic deformation and a very short window of ductile deformation. This graph would describe metal ruler which has a longer period of being elastic before being ductily bent out of shape.

7) Picture A (left) shows a person standing in front of a fault. A **fault** is a fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.
Picture B (right) shows a fold in rocks. **Folds** form when rocks bend or experience ductile deformation.

Which of these two rock features would you associate with earthquakes and brittle deformation?

The fault is most closely associated with an earthquake.

Why? *At some time prior to this photo, the fault was storing up energy by deforming elastically. When the deformation reached the elastic threshold, the rock fractured and stored energy was released as the sides of the fault moved. This sudden release of elastically stored energy is an earthquake.*

8) As illustrated in the graph below right, temperature increases with depth in Earth. As a rock mass gets warm at depth what type of deformation would you expect? Ductile

Design an experiment to test the effects of temperature on Silly Putty's deformation.

Student responses will vary but a sample experiment is below:

1) Roll room temperature Silly Putty into 3" log

2) Stretch Silly Putty rapidly until it fractures.

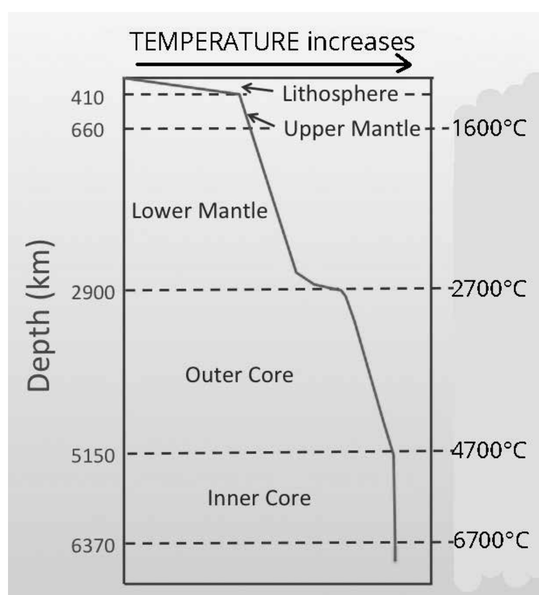
3) Note how the amount of ductile deformation increases before it fractures.

4) Repeat steps 1-3 several times.

5) Roll room temperature Silly Putty into 3" log and place in a cup of hot water for 5 minutes.

6) Stretch Silly Putty rapidly until it fractures.

7) Note how the amount of ductile deformation before the fracture.



The warm Silly Putty will have a much longer period of ductile deformation before fracturing. This is analogous to the Earth where warm rocks are more ductile than cold rocks.