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## ROCK CYCLE IN CHOCOLATE LAB - SOLUTIONS

Materials (for each group):

Chocolate (dark and white?)

Aluminum foil

Wax paper

Hot plate

Knife (doesn't need to be sharp)

Piece of plutonic rock countertop (granite, gabbro, diorite, etc)

Hand lens

Small glass jar with lid

Two Plexiglas sheets

Clamp (for metamorphism)

Divide into groups of 2-5 (depending on how many set-ups for which you have materials). Each group will need materials to work through

1. melting
2. crystallizing
3. erosion / weathering / sediment production / lithification
4. metamorphism
5. Short-circuiting the cycle
6. Comprehension

### ROCK SAMPLE LIST:

A – Banded pumice or xenolithic rock

B – Aphyric basalt and/or vesicular basalt

C – Coarse-grained granite with obvious quartz crystals and other minerals

D – Medium-grained quartz sandstone

E – Quartzite

F – Folded gneiss or folded metamorphic rock (the fold is important)

G – Conglomerate with many lithologies

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### **STAGE 1: MAKING CHOCOLATE MAGMA**

1.1 Make a hypothesis. We are going to be putting white and dark chocolate on the hot plate. Do you think the two types of chocolate will melt in the same manner? Describe what you think will happen:

1.2 Test your hypothesis. Cover the surface of the hot plate with aluminum foil and turn the hotplate to ~2 (no hotter!). Place a small chunk ( $1\text{ cm}^3$ ) of dark chocolate and a similar sized piece of white chocolate next to each other. You will need to use a stick or knife to smear the chocolate on the foil to help the entire chunk melt. **BE CAREFUL NOT TO TEAR THE FOIL WITH THE STICK** – we don't want to spill chocolate on the hot plate. Try to keep the white and dark chocolate separate. Remember to treat both samples the same (same amount of heat, smearing, time on the hot plate, etc).

1.3 Describe the results of your experiment. What happened to the chocolate? Describe how both types of chocolate melted. Did both types of chocolate melt the same? Be sure to include **viscosity** ("thickness" or "stickiness") and how much heat was required to melt each sample type.

**WHITE CH. WILL BE MORE VISCOS THAN DARK CH. AT THE SAME TEMPERATURE (DIFFERENT COMPOSITION; WAY MORE COCOA BUTTER)**

1.4 Expand your conclusions. What does this experiment tell you about how substances melt? Can you extrapolate the information you just gathered to other systems (especially rocks)?

**YES, DIFFERENT COMPOSITIONS WILL MELT AT DIFFERENT TEMPERATURES**

Before moving on to the next step, mix the white and dark chocolate together. As you are mixing these together, look at rock sample "A" in your tray. This is the result of two magmas mixing before they solidified, just like you are doing with your chocolate.

**ROCK "A" IS A BANDED PUMICE**

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## **STAGE 2: MAKING IGNEOUS CHOCOLATE**

Turn off the burner and

2.1 Now that we have made chocolate “magma,” it must cool to become an igneous “rock.”

We will cool the magma in two ways, fast and slow. What do you think will happen?

What differences do you think will result?

2.2 Bring out the polished rock slab (countertop) or tile and the beaker of ice water. Pour a small amount (~ 1/4 of your total sample) on the polished rock slab or tile. Take the rest of your sample and pour it into the ice water. Which will cool faster? Why?

### **ICE WATER SAMPLE COOLS FASTER; GREATER TEMPERATURE CONTRAST, AND WATER CAN MOVE (CONVECT)**

2.3 While your samples are cooling, answer the following questions:

- a. What geologic environment would allow magma to cool slowly? What environment would cause magma to quench (cool rapidly)?

### **SLOW COOLING HAPPENS DEEP UNDERGROUND, WHEN MAGMA IS SURROUNDED BY INSULATING ROCK**

### **FAST COOLING (QUENCHING) HAPPENS IN THE AIR OR IN WATER**

- b. Look at the slab of countertop on which your smaller sample is cooling. Then look at rock sample “B” in your tray. Describe the differences between these two igneous rocks. You can use the hand lens to look up close at each sample.

### **GRANITE SLAB IS COARSE GRAINED**

### **ROCK B IS A BASALT, WITH VERY FEW, VERY SMALL CRYSTALS SITTING IN A GROUNDMASS OF ROCK (ACTUALLY, THE GROUNDMASS IS MADE OF MICROSCOPIC CRYSTALS, WHICH IS WHY IT IS OPAQUE)**

- c. Which of these two rocks (the cooling slab or rock B) do you think cooled faster? What clues in the rock give it away?

### **ROCK B COOL FASTER, SINCE THERE ARE FEWER CRYSTALS AND THEY ARE SMALLER THAN IN THE GRANITE**

2.4 Now look at your experimental samples. AVOID TOUCHING THE SAMPLES WITH YOUR FINGERS as our newly-formed chocolate will melt much faster than it did originally (this is why it is hard to make good chocolate). Using the knife or scoop, retrieve the sample from the ice water and place it on the slab next to the other sample. Using the knife, cut each of the samples in half.

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- a. Using a hand lens, look closely at the textures of the two samples. Are there any differences?

**DIFFERENCES ARE A BIT HARD TO SEE, BUT THE SLOW-COOLING SAMPLE WILL HAVE SOME SUGAR CRYSTALS FORMING.**

- b. Now the fun part. The texture differences can be pretty minor in these samples. It is easier to tell the differences using your teeth. Carefully grind a small piece of each sample in your teeth. Can you detect any differences now? Describe them.

**THE SLOW-COOLING SAMPLE IS GRITTY, AND THE QUENCHED SAMPLE IS SMOOTH**

- 2.5 Now look back at the countertop slab and rock sample B. What do you think caused the differences in texture between these two rocks?

**DIFFERENCES IN THE COOLING RATE. GRANITE COOLED SLOWER, BASALT COOLED FASTER**

- 2.6 The texture differences between the two rock samples are significantly greater than the chocolate samples. How do you explain this?

**ROCKS COOLING UNDERGROUND COOL FOR A MUCH LONGER TIME (UP TO 100,000 YEARS), SO CRYSTALS CAN BECOME MUCH LARGER, EVEN THOUGH FORMING MINERAL CRYSTALS IS MUCH SLOWER THAN IN CHOCOLATE**

**STAGE 3: MAKING CHOCOLATE SEDIMENT**

At this stage, we're going to have to cheat a little because these processes are hard to duplicate in the lab (in fact, reproducing natural conditions in the lab is often one of the hardest parts of doing experiments!)

The formation of sediment requires processes that turn a few big objects into a lot of little objects. Use the knife to cut your igneous chocolate samples into small chunks. Use the knife to scrape flakes and chips of chocolate from the original block to increase the volume of your sample (see your TA for more chocolate if you don't already have some).

- 3.1 You now have a pile of a various types and compositions of material. In geology this is called sediment. What will it take to turn this pile of chocolate sediment into a cohesive mass (a rock)?

**A SMALL AMOUNT OF PRESSURE. IDEALLY, IT WOULD ALSO TAKE SOMETHING TO BOND IT ALL TOGETHER (CEMENT) BUT THE CHOCOLATE FRAGMENTS WILL MELT SLIGHTLY AT THE EDGES, ACTING AS CEMENT**

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- 3.2 Place all the sediment on a piece of aluminum foil and wrap the sediment in the foil. Place the foil envelope between the two pieces of Plexiglas and put the heaviest rock available on top of the Plexiglas. Why put the rock on top of the sample? What geologic process does this represent?

**THE ROCK REPRESENTS NEW SEDIMENT THAT BURIES THE ORIGINAL SEDIMENT PILE. IT IS THE WEIGHT OF THIS OVERBURDEN THAT LITHIFIES THE SEDIMENT INTO ROCK.**

- 3.3 While the chocolate sample is sitting under a rock, use the hand lens (magnifying glass) to look up close at sample D. This is a sedimentary rock that formed from sediment produced from rocks like sample C. Describe the differences between rocks C and D.

**ROCK C IS A COARSE GRANITE WITH LOTS OF QUARTZ. ROCK D IS A MEDIUM GRAINED QUARTZ SANDSTONE. IN THE SANDSTONE, THE CRYSTALS ARE ROUNDED, AND MORE OF IT IS QUARTZ**

- 3.4 The light-gray, almost transparent grains in rock C are quartz. Can you identify quartz in rock D? How is the quartz different in rocks C and D?

**QUARTZ IN ROCK C (GRANITE) IS TRANSLUSCENT WITH SHARP EDGES  
QUARTZ IN ROCK D (SANDSTONE) IS OPAQUE BECAUSE THE FACES HAVE SMALL GROOVES IN THEM CAUSED BY ABRASION**

- 3.5 Estimate the percentage of sample C that is quartz. Do the same for sample D. Are there any other minerals present in either sample? Describe (or name) them. Assuming that sample D is formed the sediment from sample C, is anything missing in sample D? What happened to that material?

**THIS DEPENDS ON YOUR SPECIFIC SAMPLES, BUT CHANCES ARE THAT ANY MICAS AND MAFIC MINERALS ARE LARGELY ABSENT FROM THE SANDSTONE. THESE MINERALS ARE SOFTER AND HAVE BEEN BEATEN AND DISSOLVED AWAY.**

- 3.6 We've cheated here by manually creating sediment by breaking down the large piece of chocolate into shavings and chunks. How do you think this happens in nature with rocks? What processes do you think might be involved?

**ABRASION FROM ROLLING DOWN A RIVER, ROCKS FALLS, FREEZE/THAW, ETC.**

- 3.7 Take the knife and cut a few more shards of chocolate from the original piece. On the left side below (under "before"), draw one or two of the shards. Now put the shards in the small bottle and close the lid. Shake the jar vigorously for 1 minute. Look at the shards again. What has happened to them? Draw what the shards look like now on the right (under the word "after").

BEFORE

AFTER

**THIS DRAWING SHOULD REFLECT  
MORE ROUNDED EDGES, MAYBE  
MORE ROUNDED CLASTS**

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What would happen if you shook the jar for 5 minutes? An hour?

**THE ROUNDING WOULD BE MORE DRAMATIC, AND THE CLAST WOULD GET SMALLER AND SMALLER**

- a. Compare the crystals in sample C and D. Do you see the results of this process in sample D? What geologic process causes this effect? Comparing the shape of the crystals in C and D, and considering that quartz is much harder than chocolate, estimate how long this process might have gone on.

**YES, THERE IS EVIDENCE OF THIS PROCESS; IT IS ABRASION. THIS PROCESS WOULD TAKE HUNDREDS TO THOUSANDS OF YEARS**

- 3.8 Now remove the rock from the sample and unwrap the foil envelope. What has happened to the sediment? Is it hard? Is it soft? What are two things that would make this “rock” more cohesive?

**MORE PRESSURE, AND SOME SORT OF CEMENT**

In geology, this process is called **lithification**. This is how sediment is converted to sedimentary rock, and is an essential process in the formation of much of the Earth’s crust and most of the rocks you see around you.

**NOTE:** set aside a small portion of your sedimentary chocolate “rock” for later comparison

#### **STAGE 4: MAKING METAMORPHIC CHOCOLATE**

Take the sedimentary rock you’ve just created and put it on wax paper. The rock may come off in pieces, so just stack the pieces on top of one another. Scrape or break some more chocolate on the sedimentary rock to increase the volume of your sample, and be sure to use different colors. Wrap the chocolate in the wax paper to create as small and tight an envelope as you can.

- 4.1 In order to make a sedimentary rock we used the weight of a rock on top of the sample. Predict what will happen if we apply more pressure. Consider what will happen on the scale of each grain and on the scale of the sample as a whole.

Place the envelope between the Plexiglas sheets and, using the clamp, squeeze the sample as tightly as you can. While it is pressing, answer the following questions:

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4.2 Why are we using a clamp now, rather than just adding another rock to the sedimentary apparatus? What does this say about the differences between the sedimentary and metamorphic environments?

**METAMORPHIC ENVIRONMENTS HAVE SIGNIFICANTLY HIGHER PRESSURE (AND TEMPERATURE)**

4.3 Look at samples D and E. These rocks are composed of the same material and have the same composition. Using your hand lens, examine the details of rocks D and E. Describe the difference between them. Be sure to include the differences in the shape of the grains and how the grains contact one another.

**ROCK D IS A QUARTZ SANDSTONE, ROCK E IS A QUARTZITE. IN ROCK E, INDIVIDUAL QUARTZ GRAINS ARE HARD TO DISTINQUISH**

- a. Rock E is the metamorphosed version of rock D. What does that mean? Does this fit in with your hypothesis you described in question 4.1? Specifically, what matches your hypothesis? What doesn't?

4.4 Remove the clamp from your experimental sample and unwrap the wax paper envelope. What has happened to the sample? Compare this sample to the sedimentary sample you set aside, using **both words and a drawing**.

**THE SAMPLE WILL BE A LIMP BUT COMPACT WAFER OF MARBLED CHOCOLATE. IT WILL BE MUCH STRONGER THAN THE SEDIMENTARY VERSION**

4.5 Now wrap up the sample in the *very small and tight* wax paper envelope again. This time *set the envelope on its side* between the Plexiglas sheets and apply ONLY MODERATE PRESSURE with the clamp (if you squeeze it too hard it will ruin the experiment). Predict what the resulting sample will look like.

- a. What geologic process are we trying to replicate in this part of the experiment? Where (or in what context) might this type of event occur?

**THIS REPRESENTS A FOLDING EVENT, SUCH AS MOUNTAIN BUILDING**

4.6 Release the clamp and carefully unwrap the envelope. What changes have occurred? Compare this sample to the first metamorphic sample you created (refer back to question 4.4 for your description of the first sample). **Use words and a drawing.**

**NOW THE SAMPLE SHOULD LOOK SIMILAR BUT BE FOLDED.**

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- 4.7 Look at rock F, another metamorphic rock. Consider how much additional pressure was required to form the metamorphic sample you just created over that required to create a sedimentary sample. With respect to depth, where do you think a rock like F might form?

**ROCK F IS A METAMORPHIC ROCK WITH AN OBVIOUS FOLD IN IT. THIS WOULD REQUIRE A SIGNIFICANT AMOUNT OF PRESSURE. ROCKS LIKE THIS COMMONLY FORM 5-20 KM BELOW THE SURFACE**

- 4.8 We have used pressure to metamorphose this sample. Is there another tool we could use to change the shape and texture of the sample? What is it? How could we include that in our experimental design?

**HEAT – WE COULD USE A HAIR DRYER ON THE PRESSURIZED SAMPLE.**

- 4.9 What do you think would happen if we added even more pressure to this sample? What if we used the tool you discussed in question 4.8? What would eventually happen?

**EVENTUALLY THE “METAMORPHIC” CHOCOLATE WILL MELT AGAIN, AND THE ENTIRE PROCESS WOULD START OVER.**

#### **STAGE 5: SHORT-CIRCUITING THE ROCK CYCLE**

- 5.1 Imagine taking the metamorphic sample you just created and cutting it into small pieces (like you did with the igneous sample) and compress it with the weight of a rock. What type of rock would this represent?

**ANOTHER SEDIMENTARY ROCK, BUT WITH METAMORPHIC CLASTS IN IT RATHER THAN IGNEOUS**

- a. Thinking geologically, how could this happen? What would need to occur in order for the metamorphic sample to be turned into sediment? Considering your response to question 4.7, and given that the rate of many geologic movements are in cm per year, how long do you think it might take for this to occur (give a rough estimate)?

**UPLIFT AND EROSION OF OVERLYING ROCK. THIS COULD TAKE MILLIONS OF YEARS**

- 5.2 What would happen if you took the igneous sample you created and squeezed it with the clamp? What type of “rock” would result? Would it look the same as the sample you created in the experiment?

**A METAMORPHIC ROCK, BUT WITH IGNEOUS MATERIALS.  
NO, IT WOULDN’T HAVE AS MANY LITTLE PIECES STUCK TOGETHER.**

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## **STAGE 6: THE STORY OF THE ROCKS**

Examine rock G. In a concise paragraph (with proper sentences and grammar) write the “life story” of this rock in the context of the rock cycle. Ask your TA if you have trouble identifying parts of the rock.

**ROCK G IS A CONGLOMERATE WITH MANY DIFFERENT LITHOLOGIES. THE STORY SHOULD INCLUDE A DESCRIPTION OF HOW EACH OF THE ROCKS REPRESENTED BY THE CLASTS CAME TO BE FORMED, HOW ALL THOSE ROCKS WERE TURNED INTO CLASTS AND DEPOSITED IN THE SAME LOCATION, AND HOW ALL THE CLASTS WERE LITHIFIED INTO A SINGLE ROCK.**

**THIS IS ESPECIALLY TRICKY IF ANY OF THE CLASTS ARE SEDIMENTARY**