Lab 3: Igneous rocks, volcanoes and volcanic hazards

Igneous rocks

1. An igneous rock may be identified by either its texture or its characteristic mineralogy and grain size. The rocks in the table below can be identified by their grain size and mineralogy. Use Table B-1a to aid your identification. For predominant grain size, simply write either “coarse” or “fine”.

<table>
<thead>
<tr>
<th>Rock #</th>
<th>Felsic, mafic or intermediate?</th>
<th>Predominant grain size</th>
<th>Rock name</th>
</tr>
</thead>
<tbody>
<tr>
<td>R4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Look at samples R-10 and R-11, two very common rocks in the Cascades.

a. R-10 is called granodiorite. Is it mafic, felsic, intermediate, or in-between two of the categories? If in-between, which two classifications is it in between? (Hint: look at the name)

b. R-11 is called dacite. Same question as part a. (Hint: it is the extrusive equivalent of granodiorite)

c. Why is it not weird that if you find a lot of one of these rocks in the Cascades, that you find a lot of the other as well?
3. The rocks in the table below can be identified by their texture. Use Table B-1b to aid your identification. Under the texture column, write the descriptive word or words from Table B-1b that helps you categorize the rock.

<table>
<thead>
<tr>
<th>Rock #</th>
<th>Texture</th>
<th>Rock name</th>
</tr>
</thead>
<tbody>
<tr>
<td>R12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B-1a. Igneous rocks which are identified by their composition/grain size

<table>
<thead>
<tr>
<th>COMPOSITION (Minerals present)</th>
<th>Felsic</th>
<th>Intermediate</th>
<th>Mafic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse-grained (mostly visible grains)</td>
<td>quartz orthoclase biotite Na-plagioclase</td>
<td>Na-plagioclase amphibole pyroxene biotite</td>
<td>Ca-plagioclase olivine pyroxene</td>
</tr>
<tr>
<td>Fine-grained (mostly invisible grains)</td>
<td>RHYOLITE</td>
<td>ANDESITE</td>
<td>BASALT</td>
</tr>
</tbody>
</table>

Table B-1b. Igneous rocks which are identified by their texture

1. Is the rock **glassy** on any fresh surface? Yes — Obsidian
   No — Go to #2.

2. Is the rock **vesicular** (containing gas bubbles)? Yes — Go to #3
   No — Go to #4

3. Is the rock dark-colored on a fresh surface? Yes — Scoria
   No — Pumice

4. Is the rock composed of large pieces of broken rocks? Yes — Breccia
   No — Go to #5

5. Is the rock well-**cemented** (doesn't crumble easily)? Yes — Welded tuff
   No — Tuff

Tuff and pumice are sometimes difficult to tell apart; however, a simple test distinguishes them: pumice floats on water and tuff sinks.
4. Get a sample of rock R-17, which is cut and polished **thunderegg**. Thundereggs are a type of **geode**, which make beautiful bookends and household decorations. The exterior rock of these thundereggs, which are from the Priday Agate Beds near Redmond, Oregon, is an **andesitic basalt**, and the interior material is **milky quartz** (I tell you this because I don’t want you to perform the usual mineral tests on these!). Write a **short history** of how this rock came to be; in other words, start from magma and tell me what happened to make this rock. Hint: it’s not a one-event history.

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**Volcanoes**

5. The **viscosity** of a fluid is its ability to resist flow; higher viscosity means that the fluid doesn't flow very fast. Mafic magma is very fluid compared to more felsic magmas. As a result, mafic lava travels further from the volcano than does felsic lava, which tends to pile up near the eruption point. Felsic lava, because of its viscosity, also traps **volatile**s (gases). Circle the correct choice below:

a. Which temperature magma would tend to have less viscosity (more fluidity)?

- 1200°C
- 900°C
- 600°C

b. Which temperature magma would tend to have more iron in its molten state?

- 1200°C
- 900°C
- 600°C

c. Which temperature magma would contain the **least** amount of dissolved gases, and therefore be more fluid?

- 1200°C
- 900°C
- 600°C

d. So which word best describes the composition of the magma that satisfies the temperature requirements above?

- mafic
- intermediate
- felsic
6. Using the results of question 5, answer the following questions with mafic, felsic, intermediate or any:

a. Which magma will likely erupt explosively?

b. Which magma will likely erupt effusively (quiescently)?

c. Which magma will produce volcanoes with steep slopes?

d. Which magma will produce volcanoes with gentle slopes?

The “2. Volcanism” raised relief model

7. a. Give the name of the rock most likely to be found on:

Volcano 21
Volcano 28
Volcano 25

b. Along the northern edge, find features 37 and 38 and identify them.

Feature 37 (the specific kind is called a laccolith)

Feature 38

8. How does feature 38 make it to the surface? In other words, how do features like 38 ever get exposed and allow geologists to study them?

Hazards of volcanoes

The Volcano Explosivity Index (VEI) was developed by volcanologists Chris Newhall and Steve Self in 1982 to gauge the explosiveness of a particular eruption from characteristics like the height of the ejecta plume, the total volume of ejecta, and other factors. This could be used then to assess the danger a given volcano might pose to its surrounding communities.
<table>
<thead>
<tr>
<th>VEI</th>
<th>Plume height (m)</th>
<th>Volume of ejecta (km³)</th>
<th>Classification</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt;100 m (&lt; 0.1 km)</td>
<td>0.000001</td>
<td>Hawaiian</td>
<td>Kilauea, now</td>
</tr>
<tr>
<td>1</td>
<td>100 – 1000 m (0.1 – 1 km)</td>
<td>0.00001</td>
<td>Hawaiian/Strombolian</td>
<td>Stromboli, now; Nyiragongo, 1982</td>
</tr>
<tr>
<td>2</td>
<td>1 – 5 km</td>
<td>0.001</td>
<td>Strombolian/Vulcanian</td>
<td>Colima, 1991; Galeras, 1992</td>
</tr>
<tr>
<td>3</td>
<td>3 – 15 km</td>
<td>0.01</td>
<td>Vulcanian</td>
<td>Galeras, 1924; Ruiz, 1985</td>
</tr>
<tr>
<td>4</td>
<td>10 – 25 km</td>
<td>0.1</td>
<td>Vulcanian/Plinian</td>
<td>Sakura-jima, 1914; Galunggung, 1982</td>
</tr>
<tr>
<td>5</td>
<td>&gt;25 km</td>
<td>1</td>
<td>Plinian</td>
<td>St. Helens, 1980</td>
</tr>
<tr>
<td>6</td>
<td>&gt;25 km</td>
<td>10</td>
<td>Plinian/Ultra-Plinian</td>
<td>Krakatau, 1883; Vesuvius, 79AD</td>
</tr>
<tr>
<td>7</td>
<td>&gt;25 km</td>
<td>100</td>
<td>Ultra-Plinian</td>
<td>Tambora, 1815</td>
</tr>
<tr>
<td>8</td>
<td>&gt;25 km</td>
<td>&gt;1000</td>
<td>Ultra-Plinian</td>
<td>Toba. 74000 yrs BP</td>
</tr>
</tbody>
</table>

Clearly, Mt. St. Helens is capable of a VEI 5 eruption. To translate this into human effects, two researchers, John Ewert and Christopher Harpel, came up with a Volcano Population Index or VPI. Through measurements of the eruptions of Central American volcanoes, which are similar to the Cascades volcanoes, they discovered that VEI 5 eruptions warrant evacuations of all people within 10 km (6 miles) of the volcano’s crater. The VPI is the number of people who therefore are in need of evacuation for a potential VEI 5 event.

9. Look at the Mt. Rainier, Glacier Peak and Mt. Baker maps. Use the scale to measure 10 km away from the crater in any direction (so a circle of radius 10 km around the crater). On the table on the next page, list any towns or cities within your boundary for these volcanoes.
<table>
<thead>
<tr>
<th>Volcano</th>
<th>Towns and cities within 10 km</th>
<th>VPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt. Rainier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glacier Peak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mt. Baker</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. Use a census reference like http://www.ofm.wa.gov/pop/ to calculate the VPI for each volcano. If there are no towns or cities within 10 km of a particular volcano, or else they are not listed in the census, write “0”.

In addition to ejecta and explosions, volcanoes with glaciers can produce mudflows when glacial meltwater combines with the rock and sediment on the mountain’s flanks. These mudflows are known by the Indonesian word *lahar*.

The map on the next page shows the paths of two lahars that descended from Mt. Rainier. What makes this a little scary is that neither of these events seems to be related to a major eruption of the volcano – a lahar can happen simply because of increased heat flow from some deep magmatic source melting the glaciers.

11. Notice that the paths of the lahars are curved. Given the town names these lahars pass through, give the specific name(s) of the geographic features these lahars are following.

Osceola Mudflow —

Electron Mudflow —

12. a. From the map and using a piece of string, measure the distance the Osceola Mudflow traveled. Assume the lahar began at the summit of Mt. Rainier.
b. The speed of the front of a lahar has been measured for several recent events. The average speed seems to be about 40 km/hr. Using this speed, how long after the initial event that triggered the mud to start moving at the summit did it take for the lahar to get to Greenwater? to Auburn? (Good thing that no one was living around there at the time!)

The final hazard discussed is tephra, or less formally, ash. This finely-pulverized rock from a volcano can drift a long way in the wind. Tephra is a respiration hazard, which can result in silicosis because the particles stick to the inner lining of the lung. Tephra can also destroy engines, since the fine particles can cause pistons and valves to seize (don’t drive through a tephra fall if you can help it!). Finally, if an eruption can send tephra to the top of the troposphere, or even into
the stratosphere, the fine particles can block light and therefore reduce the amount of sunlight that reaches the surface of the earth. In effect, a big eruption can cool the earth. Mt. Pinatubo in the Phillipines ejected enough material in its 1991 eruption to cool the northern hemisphere by nearly 0.5°C for three years, which doesn’t sound like much. This difference, though, shortened the growing season by nine days, which may have caused some crops in northern countries to fail.

Go to a site like http://volcano.und.edu/vwdocs/volc_images/north_america/msh_ash.html or a printed reference that has a map of the distribution and thickness of ashfall from the 1980 Mt. St. Helens eruption.

13. a. Which way was the wind blowing on May 16, 1980?

b. Note that, as expected, ashfall was heaviest around the volcano. However, there seems to be another significant peak some distance from the volcano. Suggest a reason why ashfall amounts did not uniformly decrease from the volcano.

Igneous summary

The distribution of the different types of volcanoes around the world seemed inexplicable to earth scientists even in the last century. Plate tectonics, though, provided the framework to allow explanations of why a particular type of volcano would occur in a given area.

You will examine plate tectonics more closely in a later exercise; for now, here are a few rules of thumb:

- a divergent plate boundary volcano (such as one on a mid-ocean ridge) produces basalt
- a convergent plate boundary volcano (such as one located near a subduction zone) produces andesite or dacite
- an oceanic hotspot volcano, located on the interior of an oceanic plate, produces basalt
- a continental hotspot volcano, located in the interior of a continental plate, produces rhyolite
14. Given those rules, fill in the table below:

<table>
<thead>
<tr>
<th>Volcano</th>
<th>Tectonic setting</th>
<th>Name of rock the volcano is primarily made of</th>
<th>VEI estimate</th>
<th>Estimate of effect on climate (global, regional or local effect?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Valley Caldera (California)</td>
<td>Interior of continental plate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vesuvius (Italy)</td>
<td>Subduction zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerro Azul (Galapagos Islands)</td>
<td>Interior of oceanic plate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15. What type of volcano (shield, strato- or maar) is each?

Long Valley Caldera —

Vesuvius —

Cerro Azul —

**Weathering**

Sedimentary rocks are those that are formed either by direct deposition of material by crystallization or organisms or through sediment settling under gravity. The settled sediment or biological material will **lithify**, in which it will be **compacted** and then chemically **cemented** into a rock.

*Weathering samples W1 through W6, sedimentary structure specimen S1 and rock samples R18 through R28 and R33.*

16. Samples W1 and W2 are igneous rocks; W1 is granite and W2 is gabbro. Sample W3 is a partially **weathered** igneous rock. Sample W4 is beach sediment.

a. Identify the minerals in the **clasts** breaking off of W3.
b. Did sample W3 start off as W1 or W2?

c. Look at sample W4 with a hand lens. Did this sediment come from W1 or W2?

d. When sample W4 compacts and **lithifies**, what will its basic rock name be?

e. What would a beach composed of sediment from the weathering of a **pluton** made of W2 look like? (Hint: think of Hawaiian beaches)

17. **Lithification** involves both **compaction** and **cementation**. W5 and W6 are glacially deposited sedimentary rocks of the same composition. Which has undergone more compaction? How can you tell?

18. a. Sedimentary rocks are held together by **cement**, a non-mineral chemical compound, which forms bonds (though not as strong as chemical bonds) between mineral grains. The three common cements are **silica** (SiO₂), **calcite** (CaCO₃) or **iron oxide** (rust). How would you identify each cement (think of a test for each)?

   Iron oxide —  Silica —

   Calcite —

b. Look at rock samples R18 and R19. What is the cement that holds each together?

   R18 __________________ R19 __________________

19. How does the cement get into these rocks?