

### Soil Formation & Chemistry

1. We have learned that soils can form by the reaction of water & acids like  $\text{H}_2\text{CO}_3$  with rocks near the Earth's surface. These reactions tend to remove easily leached components, and leave behind new minerals that are enriched in hard-to-leach elements. In this exercise we will work through an example, looking at the chemistry of the transformation of a volcanic rock (basalt) to extremely weathered soil.

Download the accompanying paper (Chesworth, 1981), and turn to Table 1, which lists the abundances of various components of a French soil sequence. L.O.I. stands for "Lost on Ignition" – typically meaning water, organic material, and the like that turns to vapor or burns when the sample is heated. For the sake of simplicity in this homework we'll ignore L.O.I. – assuming it represents pore water and other stuff that wasn't part of the parent rock.

The intensity of weathering increases from left to right in Table 1 of the Chesworth paper, from more-or-less fresh basalt (#1-#3) to clay+oxide rich weathered samples on the right (#10-#12), along with some soil samples that are loose and crumbly (#13-#15). Make a plot of wt% vs. sample # for  $\text{SiO}_2$ ,  $\text{MgO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{Al}_2\text{O}_3$  and  $\text{TiO}_2$ . You don't need to plot every sample, just 4-5 ranging from #1 to #12, and at least one of #13-#15. Feel free to use a graphing/spreadsheet program like Excel to speed up the process. Which elements decrease in abundance through #12? Which increase? How does this behavior correlate with the charge of the cation?

2. Do #13-#15 follow this pattern for every element? Can you think of a reason for the relationships/differences you observe in these samples? (Hint: look in the Chesworth pdf text if you're stuck)

3. In order to quantify the geochemical impact of soil formation & weathering, it is important to establish how much of each element has been leached, and how much is retained. Typically this is done by using one or more "unleachable" elements as a marker that is conserved during soil formation.

Calculate the average wt% abundances of  $\text{SiO}_2$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Al}_2\text{O}_3$  and  $\text{TiO}_2$  in the three relatively unweathered basalt samples (#1-#3) – we will assume that the parent rock for all of the other samples had this average unweathered basaltic composition.

4. Now look at sample 12. Assume we have 100 g of this sample. How many grams of  $\text{TiO}_2$  are present?

5. How many grams of average unweathered basalt would you need to have an equivalent number of grams of  $\text{TiO}_2$ ? We will take this to indicate the amount of parent rock needed to make 100 g of sample 12 "soil". This assumes sample 12 originally had the same composition as the unweathered basalt average, and retained all of its original  $\text{TiO}_2$  during weathering.

6. If these assumptions are correct, how many grams of material had been leached away by the time our 100 g sample of #12 was collected?

7. Now do the same type of calculation using  $\text{Al}_2\text{O}_3$  instead of  $\text{TiO}_2$ . Do the two oxides suggest the same amount of leaching to yield 100 g of sample 12? In your opinion, is aluminum oxide or titanium oxide more reliable for this calculation? Why?

8. Calcium and, to a lesser extent, magnesium leached from silicate rocks ends up forming carbonate minerals ( $\text{CaCO}_3$  and  $\text{MgCO}_3$ ) on the ocean floor. This process of leaching (by  $\text{H}_2\text{CO}_3$ -acidified water) and deposition as carbonate is thought to be a major long-term sink of atmospheric  $\text{CO}_2$ . How many grams of CaO and MgO are there in your 100 g sample of #12?

9. How many grams of CaO and MgO were there in the unweathered basaltic parent of sample #12 (use your result from question 5).

10. Based on question 7 and 8, and assuming all leached CaO and  $\frac{1}{2}$  of leached MgO ended up forming  $\text{CaCO}_3$  and  $\text{MgCO}_3$  in the ocean, how many grams of  $\text{CO}_2$  are removed from the atmosphere by the weathering/leaching process that made 100 g of sample 12?

11. Based on what you've learned about leaching and reactions during weathering, can you suggest some other "unleachable" elements that might be used to track soil formation processes?