Exercise 1. Earth Materials, Geologic Time, and Geological Processes

INTRODUCTION AND NOTES FOR INSTRUCTOR

The goal of this exercise is to introduce students to earth materials (minerals, rocks and regolith), the concept of geologic time, and a variety of geologic processes. This material may be review for some students, but the processes of scientific analysis that are represented by rock and mineral identification are important in understanding much of the material that follows. Geologic processes, some hazardous to humans, have been active over geologic time, and appreciation of the time scale is important if students are to understand the geologic tools of "the present is the key to the past" and "the past is the key to the future." The interaction of external and internal geologic processes creates geologic hazards and controls both resource occurrence and pollutant distribution.

Required materials: samples of minerals; igneous, sedimentary, and metamorphic rocks; regolith; demonstration minerals for mineral characteristics, hardness, cleavage, and other properties; mineral testing kit (nail, penny, hand lens, glass plate, streak plate, magnet, dilute HCl).

We suggest the following specimens for mineral and rock identification. Many have environmental implications and are mentioned in discussions of pollution, geologic hazards, or geologic resources.

Minerals: calcite, orthoclase and plagioclase feldspar, fluorite, gypsum, galena, halite, limonite, mica, pyrite, quartz, augite, hornblende, hematite, talc, olivine.

Igneous rocks: granite, rhyolite, andesite, basalt, gabbro, obsidian, porphyritic basalt, pumice, scoria.

Sedimentary rocks: conglomerate, sandstone, siltstone, shale, limestone, dolostone, bituminous coal, rock gypsum, rock salt, coquina, clay minerals (montmorillonite, lcaolinite).

Metamorphic rocks: quartzite, marble, slate, schist, gneiss. Additional possibilities: anthracite, fault breccia, and metamorphic minerals: garnet, talc, chlorite.

Regolith (unconsolidated surficial materials): to show the substrate on which human structures are built use gravel, sand, silt, clay, till, organic materials, anthropogenic fill.

QUESTIONS 1, PART A

1. Examine each mineral specimen that your instructor selects for this exercise. Determine and record in Table 1.1 all of the properties you test and/or observe. This includes determination of luster, color, cleavage, fracture, and specific gravity; and testing for hardness, streak, and other properties. Test and record the properties of the specimens and complete Table 1.1 with guidance from data in Table 1.2 in building your answer key.

2. After you have recorded the observed physical properties, with the aid of earlier information and the descriptive information about each mineral found in Table 1.2, determine the names of the minerals. Record the chemical composition of each mineral and note the information regarding their geologic, environmental, and economic significance. As you will see, some of these minerals are of particular importance because of the way they influence the environment when not properly used or when their presence is not considered.

With guidance from data in Table 1.2 complete your answer key with chemical composition and significance.

QUESTIONS 1, PART B1

1. Your instructor will provide specimens of igneous rocks for you to identify. Determine the texture, composition, and any other important characteristics of each specimen and record your observations in Table 1.4. Using the information you have compiled and Table 1.3, determine the name of each rock.

2. After you have made a record of the names and characteristics of the igneous rocks, note information regarding the geologic, environmental, and economic significance of these rocks in the proper column in Table 1.4.

Use Table 1.3 and the text in the igneous section to determine names of the igneous rocks, their significance and complete your answer key.

QUESTIONS 1, PART B2

1. Your instructor will provide specimens of sedimentary rocks for you to identify. Using the information presented in Table 1.5, determine the composition and texture of each specimen. On this basis draw your conclusions about the origin of the sediments, the process of lithification, and the name of the rock. Record this information in Table 1.6.

2. After you have identified the rocks, determine some of the important uses and geologic and environmental significance of each rock and record this in the last column in Table 1.6.
Use Table 1.5 and text in the sedimentary rock section to determine rock names, origins and the significance to complete your answer key.

QUESTIONS 1, PART B3

1. Your instructor will provide specimens of metamorphic rocks for you to identify. Using the information presented in Table 1.7, determine the texture, composition, and other properties of each specimen to identify the metamorphic rock and probable original rock. Record your observations in Table 1.8.

2. After you have identified the metamorphic rocks, note information regarding the geologic, environmental, and economic significance of these rocks in the proper column in Table 1.8. Use Table 1.7 and text in the metamorphic rock section to determine rock names, original rocks and the significance to complete your answer key.

QUESTIONS 1, PART B4

1. Your instructor will provide samples of sedimentary materials for you to identify. Use information in the description of regolith types above, and descriptions in the sedimentary rocks section of the manual, to help identify the samples, their possible origin, and their geologic significance. For example, a dry, compact mass of well-sorted, very fine-grained sediment that can be abraded with a lcnife might be a clay, formed in a lalce bed, and have low strength, slow movement of water through it, and thus not a good aquifer (but useful for containment of wastes, e.g., a potential landfill site). Coarser-grained sorted sediments reflect higher energy environments. See Table 1.5 for grain-size information.
Use grain size and composition data in Table 1.5 (sedimentary rocks) and the text in the regolith section to determine the names, environments of formation and environmental significance of the regolith materials to complete your answer key.

2. Define each of the following terms and any others assigned by the instructor.
Regolith - Unconsolidated material that overlies bedrock.
Soil (engineering) – The regolith is the engineer's soil.
Soil (biological or soil science) - Weathering horizons developed at the top of the transported regolith or from weathering of bedrock; soil considered to be capable of supporting life.
Till – unconsolidated, unsorted material deposited directly from glacier transporting debris.

3. List four possible environments of formation or origins of regolith. (Hint: See the introduction to the section "Regolith.")
Transported regolith includes deposits of fluvial, glacial, eolian, lacustrine/marine, mass wasting processes; residual regolith consists of material left behind by weathering processes acting on solid rock. This regolith may include lithified or resistant horizons. Organic processes also produce bog deposits such as peat.

4. Think of the types of materials that make up the regolith and determine which material or materials

would be most useful for:
a. A groundwater reservoir (aquifer)
gravel, sand
b. Protecting an aquifer from contamination from a gasoline spill on the land surface
clay, clayey till

5. If the local surficial geology map and county soil survey reports are available in lab or online, determine:
a. The material and origin of the regolith beneath your building or campus
Variable; see county soil survey/map for your area (See NRCS formerly SCS); or consult the campus engineering office.
b. The soil type beneath your building or campus. (Soil maps are available for most counties; they contain a wealth of data on a site, often including aerial photos.)
See the NRCS county reports, as above.

QUESTIONS 1, PART C
1. Which subdivision of geologic time represents the greatest length of time (era, period, epoch)?
Era

2. What is the length in millions of years of the:
Cenozoic Era? Tertiary Period? Quaternary Period? Eocene Epoch? Pleistocene Epoch?
65 Ma (Answers based on the 1999 GSA Time Scale, Appendix II) 63.2 Ma
1.8 Ma 21.1 Ma 1.79 Ma

3. How does the Pleistocene Epoch compare in length to the Ordovician Period?
1.79 Ma compared to 47 Ma; much shorter, about 1/26th

4. Approximately how many times longer is Precambrian time than the Cenozoic Era?
3800 Ma compared to 65 Ma; much longer, by about 58 times

5. What is the age in million years (Ma) of the boundary between the Cretaceous and the Tertiary (K/T boundary)? 65 Ma

6. Approximately how many years ago did the following geologic events occur?
Mt. St. Helens eruption ~30 y (years) (in 1980)
New Madrid, Mo., earthqualce ~200 y (in 1811–1812)
Vesuvius eruption ~1, 930 y (in 0079)
Toba eruption ~ 75,000 y

QUESTIONS 1, PART D
1. Figure 1.3 identifies many components of the geosystem, but does not show linkages between all of them. Sketch on this figure links that you think might exist between various geosystem components. If you are uncertain, it may help to refer to your text. Add to your links a few key words that explain why you think a particular link exists.
See Figure 1.3 below with heavy black arrows. Add explanations to arrows. Other links may be added.

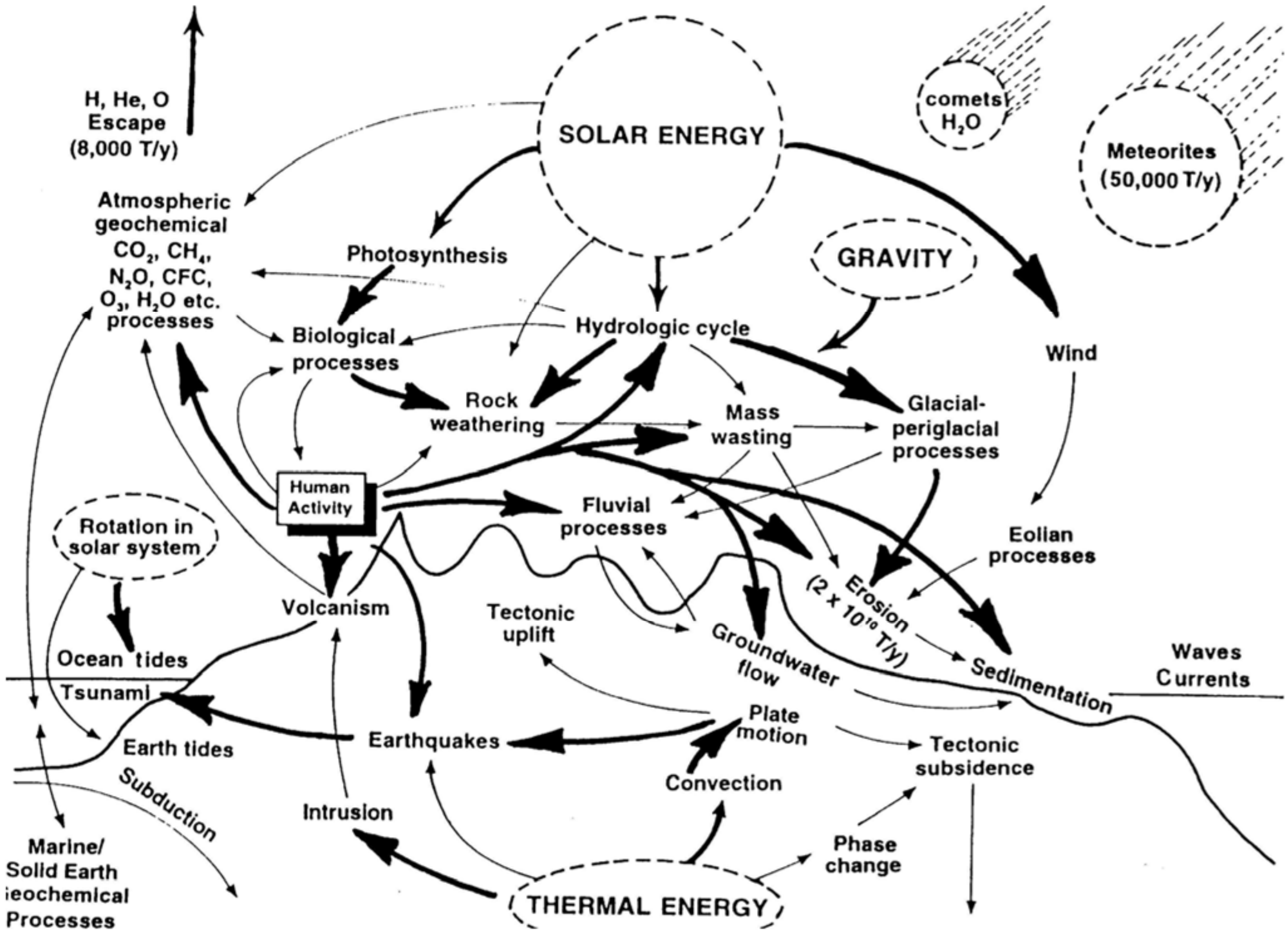

Fig 1.3. FMU3rd IM

2. Is the Earth a closed system? Explain.

From the diagram, there is exchange of both energy and mass across Earth's boundaries, suggesting an open system; however, the mass exchange is not significant in the short term so the system is considered closed on that basis. Energy exchange occurs, but only an isolated system would not have energy exchange (and such systems don't exist in the real world), so the system is considered to be a closed system. Meteorites (rock) and comets (ice) are the incoming mass; almost insignificant when compared to the mass of Earth. Mass is lost as H and He to space. Solar energy is a very significant external input to our system; it drives the hydrologic cycle and supports most of the biosphere. The third type of system, an open system can exchange both mass and energy across its boundaries; and this is a common subsystem in the Earth system.

3. According to this figure, what is the net annual gain in the mass of Earth?

42,000 T/y (input is 50,000 T/y of meteorites, and loss is 8,000 T/y of H and He.)

4. List the processes acting on or flowing through the surface of Earth.

Volcanism, human activity, fluvial processes, eolian processes and other atmospheric processes, ocean processes, glacial-periglacial processes, groundwater flow, weathering, mass wasting, erosion and sedimentation, waves/currents. Tectonism, an internal process, as with volcanism, also modifies Earth's surface, phase changes, and convection in the Earth.

5. What two energy sources drive the hydrologic cycle?

Solar energy and gravity.

6. What are the “greenhouse gases” and what do they do?
Carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and halons. Greenhouse Gases (GHG) play an essential role in the climate system. Some new gases such as CFCs (developed by modern society) also act as GHG and together with increased concentrations of natural GHG (e.g., CO2 and CH4) have produced an enhanced greenhouse effect that has the potential to make significant changes in temperatures, climate, and geologic processes.

7. What benefits for humans might accompany global warming?
Climates that are currently too cold to support a long growing season might warm enough to allow new areas to be put into crop production. There will be decreased heating and snow removal costs in some climates and possibly fewer illnesses during winter cold-and-flu season. At the same time, a system in change will have negative impacts for others, and even surprises for those expecting benefits. For example, with reduced ice cover on the Great Lakes, there has been increased lake effect snow in some areas.

The following questions refer to Figure 1.4.
8. If you can run a four-minute mile (only slightly slower than the world record pace), which geologic processes will be able to catch you? (Hint: Use the conversion factors given in Appendix 1 and refer, if needed, to exercise 3 for a discussion of unit conversion.)
A four-minute mile would be about 210,000 km/year. Therefore the following would be able to catch you: mudflow, stream flow, debris slide, rock fall, tidal currents, wind-blown sand/clay, most debris flows, and higher velocity air flow.

9. If you are driving a car at 65 miles per hour, which geologic processes will be able to catch you? 65 mile/hour = 916,000 km/year = 9.16×10^5 km/year. Rock fall, higher velocity airflow and some wind blown sand/clay would be able to catch you.

10. If fingernails typically grow at a rate of about 15 mm per year, what geologic processes are occurring at the same rate?
Soil flow, rise in sea level, slip on San Andreas fault, horizontal movement of continents, the slower glaciers, and slower moving sand dunes.

11. Soil profiles are about one meter thick in many parts of the world. How long, at an average rate of erosion, will it be before all the soil is removed (assuming that it is not replenished)?
At an average rate of 0.035 mm/year for the world it would take about 30,000 years to remove a one-meter-thick soil profile. At a rate of 0.06 mm/year (USA) it would take about 17,000 years.