Density and the Rock Cycle
Unit Schedule

Introduction
The topic for this unit is density, specifically understanding what density is and how it is determined, and applying that knowledge to understanding the rock cycle.

My audience for this unit is either a High School senior or community college Earth science class.

This unit is integral to my Earth science course because many Earth science processes are driven by density differences. A student can learn about an Earth science process in terms of what it represents, but without a solid understanding of the mechanisms by which the process exists, the student may only leave the course with a superficial or incomplete understanding of that phenomenon and why it occurs. The rock cycle is a prime example of a density-related Earth science process, because density differences are the fundamental underlying factors for many of the steps within that cycle. For example, subduction and creation of new igneous rock runs hand-in-hand with mantle convection, which is a result of density variations within the mantle. Other portions of the rock cycle, including constraints on sediment transport, accretion of terranes, or accretionary wedges, all are controlled by density differences.

Topic prior to this unit
Igneous, metamorphic, and sedimentary rocks and rock-forming minerals will have been covered just before this unit. Students will be able to identify rocks/minerals and will have a general idea of the environment of formation for samples in each rock group. The rock cycle was covered in that unit, in the sense that each rock has a protolith, or parent material, from some other portion in that cycle. That unit will hopefully set the stage for looking more in-depth at each component of the rock cycle and the way in which density differences play a role.

Topic after this unit
Climate and climate change, and density will be worked in here as well, to keep the concept alive in the course and in students' minds.

Essential questions
These were developed after the list of objectives were identified and prioritized, but I'm stating them here for clarity.

1. What role does density play in the formation of igneous, sedimentary, and metamorphic rocks?
    a. What is density? Why is density important?
    b. What factors control the density of an object/substance?
    c. Are there density differences within the Earth? If so, where, and what role do they play?

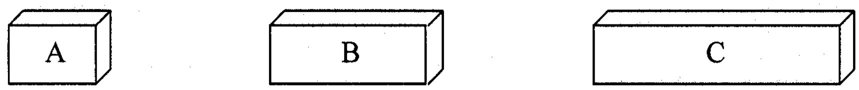
2. Is Earth growing bigger over time (i.e. is Earth's circumference increasing)?

Prerequisite knowledge:

- Basic laboratory skills
- Understanding of proportions
- Some prior exposure to density, mass, and volume
- Understanding of the three major rock groups, and ability to use basic rock/mineral identification techniques to differentiate among the groups.

Prerequisite knowledge assessment (see p.3)**:**
This assessment will be given on the day before this unit begins. It will help me guage just how much instruction needs to take place on what I have assumed will be knowledge that the students have already mastered (either in this class or in previous courses), and will help me determine the level of mastery of the concept of density itself.

The following description and pictures apply to questions 4-6: A straight, uniform board is cut into three differently sized pieces. Each piece has identical width and thickness, but different lengths. A is shortest, C is longest.



Which piece has the greatest volume?

a. Piece A
b. Piece B
c. Piece C
d. They are all the same
e. Impossible to tell without making additional measurements.

Which piece has the greatest density?

a. Piece A
b. Piece B
c. Piece C
d. They are all the same
e. Impossible to tell without making additional measurements.

Which piece has the greatest mass?

a. Piece A
b. Piece B
c. Piece C
d. They are all the same
e. Impossible to tell without making additional measurements.

Explain your reasoning for your answers to 4, 5, and 6

A jeweler cut a small chip off a large, uncut diamond. How does the density of the chip compare with the density of the original diamond?

a. The density of the chip is the same as the density of the original diamond.
b. The density of the chip is lower than the density of the original diamond.
c. The density of the chip is higher than the density of the original diamond.
d. Impossible to tell without taking a measurement.

Explain your reasoning:

In a few sentences, describe how you would experimentally determine the density of a cubic object versus an irregularly-shaped object.

The density of a material depends upon:
(circle all that apply)

A. Size
B. Shape
C. Temperature
D. Pressure
E. Homogeneity

Prior/post-knowledge assessment:
This assessment will also be given on the day before this unit begins and again on the last day of this unit. I will collect and analyze this assessment, in order to inform the unit's exercises and general scope before the first day. This assessment will shed light on my syllabus: perhaps what I have planned is too sophisticated for the students, or perhaps they are all at a higher level of understanding of this material than I had anticipated. The first class on this unit may include a discussion of some of the right and wrong answers (anonymous).

Draw a flow chart of the rock cycle.

Be sure to include:

- all pertinent rock groups.
- at least three processes operating within that cycle.
- the role of density in each portion of the cycle.

Be as complete as possible!!

If you're unsure of any of the components, make your best educated guess!

Week 1
Classes during this week will be mainly devoted to objectives at the first (lowest) level of priority:

Objectives for the first ring (worth being familiar with)
(Please see the appendix (p.11) for all standards used.)
The student will be able to:

- Use the density equation (Density=mass/volume) and variables when working with questions encountered in the unit.
- Accurately determine the density of a rock/mineral, using a triple-beam balance for mass, graduated cylinder/ruler for volume, and any other necessary equipment (based on M.L.R. Standard J).
- Know and use the format for a standard laboratory report;
  Understand the errors inherent in any laboratory work and how best to minimize those errors;
  Identify weak portions of a given density laboratory report (based on M.L.R. Standards K-L).

Depending upon the responses to the prerequisite and prior knowledge assessments, more or less than one week may be needed for this material. Though these objectives are at the lowest level of priority, they are necessary in order to fully understand concepts related to objectives at the higher levels; the concepts embedded in these objectives will be used throughout this and succeeding units, and so it is essential that this material be mastered by the students.

<u>Assessments</u>

The three above objectives will be assessed in the most basic ways (lowest on Bloom's Taxonomy, at the knowledge and comprehension level), but in ways that will show me whether the concepts associated with the outcomes were mastered. The general (subject to change) sequence of assessments is as follows:

- Formative: class and small group discussions will be used to informally assess students' understanding of these concepts. In particular, the students will be asked to come to each class with a question from the unit, which will be discussed in small groups. As Wiggins and McTighe suggest (p.88), the class will then come together for a short discussion of the most important or confusing question from each group.
- Formative: there will be a vocabulary test given, in which the students will be asked to define and demonstrate their knowledge of density. For example, they will be asked to define mass, give examples of mass units or instruments used to measure mass and define how mass relates to density. This will test the students' knowledge of the components of the density equation and how all the variables are related or found.
- Formative: there will be homework assignments (used as both formative assessments and homework assignments) given in which flawed density laboratory experiments are described. The students will be asked to revise the experiments in order to make them more scientifically valid. Alternatively, the students will be asked to find a published experiment related to density and write a short essay on the design accuracy and validity of the experiment's findings. This will informally measure their understanding of the experimental process and the need for repeatability in any experiment.
- Summative: the students will be asked to determine the density of an assigned rock or mineral and identify the rock/mineral type (igneous, sedimentary, or metamorphic). They will be allowed to choose which laboratory equipment to use and the procedure they are most comfortable with to complete the task.

<u>Sequence of assignments and class work</u>

I could spend many weeks teaching this material, but I would rather spend more time on the highest- level material, which actually builds upon this material. For that reason, many of the assignments and class work associated with the objectives for this level are also assessments, and have already been described above.

- Background reading on each concept will be assigned prior to the class meeting when the material will be covered, in the hopes that the students will be primed for that day's material.

- The students will also have an opportunity to create a general procedure to determine the density of an object based on its shape (or lack thereof), and will use that procedure to actually find the density of one or more of the rocks/minerals they learned about in the previous unit. This exercise will also help teach about proper laboratory techniques and standard laboratory write-up format, and will be inquiry-based.

Weeks 2-4
Classes during these weeks will mainly be devoted to meeting objectives at the second level of priority:

Second ring (Important knowledge and skills)
The student will be able to:

- Use density to differentiate among common rocks and minerals; especially among the three rock groups.
- Verify, evaluate, and use results of density experiments in a purposeful way. This includes analyzing and interpreting data, making predictions based on observed patterns, testing solutions against the original problem conditions, and formulating additional questions (based on M.L.R. Standard J).
- Employ graphs, tables, and maps in making arguments and drawing conclusions from density experiments; use computers to organize data from density experiments and to do research for problem solving (based on M.L.R. Standard L).
- Analyze the changes in continental position and the evidence that supports the concept of tectonic plates (M.L.R. Standard F).

Assessment
The second ring (important knowledge and skills) will be assessed in a more rigorous way, fitting the middle levels of Bloom's Taxonomy (application and analysis).

- Summative: the students will be given a density experiment to complete, and must use Excel or another software to compile their research in graphs, charts, or any other helpful medium. They will then be asked to critique their methodology and results, and write a short essay on how the experiment could be improved in the future.

- Formative: the students will write an essay on plate tectonics. They will evaluate lines of evidence and discuss whether the theory is likely to be true. *(Students' answers will help shape what we do at the third ring level.)*

Sequence of class work and assignments

- In class, the students will have a chance to use software and practice what they will eventually have to do as a summative assessment (though they won't know that in advance).

- Background reading will be assigned on the theory of plate tectonics and the supporting evidence.

- Students will study the composition of the oceanic and continental crust, including the relevant densities and causes for the differences.

Weeks 5-8
Classes during these weeks will mainly be devoted to meeting objectives at the third and highest level of priority:

Third ring (Enduring Understanding)
The student will be able to:

- Explain the role of density in each section of the rock cycle, including (but not limited to): the importance of density differences to drive mantle convection/plate tectonics; the relationship of density to temperature and pressure; the role of density in sediment transport (based on M.L.R. Standard F, N.S.E.S. Standard D; S.B. Standard C).
- Explain how a rock's geologic history is told by its location, make-up, and physical characteristics, and how density may have played a role in its history, or how density may play a role in its future (based on M.L.R. Standard F).
- Discuss the validity of an analog model in relation to a real-world process, and be able to suggest improvements on that model.

Assessment
The third ring (enduring understanding) will be assessed in the most rigorous way, fitting the highest levels on Bloom's Taxonomy (synthesis and evaluation). Performance assessments (summative at this level) will be used to measure understanding of the concepts. One such example is described below (aimed at essential question #1).

Performance Assessment #1- A Delta

Construct a 2-D geologic cross-section of a Gilbert-style delta, which is building into an ocean basin.

1. Label each major aspect of the delta, including sediment size and type.
2. Describe the sediment source.
3. Tell the story of the delta's formation, from start to finish, making sure to describe how density played a role.
4. Imagine that millions of years have passed, and your delta has been riding on its oceanic plate toward a subduction zone (the oceanic plate is being subducted). Now tell the story of the delta's future as it hits the subduction zone, incorporating the concept of density anywhere appropriate.

Rubric for Performance Assessment #1 (including facets tested)

Note: Adapted from p. 76-77 in Wiggins and McTighe, 1998.

Explanation	Application	Interpretation
Sophisticated: an unusually thorough, elegant, and inventive story; fully justified by citing relevant experiments; above and beyond simply being correct.	*Masterful:* fluent; able to use knowledge and skill and adjust understandings well to this scenario.	*Profound:* a powerful and illuminating interpretation and speculation as to the future of the delta.
In-depth: well supported by argument and relevant experiments; goes beyond what was explicitly taught; novel thinking displayed.	*Skilled:* competent in using knowledge and skill and adapting understandings to this scenario.	*Revealing:* an insightful interpretation and speculation as to the future of the delta.
Developed: an account that reflects some in-depth and personalized ideas; support from relevant experiments is sound but insufficient, as is the story as a whole.	*Able:* able to perform well with knowledge and skill in a few key areas, with a limited adaptability to this scenario.	*Perceptive:* a helpful interpretation and speculation as to the future of the delta.
Intuitive: an incomplete account but with apt and insightful ideas; extends and deepens some of what was learned in experiments; story is limited.	*Apprentice:* relies on limited knowledge and skills, perhaps needed some coaching to fully complete this scenario.	*Interpreted:* a plausible but lacking interpretation and speculation as to the future of the delta.
Naive: a superficial or fragmentary story; a borrowed idea; no meaningful reference to appropriate experiments.	*Novice:* can perform only with coaching and could not apply knowledge and skills to this scenario.	*Literal:* a simplistic or superficial speculation as to the future of the delta, with no real interpretation offered; a restatement of what was taught or read.

The following performance assessment is aimed at essential question #2, and will be used to sum up the unit. This will take the form of a classroom debate by the students.
(From Jeff Owen. Of course, a different rubric would be used to grade the following assessment.)

Performance Assessment #2- A Growing Earth?

A friend explains to you that mountain building is evidence that the Earth's circumference is increasing. Take the perspective of an Earth Scientist to make a detailed, evidence-based argument, either supporting or refuting your friend's explanation.

Sequence of assignments and class work

Exercises at this level will be mainly inquiry-based, where the teacher serves as a resource, along with the textbook, internet, library, and other classmates.

- Each student will be given a rock and will be asked to tell the rock's complete story, with a few guidelines. (Some examples include: How was the rock formed? Describe the rock's protolith.)
- The inquiry-based activity on sediment transport, described below*, will be performed at this point in the sequence.
- Students will explore reasons why subduction occurs and what drives plate tectonics, by means of background reading, group discussions with guiding worksheets or facilitation. Additionally, students will analyze subduction models (or videos) to help understand the mechanisms. For example, students will observe a lava lamp and describe what is happening, and will explore density changes with temperature and pressure.
- Students will be given class time to research and prepare for the second performance assessment. The students may be asked to write an essay on their point of view, in addition to the debate, in order to help the concepts really sink in for each student.

**An example of one inquiry-based exercise, to be tested by the performance assessment #1, (described above on page 7) is described below. Students will have read and learned a little bit about sediment transport in the last unit on sedimentary rocks. This exercise will go more in-depth on that topic.*

Constraints on Sediment Transport

Please be prepared to hand in your answers to the following questions by the end of class today.

Part 1

As a group, observe your bottle filled with sediment and water.

1. Describe the sediments present, in terms of size, shape, type, and any other way you see fit.
2. Describe the arrangement of those sediments in the bottle.
3. Make a prediction:

   What will happen to the sediment after you shake the bottle?

   Explain your reasoning!
4. Post-shaking:

   Describe the new arrangement of the sediment in the bottle.

   Was your prediction/reasoning correct? How do you know? How could you check?

5. Discuss with your group the most important factor(s) that made the sediment settle in the way that it did. (Be sure to put this in your write-up as well.)
6. This is a model for real-world sediment transport. In what ways does the model fall short of real life sediment transport? (list at least 2-3 ways)
7. Group discussion: how can you improve on this model to account for the above shortcomings?

-Short class discussion on this model, including its shortcomings and ideas for improvement –

(The teacher will make sure certain ideas for improvement are discussed, including the need for a current in the water.)

<u>Part 2</u>

The teacher now brings out the new model and asks each group to suggest factors influencing sediment transport that the class could examine with this new model. With the teacher's help, as needed, the list includes:

- *Shape*
- *Density*
- *Size (mass or volume)*
- *Velocity of the water*
- *Water depth*
- *Sorting of material*
- *Time frame*

The model is run, and a delta is formed, though the students do not necessarily know what it is.

8. In your write-up, record the list of possible influencing factors on sediment transport.
9. Before <u>each</u> factor is examined using the new model:
    - make a prediction in your write-up: how much of a factor will it be in sediment transport?
    - was your prediction correct? Why or why not? How could you check?

The students will be asked to draw cross-sections of the delta on the board and each component of the delta will be explored. The students may have to use other methods to test some of the factors in the list, such as actually taking samples at various locations along the delta and measuring the density of the sediment, or quantifying the shape of the material and the influence of that shape on the sediment's movement.

10. What sedimentary structure was made in the tank? (Include the specific name!)
    Draw a longitudinal cross-section through that sedimentary structure and label all the important components.
11. List the most important factor(s) that led to the formation of that sedimentary structure.
12. This is still a simple model of a real-world process. What are some limitations of this model?

Reading on Gilbert-style deltas will be assigned for homework, and there will be a group discussion over this exercise and relation to the reading in the following class.

Appendix and Works Cited

These standards were consulted and some or all of them have been modified as noted in each list of objectives (p.4-7).

Maine Learning Results (M.L.R.)

http://www.state.me.us/education/lres/homepage.htm

F. THE EARTH

Students will gain knowledge about the earth and the processes that change it. The earth's surface undergoes steady or sudden changes due to forces of wind, water, ice, volcanism, and shifting of tectonic plates.

Secondary grades

1. Describe how air pressure, temperature, and moisture interact to cause changes in the weather.
2. Analyze potential effects of changes in the earth's oceans and atmosphere.
3. Describe the impact of plate movement and erosion on the rock cycle.
4. Describe ways that scientists measure long periods of time and determine the age of very old objects.
5. Demonstrate how rocks and minerals are used to determine geologic history.
6. Analyze the changes in continental position and the evidence that supports the concept of tectonic plates.

J. INQUIRY AND PROBLEM SOLVING

Students will apply inquiry and problem-solving approaches in science and technology. Scientific inquiry, problem solving, and the technological method provide insight into and comprehension of the world around us. A variety of tools, including emerging technologies assist, the inquiry processes. Models are used to understand the world.

1. Make accurate observations using appropriate tools and units of measure.
2. Verify, evaluate, and use results in a purposeful way. This includes analyzing and interpreting data, making predictions based on observed patterns, testing solutions against the original problem conditions, and formulating additional questions.
3. Demonstrate the ability to use scientific inquiry and technological method with short term and long term investigations, recognizing that there is more than one way to solve a problem. Demonstrate knowledge of when to try different strategies.
4. Design and construct a device to perform a specific function, then redesign for improvement (e.g., performance, cost).

K. SCIENTIFIC REASONING

Students will learn to formulate and justify ideas and to make informed decisions. This involves framing and supporting arguments, recognizing patterns and relationships, identifying bias and stereotypes, brainstorming alternative explanations and solutions, judging accuracy, analyzing situations, and revising studies to improve their validity.

1. Judge the accuracy of alternative explanations by identifying the evidence necessary to support them.
2. Explain why agreement among people does not make an argument valid.
3. Develop generalizations based on observations.
4. Determine when there is a need to revise studies in order to improve their validity through better sampling, controls or data analysis techniques.
5. Produce inductive and deductive arguments to support conjecture.
6. Analyze situations where more than one logical conclusion can be drawn.

L. COMMUNICATION

Students will communicate effectively in the applications of science and technology. Clear and accurate communication employs appropriate symbols and terminology, models, and a variety of media and presentation styles. Communication includes constructing knowledge through reflection, evaluation, refocusing, and critically analyzing information from a variety of sources. Individuals and collaborative groups must communicate effectively.

1. Analyze research or other literature for accuracy in the design and findings of experiments.
2. Use journals and self-assessment to describe and analyze scientific and technological experiences and to reflect on problem-solving processes.
3. Make and use appropriate symbols, pictures, diagrams, scale drawings, and models to represent and simplify real-life situations and to solve problems.
4. Employ graphs, tables, and maps in making arguments and drawing conclusions.
5. Critique models, stating how they do and do not effectively represent the real phenomenon.
6. Evaluate the communication capabilities of new kinds of media (e.g., cameras with computer disks instead of film).
7. Use computers to organize data, generate models, and do research for problem solving.
8. Engage in a debate, on a scientific issue, where both points of view are based on the same set of information.

National Science Education Standards (N.S.E.S.)

http://www.nap.edu/readingroom/books/nses/html/

Standard D: Energy in the Earth system

- The outward transfer of earth's internal heat drives convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe.
- Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
- Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.

Science benchmarks (S.B.)

http://www.project2061.org/tools/benchol/bolintro.htm

C. Processes that shape the Earth

- The formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change.
- The slow movement of material within the earth results from heat flowing out from the deep interior and the action of gravitational forces on regions of different density.
- The solid crust of the earth-including both the continents and the ocean basins-consists of separate plates that ride on a denser, hot, gradually deformable layer of the earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Ocean-floor plates may slide under continental plates, sinking deep into the earth. The surface layers of these plates may fold, forming mountain ranges.
- Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.

Other works cited:

Wiggins, G., and McTighe, J., **Understanding by Design**, 1998.