Assessing the Geology Department’s statement of learning outcomes and goals

The What: One of the four major themes in the Geology Department’s learning outcomes and goals statement (attached at end of document) is that ‘students will learn the fundamental concepts of Geology’. Supporting this statement are seven bullets that describe the different areas in which the Geology Department feels our students need to demonstrate expertise. Prior to initiating our Teagle assessment plan, the Geology Department simply took it on faith that our colleagues were doing an effective job at teaching to these goals, and that our students were leaving Bryn Mawr with value-added in the seven sub-fields of Earth Science.

For our assessment loop the Geology Department focused on three of the seven fundamental concepts. It is our intent that moving forward, all seven concepts areas will be evaluated using a similar methodology.

The three currently assessed concept areas are:

1. Each graduate will demonstrate an understanding of plate tectonics and be able to describe how it operates;
2. Each graduate will demonstrate an understanding of the geologic time scale and the timing of major events in Earth history;
3. Each graduate will demonstrate an understanding of global climate change on various time scales.

Each of these three learning goals has been spearheaded by a different faculty member whose expertise, and curricular contributions to the department, addresses the stated concept area (Prof. Weil for concept 1; Prof. Marenco for concept 2; Prof. Barber for concept 3).

The main objective of our assessment loop was to assess the effectiveness with which the Bryn Mawr College geology major curriculum teaches and reinforces our stated learning goals. To do this we decided to use direct assessment using quantifiable and tractable concept specific tests.

As a background, the Geology Department started in earnest on our program’s learning goals about five years ago after a wave of retirements of senior departmental faculty. This time period marked a significant transformation of the culture in the department, from one of a ‘classic’ curriculum approach, to a more modern multidisciplinary approach to the Earth Sciences.

Armed with relatively young and gung-ho faculty we developed our statement of the Geology Department's learning outcomes and goals (attached). This list was worked on, off and on, for a full academic year. At the end of which a document was produced that was vetted by each member of the department as well as several friends/colleagues outside of the department. The
point being is that we had universal consensus on what we thought were the fundamental objectives and outcomes we had for a Tri-college student leaving Bryn Mawr College with a geology major.

So how did we go about assessing the three preliminary concept areas mention above? We decided that we would imbed quantifiable checks at several different stages of a student’s progress in the Geology Major in order to track the progress of both individual students, as well our recent graduates. The idea being we would be able to spotlight those areas that our students are underperforming according to our objectives, and thus modify our curriculum, and/or existing exercise/labs in order to reinforce those important concepts.

First, a multiple-choice concept test was developed that focused on the three learning goal areas. The tests were created by the entire geology department faculty (attached at end of document). Twenty questions were ultimately chosen for each area that was intended to track students’ basic understanding of concepts, fact-based knowledge, and important nomenclature. This was challenging, and obviously a multiple choice exam can only do some much towards these goals, but we thought this would be the most efficient and effective way to integrate the exams into our introductory classes, which tend to have relatively large numbers (between 40 and 80 students in a given semester). Implementation of the test was set up by our Institutional Research office.

The test has now been taken as a pre- and post-course test by three of our introductory classes, and by the end of this academic year we should have data from a total of six classes. Each test is taken on the students own time during the first week of our introductory geology courses. So far, 80-90% of the students are participating in the test taking. Each of the three intro Geology classes, Physical Geology (101), Historical Geology (102), and Earth Systems and the Environment (103), deals specifically with one of the three stated goals above. The tests are graded, tallied and kept on record according to student ID#. Each test was again taken at the end of each introductory course as a way to assess the effectiveness of the individual course in teaching the stated concepts – a kind of instant feedback for curricular change for the individual faculty.

Additionally, a senior-exit concept test, which parallels the three intro tests, has been initiated at the end of the mandatory senior seminar. Similar to the introductory test, this test is graded, tallied and kept on record according to ID#. The test has a mix of basic fact questions, nomenclature questions, and higher-order concept questions.

*Project Discussion and Dissemination:* The Geology department has had substantial and substantive internal discussions over the past several years on assessment, departmental learning goals, the creation of the Teagle assessment loop plan and test, etc. We have come to unanimous decisions, as much as academics can become unanimous on anything, on learning goals and outcomes, how to best assess these at the departmental level, and what we should do when deficiencies and underperformance is found – “closing the loop”. Thus, at the departmental level
we are doing well. In terms of dissemination of our ideas to other groups, it is really just getting to the point where we have meaningful data that can be interpreted and used, and thus shared with others. That said, whenever possible in a general faculty forum, members of the geology department have universally been outspoken advocates for assessment, the benefits of generating meaningful program learning goals and objectives, and being intentional about what and how we teach. It is my intention as the leader of this project to present our assessment loop at a national Geological Society of America Meeting during the 2012-2013 academic year. I will also make myself available to the Provost’s offices of the Tri-college to talk about, or present my departments Teagle work to working groups at any of the three institutions.

*Closing the Loop:* Due to the limited number of exam opportunities thus far, only minor adjustments have been made to the department’s curriculum as an outcome of the analysis of test outcomes. To this point it has been up to the individual faculty to update their lesson plans and syllabi in order to address concept deficiencies that have been identified.

For example, there were three consistently missed post-class questions by my intro student regarding the dynamics of the Earth’s interior and its relationship to plate tectonics. As a first ‘fix’ I went back to my lecture notes and slides from the first month of class – in which I cover the appropriate concepts – and made some adjustments and notes to make sure that I diversify the ways in which I talk about the concepts and to incorporate a class discussion/exercise around the ‘missed’ learning goals. Additionally, there was one question that ¾ of our seniors missed, which to me was a fundamental failure. This was eye-opening. I took for granted that my students were comfortable with the material properties of the Earth’s deep interior, but clearly I was wrong. This concept area is covered in multiple courses and, like the intro class; I will be much more thoughtful in leading discussions in this area in the future.

The faculty of the Geology department has a biannual retreat that provides a venue for us to flesh-out ideas, build consensus, develop solutions, and foster collegiality. An important agenda item on next summer’s retreat itinerary is analysis of the first two rounds of data from our intro classes and graduating seniors. These data will be used to discuss how the department can improve student understanding in the areas highlighted by exam results. It will be up to the entire department to address the concept holes in as many venues as possible – not a single member in a single class. We will also initiate assessment measures for the remaining four learning goals laid out in our *Student Learning Outcomes and Learning Goals* document.

The end objective of the Geology department’s Teagle loop is to give us a way to add a developmental perspective to our assessment of learning goals. That is, as an outcome of the loop we have quantifiable data over the career of our student’s time in the Geology so we can evaluate how a student has progressed through the instructional material and what has been added through her time in contact with Bryn Mawr Geology faculty.
Student Learning Outcomes and Learning Goals - Geology Major

- Provide a high-quality undergraduate education that combines transdisciplinary problem- and process- oriented, and quantitative approaches to the Earth Sciences.
  - Develop highly competent geoscience students prepared to analyze and comprehend the linkages among Earth system components and their physical and social context
    - Each graduate will demonstrate the ability to apply knowledge, concepts and techniques from complementary disciplines to solve problems
    - Each graduate will employ accepted laboratory and field techniques, protocols, and safety procedures
    - Each graduate will demonstrate the ability to read, construct, and comprehend thematic maps as well as derive conceptual perspectives from existing maps
    - Students will demonstrate the appropriate use of quantitative data through graphs, spreadsheets, and statistical analysis
  - Students will learn the fundamental concepts of geology
    - Each graduate will demonstrate an understanding of plate tectonics and be able to describe how it operates
    - Each graduate will demonstrate an understanding of the geologic time scale and the timing of major events in Earth history
    - Each graduate will demonstrate the ability to identify and characterize important earth materials, and to interpret the physical, chemical and biological processes by which they formed
    - Each graduate will demonstrate an understanding of the geologic time scale and the timing of major events in Earth history
    - Each graduate will demonstrate an understanding of evolution and its evidence in the fossil record
    - Each graduate will demonstrate an understanding of the internal structure of Earth
    - Each graduate will demonstrate an understanding of the hydrologic cycle
  - Educating our students about Earth's natural systems, its resources, and the impact of humans on the planet
    - Applying geoscience knowledge to address problems affecting human society, locally and globally
    - Each graduate will demonstrate the ability to make informed, scientifically based decisions regarding environmental issues, resource exploration and extraction, and anthropogenic effects on the natural world
  - Develop and communicate new knowledge to the broader community through fundamental research that uses current technologies
    - Each graduate will deliver oral presentations, demonstrating the ability to effectively communicate discipline-specific concepts
    - Each graduate will write scholarly papers using acceptable format and organization with citations to appropriate literature
    - Students will deliver presentations making appropriate use of visual or electronic media
Geology Department Introductory Student Assessment Questions

Section I

Physical Geology (Geology 101 - Weil)

1. What are the three types of plate boundaries?
   a. Transform, Conservative and strike-slip
   b. Convergent, Subduction zone and Transform
   c. Divergent, Convergent and Transform
   d. Divergent, Extensional and Convergent

2. The lithosphere includes:
   a. crust and uppermost, rigid mantle
   b. outer core and inner core
   c. outer core and lower mantle
   d. asthenosphere and mesosphere

3. What are the three chemically differentiated layers of the earth?
   a. Lithosphere, Asthenosphere, Mesosphere
   b. Crust, Lithosphere, Core
   c. Mantle, Inner Core and Outer Core
   d. Crust, Mantle and Core

4. Where is the Earth’s magnetic field generated?
   a. in the crust
   b. in the mantle
   c. in the outer core
   d. in the inner core
   e. the sun

5. What are the three ways the earth generates magmatic melts?
   a. Decompression, meteorite impact and addition of heat
   b. Decompression, addition of volatiles and addition of heat
   c. Addition of volatiles, addition of heat and an increase in pressure
   d. Radioactive fusion, an increase in pressure and addition of heat

6. Which one of the following lists most accurately describes oceanic crust?
   a. basaltic - density of 3.0 g/cm³
   b. granitic - density of 3.0 g/cm³
   c. sandstone - density of 2.6 g/cm³
   d. basaltic - density of 2.6 g/cm³

7. The Earth’s mantle is:
   a. Solid
   b. Liquid
   c. Fluid
   d. A conductor

8. Which of the following statements regarding the Plate Tectonic paradigm is FALSE:
   a. convection in the mantle helps drive plate motion
b. plate boundaries vary in length and width

c. Earth’s crust is broken up into a finite number of continental plates and oceanic plates
d. there are three type of plate boundaries in which crust is destroyed, created and conserved

9. Which one of the following descriptions of mineral characteristics is NOT true?
   a. formed of atoms
   b. organic
   c. solid
   d. definite chemical structure
   e. naturally occurring

10. Minerals form by:
   a. precipitation from a solution
   b. solid-state diffusion
   c. instant solidification (quenching) of a melt
   d. incremental growth of crystalline lattice

11. What are the two main sources of heat for the Earth’s interior?
   a. Sun and the Earth’s core
   b. Decay of radioactive elements and the Sun
   c. Primordial heat and the Earth’s core
   d. Primordial heat and the decay of radioactive elements

12. The difference in texture between plutonic and volcanic rocks is caused by:
   a. different mineralogy
   b. different rates of cooling and crystallization
   c. different amounts of water in the magma
   d. different chemical compositions

13. What controls the explosiveness of a volcano?
   a. silica and volatile content
   b. pressure and temperature
   c. depth of magma
   d. none of the above

14. The two major phenomena that cause metamorphism are:
   a. Volcanism and erosion
   b. Heating and chemical dissolution
   c. Deep burial and weathering
   d. Heating and compression

15. The elastic rebound theory
   a. explains folding of rocks.
   b. explains the behavior of seismic waves.
   c. explains the origins of earthquakes.
   d. none of these

16. Which of the following statements regarding the scientific methods is true?
   a. a hypothesis must be agreed upon by more than one scientist
b. a theory is a hypothesis that has withstood many scientific tests

c. a theory is proven to be true, and therefore may not be discarded

d. a hypothesis cannot predict the outcome of scientific experiments

17. What is the difference between a fault and a joint?

a. the hanging wall moves up on a fault and down on a joint
b. faults are low angle features and joints are vertical features

c. faults show displacement and joints do not

d. faults are planar features and joints are linear features

18. Which of the following is not an example of isostasy?

a. ocean basins are deeper than continents
b. crustal rebound
c. deep mountain roots

d. all of these are examples of isostasy

19. What are the four major elements that make up the mass of the solid earth?

a. Fe, O, Mg, Si
b. Fe, Mg, Si, Al
c. Fe, O, Si, Ca
d. Fe, H, O, Si

20. Which of the following statements about weathering is false?

a. rocks of different compositions weather at different rates
b. rainfall increases the rate of chemical weathering
c. the presence of soil slows down the weathering of the underlying bedrock

d. the longer a rock is exposed at the surface, the more weathered it becomes

Section II

Earth Systems and the Environment (Geology 103 - Barber)

1. What source of energy drives the circulation of the oceans and atmosphere?

a. tropical cyclones
b. radiation from the sun

c. heat from within the earth
d. gravitational attraction of the moon

2. The two main factors that control the density of seawater are:

a. temperature and water depth
b. pressure and salt content
c. water depth and pressure
d. temperature and salt content

3. The average depth of the world’s oceans is:

a. 4,000 meters
b. 40,000 meters
c. 8,000 meters
d. 500 meters
4. What controls the amount of water vapor in air?
   a. air temperature: cooler air can hold much more water vapor than hot air
   b. moisture supply: air closer to water bodies contains much higher amounts of moisture
   c. air temperature: warmer air can hold much more water vapor than cold air
   d. cloudiness: air beneath clouds contains more moisture than air beneath a clear sky

5. The most important source of energy for life on earth is:
   a. evaporation of water from the ocean surface
   b. electrical discharges from lightning in the atmosphere
   c. heat from within the earth
   d. radiation from the sun

6. Name a sedimentary rock type that forms in tropical environments.
   a. coal
   b. arkose
   c. evaporite
   d. diamictite

7. What controls the rate at which water can be pumped out of a groundwater well?
   a. the depth of the well
   b. the permeability of the rock or sediment unit that contains the water
   c. the flow rate of the underground river
   d. the porosity of the rock or sediment unit that contains the water

8. What are the four most abundant dissolved ions present in seawater?
   a. calcium, sodium, aluminum, carbonate
   b. sodium, sulfate, potassium, chlorine
   c. sodium, chlorine, magnesium, sulfate
   d. sodium, chlorine, calcium, carbonate

9. Name a sedimentary rock type that forms in cold environments.
   a. limestone
   b. tillite
   c. quartzarenite
   d. black shale

10. What causes seasonal temperature variations on Earth (e.g., winter vs. summer)?
    a. changes in the Earth-Sun distance through the year
    b. changes in cloud cover over different parts of the Earth through the year
    c. changes in day length through the year
    d. changes in the angle of the Sun’s rays striking different parts of the Earth through the year

11. The size of particles (grains) in a sedimentary rock tells you:
    a. how long it took for the rock to solidify
    b. the type of rock that was originally eroded to make the particles
    c. the relative age of the sedimentary rock
    d. the turbulence of the fluid that deposited the grains

12. Decomposition of organic material in a typical land environment (e.g., a forest) releases:
a. hydrogen
b. oxygen
c. carbon dioxide
d. methane

13. Why is Earth’s average surface temperature higher at the Equator than at the poles?
a. the Equator is closer to the Sun than the poles
b. polar regions are much more cloudy than equatorial regions
c. solar radiation strikes equatorial regions more directly, and polar regions more obliquely
d. the relative humidity is much higher in equatorial regions than in polar regions

14. In the long-term carbon cycle, one of the ways that carbon is added to the atmosphere is:
a. the weathering of silicate rocks
b. the eruption of volcanoes
c. the evaporation of seawater
d. the erosion and dissolution of coral reefs

15. How does a positive feedback loop influence how a system responds to perturbation?
a. perturbations are amplified
b. perturbations are diminished
c. the system is stabilized
d. the system is destabilized
e. both a and d
f. both b and c

16. The two most important greenhouse gases in Earth’s atmosphere are:
a. water vapor and carbon dioxide
b. carbon dioxide and ozone
c. carbon dioxide and methane
d. hydrogen and carbon dioxide

17. The first and second most abundant elements in the atmosphere are:
a. carbon and oxygen
b. oxygen and nitrogen
c. nitrogen and oxygen
d. hydrogen and oxygen

18. Wind is driven by variations in:
a. air temperature
b. humidity
c. clouds
d. air pressure

19. The layer of ozone in Earth’s stratosphere reduces:
a. the amount of infrared radiation from Earth’s surface emitted back out to space
b. the amount of visible light from the Sun striking the Earth surface
c. the amount of ultraviolet radiation from the Sun striking the Earth surface
d. the amount of infrared radiation from the Sun striking the Earth surface
20. How does petroleum form?
   a. oils are squeezed out of dinosaur flesh by the weight of sediments above them
   b. organic compounds in tropical plants are altered by heat and pressure
   **c. organic compounds in marine plant remains are altered by heat and pressure**
   d. limestone deposited by coral reefs are altered by heat and pressure
   e. oils and organic compounds in fish and other marine animals are squeezed into porous rocks

**Section III**

**Historical Geology (Geology 102 - Marenco)**

1. How old is Earth?
   a. 1 million years
   b. 100 million years
   **c. 4.5 billion years**
   d. 45 billion years

2. How did Earth’s oceans form?
   a. 100 year storm event
   b. **Volcanic outgassing**
   c. Melting of natural ice dam
   d. Degradation of organic compounds in the upper crust

3. How old is the earliest fossil evidence for life?
   a. 15 billion years
   b. **3.5 billion years**
   c. 120 million years
   d. 10 thousand years

4. How did the moon form?
   a. During the formation of the solar system, as the planets formed by the consolidation of gas and
dust, smaller bodies formed and were trapped by the gravitational pull of larger bodies to become
satellites.
   b. Earth’s moon was originally Earth’s twin planet but over time lost matter because of the lack of an
atmosphere, eventually relegating it to the status of satellite.
   **c. Early in Earth’s history a planet-sized body slammed into Earth causing the ejection of Earth
matter into space. This matter consolidated into a body that was trapped by Earth’s gravitational pull.**
   d. While the surface of the Earth was still molten, a massive volcanic eruption ejected vast amounts
of Earth matter into space. This matter consolidated into a body that was trapped by Earth’s
gravitational pull.

5. When might photosynthesis have evolved?
   a. **3.5 billion years as evidenced by fossil cyanobacteria**
   b. 1 billion years ago, as evidenced by the first green pigments
   c. 420 million years ago as evidenced by the first land plant fossils
   d. 100 thousand years ago, as evidenced by marine fossil data

6. How did Earth’s oceans and atmosphere become oxygenated?
   a. Volcanic outgassing
   b. Comet bombardment
   **c. Photosynthesis**
   d. Methanogenesis
7. What are the oldest widely-accepted animal fossils?
   a. The Burgess Shale fossils
   b. The Doushantuo fossils
   c. The Ediacaran fossils
   d. The Jehol fossils

8. What is the name given to the last known supercontinent?
   a. Rodinia
   b. Gondwanaland
   c. Pangaea
   d. Laurentia

9. When did land plants evolve?
   a. During the Silurian
   b. During the Cambrian
   c. During the Neoproterozoic
   d. During the Cretaceous
   e. 10 thousand years ago

10. When did vertebrates colonize land?
    a. During the Cambrian
    b. During the Devonian
    c. During the Jurassic
    d. During the Hadean
    e. 10 thousand years ago

11. What caused the extinction of the dinosaurs?
    a. A meteor struck the Earth and caused the extinction
    b. They were outcompeted by the smarter mammals
    c. Atmospheric oxygen levels decreased for unknown reasons.
    d. Extreme volcanism led to rapid climate change

12. What was Mesozoic climate like compared to today?
    a. The same
    b. Hotter
    c. Colder
    d. We don’t know

13. How old are the oldest fossils of H. sapiens?
    a. 4.5 billion years
    b. 3.5 billion years
    c. 100 million years
    d. 1 million years
    e. 400 thousand years
    f. 200 thousand years
    g. 10 thousand years

14. During photosynthesis:
    a. Plants take up O₂ and release CO₂
    b. Plants take up CO₂ and release O₂
c. Plants take up CH₄ and release O₂
d. Animals take up CO₂ and release O₂
e. Animals take up O₂ and release CH₄

15. Which of these describes a currently-studied hypothesis for the origin of life on Earth?
   a. Organic compounds were synthesized from inorganic compounds in aqueous environments
   b. We have no idea
   c. Spontaneous generation
   d. Mineral decay under heavy UV bombardment

16. What makes a good index fossil?
   a. Slow evolution
   b. Restricted distribution
   c. Large size
   d. Rapid evolution

17. What are the three evolutionary faunas?
   a. The Cambrian, Paleozoic, and Modern evolutionary faunas
   b. The Fish, Reptile, Mammal and Avian evolutionary faunas
   c. The Protist, Metazoan, and Hominin evolutionary faunas
   d. The Microbe, Plant, and Animal evolutionary faunas

18. Which of these is a valid principle of stratigraphy?
   a. The Principle of Radioactive Decay
   b. The Principle of Superposition
   c. The Principle of Chromatic Gradation
   d. The Principle of Chemosynthetic Succession

19. What is the mechanism that drives natural selection?
   a. Survival of the fittest
   b. Random genetic drift
   c. Reproductive isolation
   d. Microevolution

20. On which continent did H. sapiens evolve?
   a. North America
   b. Australia
   c. Europe
   d. Asia
   e. Africa
   f. Antarctica
   g. South America