

ES202 Geologic Time Lab Key

Your task is to complete portions of Lab 8 in your lab manual (p. 128-139)

Part 1. Short Answer. Read the lab materials and define the following terms and concepts / answer the questions.

1. Discuss the difference between relative age dating and absolute age dating, as pertaining to the geologic rock record.

Relative age dating simply describes the age of something relative to other things. So a rock layer that has layers above and below it is older than the layers above it and younger than the layers below it. Absolute age dating describes the age of something in exact units, like years. It is more specific than relative age dating. For example, one rock layer could be 425 million years old.

2. Law of Original Horizontality – Sedimentary layers (strata) and lava flows were originally deposited as relatively horizontal sheets.
 3. Law of Lateral Continuity – Lava flows and strata extend laterally in all directions until they thin to nothing (pinch out) or reach the edge of their basin of deposition.
 4. Law of Superposition – In an undisturbed sequence of strata or lava flows, the oldest layer is at the bottom of the sequence and the youngest is at the top.
 5. Law of Inclusions – Any piece of rock (clast) that has become included in another rock or body of sediment must be older than the rock or sediment into which it has been incorporated.
 6. Law of Cross-Cutting Relations – Any feature that cuts across a rock or body of sediment must be younger than the rock or sediment that it cuts across.
 7. Unconformity – A surface that represents a gap in the geologic record that formed wherever layers were not deposited for a time or else layers were removed by erosion.
 8. Angular Unconformity – An unconformity between two sets of strata that are not parallel to one another.
 9. Disconformity – An unconformity between parallel strata or lava flows.
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Part 2. Lab Activities. Complete the following lab questions.

Lab Question 1 (p.130), Lab Question 3 (p.130), Lab Question 4 (p.135), Lab Question 5 (p.135), Lab Question 8 (p.139).

1. **Oldest to Youngest:** K, J, M, E, F, L, D, C, B, A, I, H, G

3. **For Fig. 8.11, Oldest to Youngest:** F (parts of F included in P, so it came first), P (part of P included in B, so it came before B), G (doesn't cut layer B), B, R, M (doesn't intrude layer H), H, A, E, X, D, K (doesn't cut J or S), J, S.

For Fig. 8.12, Oldest to Youngest: V, C, O, M, X, K, E, B, S, Z, J, G, L, F, T, A, D, H, P, N (I interpret that N occurred during faulting of P. Since the garage is dipping into the river channel where H has formed, H must have formed before faulting P occurred), R.

4. a.) Ordovician. The fossils present appear to be Flexicalymene and Strophomena, only present during this period.
 b.) 490 to 443 million years. These fossils could have been deposited together at any time during this period. They are no younger than 443 m.y.
5. a.) Devonian. The fossils present appear to be Phacops and Mucrospirifer. Although Phacops existed during the late Silurian, the presence of Mucrospirifer restricts the age of the rock to Devonian.
 b.) 417 to 354 million years – no younger than 354 m.y.
8. a.) According to the chart on page 138, about $\frac{1}{2}$ of a half-life has elapsed when there is 70.7% parent (Uranium), and 29.3% daughter (Lead).
 b.) $\frac{713 \text{ m.y.}}{1_{T_{1/2}}} \times 0.500_{T_{1/2}} = 356.5 \text{ m.y.}$
 c.) The lava flow was deposited about 357 m.y.a, so any layer beneath it is older than that (Devonian and older).
 d.) Any layers above the lava flow are younger than 357 m.y.

LABORATORY EIGHT

Dating of Rocks, Fossils, and Geologic Events

OBJECTIVES

- A. Learn and be able to apply techniques for relative age dating of Earth materials and events.
- B. Use fossils to date some rock bodies and infer some of Earth's history.
- C. Learn and be able to apply techniques for absolute age dating of Earth materials and events.
- D. Be able to apply relative and absolute dating techniques to analyze two field sites and infer their geologic history.
- E. Be able to apply relative dating techniques to analyze logs of five wells and correlate among them.

STUDENT MATERIALS (Remind students to bring items you check below.)

- ____ laboratory manual
- ____ laboratory notebook
- ____ pencil with eraser
- ____ calculator (for Parts 8C and 8D)
- ____ ruler (cut from GeoTools sheet 1)
- ____ protractor (cut from GeoTools sheet 3)
- ____ colored pencils (optional for Part 8E)
- ____ :

INSTRUCTOR MATERIALS (Check off items you will need or provide.)

- ____ : Geiger counter and radioactive mineral or rock sample (optional: to reveal radioactive decay in Part 8C).
- ____ :

INSTRUCTOR NOTES AND REFERENCES

1. General information. Refer to Laboratory 8 on the Internet site at <http://www.prenhall.com/agi> for additional information and links related to all parts of this laboratory.
2. Geologic Cross sections. The geologic cross sections in Figures 8.9–8.12 are arranged in order of increasing difficulty.

3. Radioactive decay. To help students understand the concept of radioactive decay, it helps to demonstrate by detecting with a Geiger counter the radioactivity emitted from a radioactive rock or mineral sample.

ANSWERS TO QUESTIONS IN LABORATORY 8

Part 8A: Determining Relative Ages of Rocks Based on Their Physical Relationships

1. Figure 8.9

F (youngest, occurred last)
 R
 B
 K
 N
 S
 A
 J
 D
 M
 O
 H
 C
 L
 G
 P
 E (oldest, occurred first)

Figure 8.10

G (youngest, occurred last)
 H
 I
 R
 A
 B
 C
 D
 L
 F (occurred anytime after E)
 E
 M
 S
 J
 K (oldest, occurred first)

2. Refer to the sequence of lettered formations above for Figure 8.10.

During Precambrian time the Vishnu Schist was intruded by a body of magma that cooled to form the Zoroaster Granite. The top of the Vishnu Schist and Zoroaster Granite was then eroded to form a regional unconformity (nonconformity, S). Gravel and the Bass Dolomite were deposited atop the nonconformity. Igneous unit F then intruded the Vishnu Schist, gravel, and Bass Dolomite. The Hakatai Shale, Shinumo Quartzite, Dox Sandstone, Chuar Shales, and Nankoweap Group were deposited next atop the Bass Dolomite (in that order). Finally, this entire Precambrian sequence of rocks was tilted in a regional uplift. The top of these tilted units was eroded to form a second regional unconformity (angular unconformity, R).

During the Cambrian Period (Paleozoic Era), the Tapeats Sandstone was deposited on top of the second regional unconformity (R). Bright Angel Shale was deposited on the Tapeats Sandstone, and Mauv Limestone was deposited on the Bright Angel Shale. Sometime after this, a third regional unconformity

(disconformity) developed and eroded rocks down to the level of the Mauv Limestone.

At the present time, the modern landscape is an erosional surface that is creating a third regional unconformity. The Grand Canyon is getting deeper as the Colorado River cuts deeper into the Cambrian and Precambrian bedrock and further develops the regional unconformity. The plateau capped by the Mauv Limestone is also being eroded.

3. **Figure 8.11**

S (youngest, occurred last)
 N
 J
 K
 D
 X
 E
 O
 M (note that sequence B,R,H,A is folded, then cut by M)
 A
 H
 R
 B
 C
 G
 P
 F (oldest, occurred first)

Figure 8.12

R (youngest, occurred last)
 H
 N (occurred anytime after D)
 P (occurred anytime after D)
 D
 A
 T
 F
 L
 G
 J
 Z
 S
 B
 E
 K
 X
 M
 O
 C
 V (oldest, occurred first)

Part 8B: Using Fossils to Determine Age Relationships

- 4a. The brachiopods are *Strophomena*, an index fossil for the Ordovician Period. The trilobite is *Flexicalymene*, an index fossil for the middle to late Ordovician. (The time when these two fossils co-existed was a relative age of middle to late Ordovician).
- 4b. The Ordovician Period has an absolute age of 443–490 million years. The middle to late Ordovician has an absolute age of about 470–443 million years.
- 5a. The brachiopod is *Mucrospirifer* and the trilobite is *Phacops* (Figure 8.13). The time when these two fossils co-existed was the Devonian Period, so this rock has a Devonian relative age.
- 5b. The Devonian Period has an absolute age of about 354–417 million years.

- 6a. *Olenellus* (unit C) is a Cambrian index fossil and *Phacops* is a Late Silurian and Devonian index fossil (unit D). So the contact between units C and D must be a disconformity.
- 6b. Ordovician and Early Silurian rocks are missing.
- 6c. Bedrock now exposed at the land surface is Devonian (because it contains fossils of *Phacops*, so the rocks are at least 354 years old. If this land surface were buried today to form a disconformity, then the disconformity would represent a gap of at least 354 million years (Mississippian through Quaternary time).
- 7. Rock units A-D were tilted (due to a regional uplift or mountain building) and eroded off to form an unconformity.

Part 8C: Determining Absolute Ages by Radiometric Dating

- 8a. 1/2 of a half life (0.50 half-life) has elapsed.
- 8b. $0.50 \times 713,000,000 \text{ yr} = 356,500,000 \text{ yr}$ (about 357 million years old)
The lava flow must be less than or equal to the age of the zircon crystals (357 million years old).
- 8c. The rocks beneath the lava flow are older than the lava flow, so they are more than 357 million years old.
- 8d. The rock layers above the lava flow formed after the lava flow, so they must be less than 357 million years old.
- 9. 50% of the parent has decayed, so one half-life of 4.5 billion years has elapsed. Based on this logic, the Earth is about 4.5 billion years old.
- 10a. 94% of the parent (C-14) has decayed (because only 6% remains), so about 4 half-lives of 5730 years have elapsed. So the peat must be about 22,920 yr old.
- 10b. Younger plant roots would contaminate the peat with more C-14 and make it seem younger, while older limestone would contaminate the peat with more N-14 and make it seem older.
- 11a. **No**, the zircon crystals are weathered from older igneous rocks. The zircon crystals did not form at the same time as the sand deposit; they are older than the sand deposit.
- 11b. The radiometric age of a crystal in a rock is about the same age as the rock only if it formed at about the same time as the rock (and has not been re-heated or isotopically contaminated, as in Question 10b above).

Part 8D: Age Analysis of Two Field Sites

- 12a. The sedimentary rocks are mid-Tertiary in age based on the presence of *Fagopsis* leaf fossils within them.

- 12b.** The zircon crystals probably formed at about the same time as the sill, before it cooled but while it was being emplaced. Zircon crystals in the sill have 98.9% U-235 and 1.10% Pb-207, so the U-235 has decayed 1/64 of a half-life. Thus, the age of the sill is $0.015 \times 713,000,000 \text{ yr} = \mathbf{10,695,000 \text{ yr (10.7 million years)}}$.
- 12c.** **about 2 meters** (based on the scale provided in Figure 8.17)
- 12d.**
- Sand was deposited with *Fagopsis* leaves during mid-Tertiary time.
 - Mud was deposited (with *Fagopsis* leaves) on top of the sand during mid-Tertiary time.
 - Additional sediments were deposited on top of the mud and compacted the sand and mud into sandstone and shale.
 - The sill intruded between layers of sedimentary rock above the shale. This occurred in mid-Tertiary time, about 10.7 million years ago.
 - Earthquakes and faulting occurred to produce the fault in this outcrop and its 2 m of displacement.
 - Erosion of the rocks above the sill occurred to produce the present-day landscape. The fault may still be active.
- 13.**
- During Late Pennsylvanian or Early Permian time, plants like *Neuropteris* grew in a sandy and muddy marsh, swamp, delta, or floodplain.
 - As some of the plants died, they were buried in the sands and mud. Some of the plants formed peat layers.
 - More sediment accumulated for hundreds of meters on top of the sand, mud, and peat, so they turned to sandstone, mudstone, and bituminous coal. The plants in the sand and mud became fossilized.
 - Crustal compression caused the rock layers to fold and tilt, and the coal turned to anthracite inside folded mountains.
 - Over millions of years, the mountains were eroded to the point where the folded layers of sandstone, mudstone, and coal were present just under the landscape.
 - People excavated the landscape to expose the layers of rock and mine the coal.
 - The photograph in Figure 8.18 was taken.

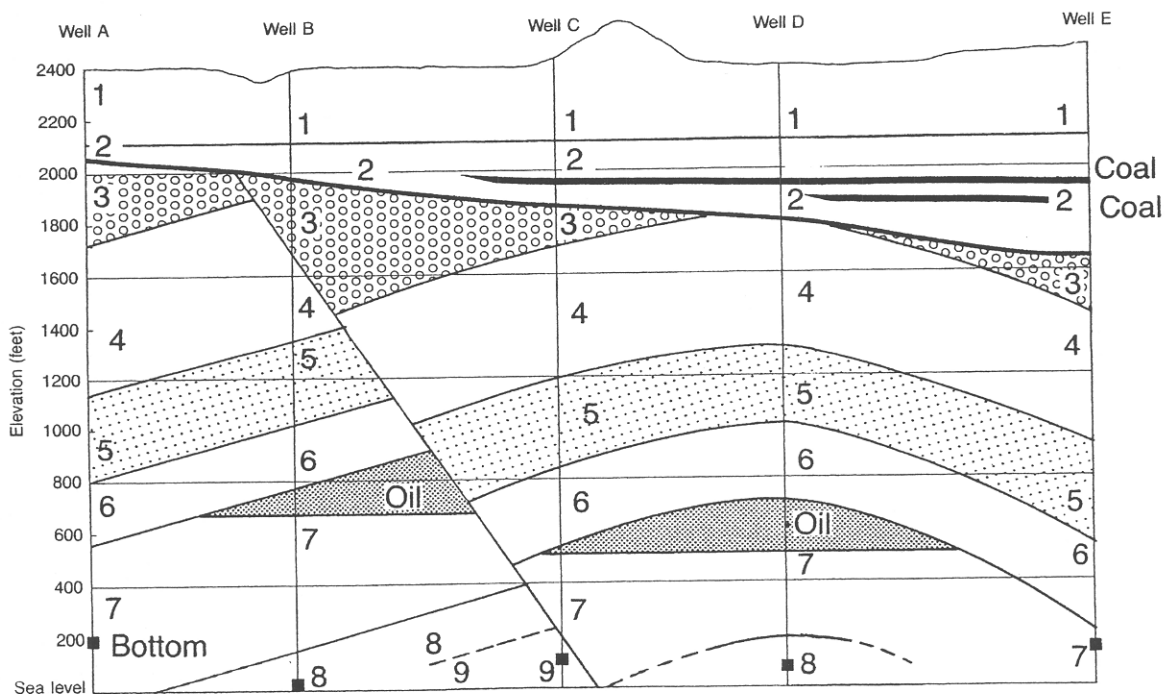
Part 8E: Construct and Interpret a Subsurface Geologic Cross Section

Refer to completed Figure 8.19 on the next page of this book.

- 14.** This is an angular unconformity (Refer to Figure 8.1). It formed because subjacent units were structurally tilted, partly eroded, and then covered by horizontally-layered Unit 2.
- 15.** The coal seams pinch out as Unit 2 thins from east to west. This indicates that the coal beds probably accumulated in topographically low areas (east side of the profile). Peat did not accumulate in areas A and B because the landscape was higher/dryer.

16. Oil is less dense than water and does not mix with water, so it rises to the top of reservoir beds that contain both oil and water. The oil wells occur at the upper end of a tilted reservoir bed where it is capped by impervious rocks at a fault (well B) and at the top of an antiform fold (wells C and D) because this is as high as the oil could migrate as it floated on the water.
17. Wells A and B have no oil, because they cut through the reservoir beds below the level where oil would have been floating on water. Wells B, C, and D all cut through the reservoir beds at a level high enough to encounter the oil.
18.
 - Units 9 through 3 are sediments deposited as horizontal sheets, one atop the other, from 9 to 3. Other units may have been present on top of unit 3, but they no longer exist, if they ever did.
 - The sequence of units 9 through 3 was folded and then cut by a normal fault.
 - Erosion removed units above unit 3 and the upper parts of units 3 and 4.
 - Units 2 and 1 were deposited (in that order) on top of the erosional surface to form an angular unconformity.
 - The top of unit 1 is at the present surface of the land and is being eroded presently to form an unconformable surface.

Completed Figure 8.19: Part 8E



Cross section showing well locations.