Core Lab 8 - Interpreting Historical Geological Events

Introduction

Historical Geology involves the study and interpretation of past events in the earth's geological history. The recognition of the vast amounts of geologic time and the ability to establish the sequence of geological events that have occurred at various places and at different times, are the focus of this laboratory exercise.

Purpose and Outcomes

The students will

- contstruct and interpret cross-sectional diagrams of the Earth using the concepts of
  - Principle of original horizontality
  - Law of superposition
  - Principle of uniformitarianism
  - Igneous intrusion/extrusion
  - Unconformities
  - Faulting and folding
  - Principle of inclusion
- apply and assess alternative theoretical models for interpreting knowledge.

Method

Part 1: Introduction to terminology and concepts

In completing this part of the laboratory exercise, students will have to reference illustrations 1.1, 1.2, and 1.3. These illustrations are hypothetical cross-sections of the earth's crust and interior.

A. Principle of Original Horizontality

Sediment, as it is deposited through weathering and erosion, forms nearly horizontal layers. Therefore if beds of sedimentary rocks are folded or inclined at an angle, it can be implied that some form of deformation took place after the sediment was deposited.

1. Indicate from illustration 1.1 the layers of rocks that this principle applies to:

   _____ _____ _____ _____

2. Which rock layer would be the oldest, D or E? Circle the answer.

B. Law of Superposition

In any sequence of rock layers, either unreformed sedimentary rocks or surface deposited igneous rocks, the youngest rocks are always at the top and the oldest at the bottom.

3. Of the rock types in illustration 1.2, A, B, D, E, and F, which are the youngest and oldest? List in order from oldest to youngest. ___ ___ ___ ___ ___.

Hypothetical Cross-Sections

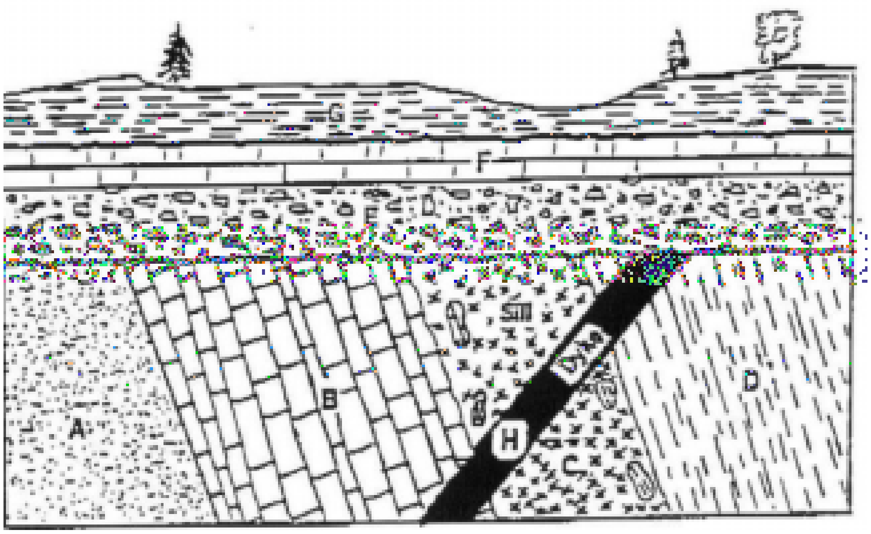


Illustration 1.1

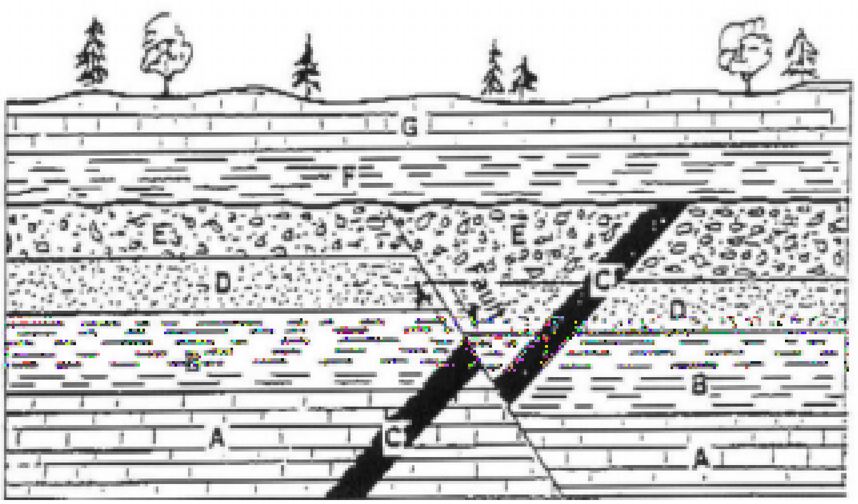


Illustration 1.2

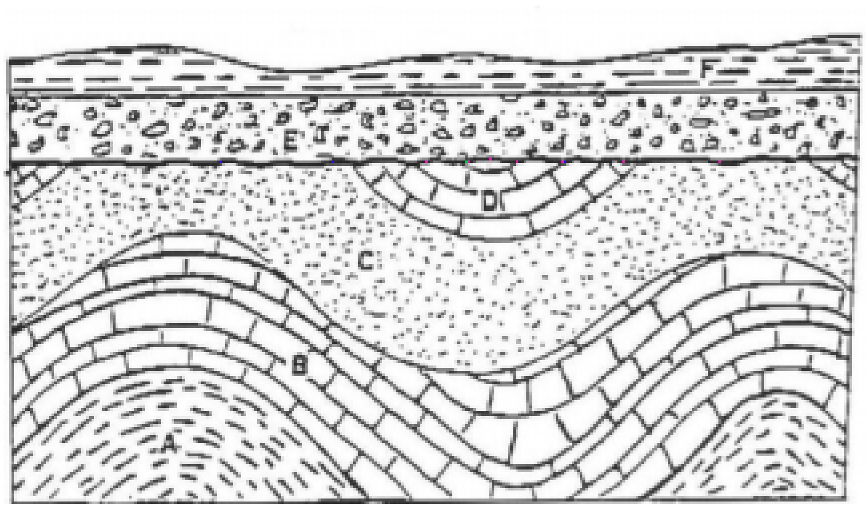


Illustration 1.3

C. Principle of uniformitarianism

When interpreting rock history by sequencing physical events, it must be recognized that the same external and internal processes happening on earth today are most similar to the processes that operated in the past. With reference to illustration 1.1, it can be assumed, based on the above principle, that the intrusions through rocks, faulting and folding, etc. occurred in the past because observable features of these occurrences can be seen today, albeit on a somewhat smaller scale.

4. What physical events can we observe on earth today that most likely occurred similarly in earth's geological history. List three.

   a)

   b)

   c)

D. Igneous Intrusions

Whenever a molten igneous intrusive rock material cuts through an existing feature, the intrusive rock is younger than the structure it cuts. In illustration 1.2, the intrusive rock C cuts through sedimentary rock layers A, B, D and E.

5. Of the rocks A, B, D and E, which one would be the youngest? ___

E. Unconformities.

As sedimentary rock material is deposited at a location, there will be an uninterrupted record of the material as it is deposited. However if there is a break or gap in the sequence of deposition, then this gap in time allows for the development of an erosional surface, clearly visible between rock layers. Such a gap or break in the rock record is an unconformity.

6. Identify the unconformity in each of the illustrations by indicating the rock layers above and below it.

   a) Illustration 1.1 ______________________________

   b) Illustration 1.2 ______________________________

   c) Illustration 1.3 ______________________________

F. Faulting

Faults involve a break between rock layers where significant movement or displacement of a rock layer has occurred. In illustration 1.2, a fault has occurred within the sedimentary layers A, B, D, and E.

7. Would the fault as labelled in illustration 1.2 be older or younger than the sedimentary beds, A, B, D, and E? _________________

G. Folding

Rock layers are subjected to tremendous pressures from within the earth's crust. These pressures cause rocks to fold, over periods of significant geological time. The time of the folding will always be at least as young as the youngest layer involved in the folding, and older than any undisturbed beds of rocks overlying the folded rock layers.

8. In illustration 1.3, which rock layers are older than the folding, and which are younger?

   a) Older rock layers ___ ___ ___

   b) Younger rock layers ___ ___ ___

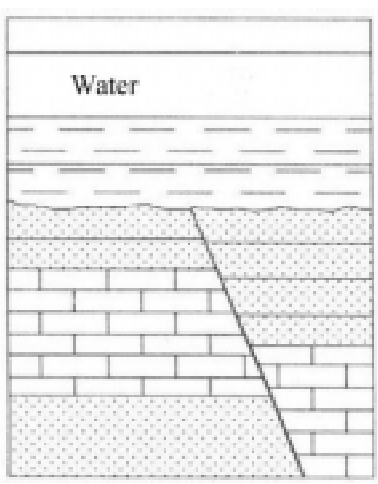
Part 2: Sequencing of Events

A. List the entire sequence of events, in order from oldest to youngest, as they have occurred in Illustration 1.2. Write the appropriate letter or event in the space below.

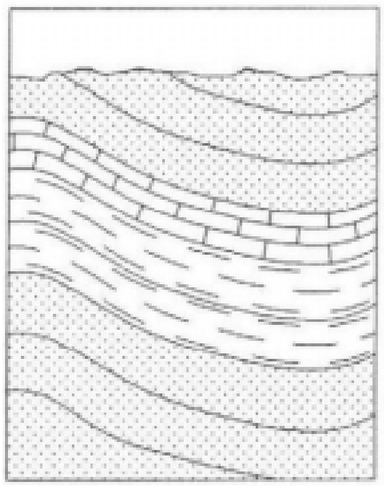
Youngest	
Oldest	

B. Using the geological symbols at the end of the lab as a key, interpret the sequence of events as shown by the diagrams below. Use short descriptive sentences to describe the events from the oldest to the youngest. Describe the events in the space at the right of each picture.

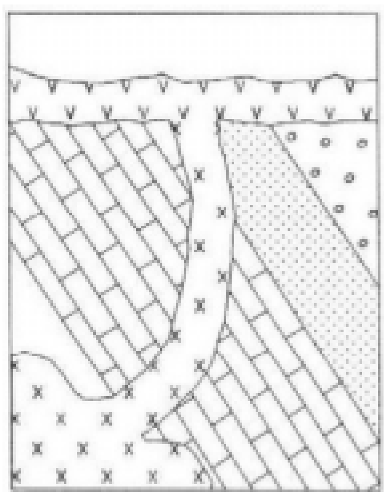
a)



b)



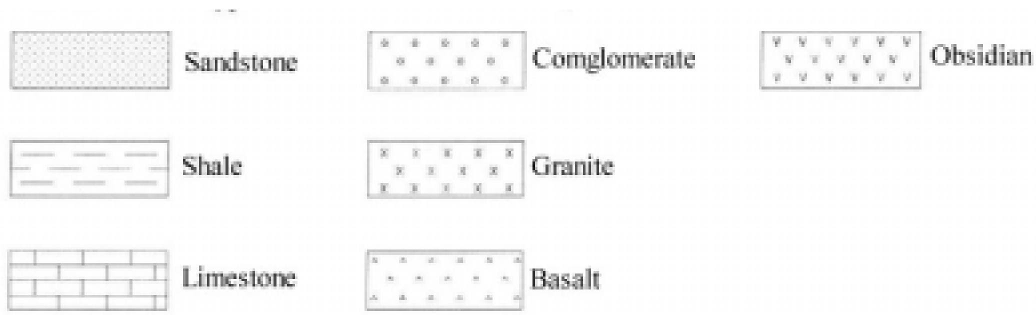
c)



Part 3: Construction of a Cross-Section

In the space provided, construct a geologic cross-section, using the following information: (Use the symbols outlined in Part 2.)

- A thick layer of evenly-bedded limestone is deposited.
- The limestone layer is subjected to a prolonged period of erosional activity.
- Sedimentary deposits of shale, sandstone and conglomerate are laid down in that order.
- All sedimentary layers are subjected to intense pressure resulting in folding.
- The folded layers are eroded significantly with a layer of conglomerate deposited on top.
- An intrusive rock material cuts through the entire structure and breaks to the surface as an extrusion.
- There is some evidence of surface erosion.



Core Lab 9 - Field Trip - Local Site(s)

Purpose and Outcomes

The students will

- observe how earth science is an integral part of the community and of everyday life.

Equipment

- hand line, rope
- boots and other appropriate clothing
- safety glasses
- magnifying glass, camera, binoculars
- plastic bags
- hammer and chisel

Procedure

Various, depending on circumstances. Note the following considerations:

- safety should be uppermost when planning a trip.
- try and have several stops along the way. The field trip should not be seen merely as either a rock collection activity or as a chance to see some local geologic structures. Incorporate both general purposes into the trip.
- several common areas may be of great interest, including the following:
  - schoolyard (place to collect some rocks)
  - rock outcrops
  - gravel pits
  - rock cuts
  - beaches and shorelines
  - mines
- The students should do advance preparation. They should not go into the trip "cold," not knowing what to expect. A carefully planned trip with clearly defined outcomes will result in more effective learning.
- Treat the field trip as a laboratory activity. Require a written report, supplemented if possible by pictures

and by physical artefacts.

Core Lab 10 - Geological Mapping

Purpose and Outcomes

The students will

- construct a geologic map.
- interpret a geologic map.
- describe how geochemical, geophysical and/or fossil data can be used to locate and analyze mineral rock or petroleum deposits.

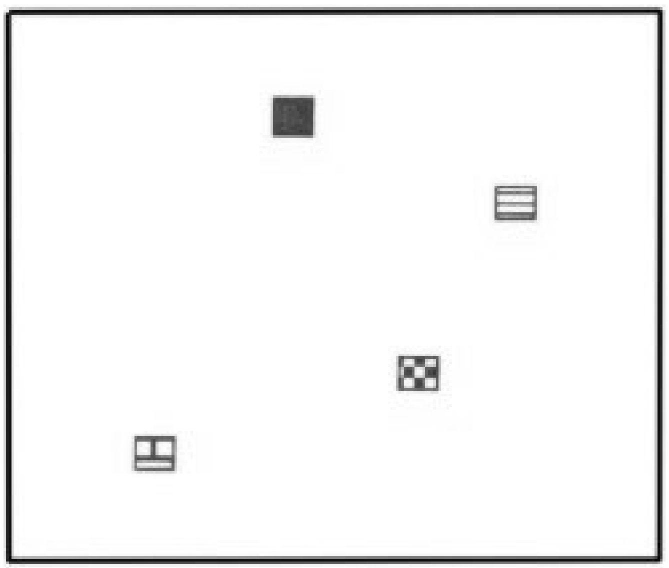
Materials

- at least six different colours of chalk
- large piece of cardboard (1 m by 1 m)
- masking tape
- single-edge razor blade or utility knife
- squared paper

Method

1. Draw a grid on the cardboard - 2 cm by 2 cm squares.
2. Place cardboard on chalkboard and mark around edge with chalk.
3. Draw and colour appropriately one of the attached maps inside the chalk boundary.
4. Tape cardboard over coloured map.
5. Cut 6 square holes, 2 cm by 2 cm, in different areas of the cardboard to represent rock outcrops. The holes do not necessarily need to match the squares of the grid.
6. Give each student the opportunity to cut one similar square.

Note: Students very quickly see this as a model of the mapping procedure and will probably start helping each other in suggesting where to cut, talking about contacts, etc. The cardboard will probably look something like this with the different patterns showing different colours of chalk.



7. Students use a sheet of squared paper provided and copy the information revealed to this point on the board. They should take this home and attempt to draw the geologic map as it is underneath the cardboard on the chalkboard.

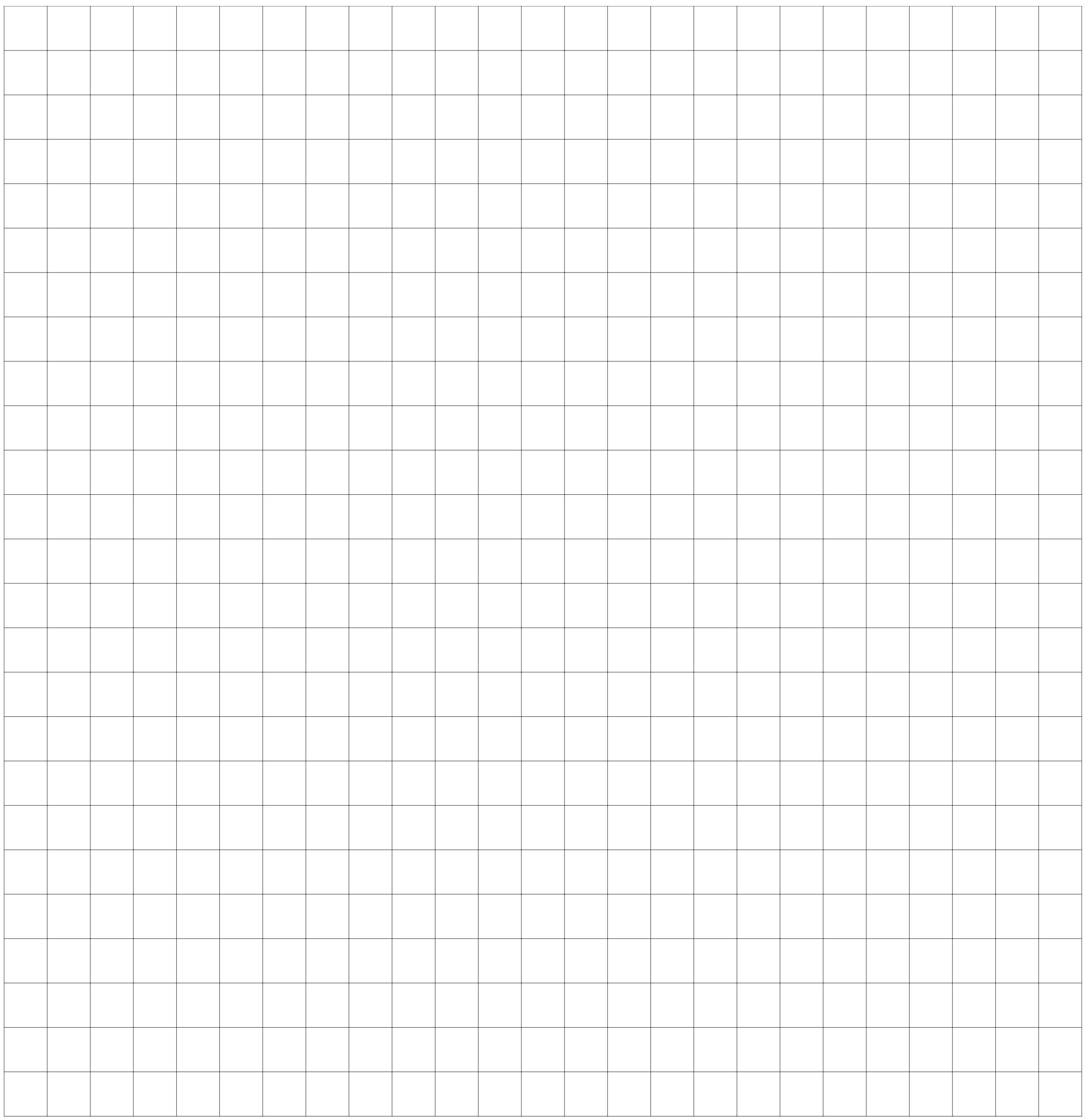
Analysis

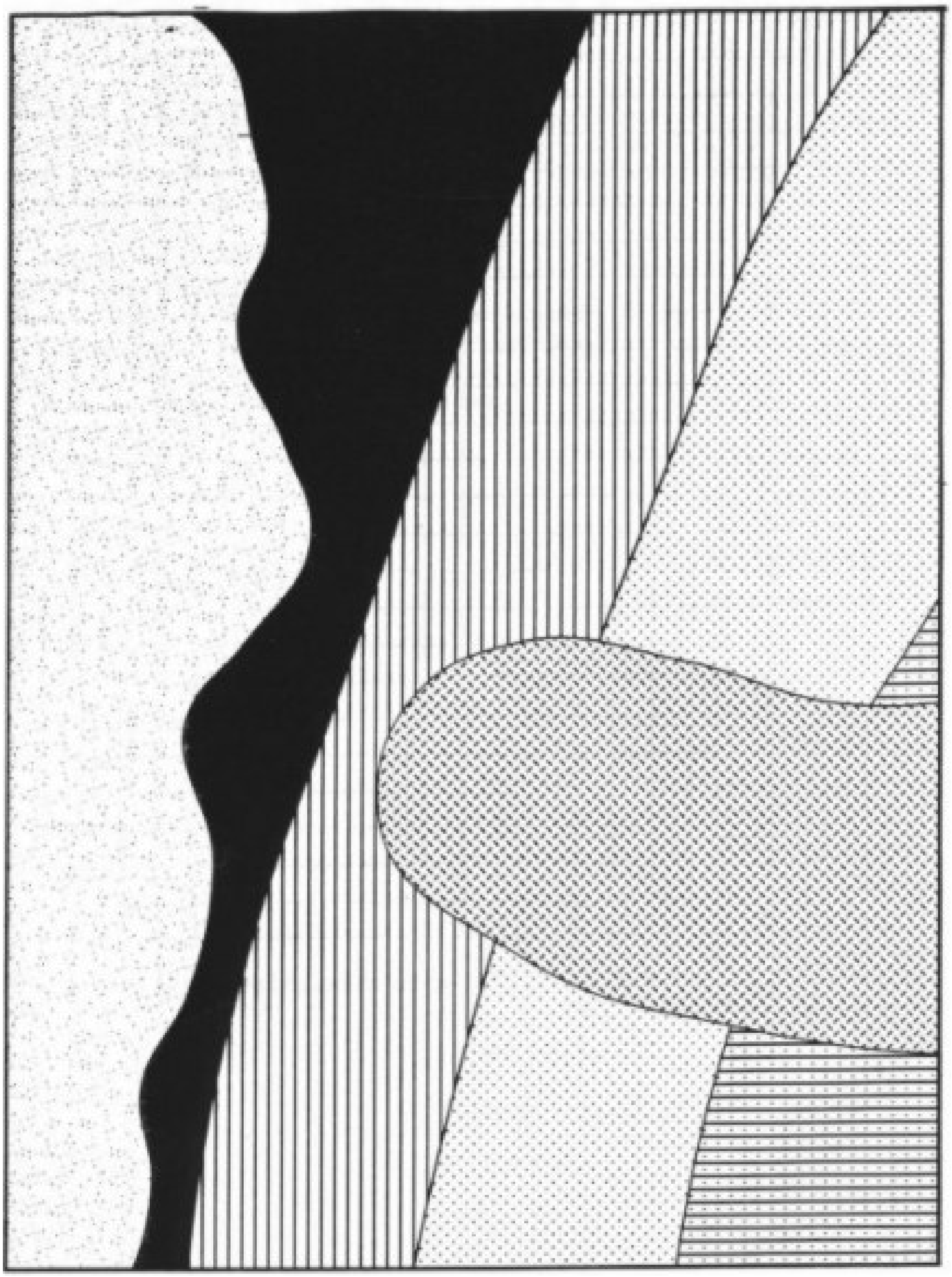
Next class, uncover the map on the chalkboard and discuss the procedure. Have each student compare his/her map with the one on the board and think about some reasons why they are not perfectly matched. The following questions and activities might help guide the discussion.

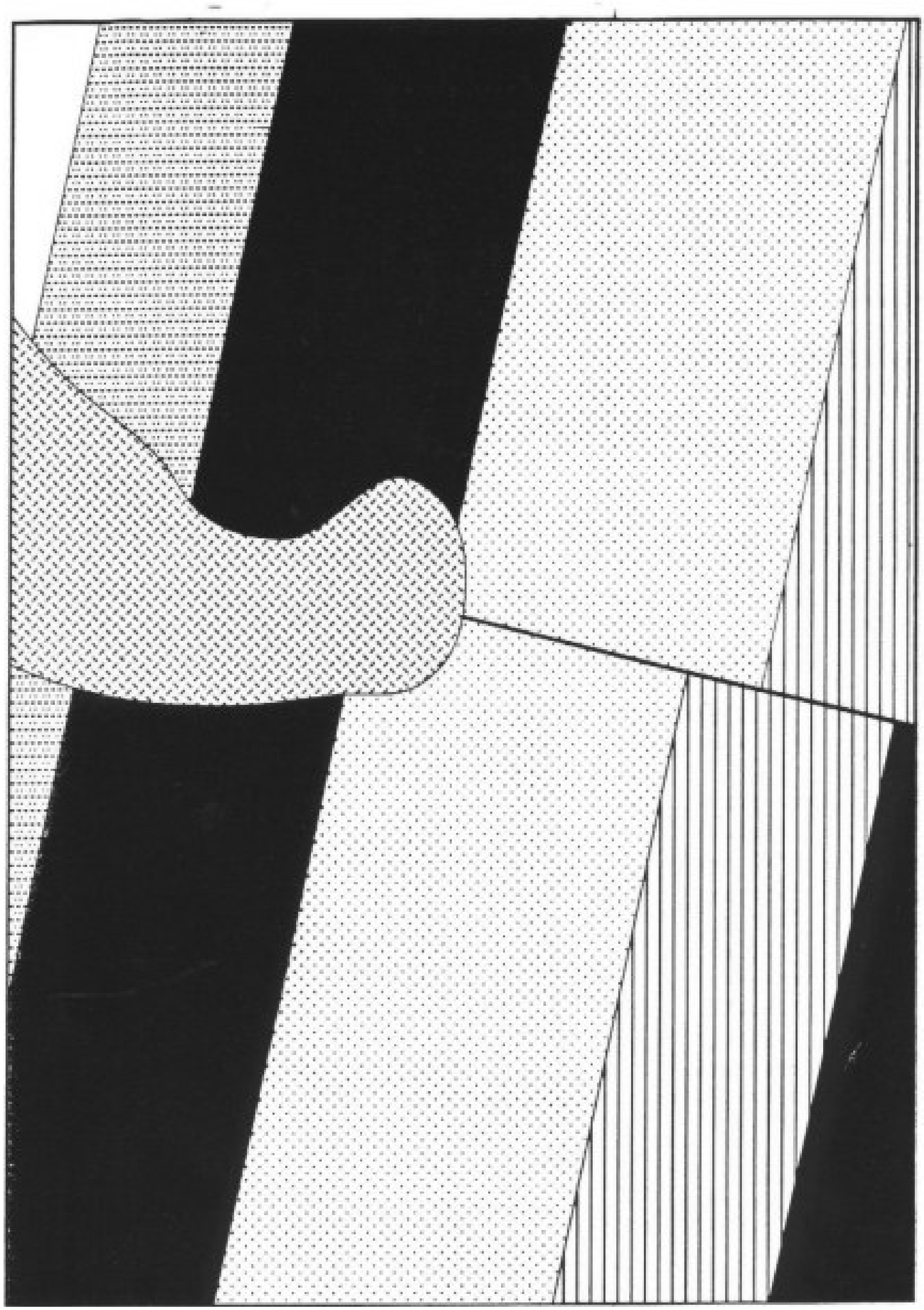
- What does each square represent?
- Why do outcrops occur?
- Was there enough information to draw an accurate map?
- Where would the best places to put more holes be? Why?
- In what ways could geologists use such a map?

- Name two geologic features shown on the map?

Note that this grid is 25 by 25 squares. Each square on this grid would represent four 2 cm by 2 cm squares on the geologic map.







Core Lab 11 - Paleontological Activities

Purpose and Outcomes

The students will

- understand how the remains of once-living organisms and their activities are preserved as fossils and what happens during compaction of the material.
- show how fossils are used to determine the age and original environment in which sedimentary rocks were formed.
- work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise.

Materials

Modern specimens of:

- bivalve (or other robust invertebrate or vertebrate skeletal remains)
- small branching twig (5-10 cm long), spruce twig with needles intact or fern
- squashable plant stem
- echinoid (if available)
- ping-pong ball
- *foot/small animal
- plasticine
- plaster of Paris or similar casting material
- *mud

(*materials for optional exercise)

NOTE: Materials from this list (apart from the foot or small animal) must be disposable, as they will be destroyed during the lab.

Fossil kit containing:

- trilobite
- graptolite
- echinoid
- gastropod
- shark tooth
- brachiopod
- coral
- bivalve
- ammonite
- mammal or bird bone (modern is OK)

- plant

Method

Fossil Preservation (taphonomy)

This exercise will demonstrate one of the ways in which fossils are commonly preserved, and what can happen to the remains of three-dimensional organisms as they flatten during compaction of the rock.

A. Moulds and casts (essentially impressions of the original living material) of fossils are often found in a variety of rocks; only mineralized or woody materials are normally preserved by this process, so it is suggested that a modern bivalve shell and a woody twig with tough leaves (e.g., spruce) be used. However, other materials may be experimented with.

1. Soften plasticine or other modelling material.
2. Press firmly onto either the exterior or interior of the bivalve shell (assign both interior and exterior to students). If using a twig, or twig with needles, press firmly into plasticine after it has been flattened.
3. Remove the object, then build up a “lip” of plasticine around the outside of the mould produced.
4. Mix up casting compound (plaster or other). After making sure that the plasticine mould is horizontal, carefully pour in the plaster to a depth of ca. 0.5 cm above the top of the hollow left by the object.
5. Leave until plaster is thoroughly dry, then carefully remove from the plasticine.
6. You now have a “fossil” cast of the original living organism. To complete the imitation fossil, it can be painted if so desired.

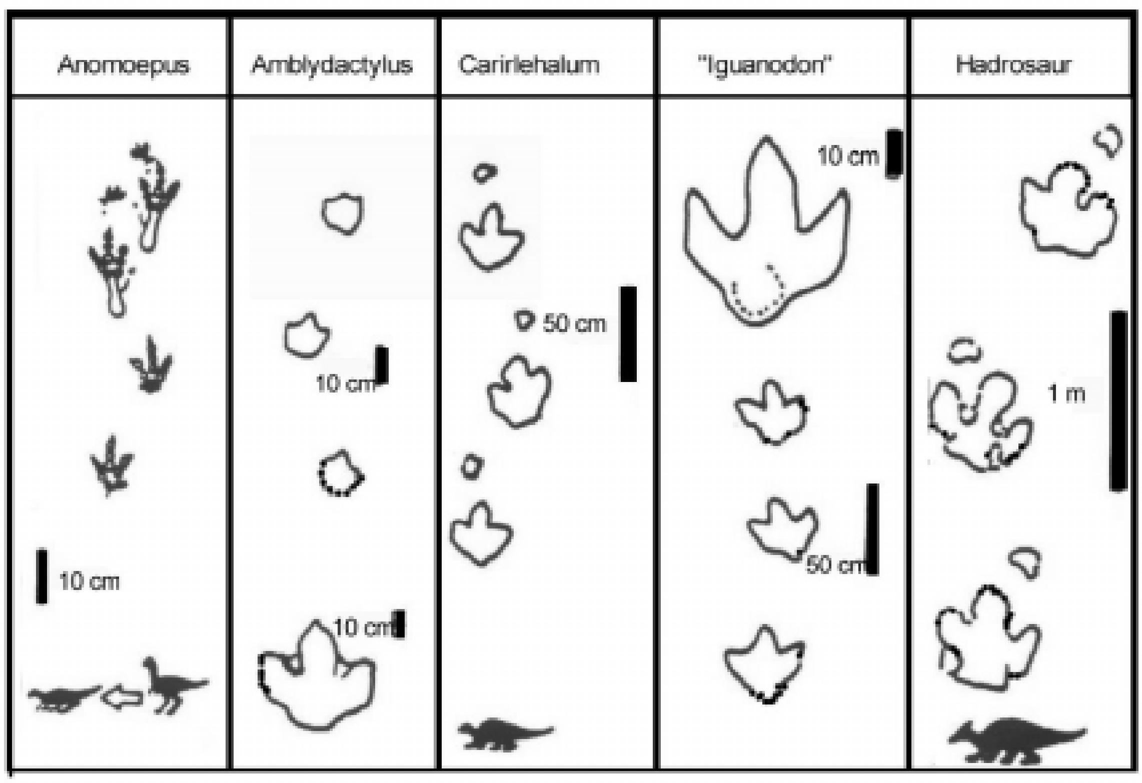
B. This section will show how softer material can be preserved through moulds and casts.

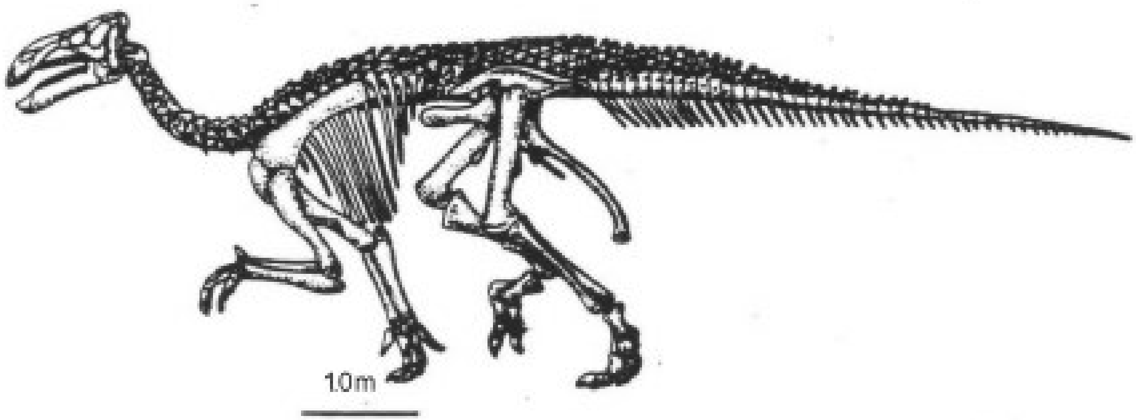
1. If using a fern frond, mix up plaster or other soft casting compound, fill a small, flat tray to a depth of approximately 1 cm, then carefully lower the fern so that it floats on the surface. Leave to harden thoroughly.
2. Remove the plaster from the tray, then carefully peel away the fern. If it is stuck firmly, it could be gently burnt off with a Bunsen burner.
3. An impression (mould) of the fern should remain. If the plaster is sufficiently robust, a cast of this could be made either with plasticine or with additional plaster. If plaster is used, make sure that a releasing compound (soap or oil may work) is first applied to the mould surface so that it can be subsequently detached.

C. (Optional, depending on weather and availability of conditions). Show how the remains of animal activities are occasionally preserved; these are known as “trace fossils”. Examples of trace fossils include burrows, footprints and coprolites (fossil feces).

1. Find a patch of relatively thick mud that can be left undisturbed to dry for a couple of days.
2. Get a volunteer to walk bare-foot through the mud. Alternatively, persuade a small pet animal to do the same (dog/chicken/iguana, etc.)!

3. After making sure that footprints result and remain behind, leave mud to harden.
4. Once hardened, make up a small frame of strong card or plastic around any footprints that are well preserved, and try to make sure that the join with the mud is relatively water-tight (e.g., with plasticine or similar).
5. Mix up plaster, then pour into frame. Leave until hardened, then remove carefully.
6. A cast of the footprint(s) should now be formed in the plaster.
7. Sketch the footprints; calculate the approximate surface area of each, and measure the average depth of the impression.
8. Measure the weight of the person (or animal) that made the footprints.
9. From the diagram below, calculate the approximate surface area for the footprint of the bipedal dinosaur Iguanodon. The weight of a typical adult Iguanodon is thought to have been about 2 tonnes (2000 kg).
10. Assuming that the maximum depth of a footprint made by either a human or bipedal dinosaur occurred when the whole weight of the body was pressed onto that single, stationary, leg, calculate the depth of footprint that Iguanodon would have made in the mud used for your experiment.





D. Most sedimentary rocks compact during lithification as water is lost and mineral grains are rearranged. The final rock may vary from 50% of its original thickness for sandstones to 10% of the original for shales. As the rock compacts, so do the remains of any organisms contained within them. Depending on the composition and original shape of the organism, a variety of changes occur.

1. Take the squashable plant stem, Ping-Pong ball and echinoid (if available), and place on a hard surface.
2. Place the slab of wood over them, then press down firmly while keeping it flat, so that each of the objects is flattened by the same amount.
3. Lift up the wood, then describe and sketch what has happened to each. Try to explain the changes in terms of flexibility and robustness of the original object, then determine if similar phenomena can be seen in any of the fossils in the fossil kit.
4. Repeat with any other living or non-living objects, if time permits (e.g., plastic cups, bivalves, flowers, etc.).

Uses of Fossils

The students will be required to first identify the types of fossils present, then use them to deduce the approximate age (geological era) and environment represented by a number of fossil assemblages. Note that because of the difficulty in providing sufficient specimens, the eras given here do not necessarily represent the true total ranges of some organisms.

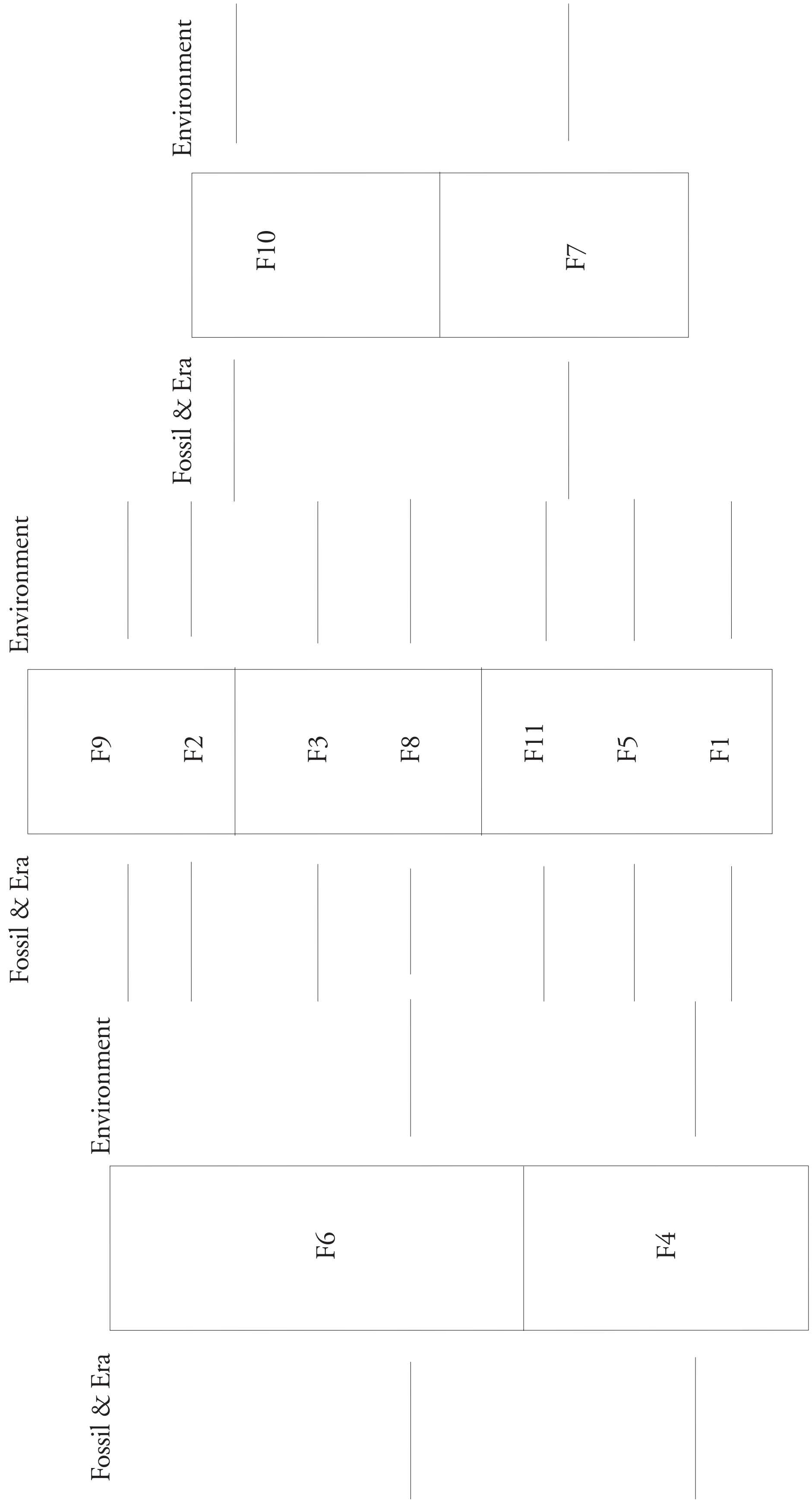
Key to Eras and Environments

FOSSIL	ERA	ENVIRONMENT
Trilobite	Paleozoic	Marine shelf
Brachiopod	Paleozoic	Marine shelf
Graptolite	Paleozoic	Deep ocean
Coral	Paleozoic	Marine shelf
Echinoid	Mesozoic	Marine shelf
Bivalve	Mesozoic-Cenozoic	Marine shelf
Gastropod	Mesozoic-Cenozoic	Marine shelf
Ammonite	Mesozoic	Deep ocean
Shark tooth	Cenozoic	Marine shelf
Mammal or bird bone	Cenozoic	Land
Plant	Paleozoic-Cenozoic	Land

Identification and Correlation

The chart attached illustrates three geological sections. The aim of the exercise is to deduce the ages and environments of the geological divisions, then to indicate how the sections correlate by drawing lines between the sections.

1. Identify the fossils using the illustrated guide included. Deduce the era(s) and environment indicated by each fossil, then insert the information in the chart.
2. Lines in each section indicate boundaries between eras. Draw lines between the sections showing how the sections correlate with each other.


Environment
F10
F7
Fossil & Era
Environment
F9
F2
F3
F8
F11
F5
F1
Fossil & Era
Environment
F6
F4
Fossil & Era

Core Lab 12 - Calculation of Sea Floor Spreading

Purpose and Outcomes

- To analyze evidence that the oceans have a dynamic nature.
- To calculate the rate, in cm/year, at which the Atlantic Ocean is expanding.
- To estimate the ages of the North and South Atlantic Ocean basins.

Materials

Materials required:

- ordinary drawing tools - pencils and rulers
- calculator
- atlas, globe or world map
- some string to help you determine distances on the globe

Method

1. Draw the mid-ocean ridge system on figure 1 below:

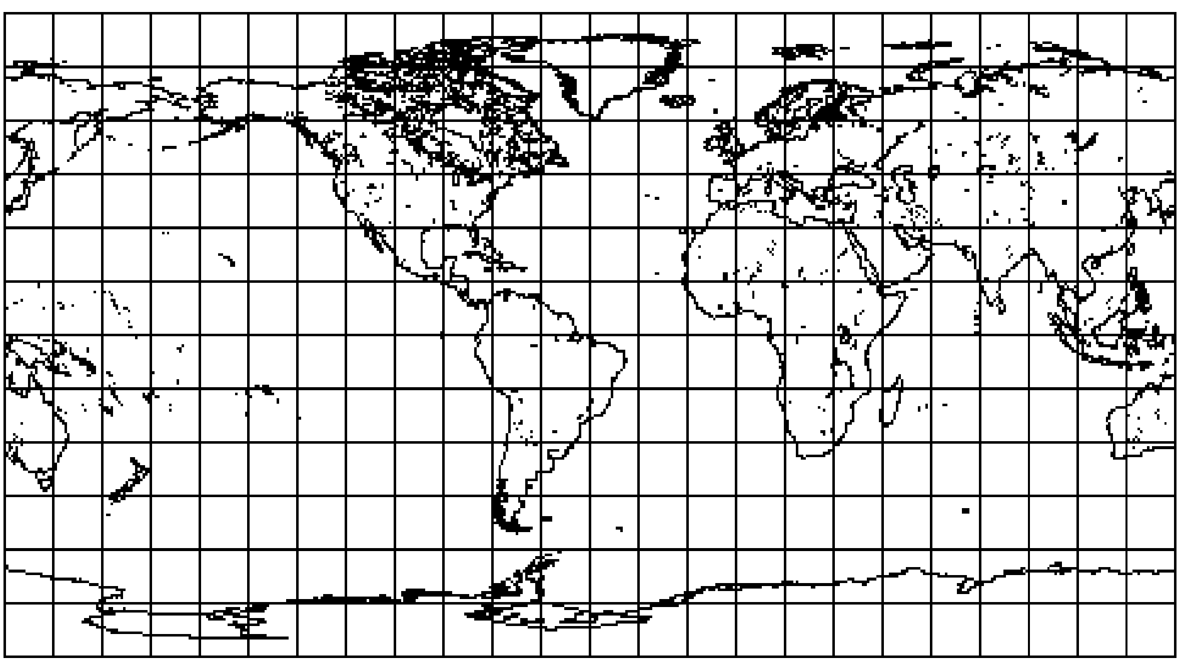


figure 1

2. Describe each feature:

   a) deep ocean trench

   b) mid ocean ridge

   c) mid ocean ridge rift valley

3. Describe how the current shapes of the continents suggest that they may have once been all part of a "super-continent."

4. Figure 7.21 in your text shows the distribution of shallow, intermediate and deep-focus earthquakes. Briefly explain how the distribution offers evidence of the dynamic nature of the world's oceans.

5. Figure 7.20 in your text illustrates how *paleomagnetism* indicates that the Earth's oceans have changed. Briefly describe how it does this.

6. Figure 2 below (similar to figure 7.19 in your text) illustrates the magnetic field reversals over the past 4 million years. The periods of normal polarity are show shaded.

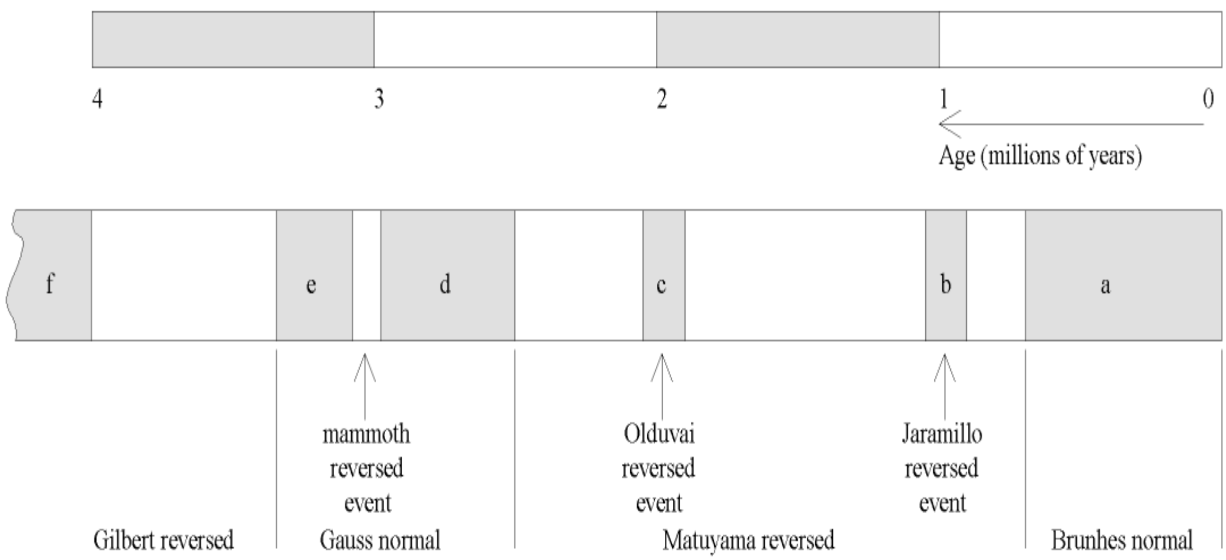


figure 2

   a) How many periods of reversed polarity has the Earth experienced over the past 4 million years?

   b) Use the scale to help you to determine the times ago when the periods of normal polarity began and ended. Mark these on figure 2.

7. Figure 3 below illustrates the polarity reversals that can be seen in the oceanic crust along the mid oceanic ridges for the Pacific, North and South Atlantic oceans. Periods of normal polarity are shown shaded.

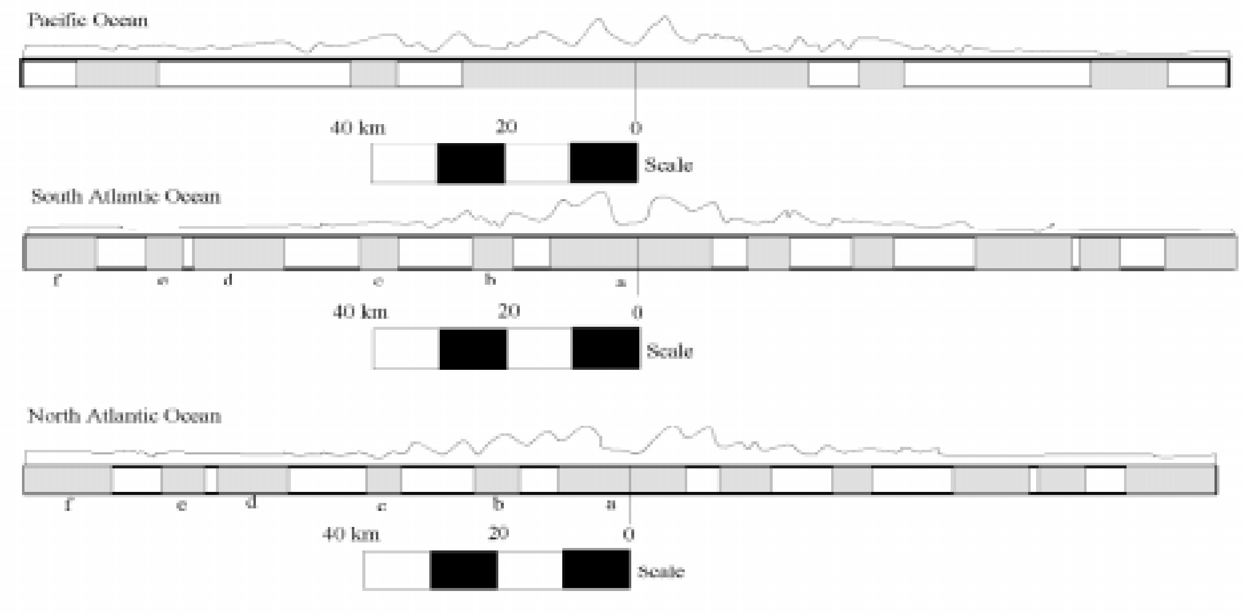


figure 3

a) Explain how the figures show that the spreading is more rapid in the Pacific than in the Atlantic

b) Use the data from figure 2 to help you annotate the periods shown in figure 3 with the appropriate times ago. NOTE: you might find it useful to label the periods “a” to “f” as is already done for the South Atlantic.

8. The distance scale in figure 3 helps you to determine the distance that any basin has spread over any given time. Note that since the basins spread in both directions, and the spreading is relatively uniform in either direction, the actual amount of spreading is actually double the amount measured on one side

a) Why is it useful to choose a time period of about 2 million years as a reference? HINT: refer to figure 2.

b) How far has each ocean floor spread in the past 2 million years?

c) What is the rate of sea floor spreading, in cm/year, for each ocean floor?

d) Organize the information from parts b) and c) in an appropriate table.

e) Explain whether your results support the information given in pages 198 and 199 of your text regarding rates of ocean floor spreading.

9 a) The data for the North Atlantic ocean floor would be appropriate for the great circle from North Carolina to the tip of Africa at about 20^o latitude. Use a map or a globe to determine the width of the Atlantic Ocean between these points.

b) Use your results from the previous question to estimate the age of the North Atlantic Ocean.

c) The data for the South Atlantic ocean floor would be appropriate for the portion of the Atlantic at a about 10^{o} South latitude. Determine the width of the Atlantic Ocean at this latitude.

d) Use your results to estimate the age of the South Atlantic Ocean.

e) What assumption are you making as you estimate the ages of the ocean basins?