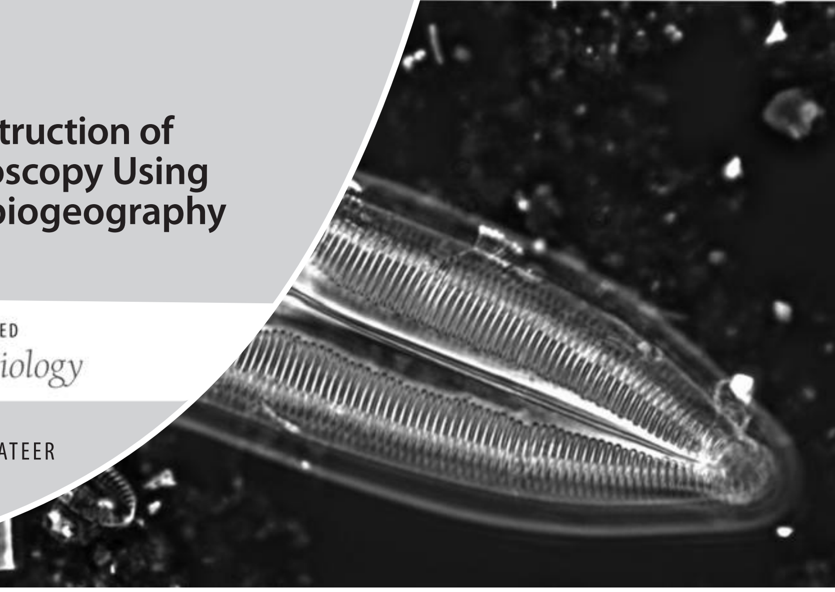
INQUIRY & INVESTIGATION

Inquiry-Based Instruction of Compound Microscopy Using Simulated Paleobiogeography



RECOMMENDED FOR AP Biology

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Abstract

The compound microscope is an important tool in biology, and mastering it requires repetition. Unfortunately, introductory activities for students can be formulaic, and consequently, students are often unengaged and fail to develop the required experience to become proficient in microscopy. To engage students, increase repetition, and develop identification skills, we have them use the microscope as a problem-solving tool to examine prepared slides of microfossils and microartifacts from a simulated archeology site to determine its paleobiogeographic history.

Key Words: *Compound microscopy; paleobiogeography; microfossils; microartifacts.*

Properly using compound microscopes is essential in biology. Introductory instruction of microscopy is often accomplished through the formulaic inspection of wet mounts and prepared slides of layered colored threads and printed letters (Alcamo, 1997; Leboffe & Pierce, 2010; Pollack et al., 2012). Here, we present a method that expands upon traditional techniques to include inquiry-based learning of microscopy. Engaged in a problem-solving scenario, students begin to see the microscope as a flexible and important tool they must master in order to solve a problem. Furthermore, by matching what they see through the microscope to reference images, they develop identification skills.

Properly using compound microscopes is essential in biology.

○ Exercise Outcomes

- This nonformulaic exercise requires students to use a microscope to solve a problem.
- Solving the problem requires repetition on the microscope, which gives students practical experience.
- Repetition on the microscope also develops identification skills.

○ Background Exercise

We introduce our students to microscopy by using prepared slides of the letter "e" and colored threads. These methods have been demonstrated extensively elsewhere and are very commonly used when instructing basic microscopy mechanics to students; an overview can be found in Leboffe and Pierce (2010). The main purpose of these two slides is to introduce image inversion by inspection of the letter "e" and to show depth of field with the colored threads. Students are instructed on magnification, field of view, and parfocal lenses when increasing the magnification of a specimen. At this point, students have developed a rudimentary understanding of the microscope (i.e., they understand how the microscope generates magnified images), but this formulaic technique does not engage students in problem-solving activities nor help them develop identification skills.

○ Paleobiogeography Microscope Activity

To stress that the microscope is a tool used by scientists during the identification of unknown specimens, we provide our students with a simulated paleobiogeography exercise. Not only does completion of this exercise help develop mastery of the compound microscope, it also demonstrates how it can be used for discovery, identification, and problem solving. Paleobiogeography is the study of historical bioartifacts in relation to ancient geographic features. By sifting through sediments, archeologists can uncover valuable clues about ancient civilizations. Bioartifacts come in many forms, but examples that work well for our exercise include sediment grains, ash, leaves, seeds, linen fibers, and microscopic organisms (see Table 1). Moreover, because sediments often layer sequentially, the inspection of bioartifacts excavated from layers can be used to retrace the rise and fall of a particular civilization and give some insight into what was happening at the time the layer was deposited.

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Table 1. Environmental conditions of each sediment layer (from Hodgson & Mateer, 2013; all prepared slides were purchased from Triarch, Ripon, WI).

Lost to Time in the Desert (Always Layer 1)	
Description	There were just too many hardships, so the people left to live elsewhere or died. Once the society was abandoned, nature took over and the ecosystem reclaimed the space, lost to the sands of a desert. A layer of sand covered the civilization, preserving bioartifacts from the past.
Prepared slides and pictures	Iron rust and linen fibers are used to represent remains of tools and textiles.
Thriving Society	
Description	A thriving society is one that can sustain itself through farming. Crops provide food and means of trade. Researchers can identify thriving societies by observing remains of crop leaves and seed banks.
	Wheat leaves and seed cross sections.
Crop Failure	
Description	Before the advent of pesticides, fertilizers, and irrigation, crop failures were common. Crop infections by bacteria and fungi could have dire consequences for the harvest.
Prepared slides and pictures	Barley blight and smutted barley.
Tsunami	
Description	Without the monitoring, forecasting, and communication we possess today, natural disasters often struck without warning. Since this region is near the ocean, tsunamis were a real threat and would inundate the coast. They could deposit oceanic organisms miles inward from the shore.
Prepared slides and pictures	Diatoms and foraminiferans.
Volcano and Fire	
Description	Volcanic eruptions were unexpected and destructive to nearby civilizations. They were extremely damaging because the ash and magma could completely bury a city.
Prepared slides and pictures	Volcanic ash and charcoal.

Our students are “introduced” to the excavation site, told to assume the role of a forensic archeologist, and informed that the excavation site appears to have had a very complex ecosystem and climate with grasslands, savannas, volcanoes, and deserts. Additionally, there is evidence that this region has experienced major natural disasters, which have caused different ancient civilizations to collapse. We tell our students that ancient civilizations typically rebuilt atop their ruins, and when researchers excavate a site, they are able to analyze the long-term history of a society in chronological order by examining the different layers. Therefore, as archeologists dig deeper into the layers, they get a snapshot of each society in that layer and also get clues about what caused it to collapse. Furthermore, because researchers do not know what happened in each layer until they excavate it, they must compare their samples to known reference images of typical artifacts and make the most likely conclusion based on the available evidence and identifications.

○ The Simulation

During the simulation, the students use microartifacts to infer specific environmental conditions and determine what caused each civilization to collapse during each time period, just as an archeologist would do at an excavation site. To start the simulation, we show the students a generic drawing representing the stratigraphy of the excavated site (Figure 1) to ensure they understand that sediments layer sequentially and hold microartifacts. They are then told that the site has five known layers, Layer 1 being the youngest and shallowest and Layer 5 being the oldest and deepest. Each layer has a different environmental condition. Layer 1 is always “Lost in Time to the Desert,” which depicts an ancient civilization that has been buried by the desert. The instructor determines the sequence of environmental conditions (from Table 1) for layers 2–5. Because we teach multiple sections of the laboratory during a semester, instructors typically change the environmental conditions associated with layers 2–5 in different classes to prevent students from sharing answers over the life of the exercise. For example, for one class, Layer 2 may be “Crop Failure”; in the next class, Layer 2 is “Tsunami”; and so on.

To solve the problem, we give the students prepared microscope slides (all purchased from Triarch, Ripon, WI) that represent the microartifacts excavated from the different layers. Each layer has two prepared slides, and no artifact is found in more than one layer. In total, students are given 10 prepared slides representing

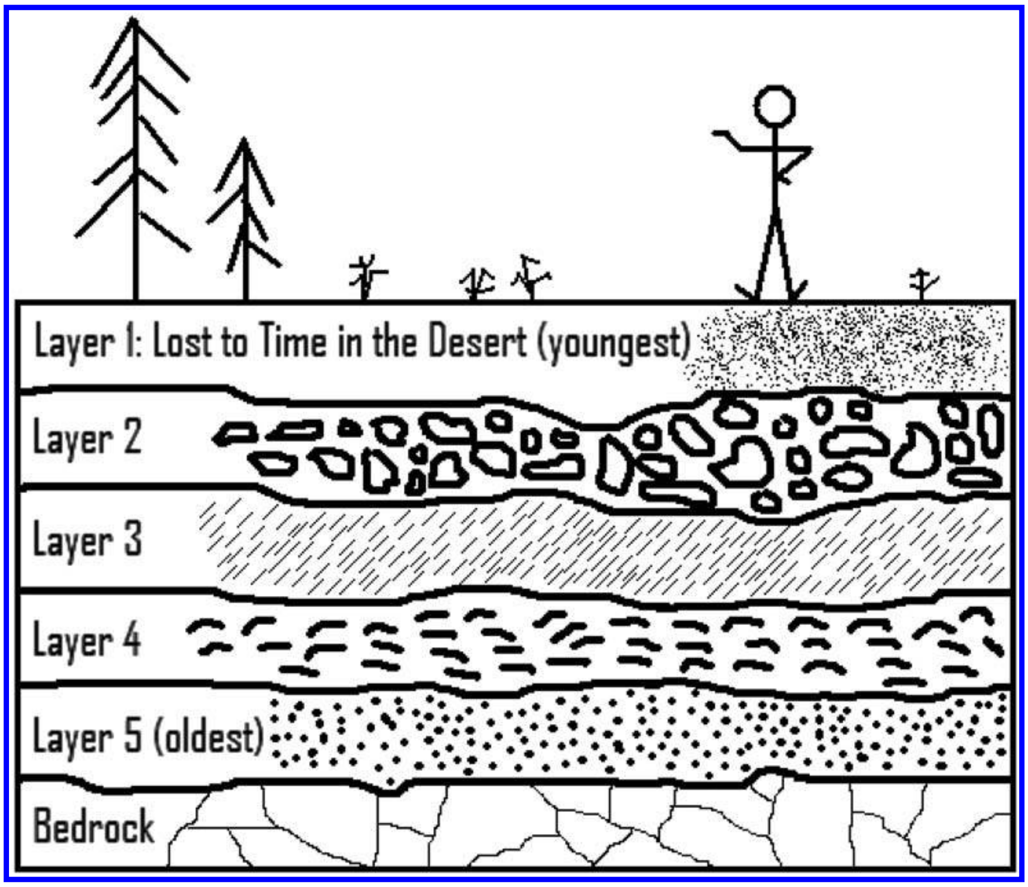

Figure 1. Stratigraphy of the excavated site. The oldest sedimentary layer is at the bottom, and the youngest is at the top.

10 different artifacts from five sedimentary layers. On a bulletin board, we hang corresponding printed pictures of microartifacts excavated from each layer at the site. Each layer has two pictures that are labeled (e.g., "iron rust" and "linen fibers" for Layer 1; also see Table 1). Essentially, these are 10 photographs of their 10 prepared slides. The printed pictures could be actual micrographs of the slides or related images of the microartifacts (Figure 2).

We inform the students which pair of slides and pictures came from Layer 1 (always "Lost in Time to the Desert") as a practice reference to get them started. The other slides and matching pictures are labeled only as "Layer A," "Layer B," "Layer C," and "Layer D" and are not in any chronological order. Also, we do not tell them which layer (A–D) had which environmental condition during the time of sedimentary deposition; that is their problem to solve. Students learn to identify their slides by

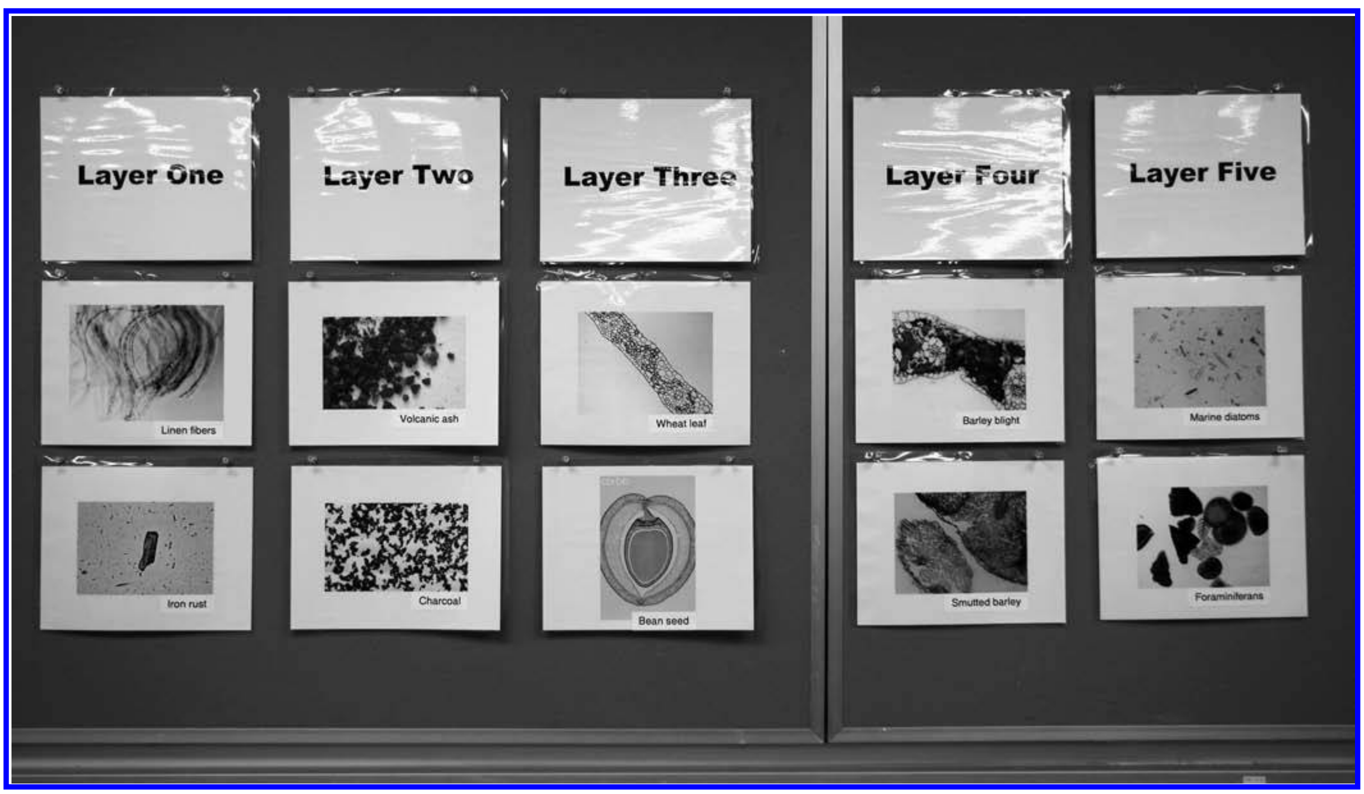

Figure 2. A photograph of the bulletin board in our teaching laboratory depicting the sedimentary layers and microartifacts.

comparing their microscopic fields of view to the matching printed, labeled pictures (Figure 2).

The assignment is completed when the students fill out an “Archeology Field Report” (Appendix). Students must analyze their slides and printed pictures and then use information written in Table 1 to determine the environmental conditions of each pair of microartifacts. Essentially, the students are matching their micro-artifacts (Layer A, Layer B, etc.) to the time sequence (Layer 1, Layer 2, etc.). For example, one possible answer would be that slides from “Layer B” were identified as “barley blight” and “smutted barley.” Students would match their slides to the labeled pictures of “barley blight” and “smutted barley” hanging on the bulletin board under Layer 4 (Figure 2).

We have successfully used this exercise to instruct biology majors and nonmajors on proper use of the microscope and to reinforce critical concepts and techniques. Students are self-sufficient with other microscope-based exercises and demonstrate confidence with the microscope throughout the semester.

○ Suggestions for Implementation

We recommend that students draw the microscopic images and use the “Archeology Field Report” or a similar written assignment. This will increase the time at the microscope and enhance attention to detail, and it can be used to compare the slides to the reference images.

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Appendix

Archaeology Field Report Name: ______________________________

Layer 1: Lost to Time in the Desert

In the circles below, draw what you see in each slide from this layer. Be sure to label each circle with the artifact or biofact that you analyzed. These slides are labeled and you should match them with the corresponding reference pictures. This will give you practice for parsimoniously matching the other pictures to their matching slides.

Total magnification _____ Total magnification _____
Specimen type: __________ Specimen type: __________

Slide Set A

In the circles below, draw what you see in each slide from this set.

Total magnification _____ Total magnification _____
Specimen type: __________ Specimen type: __________
What are your general conclusions and observations about these pieces of evidence? ___
____
From which layer did these pieces of evidence come? ___________________________

Slide Set B

In the circles below, draw what you see in each slide from this set.

Total magnification _____ Total magnification _____
Specimen type: __________ Specimen type: __________
What are your general conclusions and observations about these pieces of evidence? ___
____
From which layer did these pieces of evidence come? ___________________________

Slide Set C

In the circles below, draw what you see in each slide from this set.

Total magnification _____ Total magnification _____
Specimen type: __________ Specimen type: __________
What are your general conclusions and observations about these pieces of evidence? ___
____
From which layer did these pieces of evidence come? ______________________________

Slide Set D

In the circles below, draw what you see in each slide from this set.

Total magnification _____ Total magnification _____
Specimen type: __________ Specimen type: __________
What are your general conclusions and observations about these pieces of evidence? ___
____
From which layer did these pieces of evidence come? ______________________________