Lesson Title	Geologic time scale (introduction optical mineralogy/fossils)
Length of Lesson	30 minuets - 1 hour
Created By	Henry Stauffenberg IV
Subject	Earth Science
Grade Level	9-12 (Earth Science)
State Standards	Earth Science: 1 a, b, c, d, e, f, g; 3 e, f, g; Geology: 1 g, d
DOK Level	Earth Science: 3; Geology: 4
DOK Application	Investigate, compare, inquire, interpret, connect, analyze, design, draw conclusions, apply concepts, prove
National Standards	9 – 12 A: Inquiry; B: Physical Science; E: Science and Technology
Graduate Research Element	Thin section analysis, use of microscopes, and applied knowledge using basics into optical mineralogy and index fossil hand samples

Student Learning Goal:
The purpose of this lesson is to promote understanding of the geologic time scale thorough interactive use of fossils and thin section analysis using a cheap makeshift optical microscope. They will see various fossil critters (index fossils) and learn which ones make good time markers and others that do not. They will learn how fossils form, the ways to interpret them for earth history/processes, and connecting them to living creatures of today such as red algae, corals, and so forth. The main goal is to understand that abundant, short lived (as a species), and widespread species make excellent time markers; such as trilobites to Precambrian rock or ammonites of the Mesozoic. Gastropods (snails) are abundant and widespread but not short lived; students will be able to explain why they don't make a great index (time marker) fossil.

Mississippi State Standards
Earth Science: 1: (a) Use current technologies to explore current research related to a specific topic; (b) Formulate questions that can be answered through research and experimental design; (c) Apply the components of scientific processes and methods in classroom and laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development); (d) Construct and analyze graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs); (e) Analyze procedures, data, and conclusions to determine the scientific validity of research; (f) Recognize and analyze alternative explanations for experimental results and to make predictions based on observations and prior knowledge; (g) Communicate and defend a scientific argument in oral, written, and graphic form; 3: (e) Interpret and explain how rock relationships and fossils are used to reconstruct the geologic history of the Earth; (f) Apply principles of relative age (e.g.,

superposition, original horizontality, crosscutting relations, and original lateral continuity) to support an opinion related to Earth's geological history; (g) Apply the principle of uniformitarianism to relate sedimentary rock associations and their fossils to the environments in which the rocks were deposited.

Geology: 1: (a) Conduct a scientific investigation demonstrating safe procedures and proper care of laboratory equipment, safety rules and symbols, proper use and care of the compound light microscope, slides, chemicals; (b) Formulate questions that can be answered through research and experimental design. 2: (h) Research and describe different techniques for determining relative and absolute age of the Earth (index of fossils) and identification of minerals that make up earth mantle and crust.

National Science Education Standards of Content 9 – 12

A: Inquiry: identify questions and concepts that guide scientific investigations

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding the hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.

D: Earth Science: The origin and evolution of earth system

- Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations.
- Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system.

E: Science and Technology: Understanding about science and technology using a microscope

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.

Materials Needed (supplies, hand-outs, resources):

A geologist or geology major graduate student, access to hand sample index and non index fossils and fossil thin sections (university lab or professor collection), regular microscope with bottom light source (at least x10 or x20 zoom), microscope setup instructions, small foam plates for tray that holds mineral thin section, large sheet of polarized film that can be cut into squares, stand with vertical metal rod, 2 clamps that can attach to vertical metal rod, metal O ring (like a clamp but for beakers), hand samples of rocks and fossils that go with thin sections (see student or professor), discussion handout, worksheet handout, optional: a few optical mineralogy and fossil identification textbooks with pictures to show what to look for with mineral/fossil identification and correlation tables of rock ages to index fossils.

Recommended fossils: Ammonites, Trilobites, Gastropods (snails), Algaes, Corals, Crinoids, Microbial mats, Fern and Flowering plants, Nautiloids, Foramnifera, Nummelites, Bivalves, Brachiopods, Molluscs, and anything else that can be accessed from a geology collection. Normally professors have preselected samples for their students when it comes to index fossils and rock dating.

Lesson Performance Task/Assessment:

- Completion of lab activity and ability to inquire about what they analyzed
- Able to define index fossil and purpose for geologic time scale
- Ability to explain non useful index fossils like gastropods
- Ability to explain using fossils when flowering plants emerged and why important
- Using resources to correlate identified fossils to rock ages
- Ability to connect what they learned in classroom, and fossils, to real world organisms

Lesson Relevance to Performance Task and Students:

- To gain lab practice and experience using microscopes and thin sections
- Using available resources to define/investigate index fossils
- To connect fossils with modern day living organisms
- To promote inquiry about age of flowering plants, types of coral/algae, and organism evolution over geologic time
- Using index fossils to grasp geologic time scale (age of rocks)
- Understanding how a microscope with polar films works
- Connecting evolution to geologic time scale and real world application of dating technique and deeming useful info from dead organisms

Anticipatory Set/Capture Interest:

Tell students they are about to see something not many people outside of the geosciences get to see in the classroom. Let them examine fossils and microscope samples first and then give out the worksheet and discussion; or, give a mini lecture on fossils and geologic time scale first and seed questions into their minds (why do we not see any trilobites anymore?) that they will have to investigate with samples in lab.

Guided Practice:

Refer to microscope setup handout. Give students some lecture or guided questions before they begin activity. May start by defining what makes an index fossil or setting up the scenario that they will investigate such as dating unknown rocks. Give them the worksheet handout (materials section) and let them explore lab. Walk around and make sure students understand the questions and guidance of the worksheet. After lab activity (finishing of worksheet) gather everyone for a discussion. Describe what they saw in microscope (when polar films in place) and answer questions that follow with fossils in thin section. Then move on to hand samples/worksheet. Answer any questions on

worksheet first. Then give reinforcing lecture about useful of index fossils to time scale, importance of age of flowering plants, importance of algae structure/fossil evolution, and so forth. Before the Cretaceous non coated seeds and ferns (spore based reproduction) dominated the fossil record. In Cretaceous and after leaf and flower plants emerged along with coated seeds, show this with fossil samples. Articulated red algae (in thin section and hand sample) indicate a low energy wave environment (hence moving nature). Crustal red algae is ridged and indicates a high energy wave environment and possible an uprooted structure than rolled around. Compare the fossil samples to each other and modern specimens. Overall, just go with what story each fossil tells and connect that to evolution and the geologic time scale. Keep it interactive by asking students to take part in discussion and stay to the interesting parts, sponges and shells get boring after a while. Keep it like a story from Precambrian all the way through Cenozoic.

Independent Practice:
Students working with microscopes and fossil hand samples and recording observations and answering worksheet handout.

Remediation and/or Enrichment:
Remediation: individual IEP, partner with helpful student, shorten assignment(s), make lesson more walk through intensive.

Enrichment: Go into more problematic fossils for geologic time scale. Ask more difficult questions about fossil evolution compared to today.

Check(s) for Understanding:

- Tell me what an index fossil is?
- Why would sample A make a better index fossil than sample B?
- What can these fossils tell us about evolution?
- What can you tell me about flowering plants vs. non flower plants using the fossil record and geologic time scale?
- What did you learn? How does it apply to real world?
- Based on the resources in front of you what fossils did you (or we) identify? How and why could they be useful for determining a rocks age?

Closure:
End discussion with lesson relevance and connection to graduate school/college.

Possible Alternate Subject Integrations:

Physics: optics and polarization with the microscopes

Teacher notes:

- Thin sections are fragile and expensive. Don't smudge them and handle with delicate care. Take the time to explain to students proper handling of samples and microscope.
- Have plenty of fossil hand samples. Coordinate with a college professor (Geologist/Paleontologist) to get what you need; supplies, info, and advice.