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MUSICA OTL Lesson: Rock Formation and Stratigraphy

Author Name: Clint Harris

PART 1a. Lesson Overview

Grade and Subject High school or first year of college	**Instructional Time Required** (Minutes) 240 minutes (4 hours) Five 50-minute class periods
Unit Title (Topic)	**Rock Formation and Stratigraphy**
Anchoring Phenomenon	**Phenomenon:** The formation of the Grand Canyon. **Driving Questions:** 1. How do the rock layers exposed in the walls of the Grand Canyon provide a record of Earth's history and environmental changes that have occurred over time? 2. How can rivers shape the Earth's surface (landscape) into distinct topographic forms? 3. How has the interplay between uplift due to tectonic activity and river processes sculpted the landscape of the southwestern part of the Colorado Plateau (Northern Arizona)? Use the Colorado River and the Grand Canyon as the example. **Curriculum Spark:** Students watch two short AIRVŪZ drone video footage of the Grand Canyon (United States) and the Chicamocha Canyon (Colombia). They make observations and formulate questions using the "I Notice/I

	Wonder" instructional strategy. This instructional strategy helps students create questions from the information presented by writing down what they notice and wonder about a new topic and provides an opportunity to gauge student engagement and determine prior knowledge.
Learning Goals/ Lesson Topics (for 2-3 lessons)	**Students will be able to:** • develop models that illustrate the composition of rocks that form the Grand Canyon. • construct explanations for how geoscience processes, like tectonic uplift and river dynamics have changed Earth's surface. • describe how different types of rocks form across different spatial and temporal scales. • explain and apply laws of stratigraphy.
Select grade level NGSS Performance Expectations (PEs)	***Select grade-level NGSS Performance Expectations (PEs) that support student learning goals.*** *For the NGSS, the PE color coding reflects its 3-dimensional learning components. Search the Evidence Statements for details on what students should know and be able to do after they complete the lessons that comprise the unit.* **Science and Engineering Practices (SEP)** **Disciplinary Core Ideas (DCI)** **Cross Cutting Concepts (CCC)** **HS-ESS2-1.Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** **HS-ESS2-2.Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.** **HS-ESS1-6.Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.**

	HS-ESS2-7.Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

PART 1b. Standards

***Unpack the 3-D learning components** of the NGSS Performance Expectations or your state's standards (Texas TEKS) in the table **below.** For NGSS guidance, see **the NGSS Topic Arrangements** and **NGSS DCI Arrangements (NSTA)** Use tools to **unpack** each PE separately.*		
Science and Engineering Practices (SEP)	**Disciplinary Core Ideas (DCIs)**	**Cross-cutting Concepts (CCCs)**
	HS-ESS2-1	
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS2.A: Earth Materials and Systems** • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** • Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

	framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (ESS2.B Grade 8 GBE)	
	HS-ESS2-2	
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	**ESS2.A: Earth Materials and Systems** • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.	**Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system.
	HS-ESS1-6	
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to	**ESS1.C: The History of Planet Earth** • Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.

explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. • Models, mechanisms, and explanations collectively serve as	record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.	

tools in the development of a scientific theory.		
HS-ESS2-7		
Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Construct an oral and written argument or counter-arguments based on data and evidence.	**ESS2.D: Weather and Climate** • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. **ESS2.E Biogeology** • The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.

PART 1c. Lesson Background

Teacher Preparation

Student Misconceptions	Scientific Terminology
• Weathering and erosion are often used interchangeably. • Erosion only occurs quickly and visibly. • Sedimentary rocks require immense pressure to form. • All rock layers are the same age. • Metamorphic rocks always have visible layers or bands. • Sedimentary rocks are always soft and fragile.	• Stratigraphy • Cross-bedding • Clasts • Unconformity • Erosion • Down-cutting

Background Reading/Viewing
1. History Channel documentary about the Grand Canyon 2. Basic Principles of Stratigraphy Reading Materials

PART 2. Lesson Plan

Materials
• Large screen to show I notice/I wonder videos • Computers (1 per group) for Immersive Virtual Field Trip (iVFT) exploration (iVFT is tablet compatible, but not tablet-friendly) • Printed worksheets for the Grand Canyon Cross-Section lab • Colored pencils that match the colors on the Grand Canyon Cross-Section Lab Worksheet

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Instructional Plan
Part A (20 Minutes) - I Notice/I Wonder

Students watch portions of two short AIRVŪZ drone video footage of the Grand Canyon (United States) and the Chicamocha Canyon (Colombia). They compile observations and formulate questions using the "I Notice/I Wonder" instructional strategy. This instructional strategy helps students create questions from the information presented by writing down what they notice and wonder about a new topic. Teachers should facilitate a class discussion after students have watched the video and encourage them to share their observations and questions. Students may have noticed and have questions about the features they see in the videos, the coloration of the strata, the slopes of the different rock layers, for example. Some students and teachers may have personal knowledge/ experience with these canyons. I Notice/I Wonder also provides an opportunity to gauge student engagement and determine prior knowledge.

Video 1: Grand Canyon at Sunset - 4K Drone

The Grand Canyon, cut by the Colorado River in the high plateau region of northwestern Arizona, U.S., is the world's deepest canyon (on land). It has a maximum depth of over 2000 meters (over 6000 feet). Nearly two billion years of the Earth's geological history has been exposed as the Colorado River and its tributaries cut their channels through layers of rock while the Colorado Plateau was uplifted (a process known as rejuvenation). The colorful rocks (red, pink, buff, gray, green and pink, brown, and violet) exposed in the walls of the canyon record much of the early geologic history of the North American continent.

Video 2: The Chicamocha Canyon

The Chicamocha Canyon (*Cañón del Chicamocha*) in north central Colombia was carved by the Chicamocha River. It is located in a tectonically active plate boundary zone near the MUSICA project study area. The Canyon is a steep-sided, 2000-meter-deep canyon, second in size to the Grand Canyon. Like the Grand Canyon, Chicamocha Canyon cuts through rock formations that span billions of years, from the Precambrian to the Pleistocene age. The oldest rocks are represented by the crystalline basement. The rock formations tell the story of a sequence of events that occurred from the Precambrian to the present, including rejuvenation due to tectonic activity.

Note: I Notice/I Wonder is a way to get students engaged and thinking about the topic you are teaching in a scientific manner. It mimics the beginning of the scientific method. Students are shown a picture/video/demonstration. They are asked to write down any observations in one column labeled "I Notice" and questions they have based on these observations in a second column labeled "I Wonder". Once students are finished, the teacher leads a class discussion based on these observations and questions and encourages students to think deeply by asking them to elaborate on their observations.

Part B (150 minutes) - Grand Canyon Immersive Virtual Field Trip (iVFT) Exploration

Created by researchers at Arizona State University and partners, the Grand Canyon iVFT introduces students to one of the most remarkable natural wonders in the world. Students can zoom in and out to visually observe different locations within the canyon, discover key concepts, examine rock units and the characteristics unique to each rock type, learn what the colors of the rocks and the layers of the canyon wall tell us about the past and how these layers were deposited, and watch experts deliver short video lectures. Through these explorations, they will learn about concepts such as rock units, rock types, layering, rock formation, banding, cross bedding, uplift, erosion, Steno's Laws of Stratigraphy, and explore the rock layers of the canyon walls to discover how Earth's history has changed over geologic time.

Before launching the iVFT, teachers should prepare students for the activity by giving a lecture to acquaint students with the location and geology of the Grand Canyon, review terminology and key concepts, and introduce them to the geologic time scale with a focus on relative time and Steno's laws of stratigraphy. The lecture is broken up into three parts: Rock Types, Steno's Laws, and the Formation of the Grand Canyon. These can be taught all at once or broken up over multiple class periods.

The teacher should first walk students through the shorter unit, *Layers and Superposition* exploration as a class, and then they should instruct students to go through the *Mystery of Blacktail Canyon* exploration on their own or with a partner.

After the students explore the *Mystery of Blacktail Canyon*, the teacher will give students a short quiz (quiz key) to "check for understanding."

Part C (60 minutes) - Grand Canyon Cross-Section Lab

In this challenge-based learning activity, students will make predictions about the composition of rocks that make up the Grand Canyon. The goal of this activity is to activate students' spatial thinking to facilitate a deeper understanding of the structure of Earth's shallow subsurface. The materials required for the Grand Canyon Cross Section Lab have been adapted from the GET

Spatial Learning Network, including a worksheet and a set of Grand Canyon Tutorial Slides that explain the concepts of geologic maps, cross sections, and core samples. The lesson is divided into three parts.

The teacher will first walk students through the tutorial slides to introduce the challenge and to refresh students' memories about key concepts. Using the geologic map of the Grand Canyon provided on the worksheet, students will draw their initial prediction for the subsurface cross-section.

Then, students will then examine core samples, which provide data on the depth and thickness of each rock layer. Students will use these core samples to revise their cross-section sketch. They can use fictional geologists, Bev and Raheem's, revisions for reference (in the tutorial slides) as to whether they sketched theirs correctly.

Finally, students will explore uplift and river dynamics to explain why the rock formations in the Grand Canyon look the way they do.

Note: Teachers must read and do the lab activity before implementing it in the classroom. Teachers should observe students and attend to how students are using this core data as feedback to revise their understanding.

Part D (25 minutes) - Canyon Comparison Wrap-up

To wrap up the lesson, students will revisit the two videos watched in Part A to demonstrate that they can relate elements of what they learned about the Grand Canyon to Colombia's Chicamocha Canyon. Teachers should show the videos again and have students take notes on similarities and differences between each canyon. Students will create a Venn diagram comparing the two canyons and write a short explanation as to how they think the Chicamocha Canyon formed. Once students are done, teachers will lead a class discussion about the students' observations. Students may note similarities in size, rock type, and structure. They may note differences in color, vegetation, and shape of the canyon. Teachers should have students think about how the vastly different climates would impact the erosion, impacting the shape of both canyons. They should also encourage students to think about how the vastly different vegetation might impact the way geologists do their work. Students should be able to explain that the Chicamocha Canyon formed due to uplift from plate tectonics, followed by erosion from a river system cutting through the rock, similar to the Grand Canyon.

PART 3. Assessment

Evidence of Learning
Students are able to explain how a landscape is the result of a broad range of geoscience processes occurring at different temporal and spatial scales. Students use reasoning, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to connect the evidence and support an explanation for how tectonic uplift combined with erosion, movement, and the deposition of sediment created the Grand Canyon. Students are able to identify the corresponding timescales for each identified geoscience process. Students demonstrate that they can relate elements of what they learned about the Grand Canyon to Colombia's Chicamocha Canyon.

Resources/ References

Arizona State University, immersive Virtual Field Trips (iVFT): Seeking Answers Through Exploration, online at https://vft.asu.edu/index.html

Bentley, C., Layou, K., Kohrs, R., Jaye, S., Affolter, M. & Ricketts, B. Basic Principles of Stratigraphy. In Historical Geology. OpenGeology: LibreTexts Geosciences. https://geo.libretexts.org/Bookshelves/Geology/Historical_Geology_%28Bentley_et_al.%29/12%3A_Stratigraphy_-_The_Pages_of_Earth%27s_Past/12.04%3A_Basic_Principles_of_Stratigraphy

Drone Videos

AIRVŪZ , Grand Canyon at Sunset - 4K Drone, online at https://www.airvuz.com/video/Grand-Canyon-at-Sunset---4K-Drone?id=5a4a8ef5c9877840bf98d189&ccid=58e28b900d7336015b450399

AIRVŪZ , Chicamocha Canyon, online at https://www.airvuz.com/video/Santander-Colombia---Chicamocha-Canyon?id=593ee0223b6e4a3dcbbd453b

McLaughlin, Jessica A., Doug Lombardi, Alexandra Davatzes, Allison J. Jaeger, and Thomas F. Shipley, Margaret A. Holzer, Janelle D. Hopkins, Grand Canyon Cross Section Lab, online at https://serc.carleton.edu/getspatial/activities/grand_canyon_lab.html

The History Channel. (2024). The Formation of the Grand Canyon | How the Earth Was Made. Season 2 Episode 1. Accessed via YouTube. https://www.youtube.com/watch?v=w388SQ42Mes

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This lesson planning template was adapted for the NSF-sponsored MUSICA project by Katherine Ellins and Marlena Jones, using materials that were developed by CIRES Education & Outreach at the University of Colorado Boulder. CIRES teaching materials are available at https://cires.colorado.edu/outreach/resources/planning-templates.