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Where Land Meets the Sea

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Grade Level
High School

Subject Area
Earth Science, Oceanography

VA SEA is a collaborative project between the Chesapeake Bay National Estuarine Research Reserve, the Virginia Institute of Marine Science's Marine Advisory Program, and Virginia Sea Grant. The VA SEA project is made possible through funding from the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center.

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Sea Grant Virginia

Title: Where Land Meets The Sea
Focus: Use graphs of sediment cores to determine how coast lines change
Grade Level Earth Science; target grades 9 - 12, optional add on for Oceanography

Table of Contents

VA Science Standards

ES.1 The student will demonstrate an understanding of scientific and engineering practices by:

- Asking questions and defining problems
- Planning and carrying out investigations
- Interpreting, analyzing, and evaluating data
- Constructing and critiquing conclusions and explanations
- Obtaining, evaluating, and communicating information

ES.10 The student will investigate and understand that oceans are complex, dynamic systems and are subject to long- and short-term variations.

- Environmental and geologic occurrences affect ocean dynamics

ES.9 The student will investigate and understand that many aspects of the history and evolution of Earth and life can be inferred by studying rocks and fossils. Key ideas include

- Superposition, cross-cutting relationships, index fossils, and radioactive decay are methods of dating rocks and Earth events and processes

Learning Objectives

- ✓ Students will make observations about sediment types
- ✓ Students will interpret graphic data into sediment descriptions
- ✓ Students will apply interpretations to determine how coast lines change over long time scales
- ✓ Students will discuss the importance of multiple datasets
- ✓ Students will use data to develop a hypothesis

Part I: Where Land Meets The Sea Lesson Plan

Total length of time required for the lesson

60-80 minutes total; Advance preparation of lab materials – 5 minutes, Lab setup – 5 minutes, Introduction – 10 minutes, Activity – 40 to 50 minutes, Discussion – 15 minutes, Breakdown and clean-up – 5 minutes.

Key words, vocabulary:

- **Subenvironment**: A small environment that is nested in a larger environment.
- **Sediment**: The loose soil found in each location. Classified by the size of the individual grains found (clay, silt, sand, pebbles).
- **Sedimentology:** The study of sediments to understand how Earth has changed.
- **Walther's Law:** Environments that are next to each other at a single time become stacked vertically in geologic time.
- **Sediment core:** A tube of sediment extracted from the Earth
- **Paleo-environmental reconstruction:** determining the past subenvironment from the sediments observed in a sediment core

Background information

Coastal Environments. Coastlines are dynamic systems at the convergence of winds, waves, and tides. All of these systems act as both erosional and depositional systems which move particles from the water to the land and back to the water. The different strengths of the systems allow for some particles to get dropped while others are moved. The collection of particles found in any environment is called sediment. The size of the sediment particles, along with other environmental factors such as the local biology, can therefore become features used to determine what the environment is (Wentworth, 2022).

Sediment cores and graphic core logs. The sediments in todays modern environments can easily be observed, but trying to learn how those environments have changed is much more difficult. As time moves forward, the standard indicators we use to determine coastal environments is typically not present anymore. Therefore, instead of looking for the water level or the types of plants and animals present to determine the environment, sediments are used instead. Sediment cores are tubes of sediment that are extracted from the Earth. Using these the sediments can be observed in the order in which they were deposited which allows for past environments to be reconstructed. However, because sediment cores are big, heavy, and difficult to transport, often, the data contained in a sediment core is graphically described in a graphic core log. Here, standard tools and symbology are used to describe the sediment grain sizes observed in a sediment core along with any biological or structural indicators which might help determine the environment from which a given package of sediments came. All of the graphic core logs used in this exercise and presentation materials are simplified from datasets provided by Cahoon et al. (2021; geologic map).

Student handouts

- *Where Land Meets The Sea* worksheet 01
- Graphic Core Log Legend
- Subenvironment sediment descriptions information card
- Core location map (This should be printed in color)
- Graphic Core Log SEA 01
- Graphic Core Log SEA 02
- Graphic Core Log SEA 03
- Graphic Core Log SEA 04
- Graphic Core Log SEA 05

Materials & Supplies

- Colored pencils/markers/crayons/etc.
- Ruler
- Computer and projector for accompanying PowerPoint
- Dry erase board/easel
- Scrap paper and pencils

Classroom Set up

- Students should work in groups of four to five students
- Designed for 5 groups, can be scaled down depending on class size

Procedure

Advance preparation of lab materials – 15 minutes

Prepare lesson activity by printing graphic core logs, graphic core log legend, information cards, and worksheet in advance.

Each group should have a copy of:

- One graphic core log
- Graphic core log legend
- Sediment description information card
- Core location map

These items are reusable and can be laminated to ensure longevity. All printouts/handouts are black and white with the exception of the Core Location Map.

Differentiate and enrichment options

The graphic core logs used in this exercise were developed to have different levels of difficulty to allow teachers the option for differentiation and enrichment.

- SEA 01 = Basic

- SEA 02, SEA 04, SEA 05 = Standard
- SEA 03 = Advanced

Core logs SEA 03 and SEA 04 are very similar. If it is necessary to only use four graphic core logs, eliminate one of these. There will be no change to any of the conclusions and results in the exercise that follows.

Each student should have their own copy of:

Where Land Meets the Sea worksheet.
These are not designed to be reusable; print in black and white.

Engagement

Begin the PowerPoint, *Where Land Meets The Sea*. See slides for specific notes with suggested dialog and discussion points.

- Start by focusing on slides 1 & 2 which asks the students to observe a picture and see what different coastal environments they see.
- Ask students:
    - What are the different environments on the worlds coasts? Can you name a few in this picture?
    - Do you notice anything about where the marsh is? Where the beach is?
        - Hopefully the students will notice that where the waves are crashing, the beach is sandy, but behind the beach, there aren't any waves, and the area is marshy or muddy.
    - If the students are unfamiliar with this, point it out to them or ask guiding questions to help them notice this.

Exploration

- Discuss the modes of deposition for each of the four subenvironments in the PowerPoint (marsh, dune, beachface, nearshore). (Slides 3-7)
    - Make sure to highlight the process by which each of these systems get sediments.
- Introduce that there are many different types of sediment. (Slides 8 &9)
    - Introduce the concept that sediment of different sizes have different weights.
        - This change in weight means that it takes more energy to move bigger sediments than smaller ones.
    - Ask the question: "If you're standing in a marsh, what kind of sediment do you expect to see? What about the beach"
        - Answer: Marsh = mud, Beach = sand
- Explain that mud is made of two types of sediment, clay and silt and these are very small particles that weigh less than larger sediments like sand.
    - Ask the question: "Does it take more or less energy to move mud than the amount of energy to move sand?"
        - Answer: I takes less energy to move mud than sand.
    - Ask the question: "So, looking at where the marsh is and where the beach is, where do you think there is the most energy in this system?"

- Answer: there is more energy on the beach than in the marsh.

- Introduce the concept that there are other things in coastal environments besides sediment. (Slide 10)
  - Ask the question: What else might you find in these environments?
    - Possible answers:
      - Marsh- plants and shells
      - Dunes- grass
      - Beachface: pebbles, and broken shells
      - Nearshore: Ripples and worms
  - Ask the question: What differences do you think there might be in these things between the different subenvironments?
    - Possible answer: complete or whole shells in the marsh and nearshore, but broken on the beach face.
    - Possible answer: different types of grass between the dune and marsh
- Return to the original image (slide 11), and ask the students to describe what they expect to see in any given subenvironment.
  - Note- this is just to get them thinking about how these environments differ. They will answer this question in the exercise.
- Introduce that everything so far has been for a single point in time. But if we go back in time, the environment looked different because the sea-level is always changing.
- Introduce Walther's Law: Environments that are next to eachother at a single point in time, get stacked vertically in geologic (longer) time. (Slides 12 &13)
  - This is the end of the introduction/background
- Introduce what the students will be doing in their exercise as "Paleo-environmental reconstruction through sedimentology". Or determining the past environment by using sediments.
  - Make the comparison that this time instead of imaging standing on a beach, I'm going to hand you some sediment. You're job is to use the sediments to interpret the subenvironment it came from. All the students are doing is working backwards.

Explanation

- Split the class into five groups
- Explain to the class that each group will receive a single graphic core log, an information card about the expected sediments from each subenvironment, and a location map of all 5 graphic core logs in the exercise.
  - Note- there are six cores noted on the location map and the labels on the cores do not match the labels on the map. This is by design and will aid in answering questions on the worksheet.
- Handout the worksheets.
- Walk through the example "Introducing Graphic Core Logs" in the PowerPoint to help students learn to read and interpret the graphs.
  - This is the hardest part but most important part – teaching students to read a different kind of graph to extract data. They are used to being given information and graph it. This requires students to read a graph and extract the data.
  - Step through the slides to show the steps the students will complete for each unit of sediments in their graphic core logs.

- **Step 1:** Determine the primary grain size by reading the width of the bounding box.
- **Step 2:** Determine the secondary and tertiary grain size by reading the symbols in each unit.
- **Step 3:** Identify any structures of biota present in each unit
- **Step 4:** Convert these observations into a complete sentence that describes the sediment in each unit.
- **Step 5:** Refer to their information cards to determine which of the four subenvironments this unit is. Use a dry erase marker to label the graphic core log
- **Step 6:** Repeat these steps for all of the units present on their graphic core logs.

- Once all groups are finished with their interpretations, have them complete a gallery walk. Groups of students will move through the room and observe the other graphic core logs and students interpretations. They will then have the opportunity to go back to their own logs and make corrections.

Elaboration

Have the students fill out the worksheet and answer the questions. See if they can identify which core they have from those on the map.

Alterations to lesson plan for time constraints

- Consider the following as modifications based on classroom and time for activity:
  - Ask the students to assign a color to each primary grain size, and only color in this element into the worksheet. This saves time in transferring data.
  - Rather than giving each group a different graphic core log, give each of them the same core logs, or reduce the number of core logs used to allow for more collaboration between the students.

Evaluation

- Suggested wrap up questions and answers:
  - What controls the grain size of sediments that are deposited in a system?
    - Water flow velocity/ energy in the system
  - All of the examples given here are of sea-level rising. What might a graphic core log look like if sea-level had fallen?
    - This is an open ended question. Generally you want them to put the subenvironments in the right order. If sea-level is falling then nearshore -> beachface -> dune for example.
  - This study uses a single core (or set of cores on one transect if you do the optional add in). Ask the students to brainstorm how far away from the core or transect the conclusions they found are applicable? (A few feet? Miles? 10's of miles?)
    - One core- 1-20 feet, a transect 50-100 feet. Or something like that.
  - Would this same method work if the coast was not sandy? What if it was a rocky coast like California? How would it be different? What subenvironments do you think you'd observe?
    - Yes it still works, but instead of beachface and marsh, it would be bedrock.

- This exercise includes four coastal subenvironments, but there are many others. Name one that isn't included and describe what the sediments might be like in that unit.
  - Many different options here.
    - Spits – medium to coarse sand, broken shells, similar to beachface.
    - Open bays or lagoons – silty and clayey, shells and shell fragments, no plant material.
    - As long as the environment is coastal and the sediment is finer for lower water velocity and coarser for higher velocity, give the student credit.

Assessment

Students will be assessed based on their performance on the sediment descriptions, identifying the correct subenvironment, and worksheet questions.

Where Land Meets The Sea worksheet_01

Name___________________

Date____________________

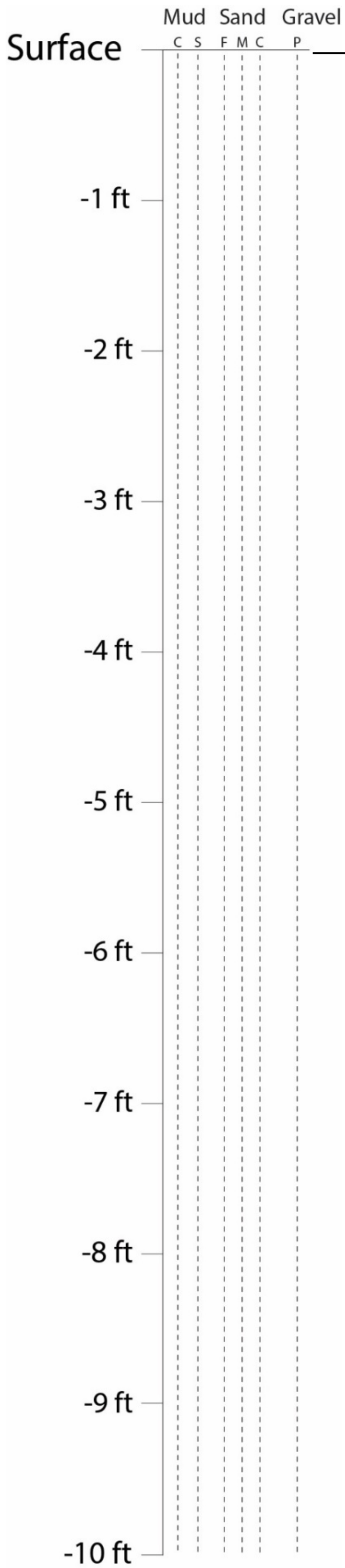
Introduction. Coastal environments are subjected to a number of different processes like waves, tides, and winds, that bring in sediment of all different sizes. This then creates a series of subenvironments with predictable sizes of sediment grains that scientists can use later, after the water is gone and the plants have died, to determine what that environment used to be. This is done by collecting sediment cores. Much like sticking a straw into a cup and pulling up some liquid, scientist stick long tubes in the ground and pull up sediments. These sediments are then studied, a process called sedimentology, to understand how the coast line has changed in the past. Once they have been studied and described, the data gleaned from sediment cores are displayed in a type of graph called a graphic core log.

The class has received a graphic core log that was collected along the Eastern Shore of Virginia. In each core log, a series of symbols and features are used to describe the sediment layers that were observed. Your job is to interpret the graphic core log and convert it back into a written sediment description. Then using the information provided to you about the sediment core itself, and the sediments associated with different coastal subenvironments, determine what different subenvironments are present in the core.

Instructions: Part 1

- With your group, study the graphic core log.
- Use your best artistic abilities to transfer the graphic core log to your worksheet below and fill out the accompanying table. Make sure to include:
    - The primary grain size of the sample
    - The secondary grain size (if present)
    - Identify any structures present
    - Identify any biota present
    - Count the number of teeth present in an individual
- Once the graphic core log has been copied and all features have been identified, use the terms on the graphic core log legend to write a complete sentence that describes the sediments in each unit. Record this on the chart below.
        - *E.g., "This unit is composed of fine sand and medium sand with heavy mineral laminations and roots."*
    - You Should notice that there are several different sedimentary layers or packages. Make sure to complete this for all of the layers present.
- Refer to the subenvironment information cards to determine the subenvironment that each sedimentary package represents.
- Write your determined subenvironment on the master graphic core log (the large laminated one handed out to your group) using a dry erase marker, and include your answer in the chart below.

Core ID:



Primary grain size	**Secondary grain size**	**Biota**	**Structure**

After completing the observations above, complete the following table:

Unit Depth	Written Sediment Description	Subenvironment classification

STOP!

Instructions for part II:

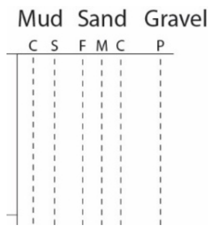
- As a group, walk around and look at the other groups graphic core logs and the subenvironments they assigned to the different units.
    - While doing this, think about your own conclusions.
    - Think about the sediment descriptions you wrote. Do they match the subenvironment sedimentary descriptions? Is there anything you'd like to change?
- Return to your group and review your conclusions. Make changes as appropriate.
- Discuss your findings with your group and classmates before finishing the questions at the end of the worksheet.

Complete the questions below.

1. Take a look at the location map. Which dot do you think is the location that your core was collected from?

2. Based on the order of subenvironments you see in this graphic core log, is sea-level rising or falling?

3. What would you expect the next unit to be? Do your best to draw what that unit would look like in a graphic core log.



4. Only four coastal subenvironments were discussed in this exercise. What are some others and what kind of sediments would you expect to find in each?

Instructor Key: Where Land Meets The Sea_01

Name__ Instructor Key_

Date____________________

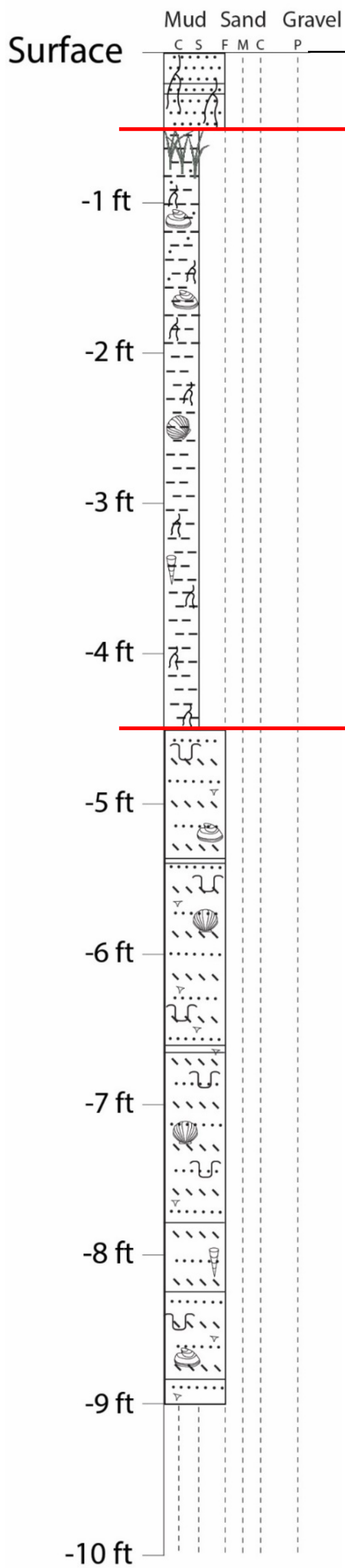
Introduction. Coastal environments are subjected to a number of different processes like waves, tides, and winds, that bring in sediment of all different sizes. This then creates a series of subenvironments with predictable sizes of sediment grains that scientists can use later, after the water is gone and the plants have died, to determine what that environment used to be. This is done by collecting sediment cores. Much like sticking a straw into a cup and pulling up some liquid, scientist stick long tubes in the ground and pull up sediments. These sediments are then studied, a process called sedimentology, to understand how the coast line has changed in the past. Once they have been studied and described, the data gleaned from sediment cores are displayed in a type of graph called a graphic core log.

The class has received a graphic core log that was collected along the Eastern Shore of Virginia. In each core log, a series of symbols and features are used to describe the sediment layers that were observed. Your job is to interpret the graphic core log and convert it back into a written sediment description. Then using the information provided to you about the sediment core itself, and the sediments associated with different coastal subenvironments, determine what different subenvironments are present in the core.

Instructions: Part 1

- With your group, study the graphic core log.
- Use your best artistic abilities to transfer the graphic core log to your worksheet below and fill out the accompanying table. Make sure to include:
    - The primary grain size of the sample
    - The secondary grain size (if present)
    - Identify any structures present
    - Identify any biota present
    - Count the number of teeth present in an individual
- Once the graphic core log has been copied and all features have been identified, use these terms to write a complete sentence that describes the sediments in a unit.
    - You Should notice that there are several different sedimentary layers or packages. Make sure to complete this for all of the layers present.
- Refer to the subenvironment information cards to determine the subenvironment that each sedimentary package represents.
- Write your determined subenvironment on the master graphic core log using a dry erase marker.

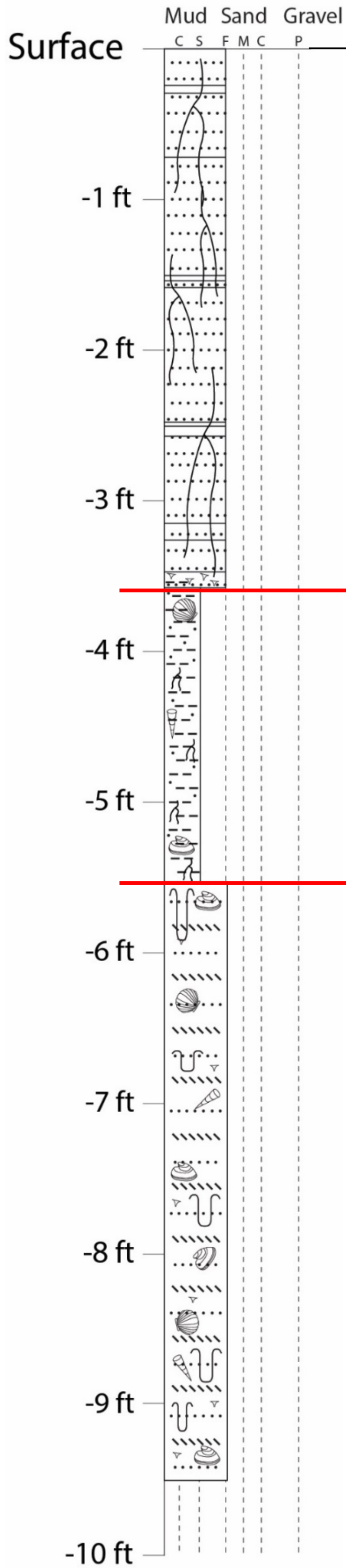
Core ID: SEA 01



Primary grain size	Secondary grain size	Biota	Structure
Fine sand	None (sand)	Roots & rootlets	Heavy minerals
Silt	Clay	Marsh, Roots & rootlets, shells	None
Fine Sand	Silt and sand	Shells, shell fragments	Heavy minerals, burrows

Unit Depth	Written Sediment Description	Subenvironment classification
0.0 - 0.5 ft	This unit is a fine sand with roots long roots and rootlets and heavy mineral laminations.	Dune
0.5 – 4.5 ft	This unit silt with clay and contains marsh grass, roots and rootlets and whole shells.	Marsh
4.5 – 9.0 ft	This unit is fine sand with silt, whole shells, fragments, and contains heavy minerals and burrows.	Nearshore
[redacted]		

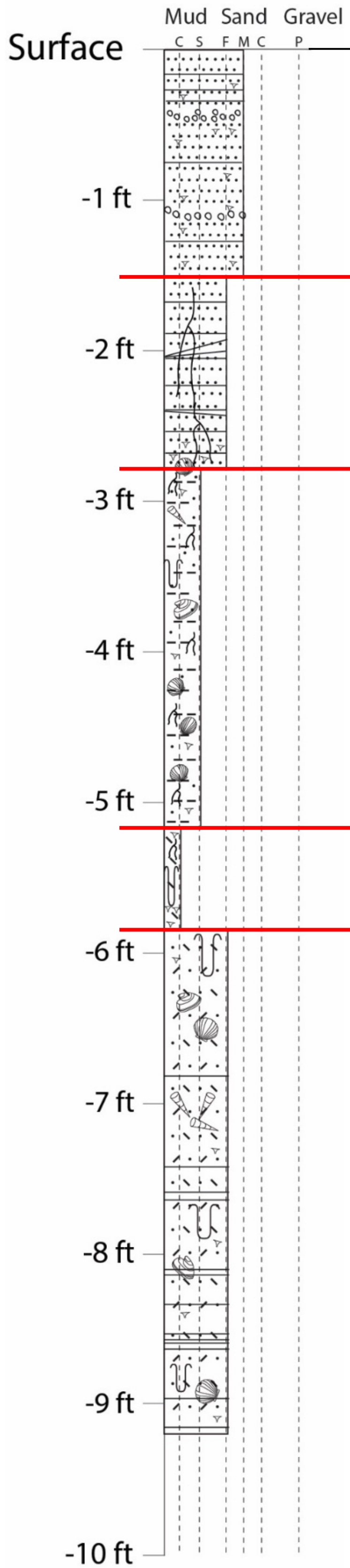
Core ID: SEA 02



Primary grain size	Secondary grain size	Biota	Structure
Fine sand	None (sand)	Roots & rootlets, shell fragments	Heavy minerals
Silt	Clay	Roots & rootlets, shells	None
Fine Sand	Silt and sand	Shells, shell fragments	Burrows

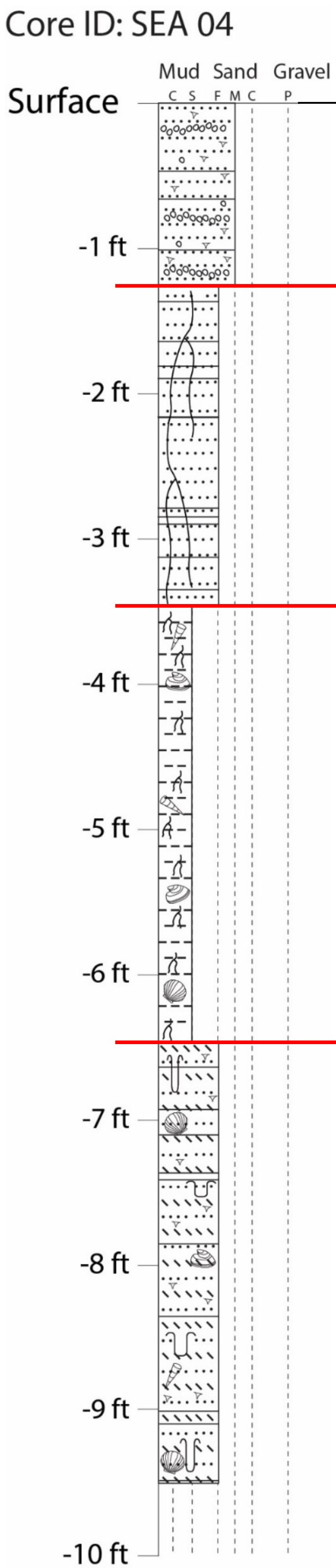
Unit Depth	Written Sediment Description	Subenvironment classification
0.0 – 3.7 ft	This unit is fine sand with long roots and rootlets and contains shell fragments and heavy minerals.	Dune
3.7 – 5.5 ft	This unit is silt with clay and sand, and contains roots and rootlets, and whole shells.	Marsh
5.5 – 9.5 ft	This unit is fine sand with some silt and contains whole shells and shell fragments with burrows.	Nearshore

Core ID: SEA 03



Primary grain size	Secondary grain size	Biota	Structure
Medium sand	Pebbles	Shell fragments	Heavy minerals
Fine sand	None (sand)	Roots & rootlets, shell fragments, shells	Heavy minerals
Silt	Clay and sand	Shells, shell fragments, roots and rootlets	Burrows
Clay	Silt	Shell fragments, roots and rootlets	Burrows
Fine Sand	Silt and sand	Shells, shell fragments	Burrows, heavy minerals

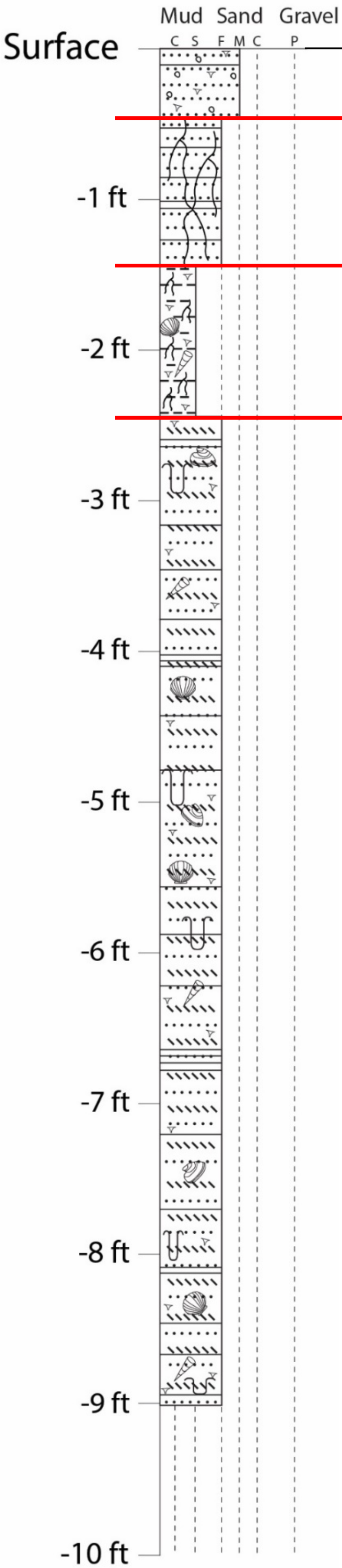
Unit Depth	Written Sediment Description	Subenvironment classification
0.0 – 1.5 ft	This unit is mostly medium sand with pebbles, and it contains shell fragments and heavy minerals.	Beachface
1.5 – 2.8 ft	This unit is fine sand and contains long roots and rootlets, shell fragments, and whole shells with heavy minerals.	Dune
2.8 – 5.2 ft	This unit is mostly silt with some silt and sand and contains whole shells, shell fragments, roots and rootlets, with some burrows.	Marsh
5.2 – 5.8 ft	This unit is mostly clay with some silt and contains shell fragments, roots and rootlets, and burrows.	Marsh
5.8 – 9.2 ft	This unit is mostly fine sand with some silt and contains whole shells and shell fragments with burrows and heavy minerals.	Nearshore



Primary grain size	Secondary grain size	Biota	Structure
Medium sand	Pebbles	Shell fragments	Heavy minerals
Fine sand	None (sand)	Roots & rootlets	Heavy minerals
Silt	Clay	Shells, roots and rootlets	None
Fine Sand	Silt and sand	Shells, shell fragments	Burrows, heavy minerals

Unit Depth	Written Sediment Description	Subenvironment classification
0.0 – 1.2 ft	This unit is medium sand with pebbles and shell fragments and contains heavy minerals.	Beachface
1.2 – 3.5 ft	This unit is fine sand and contains long roots and rootlets with heavy minerals.	Dune
3.5 – 6.5 ft	This unit is mostly silt with some clay and contains whole shells, and roots and rootlets.	Marsh
6.5 – 9.5 ft	This unit is mostly fine sand with some silt and contains whole shells and shell fragments with burrows and heavy minerals.	Nearshore

Core ID: SEA 05



Primary grain size	Secondary grain size	Biota	Structure
Medium sand	Pebbles	Shell fragments	Heavy minerals
Fine sand	None (sand)	Roots & rootlets	Heavy minerals
Silt	Clay	Shells, roots and rootlets	None
Fine Sand	Silt and sand	Shells, shell fragments	Burrows, heavy minerals

Unit Depth	Written Sediment Description	Subenvironment classification
0.0 – 0.5	This unit is medium sand with pebbles and shell fragments and contains heavy minerals.	Beachface
0.5 – 1.5 ft	This unit is fine sand and contains long roots and rootlets with heavy minerals.	Dune
1.5 – 2.5 ft	This unit is mostly silt with some clay and contains whole shells, and roots and rootlets.	Marsh
2.5 – 9.0 ft	This unit is mostly fine sand with some silt and contains whole shells and shell fragments with burrows and heavy minerals.	Nearshore

Instructions: Part 2

- As a group, walk around and look at the other groups graphic core logs and the subenvironments they assigned.
    - While doing this, think about your own conclusions.
    - Think about the sediment descriptions you wrote. Do they match the subenvironment sedimentary descriptions? Is there anything you'd like to change?
- Return to your group and review your conclusions. Make changes as appropriate.
- Discuss your findings with your group and classmates before finishing the questions at the end of the worksheet.

Complete the questions below.

1. Take a look at the location map. Which dot do you think is the location that your core was collected from? Why?

   SEA 01 – A (could also be B)
    - Thin dune with a thick marsh underneath. Shouldn't be along the beachface or nearshore. Should be on the backside of the island in the photograph.

   SEA 02 – D
    - Thick dune at the surface. The students should be able to see the dune ridge in the photograph. Only one core was collected along that ridge.

   SEA 03 – C or E
    - Beachface at the top means this core had to be collected from either C, E, or F. The thickness of the beachface suggests that it's been a beach the longest which means the answer should be C or E. Either answer is acceptable though.

SEA 04 – C or E

- Beachface at the top means this core had to be collected from either C, E, or F. The thickness of the beachface suggests that it's been a beach for a while which means the answer should be C or E. Either answer is acceptable though.

SEA 05 – F or E

- Beachface at the top means this core had to be collected from either C, E, or F. The thickness of the beachface and underlying nearshore should suggest that this environment hasn't been exposed for very long and is probably the youngest of the group.

2. Based on the order of subenvironments you see in this graphic core log, is sea-level rising or falling?

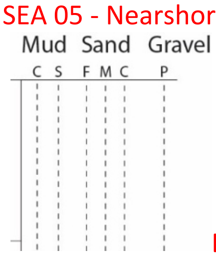
Sea level is rising in all cases. The environments from bottom to top are moving landward.

- The key here is for the students to read the cores from bottom to top and realize that time is moving forward. Then that the environments are getting closer to sea level which suggests that sea level is rising. The nearshore at the base may though the students off. This is because typically the environment becomes flooded and then these units form as sea level continues to rise.

SEA 01 – Nearshore -> Marsh -> Dune.
SEA 02 – Nearshore -> Marsh -> Dune
SEA 03 – Nearshore -> Marsh -> Dune -> Beachface
SEA 04 – Nearshore -> Marsh -> Dune -> Beachface
SEA 05 – Nearshore -> Marsh -> Dune -> Beachface

3. What would you expect the next unit to be? Do your best to draw what that unit would look like in a graphic core log.

SEA 01 – Beachface
SEA 02- Beachface
SEA 03 – Nearshore
SEA 04 – Nearshore
SEA 05 - Nearshore



Drawing should resemble the unit from the core logs.

4. Only four coastal subenvironments were discussed in this exercise. What are some others and what kind of sediments would you expect to find in each?

Open ended question that asks the students to draw on 1) the relationship of system energy and grain size, and 2) the relationship of the system and the water presence/absence. Some potential answers:

Spits – medium or coarse sand with broken shells.
Mangroves – silt and clay with plants and whole shells
Barrier islands – medium and coarse sand with pebbles, broken shells, whole shells, and marsh grass
Tidal flats – Medium or fine sand with heavy mineral laminations, shells, shell fragments, and burrows
Tidal Creeks – medium or coarse sand with pebbles, whole shells, and broken shells

General rule of thumb:

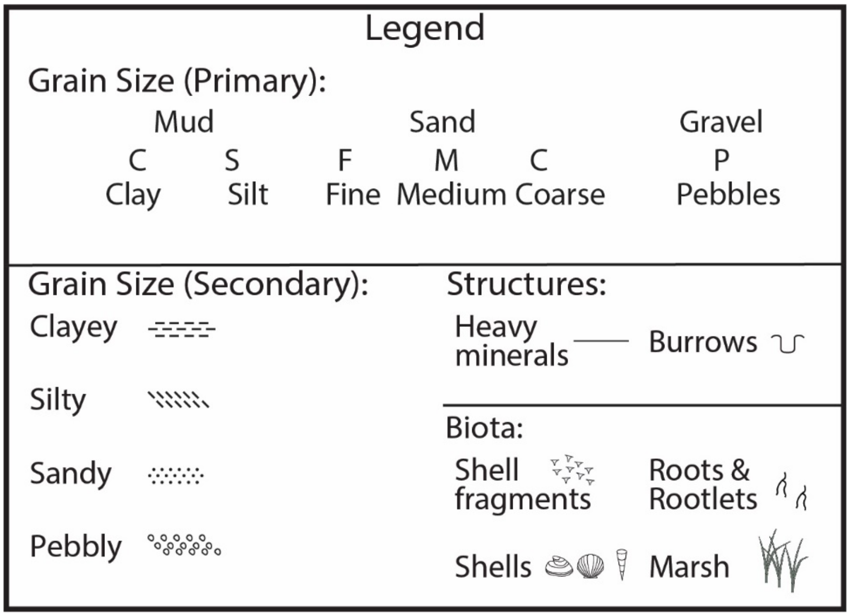
Fast flowing water or waves = coarse sand, pebbles, broken shells, and no plants.
Slow flowing water or tides = fine sand or mud, whole shells, plants and burrows.

Handouts:

Subenvironment sediment description card

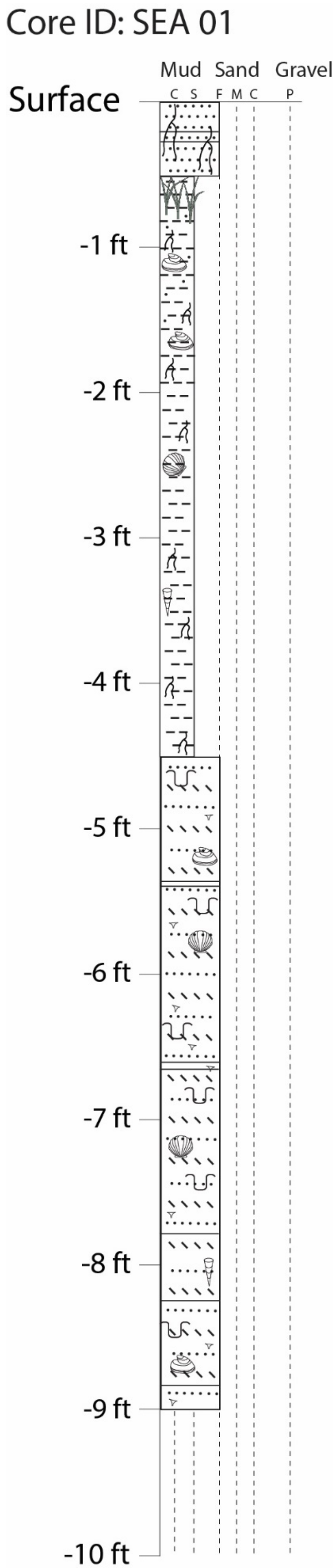
Subenvironment	Typical sediments found	Primary Process For Sediment Delivery
Marsh	Muddy. Silt is usually dominant with clay and sometimes fine sand. This unit has a lot of biological activity and low energy so expect full shells and roots and rootlets. Very low energy system prevents structures. Occasionally has shell fragments.	Sediment carried in by tides and captured by marsh grass leaves.
Dune	Sandy, usually fine but can sometimes have medium sand. Grasses grow on the top that have long roots and rootlets that extend down through sediments. Because of changing winds, this unit often has heavy mineral laminations.	Sediment blown from the beachface landward by winds
Beachface	Constant crashing of waves on the beach prevent almost any organisms from living here. But that wave energy does a good job of breaking up shells. Expect medium or coarse sand with pebbles. Might have shell fragments. Also stronger waves during storms might lead to heavy mineral laminations.	Strong waves on the beachface leaving coarse sediment and removing fine sediment.
Nearshore	The sediments in this area are never above water so there should be no plants here, but expect a lot of shells, and shell fragments. This sediment is brought here from waves on the beachface so expect fine sand and maybe silt. Variable waves may lead to structures like heavy mineral laminations, while a the fine sand makes a perfect habitat for burrowing organisms.	Fine sediments removed from the beachface are pulled to the nearshore where they are moved by waves underwater.

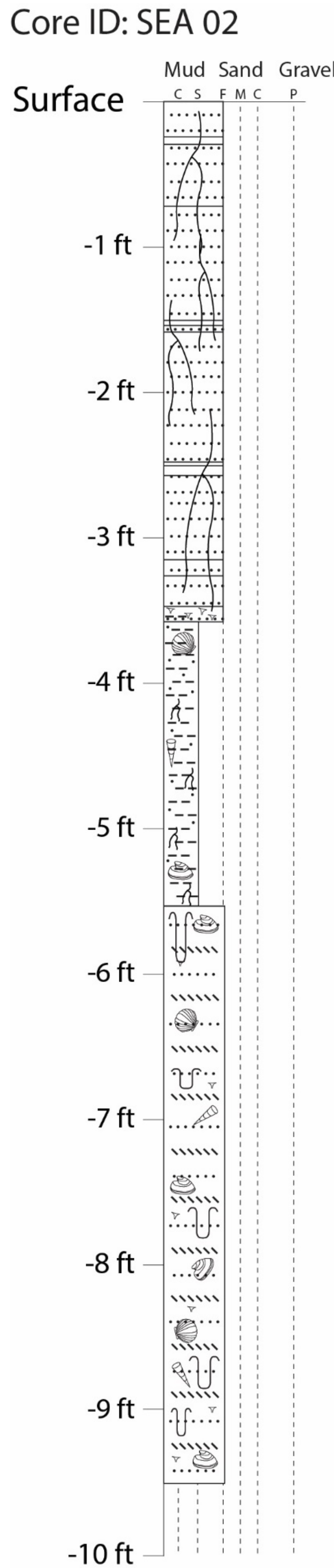
Legend for graphic core logs

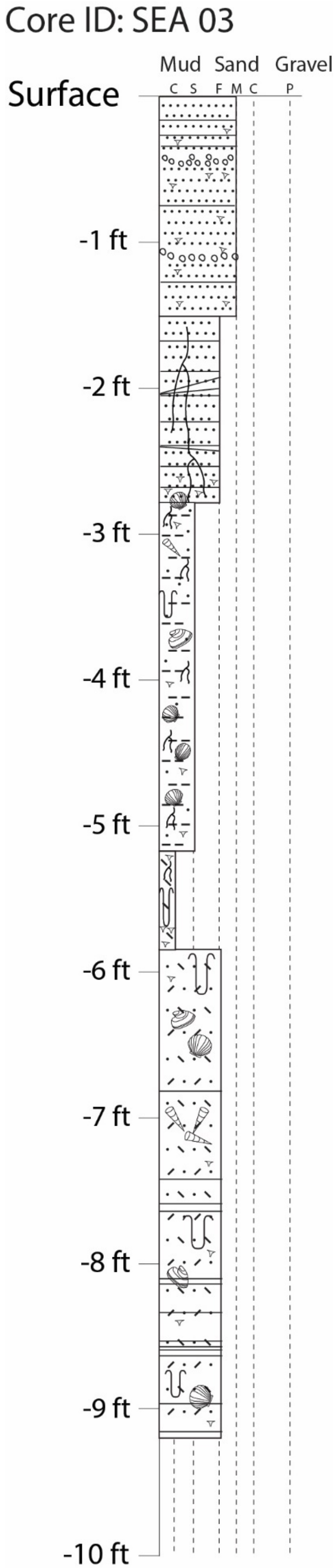


Sediment core location map

Graphic Core Logs:

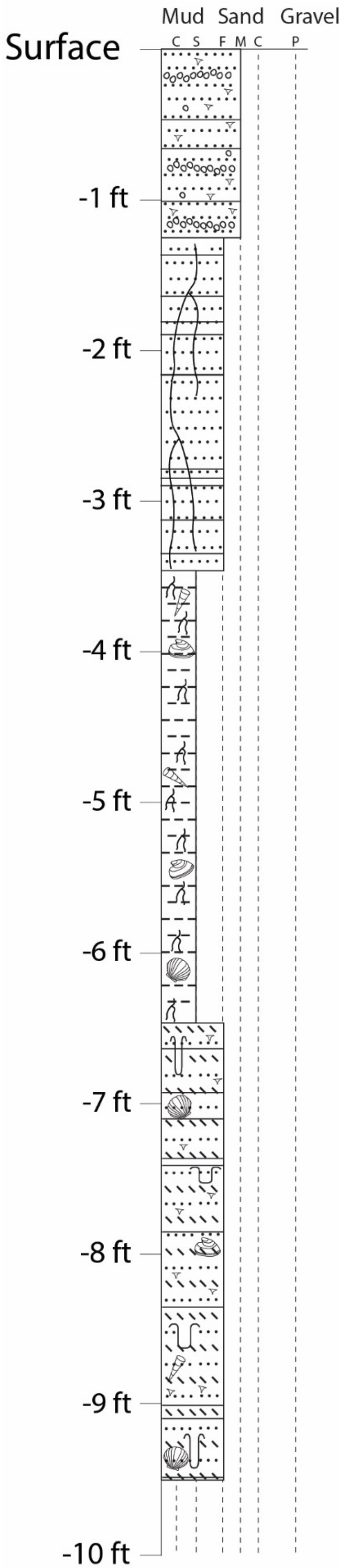




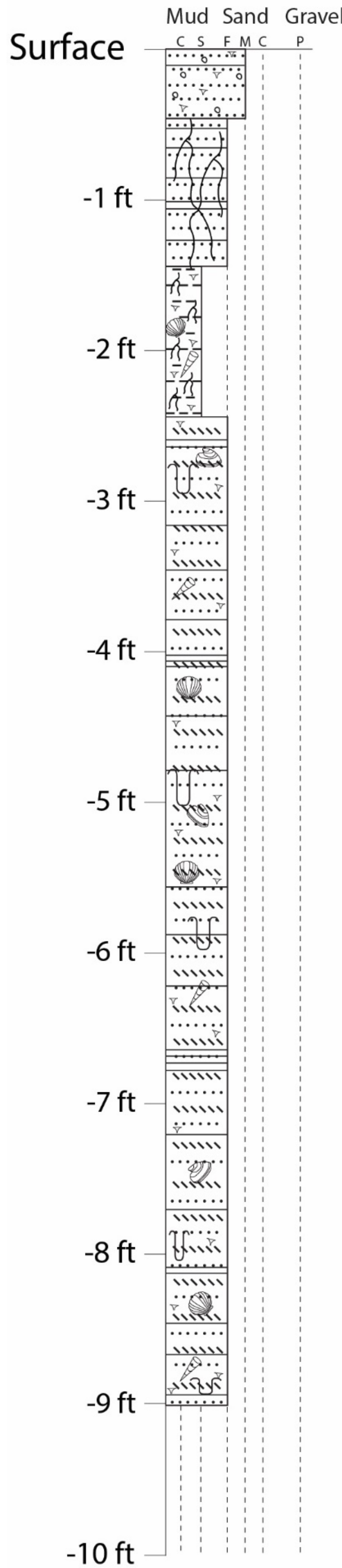


Core ID: SEA 03
Mud Sand Gravel
C S F M C P
Surface
-1 ft
-2 ft
-3 ft
-4 ft
-5 ft
-6 ft
-7 ft
-8 ft
-9 ft
-10 ft

Core ID: SEA 04



Core ID: SEA 05



Part II: Where Land Meets The Sea lesson plan

Total length of time required for lesson

40 - 50 minutes total; Advance preparation of lab materials and lab setup – 5 minutes, introduction – 5 minutes, Activity – 20-30 minutes, Discussion – 5 minutes, Breakdown and clean-up – 5 minutes.

Key words, vocabulary:

- **Stratigraphy-** Using many sediment cores to interpret the different subenvironments that are underneath the surface.
- **Stratigraphic cross section-** A type of graph that uses many sediment cores, adjusted for elevation, to draw out the different subenvironments or units and at what depths below the surface those units occur.
- **Mean sea-level-** The average elevation of the ocean today. This takes the average height of the ocean including tides and waves.
- **Sea-level curve-** a graph that shows the elevation of the ocean on the y-axis and time on the x-axis. A sea-level curve tells you how sea-level has changed over time.

Background information:

Stratigraphy and stratigraphic cross sections. Often times, when using sediments and sediment cores to interpret coastline change, many cores are collected along a transect, or line. This allows for a more complete view of how the entire system has changed over time rather than just one particular point along the coast. The field of stratigraphy is the study of the different layers of sediments which underlie a particular environment. These different layers were each deposited in a subenvironment and each of those subenvironments tells us something about how the coastline has changed. Creating a stratigraphic cross section mean we put all of the cores together in order and looking at the stratigraphy of the whole system. In doing this, you can observe all of the different layers in several different cores.

Sea-level. As sea-level rises and falls, the location of the coastal environments also shifts. All of the subenvironments observed in part I (nearshore, beach, dune, and marsh) have a specific relationship to sea level. The beach exists where it does because this is where the waves are crashing, creating the most energy and depositing a characteristic suite of sediments. Similarly, the marsh must be covered by water sometimes and exposed to the air at others while also being exposed to waves which erode these finer sediments. By understanding the mechanisms that allowed a particular environment to be deposited (sedimentology), the elevation at which that environment was deposited (stratigraphy), and how the whole system has changed over time (stratigraphic cross sections), you can extract how sea-level has changed over time.

In this optional add on, the students will use the sedimentology of the sediment cores they interpreted in part I to draw first draw stratigraphic cross section, and then use that to interpret how sea-level has changed over time.

Student handouts

- *Where Land Meets The Sea 02* worksheet
- Expanded subenvironment sediment descriptions information card
- All Graphic Core Log_ Unlabeled sheet (1 per group)
- Graphic Core Log Legend
- Core location map
- Construction paper (1 sheet, suggested 11X17; though anything larger than the standard 8.5x11 will work).

The graphic core log legend and expanded subenvironment sediment descriptions information card can be laminated for long term use and storage.

It might be helpful to have the students also refer to their completed "Where Land Meets The Sea 01" worksheet.

Materials & Supplies

- Scissors
- Glue stick, glue, or tape
- Construction paper (suggested 11X17; though anything larger than the standard 8.5x11 will work).
- Ruler
- Pencils
- Calculator (optional, basic arithmetic required)

Classroom Set Up

Each group should have a copy of:

Expanded subenvironment sediment descriptions information card
All graphic core log_unlabeled sheet
Graphic core log legend
Expanded core location map
Construction paper

Each student should have their own copy of:

Where Land Meets The Sea 02 worksheet
These are not designed to be reusable; print in black and white.

Procedure:

Advance preparation of lab materials – 5 minutes

Prepare lesson activity by printing and laminating the graphic core log legend, expanded sediment description cards, and core location map. Print the "All Graphic Core Log_Unlabled" sheet (1 per group), and worksheet (1 per student). Distribute one sheet of construction paper per group.

Engagement and Exploration

- Open up PowerPoint presentation *Where Land Meets The Sea, slide 24.*
- Introduce the idea that a single sediment core provides a lot of information about a single spot along a coast. To fully understand how the entire region has changed, you need to use many sediment cores. In this exercise you will be graphing sea-level change.
- Introduce the term "Cross Section"
    - A type of graph that identifies units in several sediment cores to describe the underlying geology of an entire region.
- Use the PowerPoint to step through how to set up the core logs (Slides 24 & 5)
- Then use the same skills developed in the first section to identify the subenvironments.
- Introduce that each of these subenvironments has a specific relationship to sea level. This is due to the processes by which the sediment is delivered to they system.
    - One example is that a dune has to be above sea level since the sand that is there is delivered by wind. Similarly, the nearshore has to be below water since the sand is moved around and flattened by the movement of water.
- Once this is complete, we can determine the elevation of the unit from the core log and adjust for sea level at the time the unit was deposited. This can be completed in a table.
- Use these data to plot a graph of sea level over time.

Elaboration

- The graphic core logs are the same as those used in part I with the exception that now the depths are not present. The students will first have to adjust this for the elevation of the ground at which the sediment core was collected.
    - Alternatively, this can directly follow from the first part and graphic core logs can be posted on a table in the classroom or on a board, and the labels on the y-axis crossed out and relabeled. This may save time and materials if the add on directly follows from part I.
- Have the students complete the cross section
- Then complete the accompanying worksheet.

Evaluation

The goal of this exercise is for students to learn that sedimentary environments have a correlation with sea level at the time they are deposited because of the mechanisms that deliver and rework the sediments in that environment. Suggested follow up questions and answers:

- Some recent sea-level studies say that sea level will increase by 3 feet along Virginia's coastlines by the year 2100. What do you think will happen to this environment if that is the case?

- As sea-level rises, the environments will shift landward. This specific region will then be fully submerged and will be covered by nearshore sediments.

- In both parts I and II we highlighted large organisms that are found in coastal environments (shells and roots). But there are a lot of other organisms that make this area their home. How do you think changing sea-level will impact those other organisms?
  - As sea-level rises, the organisms habitat changes, so the organism will have to move to where their new habitat is.
- About 50 miles inland from the east coast of Virginia, paleontologists have found bones from very large ocean animals like whales and sharks 30 feet above sea level. Also, about 0.5 mile into the ocean, archaeologists have found Native American settlements at 20 feet below sea level. What does this tell you about sea-level change in the past?
  - At some point in the past, sea-level was more than 30 feet higher than today, so the water was deep enough for whales and sharks to live there. At another point, sea level was at least 20 feet lower than today so humans could live on the coast. This tells us that sea level has changed many times over time and has been both much higher and much lower than it is today.

Assessment

Students will be assessed based on their stratigraphic cross section, paleoenvironmental reconstruction, plotting the sea-level curve, and answers to the questions at the end of the worksheet.

Key items to look for include:

- Stratigraphic cross section:
  - Relabeling the y-axis on each graphic core log based on the information provided to them in the worksheet.
  - Adjusting the elevations of the graphic core logs such that "0" is aligned.
  - Drawing the lines across all cores to group subenvironments.
- Paleoenvironmental reconstruction:
  - Classifying the different subenvironments across all cores.
- Sea-level curve:
  - Labelling all axes
  - Determining the elevation of the unit and performing to calculations to determine sea-level at the time that unit was deposited.
  - Plotting the graph

Where Land Meets The Sea_02 worksheet

Worksheet pages should direction follow the end of "Where Land Meets The Sea 01" Worksheet

Name ___________________________

Date _____________________________

Introduction: Sediment cores and graphic core logs provide a wealth of information about a single point on the coast line. However, to fully understand how the entire coastal system or region has changed, often, multiple sediment cores are collected along a transect, or line. These cores, once corrected for the elevation from the location they were collected, are placed alongside eachother. Then scientists try to match up the different subenvironments across all of the cores to better understand how the entire system has changed over time. In this part of the exercise, this is what you are going to do. Here, you are going to try to plot out the elevation of the sea using these same cores.

Instructions:

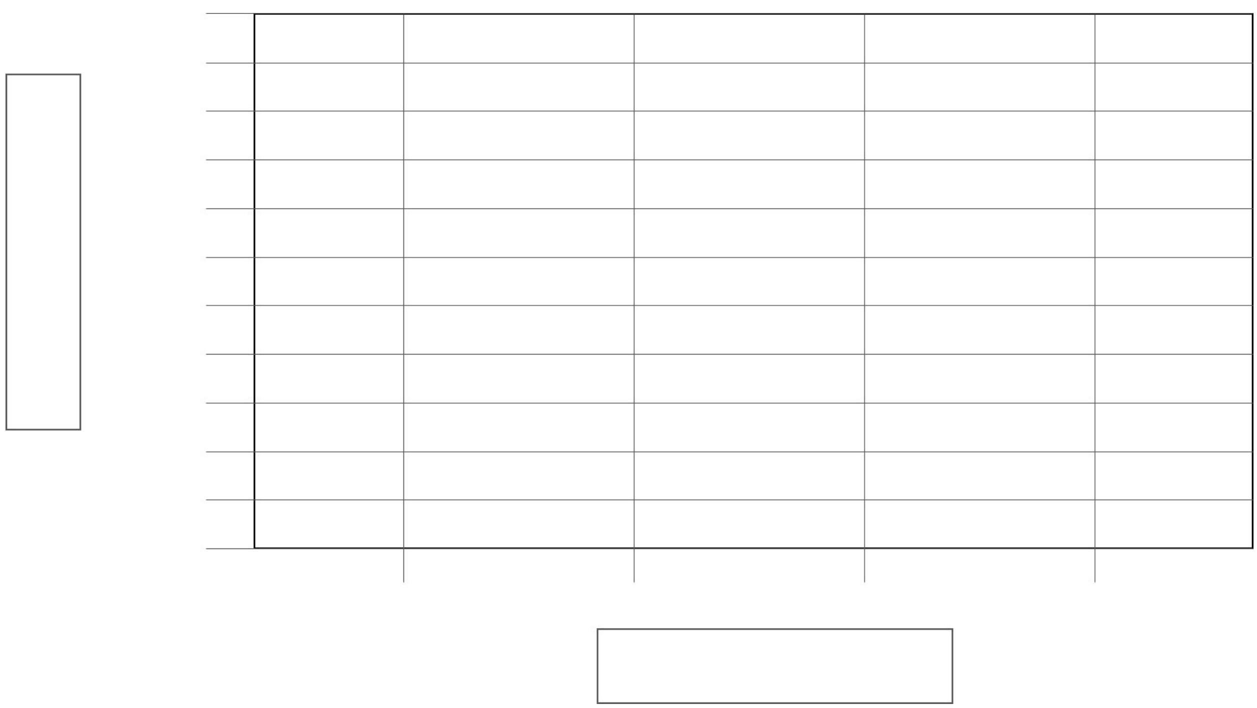
- Use scissors to cut out all 5 graphic core logs from the sheet provided to you.
- Work with your classmates to put the cores in order from landward to seaward using the expanded Core Locator Map.
- Adjust the y-axis of each core log based on the surface elevation of the location that each core was collected. Recall that the tick marks on the graphs are 1 foot intervals, and the elevations decrease down the core. Starting elevations for each of the cores are:
    - SEA 01 = +0.75 ft
    - SEA 02 = +3.5 ft
    - SEA 03 = +3 ft
    - SEA 04 = +1 ft
    - SEA 05 = 0 ft
- Now adjust the heights of each graphic core log so that "0" is at the same place and mount them, in order, on the construction paper.
- Draw a blue line on the construction paper to indicate where "0" is.
- Draw a tan line across the tops of each core log to indicate the land surface.
- Use a red colored pencil to mark the tops and bottoms of the observed units across all the graphic core logs.
- Once you have all of the units marked out across the transect, label each subenvironment.
- Use the unit description cards to fill out the table below. For the final column, if the subenvironment lies above sea level, subtract column 3 from column 4, but if the subenvironment lies below sea level add columns 3 and 4.

Time Step (from bottom to top, lowest unit = T1)	Subenvironment	Relationship to sea level	Observed unit elevation (from unit description cards)	Sea level (unit elevation + relationship to sea level)

T1				
T2				
T3				
T4				

Use the data in the table to draw a line graph of sea-level change over time.

- Make sure to label all axes and include units
- Use time steps (T1, T2….) in the absence of absolute ages of the subenvironments



Questions:

1. On the new axes on the graphic core logs, what does “0” represent?

2. Take a look at the marsh subenvironment on your cross section. Do you notice any patterns about that particular unit? Provide a hypothesis for those patterns.

3. Can you provide a hypothesis for how the top subenvironment in core SEA 03 was deposited?

4. This cross section is from a barrier island. Barrier islands are long thin strips of sand that sit in the ocean and are separated from the mainland. How does this land feature explain the presence of the nearshore subenvironment at the bottom of every graphic core log?

Where Land Meets The Sea_02 worksheet

Worksheet pages should direction follow the end of "Where Land Meets The Sea 01" Worksheet

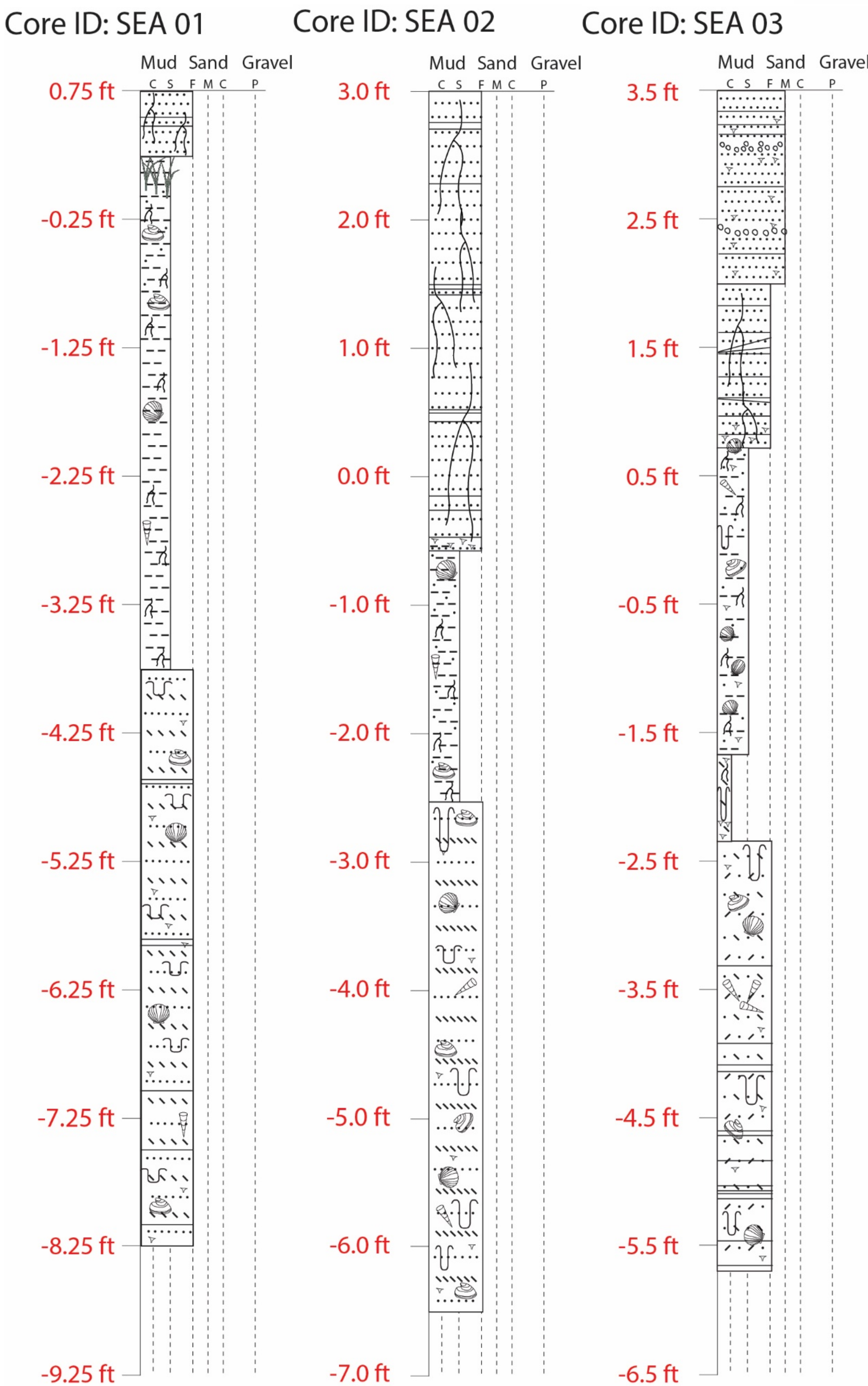
Name ______________________________

Date ________________________________

Introduction: Sediment cores and graphic core logs provide a wealth of information about a single point on the coast line. However, to fully understand how the entire coastal system or region has changed, often, multiple sediment cores are collected along a transect, or line. These cores, once corrected for the elevation from the location they were collected, are placed alongside eachother. Then scientists try to match up the different subenvironments across all of the cores to better understand how the entire system has changed over time. In this part of the exercise, this is what you are going to do. Here, you are going to try to plot out the elevation of the sea using these same cores.

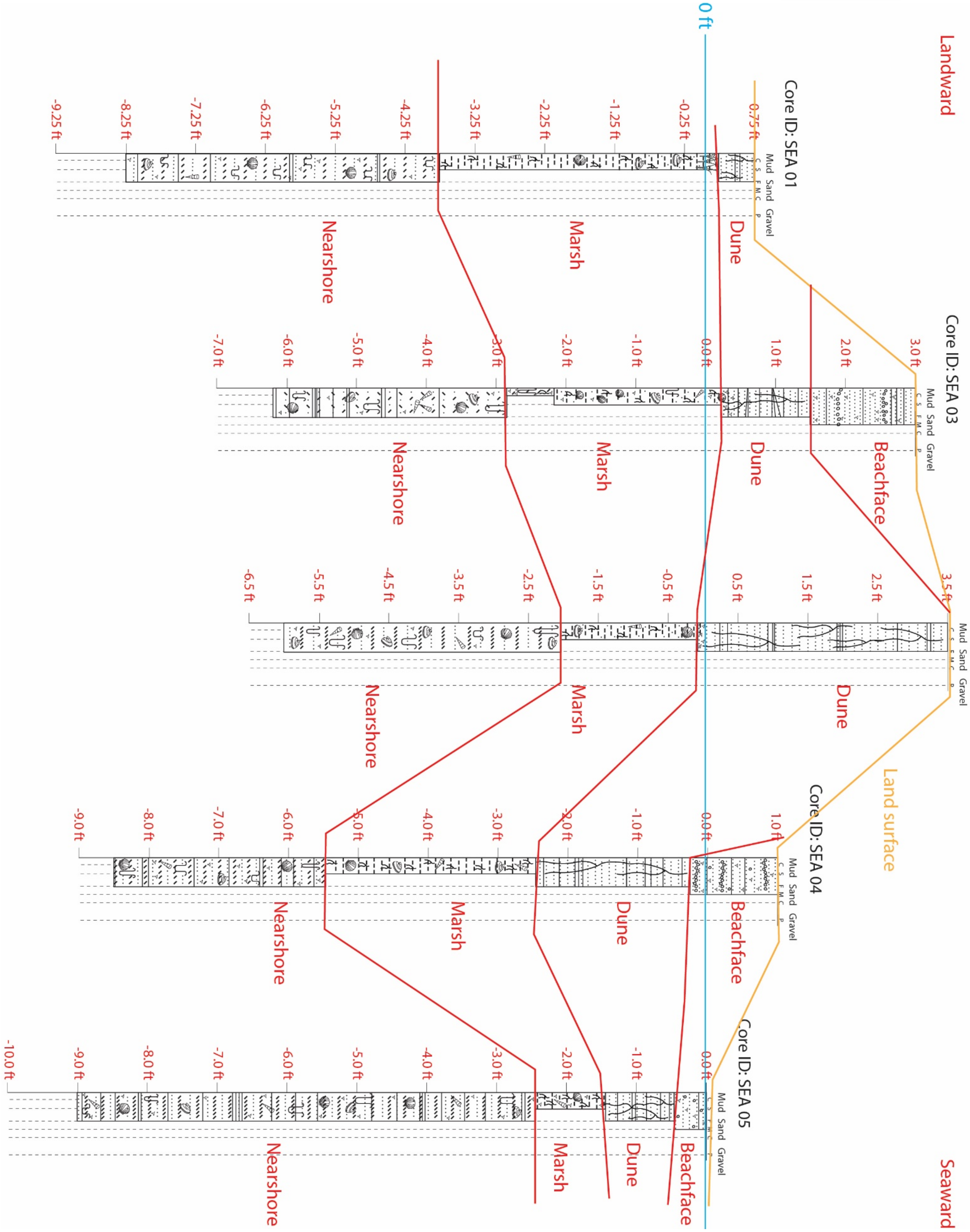
Instructions:

- Use scissors to cut out all 5 graphic core logs from the sheet provided to you.
- Work with your classmates to put the cores in order from landward to seaward using the expanded Core Locator Map.
    - You may need to visit the other groups to determine what that order should be.
        - Correct order from landward to seaward:
            - SEA 01
            - SEA 03
            - SEA 02
            - SEA 04
            - SEA 05
- Adjust the y-axis of each core log based on the surface elevation of the location that each core was collected. Recall that the tick marks on the graphs are 1 foot intervals, and the elevations decrease down the core. Starting elevations for each of the cores are:
    - SEA 01 = +0.75 ft
    - SEA 02 = +3 ft
    - SEA 03 = +3.5 ft
    - SEA 04 = +1 ft
    - SEA 05 = 0 ft
- Now adjust the heights of each graphic core log so that "0" is at the same place and mount them, in order, on the construction paper.
- Draw a blue line on the construction paper to indicate where "0" is.
- Draw a tan line across the tops of each core log to indicate the land surface.
- Use a red colored pencil to mark the tops and bottoms of the observed units across all the graphic core logs.
- Once you have all of the units marked out across the transect, label each subenvironment.
- Use the unit description cards to fill out the table below. For the final column, if the subenvironment lies above sea level, subtract column 3 from column 4, but if the subenvironment lies below sea level add columns 3 and 4.



Core ID: SEA 01
Core ID: SEA 02
Core ID: SEA 03
Mud Sand Gravel
C S F M C P
0.75 ft
-0.25 ft
-1.25 ft
-2.25 ft
-3.25 ft
-4.25 ft
-5.25 ft
-6.25 ft
-7.25 ft
-8.25 ft
-9.25 ft
3.0 ft
2.0 ft
1.0 ft
0.0 ft
-1.0 ft
-2.0 ft
-3.0 ft
-4.0 ft
-5.0 ft
-6.0 ft
-7.0 ft
3.5 ft
2.5 ft
1.5 ft
0.5 ft
-0.5 ft
-1.5 ft
-2.5 ft
-3.5 ft
-4.5 ft
-5.5 ft
-6.5 ft

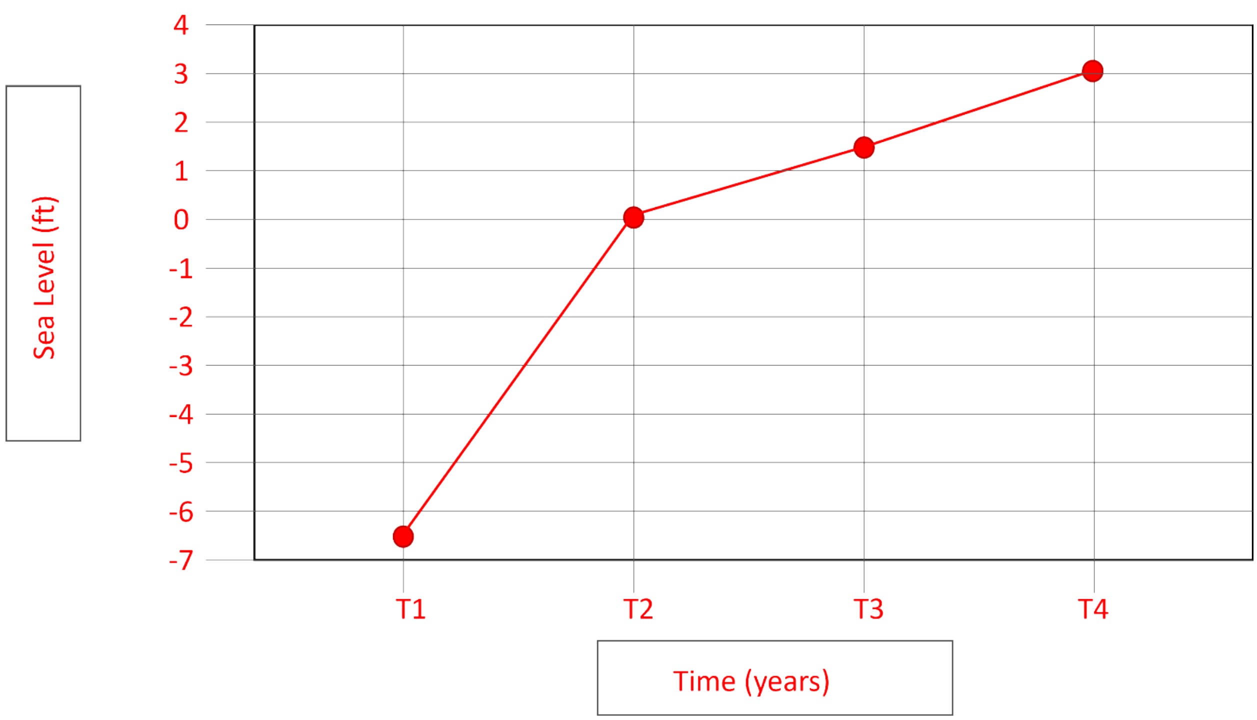

Core ID: SEA 04
Core ID: SEA 05
Mud
Sand
Gravel
C S F M C P
1.0 ft
0.0 ft
-1.0 ft
-2.0 ft
-3.0 ft
-4.0 ft
-5.0 ft
-6.0 ft
-7.0 ft
-8.0 ft
-9.0 ft
-10.0 ft


Landward
Seaward
0 ft
Land surface
Core ID: SEA 01
0.75 ft
-0.25 ft
-1.25 ft
-2.25 ft
-3.25 ft
-4.25 ft
-5.25 ft
-6.25 ft
-7.25 ft
-8.25 ft
-9.25 ft
Dune
Marsh
Nearshore
Core ID: SEA 03
3.0 ft
2.0 ft
1.0 ft
0.0 ft
-1.0 ft
-2.0 ft
-3.0 ft
-4.0 ft
-5.0 ft
-6.0 ft
-7.0 ft
Beachface
Dune
Marsh
Nearshore
Core ID: SEA 02
3.5 ft
2.5 ft
1.5 ft
0.5 ft
-0.5 ft
-1.5 ft
-2.5 ft
-3.5 ft
-4.5 ft
-5.5 ft
-6.5 ft
Dune
Marsh
Nearshore
Core ID: SEA 04
1.0 ft
0.0 ft
-1.0 ft
-2.0 ft
-3.0 ft
-4.0 ft
-5.0 ft
-6.0 ft
-7.0 ft
-8.0 ft
-9.0 ft
Beachface
Dune
Marsh
Nearshore
Core ID: SEA 05
0.0 ft
-1.0 ft
-2.0 ft
-3.0 ft
-4.0 ft
-5.0 ft
-6.0 ft
-7.0 ft
-8.0 ft
-9.0 ft
-10.0 ft
Beachface
Dune
Marsh
Nearshore
Mud Sand Gravel

Time Step (from bottom to top, lowest unit = T1)	Subenvironment	Relationship to sea level	Observed unit elevation (from unit description cards)	Sea level (unit elevation + relationship to sea level)
T1	Nearshore	-8 feet	-2 feet	-6 feet
T2	Marsh	0	0 feet	0 feet
T3	Dune	+2 feet	+3.5 feet	+1.5 feet
T4	Beachface	0	+3.0 feet	+3.0 feet

Use the data in the table to draw a line graph of sea-level change over time.

- Make sure to label all axes and include units
- Use time steps (T1, T2….) in the absence of absolute ages of the subenvironments



Questions:

5. On the new axes on the graphic core logs, what does "0" represent?
    a. 0 is sea level. This is the average height of the ocean today.

6. Take a look at the marsh subenvironment on your cross section. Do you notice any patterns about that particular unit? Provide a hypothesis for those patterns.
    a. Several possible answers.
        i. Primary answer: The marsh becomes thinner from landward to seaward. This is because marsh builds up in tidal environments, but is eroded away by waves. When it is on the seaside, it is eroded and is thinner.
        ii. Alternative answer:
            1. It gets lower from landward to seaward. This is because the marsh exists at sea level. So as sea level has risen, the marsh has gotten higher.
7. Can you provide a hypothesis for how the top subenvironment in core SEA 03 was deposited?
    a. SEA 03 is topped with beachface sediments. These sediments are higher than the beachface on the seaward side of the dune, and also are completely behind the dune. This means that sediments from the beach had to get pushed up and over the dune to to be deposited here. Any reasonable hypothesis that would move sediment inland is acceptable.
    b. Possible answers:
        i. During a hurricane, storm waves got much higher than normal and pushed these sediments over the dune.
        ii. During a very high tide, these sediments were pushed over the dune.
        iii. The beachface sediments were deposited before the dune developed.

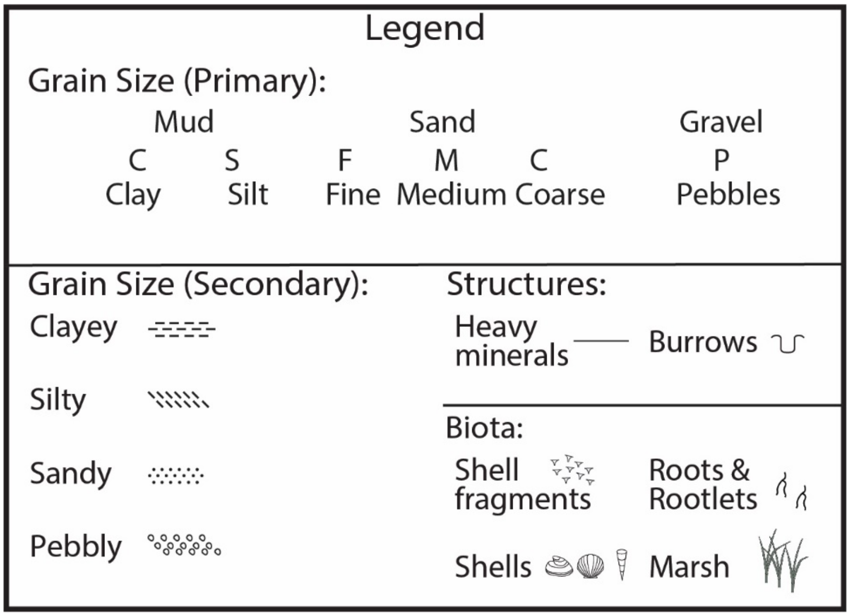
8. This cross section is from a barrier island. Barrier islands are long thin strips of sand that sit in the ocean and are separated from the mainland. How does this land feature explain the presence of the nearshore subenvironment at the bottom of every graphic core log?
    a. Before the barrier island formed, this whole region would have been underwater and there would be no features above sea level. So the whole area would have been a nearshore subenvironment and the beachface, dune, and marsh would have been along the mainland.

Handouts:

Expanded subenvironment description card

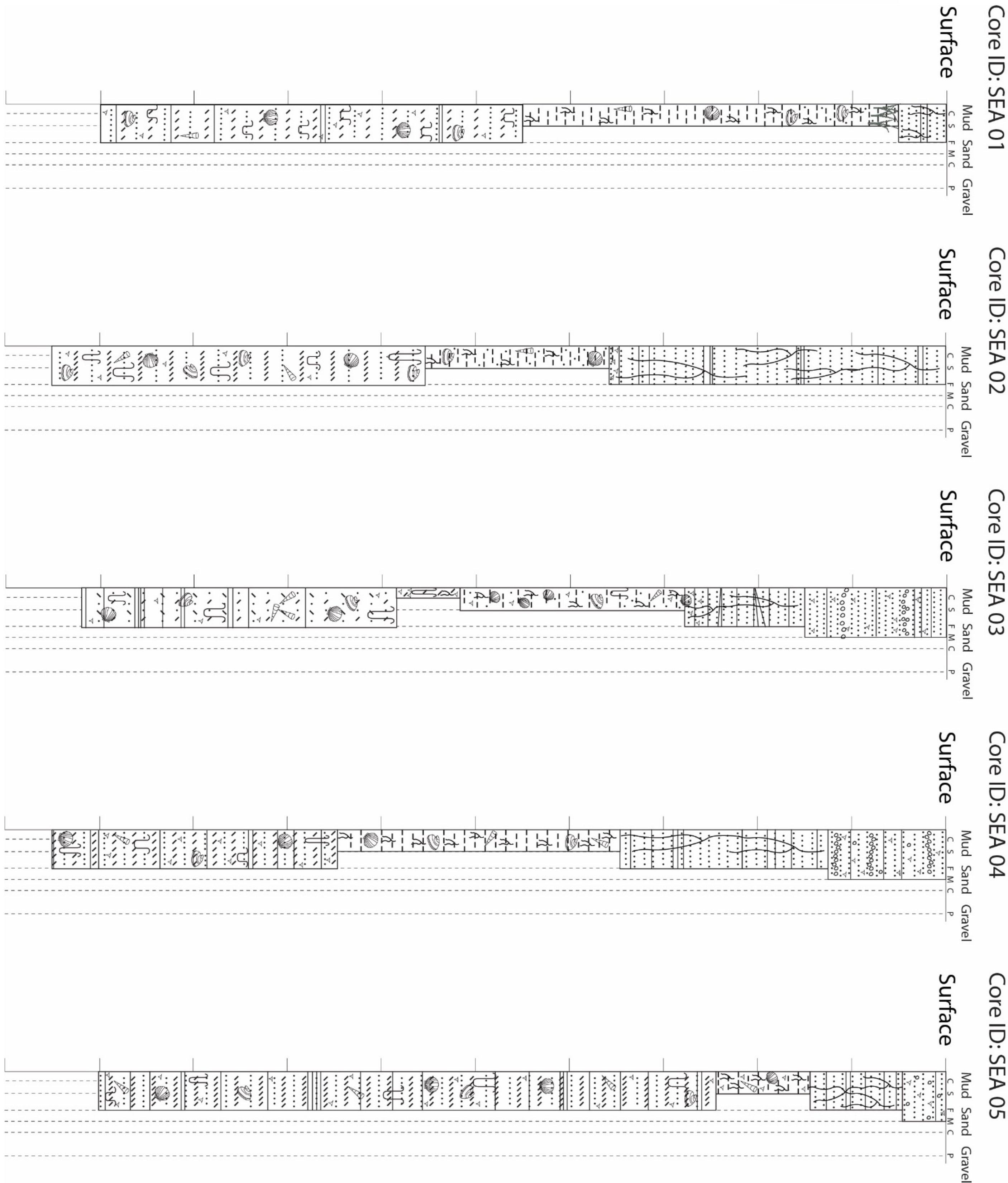
Subenvironment	Typical sediments found	Primary Process For Sediment Delivery	Elevation relative to sea level
Marsh	Muddy. Silt is usually dominant with clay and sometimes fine sand. This unit has a lot of biological activity and low energy so expect shells, shell fragments, and roots and rootlets. Very low energy system prevents structures. Occasionally has burrows.	Sediment carried in by tides and captured by marsh grass leaves.	At sea level Marshes occur in the intertidal zone, or between high and low tide.
Dune	Sandy, usually fine but can sometimes have medium sand. Grasses grow on the top that have long roots and rootlets that extend down through sediments. Because of changing winds, this unit often has heavy mineral laminations.	Sediment blown from the beachface landward by winds	2 feet above sea level Dunes are always above the water by 2 - 5 feet in Virginia.
Beachface	Constant crashing of waves on the beach prevent almost any organisms from living here. But that wave energy does a good job of breaking up shells. Expect medium or coarse sand with pebbles. Might have shell fragments. Also stronger waves during storms might lead to heavy mineral laminations.	Strong waves on the beachface leaving coarse sediment and removing fine sediment.	0 feet The beach occurs where the water meets the land so it is always at or just above sea level accounting for tides.
Nearshore	The sediments in this area are never above water so there should be no plants here, but expect a lot of shells, and shell fragments. This sediment is brought here from waves on the beachface so expect fine sand and maybe silt. Variable waves may lead to structures like heavy mineral laminations, while a the fine sand makes a perfect habitat for burrowing organisms.	Fine sediments removed from the beachface are pulled to the nearshore where they are moved by waves underwater.	8 feet below sea level. The nearshore is always underwater. So it is at least four feet below sea level.

Legend for graphic core logs



Expanded Core Location Map

All Graphic Core Logs_Unlabelled


Core ID: SEA 01
Surface
Mud Sand Gravel
C S F M C P
Core ID: SEA 02
Surface
Mud Sand Gravel
C S F M C P
Core ID: SEA 03
Surface
Mud Sand Gravel
C S F M C P
Core ID: SEA 04
Surface
Mud Sand Gravel
C S F M C P
Core ID: SEA 05
Surface
Mud Sand Gravel
C S F M C P

Acknowledgments

K. Cahoon et al. (2021) provided the data necessary to generate the simplified graphic core logs and interpretations used in this lesson plan. K. Cahoon worked together with C. Clarke, M. Fenster, J. Vaughn, and C. Hein to develop the research (Cahoon et al., 2021; Cahoon et al. 2023). This lesson plan benefited from review by L. Lawrence, B. Smith, and C. Cackowski, S. Nuss, M. Thayer and VIMS. Support for the lesson plan was provided by Virginia Scientists and Educators Alliance.

References and further reading:

Wentworth C.K., 1922, A scale of grade and class terms for clastic sediments. United States Geological Survey Special Report, 16 pg.

Cahoon K.C., Clarke C.G., Fenster M., Vaughn J. Hein C.J. 2021. Onshore-offshore surficial geologic map of the Wachapreague quandrangle with additional surrounding fractions of the Pungoteague, Accomack, Metompkin, Exmore, Wachapreague East, Nassawadox, and Quinby quadrangles (1:62,500). United States Geological Survey National Cooperative Mapping Program, 1 sheet.

Rovere A., Raymo M., Vacchi M., Lorscheid T., Stocchi P., Gómez-Pojul L., Harris D., Casella El., O'Leary M., Hearty P., 2016, The analysis of last interglacial (MIS 5e) relative sea-level indicators: reconstructing sea-level in a warmer world: Earth Science Reviews v. 159, p. 404-427.