Exploring Sanctuary Landscapes

Grade Level

5–8 or higher

Timeframe

45 minutes or more

Materials

- Computer, projector and screen
- Visual materials (all available to download)
- Text documents (all available to download)

Key Words

Coastline, deposition, erosion, geology, headland, longshore current, seasonal storms

Standards

NGSS: MS-LS2-4.
CCSS: W.6.10. SL.6.4.
Ocean Literacy Principles: 2.
Climate Literacy Principles: 7, 3.
Details at end of lesson

Stacks and a sandy beach at Olympic Coast National Marine Sanctuary: What forces created them and how do they change seasonally?
Photo: Roger Mosley from Pixabay

Activity Summary

This lesson engages students with phenomena impacting coastal landscapes at East Coast and West Coast national marine sanctuaries. Students will examine coastal landscapes using photographs and/or Google Earth and hypothesize why they see differences. They will explore the geologic and ocean forces that created the diverse features and investigate where and when they might be most likely to find buried treasure. Enrich/Extend options include hands-on activities for students to model the geologic and ocean forces with sand or clay.

Learning Objectives

Students will:

- Describe physical differences between coastal landscapes.
- Hypothesize about the geologic processes that formed these landscapes.
- Hypothesize how the ocean impacts coastal landscapes.
- Argue from evidence to explain how seasonal storms impact beach erosion.
- Explain why monitoring physical changes in beaches is important.

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Background Information

National marine sanctuaries are a network of underwater areas in the ocean and Great Lakes that protect America's most iconic natural and cultural marine resources. National marine sanctuaries contain diverse and dynamic coastal environments: from rocky shorelines and monoliths in Olympic Coast National Marine Sanctuary to sandy beaches at Florida Keys National Marine Sanctuary. A variety of geologic processes have shaped these coastal areas.

In general, the coastal environment can be defined as that area lying at the interface between land and the ocean (or other large body of water). It includes both the zone of shallow water within which waves are able to move sediment, and the area landward of this zone, including beaches, cliffs and coastal dunes. This area is affected to some degree by the direct or indirect effects of waves, tides and currents. The coastal environment itself may extend inland for many miles.

A variety of factors—including wave energy, tidal range, sediment supply, beach materials, continental-shelf slope and width and past geologic history (e.g., glaciation, volcanism and plate movement)—characterize coastal environments. Over time, the interaction of coastal processes and an area's geologic setting leads to the development of characteristic and dramatic coastal landforms.

Why are the East and West Coasts So Different?

The West Coast is complex and changeable because of tectonic activity, mountain building and land subsidence. No major seismic activity occurs along the East Coast, and the topography is relatively flat.

Bahia Honda State Park, Florida Keys National Marine Sanctuary; Photo: B & B CC BY-NC 2.0

In contrast, the West Coast is seismically active. Large faults are adjacent to the coast such as the Cascadia subduction zone off the Pacific Northwest and San Andreas fault along California. The San Andreas fault forms the tectonic boundary between the Pacific Plate and the North American Plate. Much of the coastline consists of steep, rocky cliffs and terrain that shifts up and down during tectonic activity.

Drakes Beach, Point Reyes National Seashore, near Greater Farallones National Marine Sanctuary; Photo: National Park Service

Erosion and Deposition at Work

The Pacific Ocean generally brings in bigger waves than the Atlantic. Wave-cut cliffs, sea arches and sea stacks, found in West Coast sanctuaries, form through the process of erosion. Waves can force thousands of tons of water against land, causing softer or more fractured rock to wash away. Wind also erodes particles from rock and other landforms.

Some coastal areas are dominated by erosion, such as the Pacific coast of the U.S., while others are dominated by deposition, such as the Atlantic and Caribbean coasts. The main factor in determining if a coast is dominated by erosion or deposition is its history of tectonic activity. Areas on the East Coast have relatively little topographic relief, and there is now minimal erosion of coastal bedrock. Sediment being deposited typically comes from large rivers.

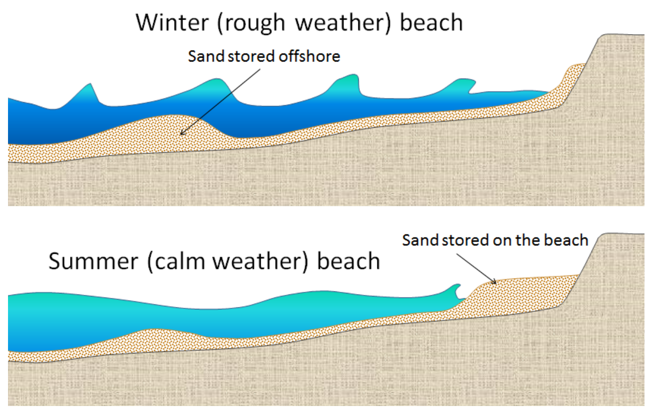
Beach Formation

Beach sand originates mainly from rivers and streams, which carry it directly to the ocean. Sand also comes from the gradual weathering of exposed rock formations and cliffs along the shore, and from pounding waves that break shells, coral and other skeletal remains into small fragments. Wave action, wind and currents move sand up and down the coast. This movement is called longshore transport (via longshore currents). Sand is also moved onshore and offshore by waves, tides and currents.

Erosion and accretion of sediment on coasts are natural processes influenced by the beach slope, sediment size and shape, wave energy, tides, storm surge and nearshore circulation, among other things. Human activities such as dredging, river modification, removal of backshore vegetation and installation of protective structures such as breakwaters can profoundly alter coastlines, mainly by affecting the sediment supply. Rivers in the West deliver more sediment to the coast from younger mountains than those in the East.

Seasonal Changes

Beach profiles change seasonally along the shoreline, showing marked differences in slope between summer and winter. Winter storms shape the coastline, prompting erosion and even landslides that may impact coastal habitats and species. During storms, high-energy waves often erode sand from the beach and deposit it offshore as submerged sandbars. Sand often does not move far; it is then moved back onshore by low-energy waves in periods of calm weather. Sand that is moved offshore by winter storms typically leaves steep narrow beaches. The gentle waves of summer typically create wide, gently sloping beaches.



Seasonal differences on beaches where the winter conditions are rougher and waves have a shorter wavelength but higher energy; Sand from the beach is stored offshore in winter. Photo and caption adapted from Earle, S. (2019). *Physical Geology* CC BY 4.0: https://opentextbc.ca/geology/chapter/17-3-landforms-of-coastal-deposition

Importance of Monitoring

Monitoring changes in beaches and coastal landforms is important for several reasons. Beach erosion threatens homes, businesses and infrastructure located along the coast. Understanding and predicting how seasonal storms, flooding and erosion will impact areas can help communities prevent damage. Sea level rise due to climate change impacts beaches and coastal areas. The number of extreme weather events is also increasing. Scientists, governments and resources managers need to understand how storm surges in combination with sea level rise will affect coastlines to identify vulnerable locations and plan for mitigation.

Beach Watch, a long-term, volunteer beach monitoring program at Greater Farallones National Marine Sanctuary, helps sanctuary staff detect physical changes and natural or human-caused disturbances to coastlines. Data provides information on the erosion and deposition of beaches along the California coast by photo-documenting the shoreline. This time series of beach profiles is an important part of understanding the variability of the shoreline and impacts from climate change, storms events and sea level rise.

Beach Watch volunteers conduct a regular beach survey along the shoreline of Greater Farallones National Marine Sanctuary. Photo: NOAA

Learn more:

"Beaches." Olympic Coast National Marine Sanctuary: https://olympiccoast.noaa.gov/science/habitat/beaches.html

"Beaches and Coastal Landforms." National Park Service: https://www.nps.gov/subjects/geology/coastal-landforms.htm

"Coast." National Geographic Society: https://education.nationalgeographic.org/resource/coast

"Dynamic Coastlines Along the Western U.S." Pacific Coastal and Marine Science Center, USGS: https://www.usgs.gov/centers/pcmsc/science/dynamic-coastlines-along-western-us

"Erosion." National Geographic Society: https://education.nationalgeographic.org/resource/erosion

"Resource Issues: Coastal Armoring and Erosion." Monterey Bay National Marine Sanctuary: https://montereybay.noaa.gov/resourcepro/resmanissues/coastal.html

"Sea Level Rise and Coastal Cities." National Geographic Society: https://education.nationalgeographic.org/resource/sea-level-rise-and-coastal-cities

Vocabulary	
Abrasion	The physical process of rubbing, scouring or scraping whereby particles of rock are eroded away by friction
Beach profile	The shape of a beach when viewed in cross section; includes the slope of the beach from the berm, or top of the beach, to the water line
Coast	The area that extends inland from the shore as far as ocean-related features can be found
Coastline	Area where land meets water; where the highest storm waves affect the shore

Deposition	Process in which sediments, soil and rocks are added to a landform; can build up layers of sediment.
Erosion	Action of surface processes (such as water flow or wind) that removes soil, rock or dissolved material from one location and then transports it to another location; erosion is distinct from weathering, which involves no movement
Headland	A raised area of land that has a steep cliff on one side, overlooking and extending out into the ocean
Longshore current	Current that flows parallel to the coast in the area of breaking waves
Longshore (littoral) drift	Movement of sediments along a coast by a longshore current
Shore	The area that extends between the lowest tide level and highest elevation on land affected by storm waves
Shoreline	The line that marks contact between land and sea: as tides rise and fall, the position of the shoreline migrates

Preparation

- Print copies of the "Sanctuary Landscapes" handout for each student, or distribute it electronically.
- Print copies of the images and description cards in the "Exploring Sanctuary Landscapes images for print" PowerPoint for each group of 3–4 students, or distribute the file electronically.
- Prepare to share the interactive "Exploring Sanctuary Landscapes" PowerPoint presentation with the class.
- Prepare to show one or more short videos listed below.
- Review the Enrich/Extend options at the end of the lesson, including an option to create hands-on models of the described phenomena.

Procedure

Engage

- Show students one or more short videos of various sanctuaries (or use Google Earth). Options:
    - Cape Flattery in Olympic Coast National Marine Sanctuary (to 1:14): https://sanctuaries.noaa.gov/vr/olympic-coast/makah-tribe
    - Bahia Honda State Park in Florida Keys National Marine Sanctuary: https://earth.google.com/web/search/Bahia+Honda+State+Park,+Florida
    - Greater Farallones National Marine Sanctuary: https://farallones.noaa.gov/about/special.html; Specific Google Earth options within the sanctuary:

        - Bodega Head: https://earth.google.com/web/search/Bodega+Head,+Bodega+Bay,+CA
        - Glennen Gulch in the Point Arena: https://earth.google.com/web/search/Glennen+Gulch,+California
        - Point Reyes: https://earth.google.com/web/search/Point+Reyes,+CA

- Ask students to think about and discuss these questions with a partner:
    - "How would you describe these different landscapes?"
    - "How do the coastlines differ between these locations?"
    - "Why do each of these locations look different?"
- After 2–3 minutes, ask students to share their ideas with the class.
- Discuss student ideas and tell them they will be exploring geologic and ocean mysteries within our national marine sanctuaries: Why do coastlines on the East and West Coasts look so different? Why do beaches change over time? What processes shape these areas?

Explore

- Ask students to form groups of 3–4. Pass out the two sets of cards in the "Exploring Sanctuary Landscapes images for print" PowerPoint to each group, or distribute the file electronically. One set of cards has photos of four different sanctuary landscapes and the second set has descriptions of geologic and ocean processes that formed the features.
    - Ask the groups to try to match the description cards with the photos of sanctuary landscapes. They should explain their ideas in science notebooks.
    - Once they have matched the cards and recorded their ideas, pass out the "Sanctuary Landscapes" handouts, one for each student. Invite groups to read the news article about buried treasure in the Monterey Bay area and answer the first question about when they might have a better chance of finding treasure.
    - Ask the groups to explore sanctuary websites and/or zoom in on sanctuaries with Google Earth to find information to support their hypotheses about the matching cards and buried treasure. Helpful online resources include:
        - Florida Keys National Marine Sanctuary: https://floridakeys.noaa.gov
            - "The Florida Keys are Made of Limestone." https://floridakeys.noaa.gov/ocean/limestone.html
        - Greater Farallones National Marine Sanctuary: https://farallones.noaa.gov

        - SIMoN (Sanctuary Integrated Monitoring Network) for Greater Farallones: https://sanctuarysimon.org/greater-farallones-nms/geology
        - Beaches at Greater Farallones: https://sanctuarysimon.org/greater-farallones-nms/beaches
    - Mallows Bay-Potomac River National Marine Sanctuary: https://sanctuaries.noaa.gov/mallows-potomac
        - Press and map: https://sanctuaries.noaa.gov/news/press/mallows-potomac
        - "Mallows Bay-Potomac River." National Marine Sanctuary Foundation: https://marinesanctuary.org/sanctuary/mallows-bay-potomac-river
    - Monterey Bay National Marine Sanctuary: https://montereybay.noaa.gov
        - SIMoN for Monterey Bay geology: https://sanctuarysimon.org/monterey-bay-nms/geology
        - Sandy Beaches: https://montereybay.noaa.gov/sitechar/sandy1.html
    - Olympic Coast National Marine Sanctuary: https://olympiccoast.noaa.gov
        - Beaches at Olympic Coast: https://olympiccoast.noaa.gov/science/habitat/beaches.html
        - Geology at Olympic Coast: https://olympiccoast.noaa.gov/explore/environment/geology.html
- After the groups have learned more about the forces that have shaped the sanctuaries, ask them to collaborate to answer the rest of the questions on the handout or in science notebooks.
- Tell students they can wait to complete the last question on their handout about the advice they would give to pirates on where would be best to bury treasure.
- When groups are close to completing the handout, give them a 3-minute warning and tell them they should be ready to discuss their ideas with the class.

Explain

- Open the "Exploring Sanctuary Landscapes" PowerPoint and use it to help facilitate an interactive class discussion. Use the prompts to encourage students to share their observations and discoveries. For example, what forces present at coastlines cause changes?

- Ask students: How do storms impact these different coastlines?
- Discuss these important concepts and how they relate to our national marine sanctuaries:
    - Erosion and deposition of rocks, sediments and other particles by wind, rain, waves, ice, gravity or living organisms can alter coastlines.
    - Powerful storms can cause drastic short- and long-term changes to coastlines.
    - Beach profiles change seasonally due to different wave action and water flow.
    - Powerful winter wave action removes sediment from shorelines. Gentle summer wave action re-builds beaches.
    - Headlands are formed when weaker rock eroded from stronger rock, like granite.
    - Coastal mountains formed by tectonic action along fault lines.
- Show students the photo of arches and caves at Olympic Coast National Marine Sanctuary and ask them how they formed. Discuss their ideas and how the same powerful wave action creates stacks. You might show visuals such as a short video or two (or clips) to help explain the process:
    - "Wind and Water, Meet Rock" (2:52) from National Geographic Society: https://education.nationalgeographic.org/resource/wind-and-water-meet-rock
    - "Sea Cliff Erosion" clay animation by David Doak (0:49): https://www.youtube.com/watch?v=ptxCE7gL6Rk
    - Excellent visuals and a short video (1:18) from U.S. Geological Survey: https://www.usgs.gov/programs/cmhrp/news/photo-roundup-coastal-change-hazards
- Discuss Point Reyes Peninsula and how plate tectonics and the continual motion of Earth's crust helped form it. Learn more: https://www.nps.gov/pore/learn/nature/geologicactivity.htm.
- Discuss student ideas about the Point Reyes Peninsula with the support of the visuals on the slide. Highlight how plate tectonics and the continual motion of the Earth's crust have caused the uplift that created the dramatic landforms. The San Andreas Fault has also moved land dramatically there north and south.
- Discuss how volunteers have helped us better understand and monitor our coastlines through programs like Beach Watch in Greater Farallones National Marine Sanctuary: https://farallones.noaa.gov/science/beachwatch.html.
- Discuss student ideas about the remaining handout questions (other than the last one) and their graphs for question 4.
- Ask students to complete the last question on their handout about the advice they would give to pirates on where would be best to bury treasure, based on what they

have learned about geologic and ocean forces on coastlines. They can discuss it with their group and record their ideas in science notebooks.

Enrich/Extend

- Invite students to create models of coasts that show movement of sediment and other forces at work in sanctuaries. The "Beach in a Pan" lesson plan from Monterey Bay Aquarium lists a set of materials and a student investigation sheet that you could provide: https://www.montereybayaquarium.org/for-educators/educator-professional-development/curriculum/beach-in-a-pan
- Invite students to research the history and stories of Native peoples that have stewarded coastal landscapes and natural resources since time immemorial. They can start by exploring the names of the cultures in the different areas using the interactive map at https://native-land.ca. Students can choose a culture to research, including their traditional foods and stories. Good options include these groups from the Olympic Coast and California:
  - Chumash people: https://channelislands.noaa.gov/maritime/chumash.html

    In the fall, Chumash crews paddle 23 miles across the channel to the island of Santa Cruz (Limuw). Photo: Robert Schwemmer/NOAA
  - Hoh Tribe: https://hohtribe-nsn.org/culture
  - Makah Tribe: https://makah.com
  - Quileute Tribe: https://quileutenation.org/history
  - Quinault Indian Nation: https://www.quinaultindiannation.com

  Ask students to research how Native peoples near coastlines are being impacted by climate change and threats of tsunamis. For instance, the Quinault Indian Nation is moving homes away from the shore and the Quileute Tribe built a new school further inland.
- Students can also research how the sanctuary landscapes they explored in the lesson might be impacted by the various effects of climate change. Students can discuss these with a partner or small group and record their ideas in words and illustrations. Ask the students to share their best ideas with the class, which may include increased erosion of the coastlines from sea level rise and more intense rainstorms, more destructive storm surges from tropical storms and degradation of habitat for sea

birds, sea turtles and marine mammals that depend on beaches to reproduce. You might also discuss how increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part. This also impacts beaches like those in the Florida Keys that are built, in part, by calcium carbonate shells of marine animals.

Encourage students to think of solutions to mitigate the destructive impacts of climate change. They can share them with the school and larger community through a medium of their choice, such as posters, public service announcement videos and/or audio recordings, games or skits.

- Students can explore what banks are and how geologic and ocean forces impact them with the "Fantastic Ocean Places You Can Bank On" StoryMap about Cordell, Stellwagen and Flower Garden Banks: https://storymaps.arcgis.com/stories/bd5be93dcd214d64872de7e535425477. They might also watch the video at the bottom on the page—or you can show it to the class. Then they can summarize what they learned about the banks and why they are important.
- Discuss actions being taken to restore coastal landscapes and make them more resilient at a national marine sanctuary or monument. You might share a video (or a clip), such as the one on this page about Bolinas Lagoon at Greater Farallones National Marine Sanctuary: https://sanctuaries.noaa.gov/news/feb20/greater-farallones-national-marine-sanctuary-coastal-resilience-sediment-plan.html.

Evaluate

- Ask students to write an exit ticket that argues from evidence to explain how seasonal storms impact beach erosion at West Coast sanctuaries and Florida Keys National Marine Sanctuary. They can include at what times of year they might be most likely to find buried treasure and why.
- Evaluate student contributions to group and class discussions, including about how they matched cards during the matching activity.
- Review students' answers to questions on the handout and in science notebooks.

Education Standards	
Next Generation Science Standards	Earth's Systems • MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.] Science and Engineering Practices: • Analyzing and Interpreting Data • Constructing Explanations (for science) • Engaging in Argument from Evidence • Obtaining, Evaluating and Communicating Information Crosscutting Concepts: • Cause and Effect • Energy and Matter • Patterns • Stability and Change • Systems and System Models
Common Core State Standards	Writing: W.6.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences. Speaking and Listening: SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes.
Ocean Literacy Principles	2. The ocean and life in the ocean shape the features of Earth. (a, c, e)
Climate Literacy Principles	7. Climate change will have consequences for the Earth system and human lives. (a, b, c) 3. Life on Earth depends on, is shaped by, and affects climate. (a, c) (If the second Enrich/Extend activity is completed.)

Additional Resources

"Longshore Currents." NOAA: https://oceanservice.noaa.gov/education/tutorial_currents/03coastal2.html

"Longshore Current." Lesson plan. NJ Sea Grant: https://njseagrant.org/wp-content/uploads/2014/03/longshore_current.pdf

"Storm Surge." National Geographic Society: https://education.nationalgeographic.org/resource/storm-surge

"Sea Rise and Storms on the Chesapeake Bay." National Geographic Society: https://education.nationalgeographic.org/resource/sea-rise-and-storms-chesapeake-bay

"What is Resilience?" Includes a short video (1:10) with examples of ways to make coastal communities more resilient: https://oceanservice.noaa.gov/facts/resilience.html

"Where's the Beach?" Lesson plan for grades 8–12 by Laura Rose, Virginia Sea Grant, Virginia Institute of Marine Science: https://masweb.vims.edu/bridge/datatip.cfm?Bridge_Location=archive0500.html

For More Information

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