

EXPLORING MARINE SEDIMENTS USING GOOGLE EARTH

Kristen St. John, James Madison University stjohnke@jmu.edu

Part 1. A First Look at Marine Sediments

Time est. 1 hour

Introduction

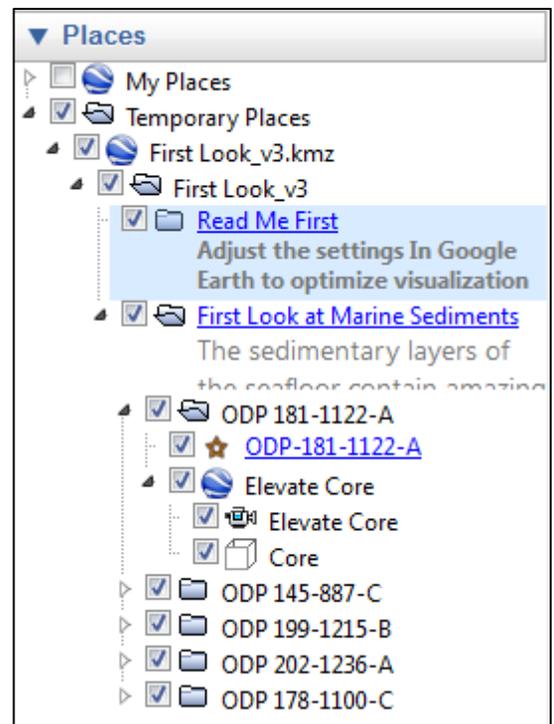


The sedimentary layers of the seafloor contain amazing stories about past ocean conditions, climates, and environmental changes. The first step in learning how to read those stories is to get familiar with the different sediment types of the seafloor. This "tour of the floor" will provide you with a first look at the sediment that is deposited in the modern ocean. You will visit five locations in the Pacific Ocean where the scientific research vessel, the *JOIDES Resolution* (<http://joidesresolution.org/>), drilled into the seafloor and recovered long cylinders of sediment. You will read about the sediment, "pull-up" cores of sediment, and view an image of the same sediment as seen under a microscope. This will give you multiple views of the seafloor: from the global scale of Google Earth, down to a 7-cm diameter core, and at the microscopic level. Comparing and contrasting your observations will help you distinguish one sediment type from another, which can lead to hypotheses about how these sediment types form.

Procedure

1. Go to the **GEODE website** <http://geode.net/exploring-marine-sediments-using-google-earth/> and click on **First Look_v3.kmz**. Save the file to your computer, and then click on the file to open it. This will automatically open the file in Google Earth. It will be located (along with all of its subfolders) under Temporary Places as shown here.
2. Click on **Read Me First**, and adjust the settings in Google Earth to optimize visualizations of bathymetric features, and read the tips and notes. Close the Read Me First pop-up page by clicking the "X" in the upper right.
3. Click on **First Look at Marine Sediments** and read the introduction (or skip if you already read the introduction above).
4. Visit each of five site locations by double clicking on the name of that location (e.g., ODP 181-1122A). Note these same sites are listed in Table 1 (next page). For each location be sure to do the following:

- a. **Read and view the site (placemark) information** by opening the place folder (e.g., ODP 181-1122A), and double clicking on the "starred" site name (e.g., ODP 181-1122A). This contains background information, links, and questions to consider as you view the sediment core images. For example you can **view photos** of the sediment that were taken through a binocular microscope. To access these images click on the links embedded in the site information. When you open an image, notice the scale bar in the lower right hand corner of the image. Depending on the image, the scale bar is 0.05 to 1 mm in length. For comparison, sand-sized grains are between 0.06 and 2 mm diameter, silt-sized grains are between 0.004 and 0.06 mm diameter, and clay-sized grains are < 0.004 mm.
- b. **"Pull up" a section of core** from the seafloor to see what the sediments looks like in the upper few meters of the ocean floor. To do this, click on the "Elevate Core-Google Earth icon" (which brings you closer to the



site of interest), then then click on the “**Elevate Core-Video Camera icon**” (which will actually elevate the core up from the seafloor). You can repeat or pause the core elevation by using the pop-up controller in the bottom right of the screen. NOTE: Do NOT unclick the subfolder with the 3-D box symbol labelled Core.

- c. **Record your observations** about water depth, geography (e.g., distance from land, bathymetric features), sediment color, texture (grain size), and composition, and your answers to site-specific questions in **Table 1 (next page)**. Below are some tips for accomplishing this task:
- i. Water Depth: look at bottom right corner of screen.
 - ii. Distance from Land: use ruler icon. But note that ruler icon won't work when elevate core is active.
 - iii. Sea Floor Bathymetry: use descriptive words like flat basin, seamount, underwater plateau, continental shelf, etc.
 - iv. Description of Sediment: describe what the sediment looks like and what it is composed of based on the information you read about each site, the photos at the microscopic level, the elevated core images, and going to Core Ref link in the site description.

Table 1. First Look at Marine Sediments - Summary Observations

	Site Locations				
	ODP 181-1122A	ODP 145-887C	ODP 199-1215B	ODP 202-1236A	ODP 178-1100C
<i>Water Depth (m)</i>					
<i>Distance from Land (km)</i>					
<i>Seafloor Bathymetric Features</i>					
<i>Sediment Description</i>					
Site Specific Questions	<i>Do you think this sediment is mostly land derived or biologically derived?</i>	<i>What factors do you think might make the surface waters here an excellent setting for bio-siliceous primary productivity?</i>	<i>Why do you think the sediment is so fine grained and uniform in composition?</i>	<i>This calcareous-rich sediment is among the most common sediment type on ridges, and seamounts, and plateaus. It is not found in the deep basins even if the surface waters were rich in calcareous phytoplankton. How might this be explained?</i>	<i>How might we get a mix of fine and very coarse sediment on the seafloor?</i>
	<i>Based on the composition of the sediment and the seafloor bathymetric features nearby, where do you think the sediment originated?</i>				<i>Based on the composition of the finer materials, and knowing that there are also large pebbles in the cores, what process(es) do you think might have been involved in transporting the sediment to this seafloor location?</i>
	<i>Notice the dark tephra (ash) layer in core. Where do you think the eruption occurred?</i>				

Part 2. Exploring the Distribution of the Primary Types of Sea Floor Sediments

Time est. 1 to 1.5 hours

Introduction

The **purpose** of this exercise is to explore empirical data on the distribution of the five primary **marine sediment types** (i.e., **lithologies**; **Table 2**) of the sea floor. Your job is to describe the surficial sea floor distribution of marine sediment types and propose hypotheses to explain the distribution patterns you see. Note that while these five sediment types are the dominant types of sediment on the sea floor, mixed lithologies are also common; these are represented by colored “**open**” circles in the Google Earth database that you will work with. Note also that lithologies can change within the stratigraphic interval represented in a core. For example, the sediment at a site on the ocean floor could alternate between glaciomarine and siliceous ooze, or gradually grade (change) from one to another as the conditions controlling sedimentation change. In addition, in any marine sediment lithology, but especially in biogenic oozes and deep sea red clays, layers of volcanic ash may be distinguishable as a minor lithology.

Table 2. Description of the Principle Marine Sediment Types

Marine Lithologic Names and symbol color used in Google Earth Map. Open circles indicate mixed sediment types, but still dominated by that primary lithology.	Descriptions
Terrigenous ● ○	Siliclastic sediment derived from the weathering of continents or volcanic islands.
Glaciomarine ● ○	Sediment containing terrigenous minerals and rock fragments, often including larger grains such as sand, pebbles, or cobbles which were transported to the sea by icebergs and sea ice.
Calcareous Ooze ● ○	Biogenic sediments composed of the hard parts of calcareous (calcite and aragonite, CaCO ₃) phytoplankton (coccolithophorids, aka calcareous nannofossils) and/or zooplankton (foraminifers). In shallow tropical settings, calcareous reef-building organisms are another source of calcareous-rich marine sediment.
Siliceous Ooze ● ○	Biogenic sediments composed of the hard parts of siliceous (opal, SiO ₂) phytoplankton (diatoms, silicoflagellates), zooplankton (radiolarians), and/or glassy sponges spicules.
Red Clay ● ○	Very fine terrigenous sediment that often contains siliceous microfossils, fish teeth, Mn-Fe micronodules, and/or volcanic glass.

The empirical data used in this exercise is derived from surface and near surface lithologic descriptions and/or smear slide (compositional sample) data from ~2500 marine site locations by the following research programs:

- The Deep Sea Drilling Project (DSDP, <http://www.deepseadrilling.org/about.htm>): global data
- The Ocean Drilling Program (ODP, <http://www-odp.tamu.edu/>): global data
- The International Ocean Discovery Program (IODP, <http://www.iodp.org/>): global data
- The Woods Hole Oceanographic Institution (WHOI, <http://www.whoi.edu/>): global data

This Google Earth marine sediment database continues to be expanded, with the goal of including data from all marine sites in the National Geophysical Data Center Index to Marine and Lacustrine Geologic Samples (http://maps.ngdc.noaa.gov/viewers/sample_index/). It is being developed by Kristen St. John, with assistance from Caroline Robinson and Cari Rand, James Madison University, as part of the NSF-funded GEODE project (<http://geode.net/>). It supplements and compliments an NSF-funded exercise on Seafloor Sediments (<http://serc.carleton.edu/NAGTWorkshops/intro/activities/29154.html>), which is an open-access chapter from St. John, K., et al., (2012) *Reconstructing Earth's Climate History: Inquiry-based Exercises for Lab and Class*. Wiley-Blackwell, 485p.

Procedure

1. Go to the **GEODE website** <http://geode.net/exploring-marine-sediments-using-google-earth/> and click on: **Surficial Sea Floor Sediment Map Data v2.kmz**. Save the file to your computer, and then click on the file to open it. This will automatically open the file in Google Earth.
2. Be sure that the **Sediment Legend** is displayed; along with one sediment type of your choice (e.g., terrigenous) by clicking on those file names. (A “check” should appear in the box next to the folder name.)
3. Rotate the globe to explore the geographic and bathymetric distribution of each sediment type. **This will be easier if you first examine each sediment type separately** (e.g., unclick everything other than terrigenous, then unclick everything other than calcareous ooze, etc). Water depth can be estimated by looking in the bottom right corner of the Google Earth page, or can be specifically determined by double clicking on the site name or symbol, which will bring up a site-specific information table, along with links to a wide range of site data and scientific reports. **Record your observations in Table 3.**
4. **Propose hypotheses** to explain the distribution patterns you see. In other words, try to address *WHY the sediment types are where they are in the global ocean?* Also consider what **additional information** you would want to obtain to test your hypotheses. **Record your ideas in Table 3.**
5. Optional Extension: Select an IODP, ODP, or DSDP core location and find out more about why that location was targeted for coring, and what the key results were from the research conducted on material recovered from that core.

To address these questions click on the information table for the core and then explore the **publications** links. The **Scientific Prospectus** will tell you about the scientific questions the wanted to address by coring the sea floor in that region. The **Preliminary Report** or the **Initial Report** will tell you about the first results from the drilling expedition, and provides detailed descriptions of the cores and the sediment compositions. The **Proceeding Report** or **Scientific Report** will provide access to results from longer term research studies, as well as a synthesis of the scientific team’s findings. Record your finding below:

- *What site did you select?*
- *Where is it located?*
- *Why was this location targeted for coring?*

- *What are some of the scientific results from research on cores from this site?*

Table 3. Observations and Hypotheses on the Distribution of Surficial Sea Floor Sediment Types.

Marine Lithologic Name and symbol color used in Google Earth Data Map. Note open circles are mixed sediment types, but still dominated by that primary lithology.	Observations About Distribution	Your Hypotheses to Explain the Lithologic Distribution	Other Information You Would Want In Order to Test Your Hypotheses
Terrigenous ● ◉			
Glaciomarine ● ◉			
Calcareous Ooze ● ◉			
Siliceous Ooze ● ◉			
Red Clay ● ◉			

Part 3. Refining Your Hypotheses on Biogenic Sediment Distributions

Time est. 1.5 hours

Introduction

Marine sediments are largely either land-derived or biologically derived. However, the two biologically derived sediment lithologies (i.e., the calcareous and siliceous oozes) have different sea floor distribution patterns. In this exercise you will have access to some additional information to explore this situation further. The new data will help you refine your hypotheses on the distribution pattern of calcareous and siliceous oozes.

Procedure

1. If it is not already open, go to the **GEODE website** <http://geode.net/exploring-marine-sediments-using-google-earth/> and click on: **Surficial Sea Floor Sediment Map Data v2.kmz**. Save the file to your computer, and then click on the file to open it. This will automatically open the file in Google Earth. Display only the Calcareous Ooze and Siliceous Ooze data, by “unchecking” all of the other marine sediment folders. It is also good to unclick the Sediment Legend as another data set will be added in a moment and their labels overlap.
2. Go to the **GEODE website** <http://geode.net/exploring-marine-sediments-using-google-earth/> and click on: **World and Regional Sea Surface Temperature.kmz**. Save the file to your computer, and then click on the file to open it. This will automatically open the file in Google Earth. Alternatively, you can get this file from: http://modata.ceoe.udel.edu/web_kmzs/World%20and%20Regional%20Sea%20Surface%20Temperature.kmz. This file displays NASA satellite derived ocean surface temperature data. Click on the Layer Transparency Box (above Layers in the bottom left panel) so that the transparency “slide bar” is visible. Slide the bar so that you can see both the sea surface temperature data and the sites of calcareous and siliceous ooze. Answer the questions below that **compare SST and biogenic sediment distribution**:
 - *What pattern do you see in sea surface temperatures (SST)?*
 - *How does the distribution of calcareous ooze compare with the pattern of SST? Describe both the general similarities and any exceptions.*
 - *How does the distribution of siliceous ooze compare with the pattern of SST? Describe both the general similarities and any exceptions.*
 - *How might surface ocean temperature play a role in the distribution of calcareous and/or siliceous oozes on the sea floor?*

3. Go to the **GEODE website** <http://geode.net/exploring-marine-sediments-using-google-earth/> and click on: **Chlorophyll.kmz**. Save the file to your computer, and then click on the file to open it. This will automatically open the file in Google Earth. Alternatively, you can get this file from: <http://mw1.google.com/mw-ocean/ocean/media/oia/files/Chlorophyll-lores.kmz>. It displays NASA satellite derived chlorophyll data for the global ocean. The unit is milligrams per cubic centimeter. **The chlorophyll content is a measure of primary biological productivity (the product of photosynthesis) in the surface ocean.** Click on the Layer Transparency Box (above Layers in the bottom left panel) so that the transparency “slide bar” is visible. Slide the bar so that you can see both the chlorophyll data and the sites of calcareous and siliceous ooze. Answer the questions below that **compare Chlorophyll concentration and biogenic sediment distribution:**

- *Where is the chlorophyll concentration in the surface ocean the highest? Why might this be? (Hint: what requirements for photosynthesis are being met?)*
- *Where is the chlorophyll concentration in the surface ocean the lowest? Why might this be? (Hint: what requirements for photosynthesis are NOT being met?)*
- *Nutrients (e.g., calcium, nitrogen, iron, silica) are essential to photosynthesis. They are supplied to the surface ocean by runoff from land or are recycled in the ocean via upwelling in areas of surface water divergence. Based on the chlorophyll concentrations, where do you think upwelling occurs on the global ocean?*
- *How does the distribution of siliceous ooze on the sea floor compare with the pattern of the chlorophyll concentrations?*
- *How does the distribution of calcareous ooze on the sea floor compare with the pattern of the chlorophyll concentrations?*
- *Which type of phytoplankton, siliceous or calcareous, appears to be most dependent on a strong supply of nutrients for their survival (i.e., is “nutrient limited”)?*
- *Notice the high chlorophyll content where major rivers empty into the ocean. This means there is high levels of biological productivity in the surface waters. Look at several places where a major river empties into the ocean. Display all of the Surficial Sea Floor Sediment Map data (i.e., click on the folders for calcareous, siliceous, glaciomarine, terrigenous, and red clays). What is the principle type of sediment at these locations? _____ Why is it not an ooze? Explain your reasoning.*

GEODE: Marine Sediment (K. St. John)

4. Deactivate the Surficial Sea Floor Sediment Map, as well as the SST and Chlorophyll layers by unclicking their files. Add a new dataset to examine: Go to the **GEODE website** <http://geode.net/exploring-marine-sediments-using-google-earth/> and click on: **Finding the CCD.kmz**. Save the file to your computer, and then click on the file to open it. This will automatically open the file in Google Earth. This will take you to a transect of sites in the North Atlantic Ocean. The carbonate (CaCO_3) concentration of the surface sediment is noted for each of these sites. Click on the file name "**Finding the CCD**" and **watch the 3 minute video** via the link provided (or go directly to the Minute Earth YouTube video: <https://www.youtube.com/watch?v=kmpzDfrqliU>), then answer the following:

- *What is the carbonate compensation depth (CCD)?*

5. **Right click** on the "**N Atlantic Transect**" path name and select "**Show Elevation Profile**". This will bring up a profile of the seafloor along this transect. Move your mouse along the profile and you can compare the water depth of the sites and the carbonate concentrations. Answer the question below on **finding the CCD**:

- *What is the sea floor feature that this transect of sites crosses?*

- *At what depth would you place the CCD in the North Atlantic Ocean? Explain your reasoning.*

- *What do you predict the sediment type to be along this transect where the percent of CaCO_3 is high? _____ What do you predict the sediment type to be along this transect where there is 0% CaCO_3 ? _____ Turn the **Surficial Sea Floor Sediment Map Data v2** back on (i.e., check the box next to the file name) to check your predictions.*

- *How does ocean chemistry serve as one control on the distribution of calcareous oozes?*

- *Do you predict the CCD to rise or fall with atmospheric global warming? Explain your reasoning.*