# Activity— Turbidites in a Jar

## Sand Dikes & Marine Turbidites

Paleoseismology is the study of the timing, location, and magnitude of prehistoric earthquakes preserved in the geologic record. Knowledge of the pattern of earthquakes in a region and over long periods of time helps to understand the long-term behavior of faults and seismic zones and is used to forecast the future likelihood of damaging earthquakes.

### Introduction

***Sand dikes*** are sedimentary dikes consisting of sand that has been squeezed or injected upward into a fissure during an earthquake.

To figure out the earthquake hazard of an area, scientists need to know how often the largest earthquakes occur. Unfortunately (from a scientific perspective), the time between major earthquakes is much longer than the time period for which we have modern instrumental measurements or even historical accounts of earthquakes. Fortunately, scientists have found a sufficiently long record of past earthquakes that is preserved in the rock and soil beneath our feet. The unraveling of this record is the realm of a field called "paleoseismology."

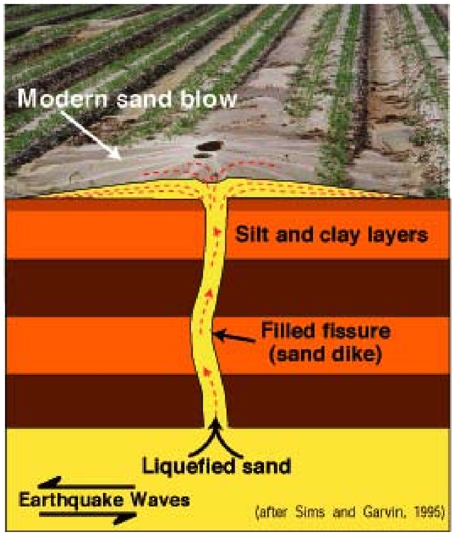
In the Central United States, abundant sand blows are studied by paleoseismologists. These patches of sand erupt onto the ground when waves from a large earthquake pass through wet, loose sand. The water pressure increases, forcing the sand grains apart until the sand starts to behave like a liquid ("liquefies"), and a slurry of sand and water is forced to the ground surface. If the age of material buried by the erupted sand can be determined (such as Native American artifacts or plant remains), then we know the earthquake must have occurred after this date. If the sand blow is itself buried by something that can be dated, then we know the earthquake happened before this date.

Paleoseismology is proving especially useful in regions where of the time between large earthquakes is usually longer than the historical record.

**Note:** Glossary is in the activity description

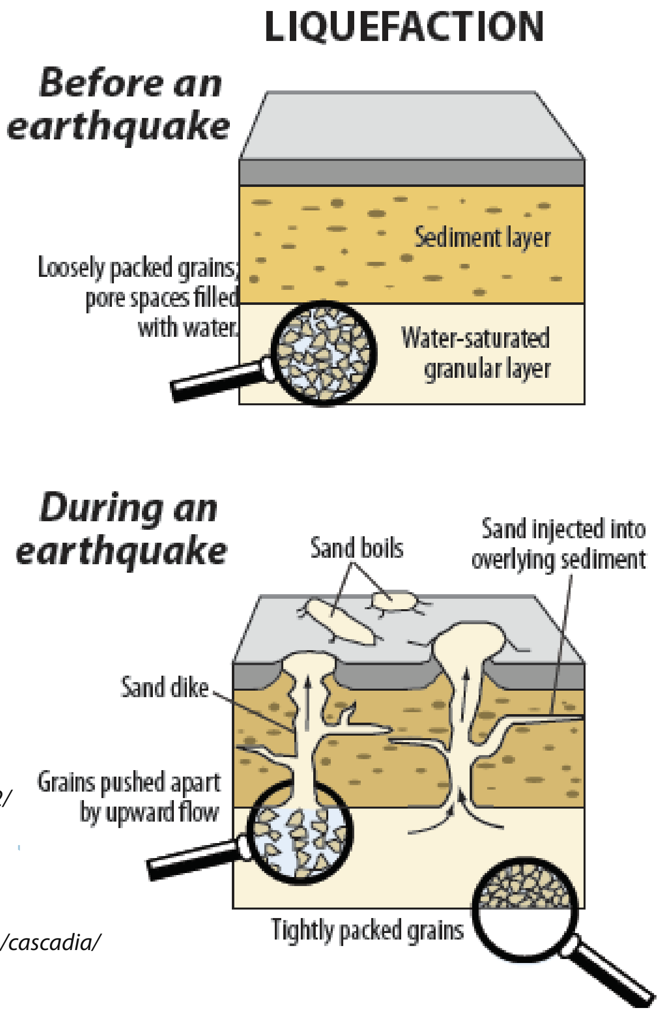
### Science Standards
(NGSS; pg. 287)

- From Molecules to Organisms—Structures and Processes: MS-LS1-8
- Motion and Stability—Forces and Interactions: MS-PS2-2
- Earth's Place in the Universe: MS-ESS1-4, HS-ESS1-5
- Earth's Systems: HS-ESS2-1, MS-ESS2-2, MS-ESS2-3
- Earth and Human Activity: HS-ESS3-1, MS-ESS3-2




*LEFT: Image* ***a****nd text from:*
** http://pubs.usgs.gov/fs/fs-131-02/fs-131-02-p3.html*

***RIGHT: image*** *from www.oregongeology.org/pubs/cascadia/CascadiaWinter2010.pdf*

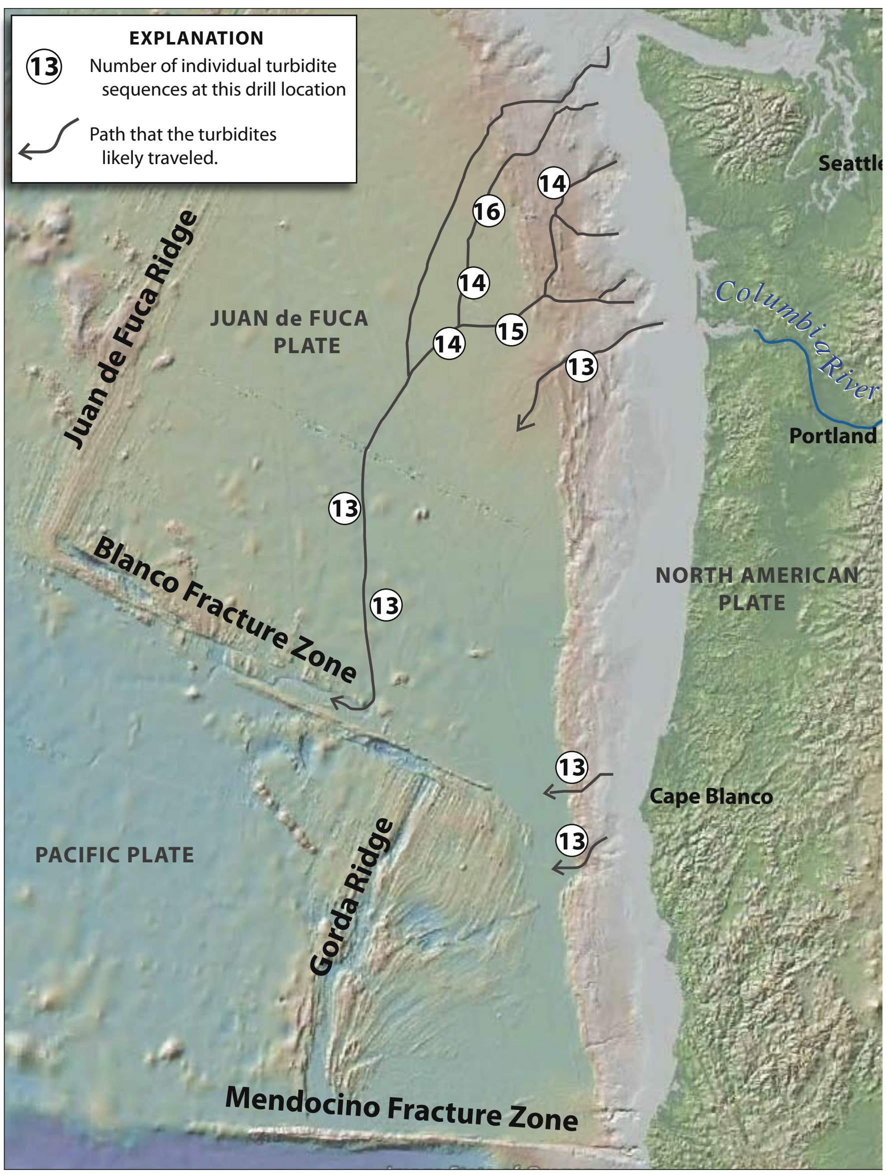


**Turbidites** usually represent deep water rocks formed offshore of a convergent margin, and generally require at least a sloping shelf and some form of tectonism to trigger density-based avalanches. Turbidites are sea-bottom deposits formed by massive slope failures where rivers have deposited large deltas. These slopes fail in response to earthquake shaking or excessive sedimentation load. The temporal correlation of turbidite occurrence for some deltas of the Pacific Northwest suggests that these deposits have been formed by earthquakes. (from USGS & Wikipedia)

Well-described, 6-minute **YouTube** video describes processes that lead to turbidite deposition: **http://www.youtube.com/watch?v=G05juwK2OTI**

Watch ~10-minute Oregon Field Guide show that shows evidence for a Cascadia tsunami in offshore deposits of sand and mud: **http://www.opb.org/programs/ofg/segments/view/1715?q=tsunami**

**Marine Turbidites—Offshore evidence for earthquakes & tsunami**




***Left:*** *Core samples taken from various drainage channels off-shore...show that 13 turbidites were deposited off coastal Washington and Oregon since the eruption of Mount Mazama (a well-dated geologic event that produced a highly visible layer within all the samples). ...turbidity currents originating from different locations occurred simultaneously during great subduction zone earthquakes. When simultaneous turbidity currents from different side channels merge, the main channel can be expected to show a single large turbidite. If the turbidites originated at different times in the side channels, the main channel would record each separate turbidite event, The consistent number of turbidites in core samples from the side and main channels indicate that the turbidity currents were likely caused at the same time and by the same event. (*source below)*

*Page size map is in the folder:*

**4. ACTIVITIES_Cascadia Earthquakes & Tsunamis**

**> Cup Cake Geology and Turbidite In a Jar**

**> MAP_Turbidites_BathymetryPNW.pdf**

***Below:*** *Turbidite sequence. County Clare, Western Ireland (USGS image).*

***Turbidite evidence for Cascadia Subduction Zone Earthquakes:** *http://www.pnsn.org/HAZARDS/CASCADIA/turbidite_record.html*

## Turbidite evidence for Cascadia Subduction Zone Earthquakes*

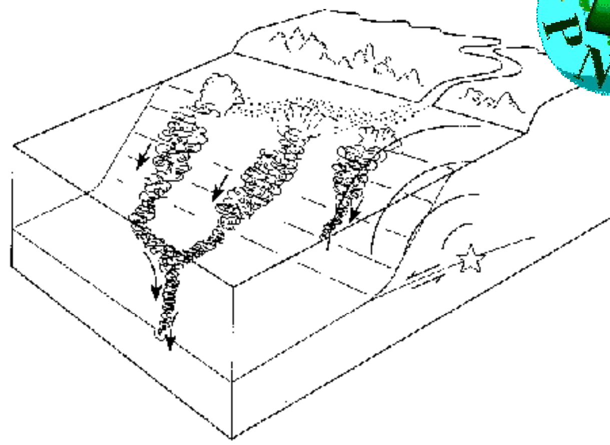
Rivers carry sediment (soil and other debris) into the ocean, and sediment collects on the continental shelf and continental slope, which slopes into deeper water. More and more material builds up on the continental shelf sea floor until it becomes unstable and slides down the continental slope, much like an avalanche, in what is called a turbidity current. The resulting layer of sediment this current deposits on the sea floor is called a turbidite.

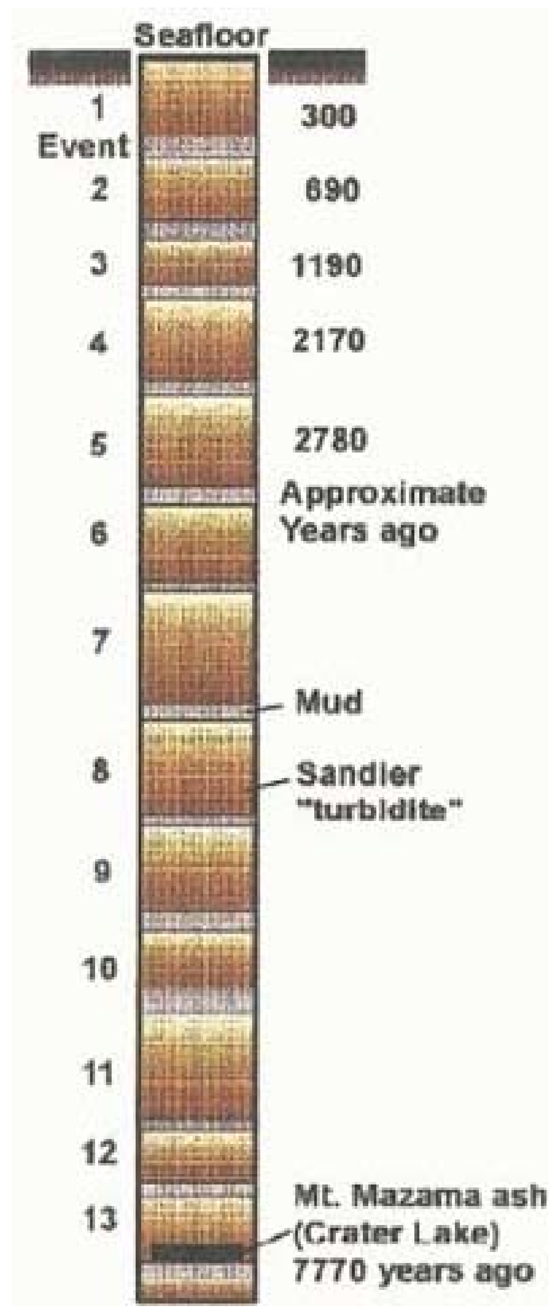
A number of events can potentially trigger turbidity currents. These events include tsunamis, storm induced waves, slope failures, and earthquakes. The turbidite record strongly suggests the latter — coastal Washington and Oregon experienced strong coast-wide shaking typical of a large subduction zone earthquake.

Core samples (example in drawing at right) taken from various drainage channels off-shore were studied by Gary B. Griggs, and all samples showed that 13 turbidites had been deposited off coastal Washington and Oregon since the eruption of Mount Mazama (a well-dated geologic event that produced a highly visible layer within all the samples). John Adams suggested that turbidity currents originating from different locations occurred simultaneously during great subduction zone earthquakes. When simultaneous turbidity currents from different side channels merge, the main channel can be expected to show a single large turbidite. If the turbidites originated at different times in the side channels, the main channel would record each separate turbidite event, The consistent number of turbidites in core samples from the side and main channels indicate that the turbidity currents were likely caused at the same time and by the same event.

Large storms are an unlikely source of a coast- wide event because these storms produce waves not much larger than smaller, more common storms. If common and rare storms produce waves that are approximately the same magnitude, the turbidite record should reflect more than 13 events in the last 5,000 years.

The 1964 Alaska earthquake generated the most recent damaging tsunami that struck the Oregon-Washington coast. Although this earthquake is one of the largest seismic events of the 20th century, it did not produce any recorded turbidites. If this large tsunami did not trigger a turbidity current, it is highly unlikely the turbidite record reflects the occurrence of tsunamis.






*from the Pacific Northwest Seismograph Network (PNSN)

In a slope failure, so much sediment develops on the inclined continental slope that it slips, much like an avalanche triggered by excessive snowfall. When enough sediment accumulates at a given point on a coastal slope, slope failure will occur. This underwater avalanche can cause turbidity currents to spread sediment throughout the underwater seachannels. Although these kinds of currents are likely to occur given enough time, the different rates of sedimentation and inclination of coastal regions make the synchronized turbidity currents implied shown in the core samples unlikely.

Cascadia zone earthquakes, on the other hand, prove to provide enough force and affect a large enough region of coast to have caused the turbidites in the core samples. Subduction zone earthquakes are cyclical and have large recurrence intervals, as do turbidity currents. Radiocarbon dating of each turbidite in Adams' core samples show a recurrence interval of about 590 years, closely matching the interval of coastal subsidence observed in coastal Washington.

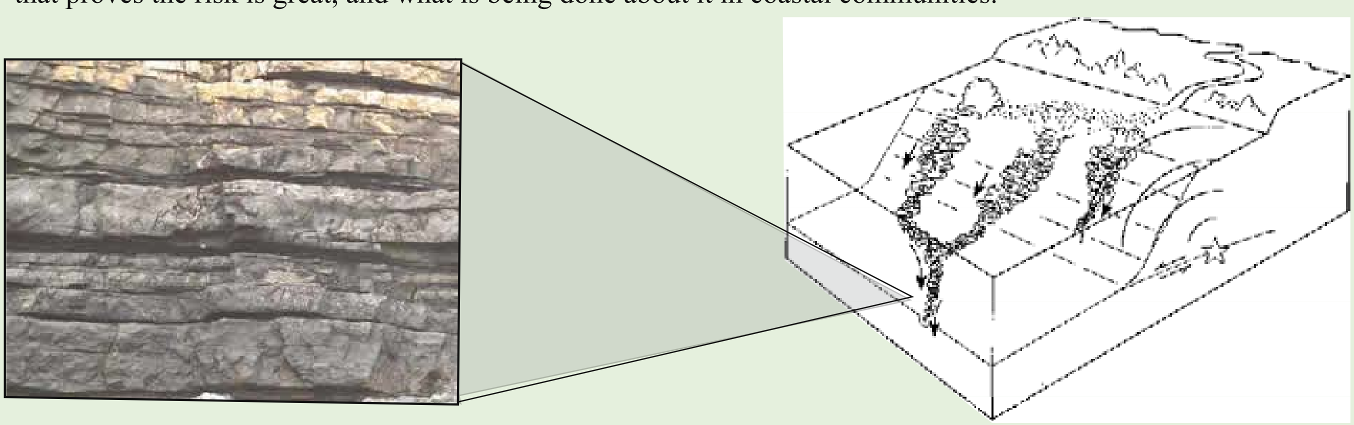
*This is file /SEIS/PNSN/HAZARDS/CASCADIA/ turbidite_record.html,*

### Turbidite Evidence for Tsunami History in the Pacific Northwest

Watch ~10-minute Oregon Field Guide show that shows evidence for a Cascadia tsunami in offshore deposits of sand and mud:

**http://www.opb.org/programs/ofg/segments/view/1715?q=tsunami**

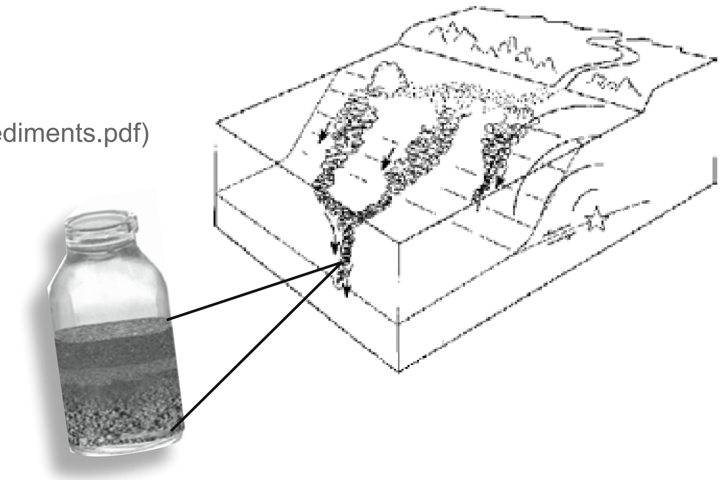
There's research to show that the tsunami risk is far more severe than scientists previously thought. We look at Indian oral tradition recounting tsunamis that seem eerily accurate in light of new research. We look at the evidence that proves the risk is great, and what is being done about it in coastal communities.



*Turbidites are sea-bottom deposits formed by massive slope failures where rivers have deposited large deltas. These slopes fail in response to earthquake shaking or excessive sedimentation load. The temporal correlation of turbidite occurrence for some deltas of the Pacific Northwest suggests that these deposits have been formed by earthquakes. Ocean-floor drilling reveals a history of collapse associated with great earthquakes.*

# Activity— Turbidites in a Jar

**(Modified from**
oceanexplorer.noaa.gov/explorations/02hudson/.../hc_bet_on_sediments.pdf)



## FOCUS QUESTION

How is sediment size related to the amount of time the sediment is suspended in water?

## GRADE LEVEL

Middle School

## LEARNING OBJECTIVES

Students will be able to investigate and analyze the patterns of sedimentation in the Cascadia Subduction Zone.

Students will observe how heavier particles sink faster than finer particles.

Students will learn that submarine landslides (trench slope failure) are avalanches of sediment in deep ocean canyons.

## LEARNING PROCEDURE

### Part I Discussion:

Using the Cascadia Subduction Zone Turbidite Map, explain the features of a passive continental margin. Introduce submarine canyons and the location of test sites. What processes could cause sediments to shake, fall and settle?

**Part II Activity:**

1. Have student groups gather the following materials:
   a. 3 large jars filled with water per group
   b. 3 - 1/2 cup samples of sediments per group
   c. 1 magnifying glass per group
   d. 1 Sediment Analysis Worksheet per student
   e. 1 plastic spoon per group

2. Have students observe and analyze the three different sediment types using the Sediment Analysis Worksheet.

3. Have students predict which of the sediment types would reach the bottom the fastest and the slowest on the Sediment Analysis Worksheet.

## MATERIALS

- Cascadia Subduction Zone Turbidite Map in the folder:
  **4. ACTIVITIES_Cascadia Earthquakes & Tsunamis**
  > **Cup Cake Geology and Turbidite In a Jar**
  > **RESOURCES**
  > **MAP_Turbidites_BathymetryPNW.pdf**
- 3 large jars with lids (e.g. Snapple bottles)
- 1/2 cup of each of the 3 various sediments (pebbles, sand, silt)
- Water - enough to fill the 3 large jars
- 1 Sediment Analysis Worksheet
- 1 Stop watch
- 1 Magnifying glass
- 1 plastic spoon
- 1 large demonstration container such as an aquarium, large jar, graduated cylinder

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4. Using a stopwatch, record on the Sediment Analysis Worksheet the time it takes a plastic spoon full of each sediment sample to fall to the bottom of each large jar.

5. Have students record observations on Sediment Analysis worksheet and predict what would happen if you put all three sediments together in one jar.

6. Add 2 spoonfuls of each sediment sample to one of the jars.

7. Put a lid on the jar.

8. Shake the jar to create a sediment-laden suspension.

9. Observe the action of all three sediments together and record the observations on Sediment Analysis Worksheet.

10. Observe the large demonstration model of a turbidite suspension with additional layers of sediment and compare them to the diagrams taken from Cascadia Subducion Zone sample sites. The sample could include 2 – 3 turbidite events. The evidence for repeated turbidite suspension events is critical to understanding how scientists use this record as evidence for great earthquake shaking events.

## Discussion:

Could they reoccur? If so, how can scientists use a turbidite record as evidence of past shaking events?

## EVALUATIONS

Students will write a paragraph summarizing what they learned about turbidity currents and the sedimentation in the Cascadia Subduction Zone sample locations.

The teacher will review each student's Sediment Analysis Worksheet.

## GLOSSARY

**Cascadia Subduction Zone:** The Cascadia subduction zone (also referred to as the Cascadia fault) is a subduction zone, a type of convergent plate boundary that stretches from northern Vancouver Island to northern California. It is a very long sloping fault that separates the Juan de Fuca and North America plates.

**Topography**: the configuration of a surface and the relations among its man-made and natural features

**Continental shelf**: A submerged border of a continent that slopes gradually and extends to a point of steeper descent to the ocean bottom.

**Continental slope:** the steep descent of the seabed from the continental shelf to the ocean bottom

**Submarine canyon:** A submarine canyon is a steep-sided valley on the sea floor of the continental slope. Many submarine canyons are found as extensions to large rivers.

**Sediments:** Sediment is naturally-occurring material that is broken down by processes of weathering and erosion and is subsequently transported by the action of fluids such as wind, water, or ice, and/or by the force of gravity acting on the particle itself.

**Suspension:** the condition of a substance whose particles are dispersed through a fluid but not dissolved in it, esp. the condition of one having relatively large particles that will separate out on standing

**Deep sea fan:** A cone-shaped or fan-shaped deposit of land-derived sediment located seaward of large rivers or submarine canyons. Synonymous with abyssal cone, abyssal fan, submarine cone.

**Turbidity currents:** A sediment-laden current that moves rapidly down the surface of a submarine slope.

**Graded bedding:** a graded bed is one characterized by a systematic change in grain or clast size from the base of the bed to the top. Most commonly this takes the form of normal grading, with coarser sediments at the base, which grade upward into progressively finer ones

**Avalanche:** mass of loosened snow, earth, rocks, etc. suddenly and swiftly sliding down a mountain, often growing as it descends

# Student Handout Sediment Analysis Worksheet

**Part I:**

1. Collect materials from teacher
    a. 3 large jars filled with water
    b. 3 - 1/2 cup sediment samples
    c. 1 plastic spoon

2. Set aside jars filled with water.

3. Analyze the three sediment samples.

4. Sketch each of the three sediment samples in the boxes below:

| Sample 1 | Sample 2 | Sample 3 |
|---|---|---|
| | | |

5. Use your magnifying glass to look at the three samples.
    a. Does each of your samples have smooth edges or rough edges?
        Sample 1: ________________________________
        Sample 2: ________________________________
        Sample 3: ________________________________
    b. Are each of your samples the same color throughout or are they made up of various colors?
        Sample 1: ________________________________
        Sample 2: ________________________________
        Sample 3: ________________________________

6. If you were to drop each of these samples into water, which one would fall to the bottom the fastest? The slowest?

7. Using your large jars, add one spoonful of sediment to your jar and with your stopwatch record the time it takes the entire sediment sample to reach the bottom. Settling time may take as much as 24 hours. Repeat procedure using individual jars for each sample.

**Jar 1** with Sample 1: ________________________ seconds

**Jar 2** with Sample 2: ________________________ seconds

**Jar 3** with Sample 3: ________________________ seconds

8. Using the observations from above, predict what would happen if you added all three samples at once to the large jar.

9. Using one of the large jars, add 2 spoonfuls of each sediment sample and wait until they settle. Then tighten the lid on the jar.

10. Shake the jar to make a sediment-laden suspension and observe what happens with all the sediments. Sketch your observations below.

11. From your observations above, explain what graded bedding means.

**Part II Demonstration Extension:**

1. Looking at the demonstration container set up in the front of the room, predict which sediment sample each type of current (surface and/or turbidity) would move.

2. Since the turbidite sample locations lie on the edge of the continental shelf, why are there soft mud and silt sediments and not pebbles or other coarse materials on the seafloor surface?

3. Write a short essay comparing an underwater turbidity current avalanche to a snow avalanche found in the mountains.