Deep Earth Academy
CONSORTIUM FOR OCEAN LEADERSHIP

Student Exercise
Inquiry into Sediment Cores

Summary

This activity serves as an inquiry-based introduction to description of sediment cores and to primary types of marine sediments, their distribution on the sea floor, and the controls that determine their distribution.

> ***To see a world in a grain of sand***
> ***And heaven in a wild flower***
> ***Hold infinity in the palm of your hand***
> ***And eternity in an hour.***
> *from 'Auguries of Innocence'*
> *by William Blake (1757-1827)*

Student Learning Goals

- Model the role of a shipboard sedimentologist and describe a split core with an inquiry-based approach.
- Develop your scientific skills of observation and description.
- Recognize the importance of being complete and consistent in recording observations in science.
- Become familiar with the primary marine sediment types, their components, their distribution, and the leading controls on their distribution.
- Develop hypotheses to explain the distribution of the primary marine sediment types.

Student Learning Objectives

After this exercise, you should be able to:

- Explain the meaning behind Integrated Ocean Drilling Program (IODP) nomenclature used in a sample identification (expedition-site-hole-core-section-sample interval).
- Describe the physical characteristics used in core description, and apply them in the description of cores.
- Synthesize visual core descriptions in a summary log or "barrel sheet."
- Explain the importance of a systematic, complete, and consistent method of recording observations.
- Distinguish among siliceous and calcareous marine microfossil groups, based on smear slide images.
- Distinguish among primary sediment classification groups, including siliceous ooze, calcareous ooze, deep sea ("red") clays, shallow and deep water terrigenous sediments (= margin sediments), and glaciomarine sediment, based on sediment composition and physical characteristics and using a Decision Tree.
- Plot sites and sediment types on a physiographic map of the sea floor using latitude and longitude coordinates.
- Construct a sediment distribution map of primary sediment types for the Pacific Ocean.
- Explain the most important factors controlling the deposition and distribution of primary marine sediment types.

Activity by

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Initial Inquiry

1. What kinds of materials might you expect to find on the sea floor?
2. Do you expect any patterns to the distribution of these materials? Why or why not?
3. Your teacher will provide you with one or more photos of a marine sediment core(s). Examine the core photo and make a list of observations and a list of questions about what you see.

Share and Discuss

As a group, share and discuss your observations and questions. Use this as an opportunity to flesh out common observations, as well as anomalies. Note some of your questions may be of a practical nature and can be addressed right away, while others may be larger hypothesis-forming questions to compile and revisit later.

4. Based on the group discussion design a way to organize and record observations about the cores that could be used by all of the students in the class for all of the cores. This means you need to come up with **categories** for observations (i.e., color) and also a means of recording them (i.e., all written, all sketch, some combination of the two?). Outline the core description template that your class will be using.

Critical thinking/Problem Solving

Shipboard sedimentologists are responsible for describing the geology of cores recovered from drilling into the sea floor. They provide the first complete description of the cores, so observation and classification are key aspects of what these scientists do. They describe the physical characteristics of the sediment seen on the split core as well as determine what type of sediment it is. This is important because the core description will be used (1) by scientists on the ship and at research institutions from around the world as a basis for sampling the core for detailed geologic study, and (2) for forming the first general conclusions about the environmental conditions and geologic history of that location on the sea floor. The shipboard sedimentologists have considerable responsibility to the scientific community at large, for they are commonly the only scientists who have the opportunity to see all the cores from each of the sites drilled during an expedition. Thus, it is very important that they describe the geology in a manner that is both complete and consistent from expedition to expedition.[1]

In this exercise you will be provided with data on the site locations of a set of cores (latitude, longitude, and water depth), a map showing the physical features of the sea floor, color photos of split cores, and a table of sediment composition data corresponding to each core.

Your Task

In Part 1 of this exercise you will model the role of a shipboard sedimentologist and describe one or more split cores. In Part 2 of the exercise you will compile your data on sediment type with that of your classmates and construct a map showing the distribution of the primary sediment types of the modern Pacific Ocean and North Atlantic Ocean. You will discuss and make hypotheses about what environmental factors control the distribution of the different sediment types on the sea floor.

With this exercise as background you will later be ready to ask bigger questions about marine sediments, such as:

How do we determine the age of marine sediment?
and

How can we use sediment cores to determine past environments and past climates?

Part 1 – Individual Investigation

5. Using the latitude and longitude from Table 1, find the drill site location of your core(s) and mark the location on your physiographic map of the sea floor. Be neat and use pencil; you will be adding more information to your map in Part 2. Note that all of the cores in Table 1 are either core number 1, 2 or 3. This means these cores are at or close to the top of the sediment sequence on the sea floor (note: each core is nearly 10 m, or 30 ft, in length, and the cores are numbered sequentially with increasing drilled depth into the sea floor). Therefore the sediment in these cores represents modern or very recent environmental conditions at that location in the ocean.
6. Use a separate page to describe your core. Be sure to follow the template designed by your class.

Mineral Composition and Smear Slide Analysis

One core description category that typically *cannot* be determined from visual observations alone is composition. Composition can, however, be determined by examining a small (toothpick-tip sized) amount of sediment under a binocular microscope and matching the grain types observed to categories of known grain types. This method is called smear slide analysis[2]. Some of the main grain types found in marine sediment through smear slide analysis are shown on pages 8 and 9 (all from http://www.noc.soton.ac.uk/gg/BOSCORF/curatorial/grain_id.html)[3]. These include minerals and mineral groups, volcanic glass, and microfossils (note: microfossils are the shells or hard-parts of single-celled plankton; after they die or are eaten by larger organisms, their shells settle to the seafloor and become sediment grains).

Table 2 includes smear slide data for all of the cores in this exercise. This data includes estimated abundances of specific minerals & microfossils, as well as information on the texture (= grain size: sand, silt, or clay-size particles) of the sediment in terms of the relative percentages of sand, silt, and clay from specific places in the core. It is always a good idea to look at the core photo to see exactly where a smear slide sample was taken – samples may be taken of representative major sediment types, and other times samples may be taken from anomalous intervals. The composition and texture of the sediment will be the primary basis for determining the sediment type.

7. Use the Decision Tree (page 15) to determine the type of sediment in your core(s). Write the name of the sediment type in the appropriate box in **Table 2**, and also add the sediment name to your Core Description log (#6 above).

Part 2 – Synthesis

8. Use colored pencils and the following color scheme to plot your sediment type on both your physiographic map of the sea floor and on the class physiographic map of the sea floor. Through group effort, the class map should ultimately contain all of the exercise core locations in the Pacific and North Atlantic Oceans and their sediment types. Transfer this compilation data to your own map.

   - Blue = Calcareous Ooze
   - Yellow = Siliceous Ooze
   - Red = Red Clays
   - Purple = Deep Terrigenous Sediment
   - Pink = Shallow terrigenous Sediment
   - Green = Glaciomarine Sediment

9. Make a list of your observations on the distribution of each of the different sediment types. Consider factors such as distance from the continents, water depth, and latitude/longitude, among others.
10. Share and Discuss. As a group, compile your observations on the distribution of sediment types. Propose hypotheses for each of the sediment types and list them.
11. Complete the Map: Using the core top sediment types as your empirical data points and your hypotheses on the controls on sediment type distribution, infer the sediment type distribution for the rest of the Pacific Ocean. In other words, draw boundaries to the different sediment regimes, so that the sea floor of the entire Pacific Ocean is colored with one of the six main sediment types. Use colored pencils to shade in the different sediment types (as in #8).

Extensions

12. Compare your sediment type distribution map to that of Rothwell (1989), which your teacher will provide. Are they generally similar? If not, where are the discrepancies?
13. Compare the North Pacific and North Atlantic sediment distributions.
    a. In what basin are glaciomarine sediments more abundant? Why might this be the case?
    b. Are calcareous-rich sediments in the North Atlantic found at the same depth, shallower depths, or deeper depths than in the North Pacific? Why might this be the case?
14. The map you constructed represents the modern distribution of sediment types in the Pacific Ocean. Do you think this map would also represent sediment type distribution in the geologic past and in the geologic future? What factors might vary (in the past and in the future) that could change the distribution of sediment types over time?
15. Examine the borehole site map for IODP-ODP-DSDP either through Google Earth for an interactive map (see: http://www.iodp.org/borehole-map for instructions), or by downloading a combined map of IODP, ODP, and DSDP sites from here: http://iodp.tamu.edu/scienceops/maps.html. Notice how few boreholes are located in the South Pacific. How do we know then what the sediment type is in the South Pacific?
16. Compare the quality of the early DSDP cores (drilled in the 1970s) to that of recent IODP or ODP cores (drilled in the 1990s and 2000s) based on the core photographs provided. How might advances in drilling technology affect core quality?

Wrap-Up

Answer the following questions:

- What did you find most interesting or helpful in this exercise?
- What was the "Sticky Science," in other words what stuck with you—what are you going to remember a few months from now?
- Does what we did model scientific practice? If so, how and if not, why not?

State of the Science

- To find out where in the global ocean the IODP scientific ocean drill ships are working today go to the Expedition Schedule: *http://www.iodp.org/expeditions/*
- To read about recent news-making ocean drilling science go to: *http://www.iodp.org/recently-in-the-news*

Supplemental Materials

- [1]Introductory text is adapted in part from Mazzullo and Graham, 1998. Handbook for Shipboard Sedimentologist, *ODP Technical Notes No. 8*, Texas A&M University. This is a great reference for graduate students about to sail as a shipboard sedimentologist for the first time.
- [2]To watch a video on how smear slides are made go to: *http://www.nisd.net/jay/joides/index.htm* and click on Preparing smear slides from core samples with Dr. St. John.
- [3]The online Curatorial Reference Pages *http://www.noc.soton.ac.uk/gg/BOSCORF/curatorial/grain_id.html* show many more marine sediment grain types than are included in this exercise. These reference images were originally compiled in a book by Rothwell, *Minerals and Mineraloids in the Marine Sediments*, which is now out of print. Additional smear slide images of microfossils taken by teachers on the 2005 School of Rock expedition are included on a free poster *Microfossils: The Ocean's Storytellers* obtained through Deep Earth Academy: *http://www.oceanleadership.org/learning/posters*
- For a one-page reference sheet on core identification nomenclature (i.e., Expedition-Site-Hole-Core-Section-Sample) go to: *http://www.oceanleadership.org/classroom/cores* and click on the link for: *What is a core?*
- To see pictures and descriptions of some of the most interesting cores stored in the refrigerators at the Gulf Coast Repository at Texas A&M University in College Station, Texas go to: *http://iodp.tamu.edu/curation/gcr/display.html*
- To learn about drilling technology and the tools that are used go to: *http://iodp.tamu.edu/tools/specs.html*

Acknowledgements

This activity was developed with funding from NSF award number 0737335, as an adaptation of the original *Core Understanding – Core Description and Lithostratigraphy* exercise by St. John and Leckie, 2005: *http://www.oceanleadership.org/classroom/core_description_activity*.

Table 1. Sea Floor Cores

Pacific Cores

Core Identification: Exped-Site&Hole-Core&Type	Physiographic Location	Latitude/ Longitude	Water Depth (m)	Reference
112-687A-2H	Peru continental shelf	-12.9/-77.0	316	Seuss et al., 1988
35-324-1	SE Pacific basin, north of Antarctica	-69/-98.8	4433	Hollister et al., 1976
28-269-1	Ross Sea, south of Australia, north of Antarctica	-61/7/+140.1	4282	Hayes et al., 1975
145-886B-2H	Chinook Trough, North Pacific abyssal plain	+44.7/-168.2	5743	Rea et al., 1993
145-882A-2H	Detroit Seamount, NW Pacific	+50.36/-167.6	3243.8	Rea et al., 1993
145-881A-1	NW Pacific, East of the Sea of Okhotsk	+47.1/+161.5	5531.1	Rea et al., 1993
145-887C-2H	Patton-Murray Seamount, NE Pacific	+54.4/-148.5	3633.6	Rea et al., 1993
19-188-2	Bering Sea	+53.8/+178.7	2649	Creager et al., 1973
18-182-1	Alaskan continental slope	+57.9/-148.7	1419	Klum et al., 1973
33-318-2	Line Islands Ridge, south central Pacific	-14.8/-146.9	2641	Schlanger et al., 1976
8-75-1	Marquesas Fracture Zone, central Pacific abyssal plain	-12.5/-135.3	4181	Tracey et al., 1971
92-597-1	SE Pacific abyssal plain	-18.8/-129.8	4166	Leinen et al., 1986
178-1101A-2H	Antarctic Peninsula continental rise	-64.4/-70.3	3279.7	Barker et al., 1991
178-1096A-1H	Antarctic Peninsula continental rise	-67.57/-77	3152	Barker et al., 1991
178-1097A-3R	Antarctic Peninsula shelf	-66.4/-70.75	551.7	Barker et al., 1991
29-278-3	south of New Zealand	-56.6/+160.1	3675	Kennett et al., 1974
202-1236A-2H	Nazca Ridge, SE Pacific	-21.4/-81.44	1323.7	Mix et al., 2003

Table 1. Sea Floor Cores
continued

Pacific Cores

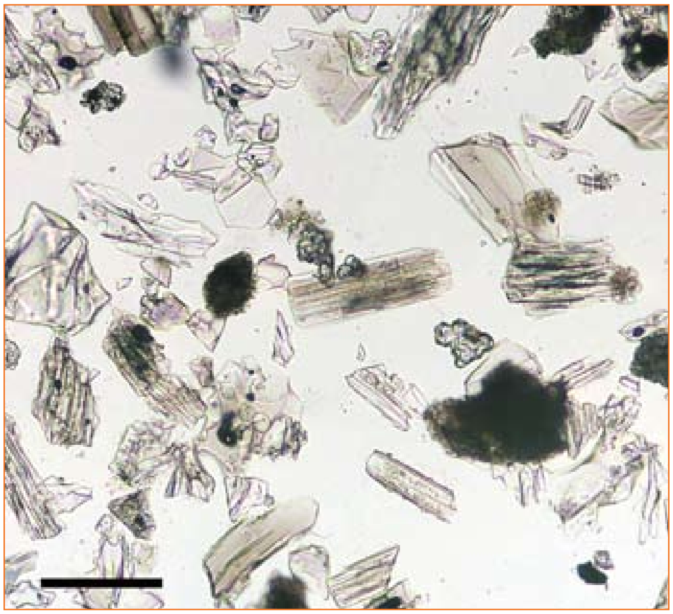
Core Identification: Exped-Site&Hole-Core&Type	Physiographic Location	Latitude/ Longitude	Water Depth (m)	Reference
206-1256B-2H	Guatemala Basin	+6.7/-91.9	3634.7	Wilson et al., 2003
8-74-1	Clipperton Fracture Zone, central Pacific abyssal plain	+6.1/-136.1	4431	Tracey et al., 1971
136-842A-1H	south of Hawaii	+19.3/-159.1	4430.2	Dziewonski et al., 1992
198-1209A-2H	Shatsky Rise, NE Pacific	+32.7/+158.5	2387.2	Bralower et al., 2002
199-1215A-2H	NE of Hawaii, North Pacific abyssal plain	+26.0/-147.9	5395.6	Lyle et al., 2002
86-576-2	West of Midway Island, North Pacific abyssal plain	+32.4/+164.3	6217	Heath et al., 1985
195-1201B-2H	Philippine Sea	+19.3/+135.1	5710.2	Salisbury e al., 2002
130-807A-2H	Ontong Java Plateau, western equatorial Pacific	+3.6/+156.6	2803.8	Kroenke et al., 1991
181-1125A-2H	Chatham Rise, east of New Zealand	-42.6/-178.2	1364.6	Carter et al., 1999
169-1037A-1H	Escanaba Trough, west of Oregon, N. California	+41/-127.5	3302.3	Fouquet et al., 1998
146-888B-2H	Cascadia margin, west of Vancouver, WA	+48.2/-126.7	2516.3	Westbrook et al., 1994
167-1010E-1H	west of Baja California	+30/-118.1	3464.7	Lyle et al., 1997
200-1224C-1H	North Pacific abyssal plain, south of the Murray fracture Zone,	+27.9/-142	4967.1	Stephen et al., 2003
127-795A-2H	Japan Sea	+44/+139	3300.2	Tamaki et al., 1990
28-274-2	north of Ross Ice Shelf, Antarctica	-69/+173.4	3305	Hayes et al., 1975

Table 1. Sea Floor Cores
continued

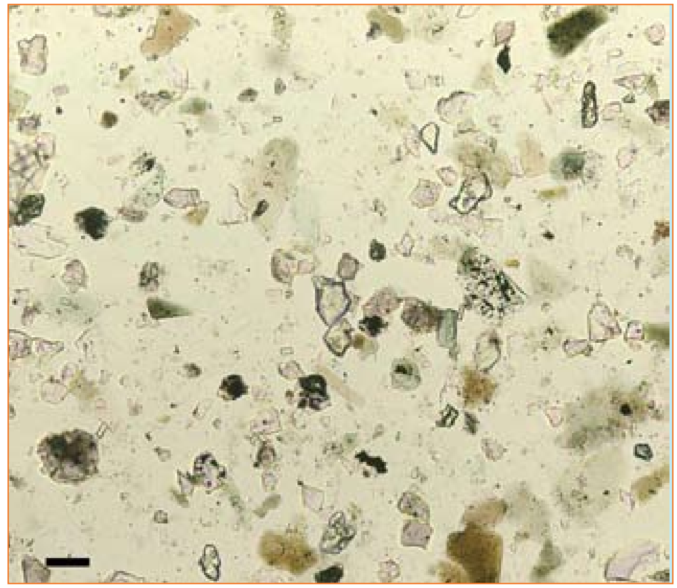
North Atlantic Cores

Core Identification: Exped-Site&Hole-Core&Type	Physiographic Location	Latitude/ Longitude	Water Depth (m)	Reference
37-333-2	western flank of mid-Atlantic ridge	+36.8/-33.7	1666	Aumento et al., 1977
82-558-3	western flank of mid-Atlantic ridge	+33.8/-37.3	3754	Bougault et al., 1995
172-1063A-2H	Northeast Bermuda Rise	+33.7/-57.6	4583.5	Keigwin et al., 1998
105-646A-2H	Labrador Sea, south of Greenland	+58.2/-48.4	3440.3	Srivastava et al., 1987
162-980A-2H	Rockall Bank, west of Ireland	+55.5/-14.7	2172.2	Jansen et al., 1996
152-919A-2H	SE Greenland, continental rise	+62.7/-37.5	2088.2	Larsen et al., 1994
174-1073-1H	New Jersey continental shelf	+39.2/-72.3	639.4	Austin et al., 1998
14-137-3H	Madeira abyssal plain	+25.9/-27.1	5361	Hayes et al., 1972

Volcanic Glass, Minerals and Mineral Groups

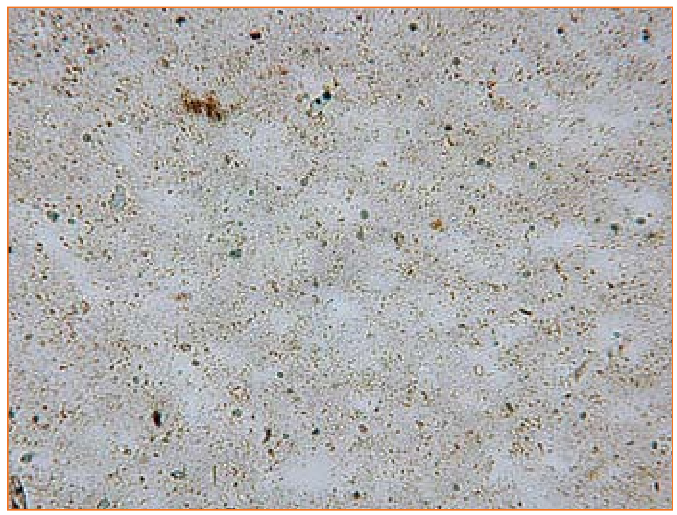


Volcanic glass. Bar scale = 0.05 mm..



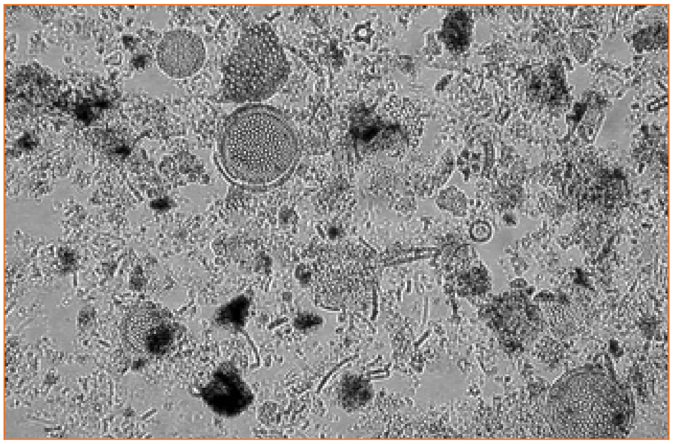
Silt-size minerals including green and brown biotite (mica) flakes. Bar scale = 0.05 mm..

Feldspar mineral surrounded by volcanic glass. Bar scale = 0.05 mm..

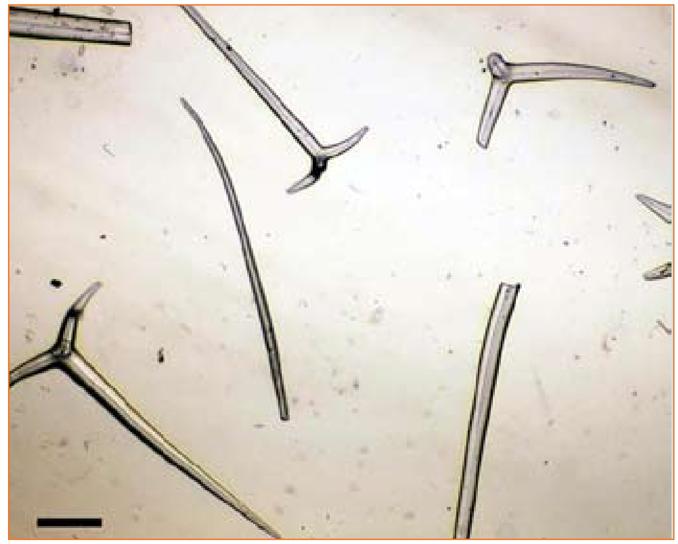


Clay minerals. Individual grains are under 4 μm (0.004 mm) in size.

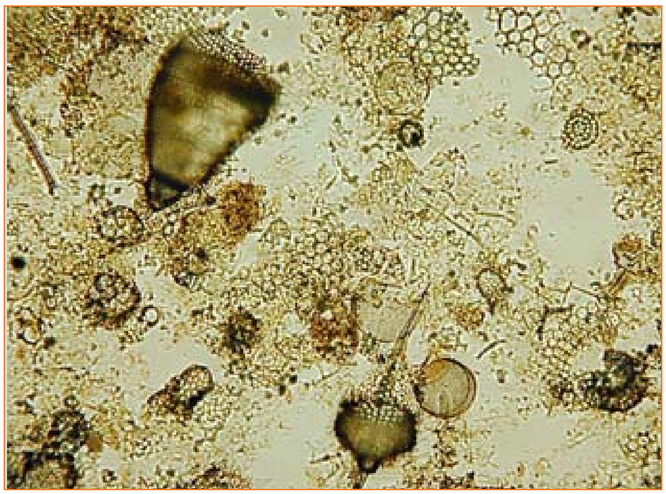
Siliceous (SiO_2) Microfossils



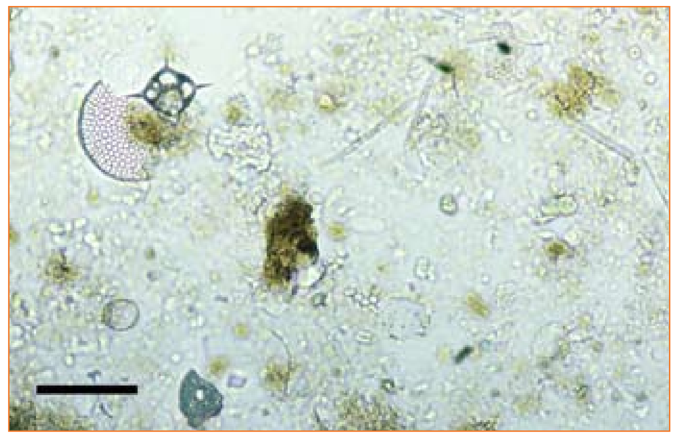
Diatoms (and clay). High power (x100) view..



Sponge spicules. Scale bar = 0.05 mm.

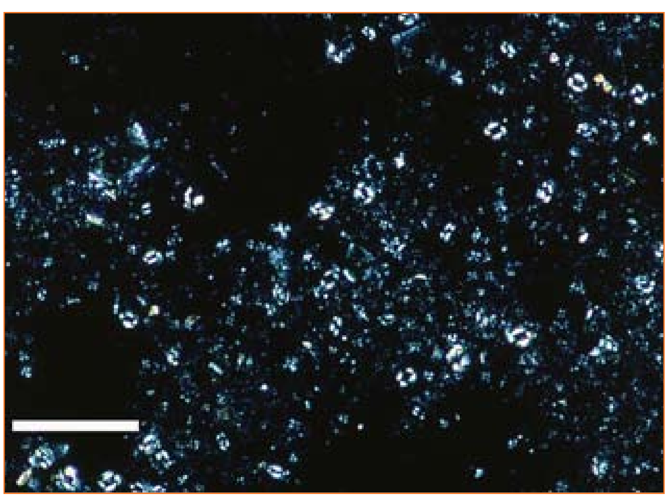


Radiolarians with some diatoms (and clay). High power (x100) view.

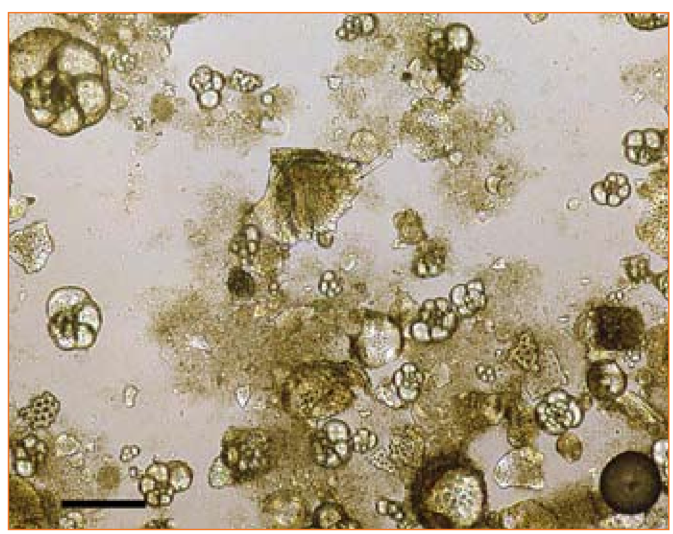


Silicoflagellate (top left) with diatom fragments, (and clay). Scale bar = 0.05 mm.

Calcareous ($CaCO_3$) Microfossils



Scatter of calcareous nannofossils (coccolith plates) seen in cross-polarized light. Note the black interference crosses shown by each plate. Scale bar = 0.05 mm.



Foraminifera (and clay). Scale bar = 0.05 mm.

Table 2: Smear Slide Sample Identification

Expedition-Site & Hole-Core & Type-Section, Interval (cm)	Sediment Texture (%)			Composition (%)																				Sediment Names	Reference
				Mineral Grains									Microfossils							Rock Frags./other					
	Sand	Silt	Clay	Accessory Min.	Calcite/Dolomite	Clay Minerals	Fe Oxide	Feldspar	Other Minerals*	Mica	Quartz	Volcanic Glass	Calc. Nannos	Diatoms	Foraminifers	Radiolarians	Silicoflagellates	Sponge Spicules	Skeletal Debirs	Carbonate Frags.	Organic matter	Nodules	Rock Fragments		
Pacific samples																									
112-687A-2H-1, 79	2	61	37	1	2	37		5			10		2	30	10								2		Seuss et al., 1988
112-687A-2H-3, 69		80	20	2	1	19		23		2	35		5										10		
112-687A-2H-5, 61		45	55	10	2	17		5			13	1										37	5		
112-687A-2H-6, 36		25	75	1		75					1	1		20											
35-324-1-1, 120	none given					40					10			50											Hollister et al., 1976
35-324-1-2, 50	none given					85					10			5											
35-324-1-3, 100	none given					35	2				3			60											
35-324-1-6, 100	none given					97			1		2														
28-269-1-1, 134	none given				5	25					10			55		5									Hayes et al., 1975
28-269-1-4, 37	none given					10					10		1	78			1								
145-881A-1H-1, 50	30	60	10								1	1		98											Rea et al., 1993
145-881A-1H-2, 11	15	40	45			45			10					45											
145-881A-1H-2, 116	40	60						4			2	94													
145-886B-2H-1, 39	2	10	88			81	2							4		3		10							Rea et al., 1993
145-886B-2H-5, 114	15	10	70			70	2	2			1			4		6		15							
145-886B-2H-6, 16	25	10	65			64	3							5		3		25							
145-882A-2H-2, 58	2	78	20			1						1	1	77				20							Rea et al., 1993
145-882A-2H-3, 34	2	85	13								1		1	78				20							
145-882A-2H-4, 80	20	75	5									1	2	96		1									
145-887C-2H-1, 75	10	82	8			7							1	72	4			10		6					Rea et al., 1993
145-887C-2H-3, 75	10	45	45			43					1			45	4	2				5					
145-887C-2H-3, 85	3	92	5			5		2			1	92													

*Other minerals includes opaques, phillipsite, phroxene, hornblende, and others

D= dominant, A= abundant, C= common, P = present, R= rare, T = trace

Table 2: Smear Slide Sample Identification

Expedition-Site & Hole-Core & Type-Section, Interval (cm)	Sediment Texture (%)			Composition (%)																				Sediment Names	Reference
				Mineral Grains									Microfossils							Rock Frags./other					
	Sand	Silt	Clay	Accessory Min.	Calcite/Dolomite	Clay Minerals	Fe Oxide	Feldspar	Other Minerals*	Mica	Quartz	Volcanic Glass	Calc. Nannos	Diatoms	Foraminifers	Radiolarians	Silicoflagellates	Sponge Spicules	Skeletal Debirs	Carbonate Frags.	Organic matter	Nodules	Rock Fragments		
19-188-2-1, 56	none given					25		5			5			65											Creager et al., 1973
19-188-2-1, 120	none given					10		2			3			85											
19-188-2-2, 75	none given					10		5			5			80											
19-188-2-3, 75	none given					10		5			5			80											
18-182-1	no smear slide data																								Klum et al., 1973
33-318-2-2, 67	none given						R						D		A				P	C					Schlanger et al., 1976
8-75-1-1, 100	none given					90			9						1										Tracey et al., 1971
8-75-1-3, 10	none given					10							90												
8-75-1-5, 10	none given					5							94		1										
92-597-1-1, 35	none given					85			13			2													
92-597-1-2, 110	none given					10			5				85												
178-1101A-2H-1, 80	1	60	39	1	3	50		8	1	2	15		4	5				2					14		Barker et al., 1991
178-1101A-2H-2, 60	1	60	39	2	3	31		8	8	3	20			2	2			1					20		
178-1101A-2H-2, 106	90	8	2		1	13		9		4	12			1	40			1					14		
178-1101A-2H-4, 61	1	75	24			5		12	20	4	18			2				1					30		
178-1101A-2H-6, 61		70	30			8		12	13	4	18			10				6					20		
178-1096A-1H-1, 0		30	70			60		5		5				30	1										Barker et al., 1991
178-1096A-1H-1, 130		20	80			80		5	6	5				1	1										
178-1096A-1H-4, 130		20	80			80		5	1	9				1	1										
178-1096A-1H-6, 30	1	25	74			74		10		15				1	1										
178-1097A-3R-1	all gravel																						100		Barker et al., 1991
29-278-3-1, 127	none given					15							10	30	10	25		10							Kennett et al., 1974
29-278-3-CC, 0	none given					2			2				3	75		3		15							

*Other minerals includes opaques, phillipsite, phroxene, hornblende, and others

D= dominant, A= abundant, C= common, P = present, R= rare, T = trace

Table 2: Smear Slide Sample Identification

Expedition-Site & Hole-Core & Type-Section, Interval (cm)	Sediment Texture (%)			Composition (%)																				Sediment Names	Reference
				Mineral Grains									Microfossils							Rock Frags./other					
	Sand	**Silt**	**Clay**	Accessory Min.	Calcite/Dolomite	Clay Minerals	Fe Oxide	Feldspar	Other Minerals*	Mica	Quartz	Volcanic Glass	Calc. Nannos	Diatoms	Foraminifers	Radiolarians	Silicoflagellates	Sponge Spicules	Skeletal Debris	Carbonate Frags.	Organic matter	Nodules	Rock Fragments		
202-1236A-2H-1, 75			100			14							57		25										
202-1236A-2H, 92			100							R			57		29										Mix et al., 2003
202-1236A-2H, 123			100							R			70		30										
206-1256B-2H-2, 113	20	16	64			100							89	9		1		1							Wilson et al., 2003
8-74-1-1, 2	none given												55	10	35	10		<1							Tracey et al., 1971
8-74-1-5, 10	none given												5	10		75		10							
136-842A-1H-1, 27	10	50	40			40		17				23				2	1	1							Dziewonski et al., 1992
136-842A-1H-2, 100	5	70	25	1		25		1	5			25		7		35	1								
136-842A-1H-4, 90		25	75	1		75		1				10				10		1							
136-842A-1H-6, 68	25	60	15	10		15		20	20			30				5									
136-842A-1H-6, 130		52	48			18		1	1			1	30	6		30	10	2							
136-842A-1H-7, 20		22	78	1		78		7	2			5		2		3	1	1							
198-1209A-2H-1, 139	none given					21							70	2	5	2									Bralower et al., 2002
198-1209A-2H-5, 138	none given				1	13							80		5	1									
199-1215A-2H-1, 60			100			90			8	2															Lyle et al., 2002
199-1215A-2H-3, 100			100			90			9	1															
199-1215A-2H-CC, 0			100			90			10																
86-576-2-1, 7		5	95			85		1			4			1		3		1				5			Heath et al., 1985
86-576-2-2, 80	1	7	92			87		1			6					2						2			
86-576-2-4, 74	30	68	2			2		1			3	93										1			
86-576-2-4, 110	1	1	98			94				1	1	1		1		2						1			
195-1201B-2H-1, 30		10	90			D		P	R		P	R													Salisbury e al., 2002
195-1201B-2H-5, 73		5	95			D		R	P		R														

*Other minerals includes opaques, phillipsite, phroxene, hornblende, and others

D= dominant, A= abundant, C= common, P = present, R= rare, T = trace

Table 2: Smear Slide Sample Identification

Expedition-Site & Hole-Core & Type-Section, Interval (cm)	Sediment Texture (%)			Composition (%)																				Sediment Names	Reference
				Mineral Grains									Microfossils							Rock Frags./other					
	Sand	Silt	Clay	Accessory Min.	Calcite/Dolomite	Clay Minerals	Fe Oxide	Feldspar	Other Minerals*	Mica	Quartz	Volcanic Glass	Calc. Nannos	Diatoms	Foraminifers	Radiolarians	Silicoflagellates	Sponge Spicules	Skeletal Debirs	Carbonate Frags.	Organic matter	Nodules	Rock Fragments		
195-1201B-2H-7, 85		10	90			D		P	P	R	P														
130-807A-2H-2, 74	10	60	30	2									75	2	20										Kroenke et al., 1991
181-1125A-2H-1, 49	25	30	45		P	R							D		P			R	P						Carter et al., 1999
169-1037A-1H-3, 80		C	A	R	R	A		R		R	C		R	R		R									Fouquet et al., 1998
169-1037A-1H-5, 62	A	C	R		R			R	R	C	A			R				R							
146-888B-2H-5, 99	70	25	5			5		10	33		5	25		2								15			Westbrook et al., 1994
146-888B-2H-6, 145		75	25			25		20	30			10	1	2							2	10			
167-1010E-1H-3, 143	5	15	80			80		2	1			9											1		Lyle et al., 1997
167-1010E-1H-4, 110		10	90			80					2	10			3								5		
200-1224C-1H-1, 70		10	90			90										10									Stephen et al., 2003
200-1224C-1H-2, 2		5	95			95												5							
200-1224C-1H-3, 70		20	80			65										30		5							
200-1224C-1H-5, 1		25	75			50										45		5							
127-795A-2H-1, 84		10	90		2	60		5			10	15		2			1	1			1				Tamaki et al., 1990
127-795A-2H-2, 146		40	60			30						10		60											
127-795A-2H-3, 45		60	40			20		15			15	45		1											
127-795A-2H-5, 81		40	60			60		10			20	10													
28-274-2-2,109	2	33	65		1	55		11	10		15			6				2							Hayes et al., 1975
28-274-2-3, 86		25	75			60			1		1			35		1		2							
28-274-2-6, 90		20	80		1	70		4	1		8			15				1							

*Other minerals includes opaques, phillipsite, phroxene, hornblende, and others

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North Atlantic samples																									
37-333-2-1, 80	5	24	71										96		4										Aumento et al., 1977
82-558-3-3, 75	none given				2	9							87		2										Bougault et al., 1995
82-558-3-6, 75	none given				5	9							84		2										
172-1063A-2H-3, 62		40	60		R	D	T		T		A		C	R	T	T	T	R							Keigwin et al., 1998
172-1063A-2H-6, 66		25	75		R	D	T		T		C		A	C	T	T	T	C							Keigwin et al., 1998
105-646A-2H-1, 60	5	60	35		35	30					35														Srivastava et al., 1987
105-646A-2H-2, 87	5	85	10	5	5	10		10	5		65														
105-646A-2H-5, 33	10	55	35		15	25		5			35		3	10	2			5							
162-980A-2H-1, 90	20	30	50	2		8				1	11		50	4	13	5		3							Jansen et al., 1996
162-980A-2H-3, 80	10	40	50			50			5	5	10		30												
162-980A-2H-6, 80	10	60	30	5		25		15	3	5	20		10		7			2					3		
152-919A-2H-1, 76	3	81	16			16		7	2		40	15				10		3					7		Larsen et al., 1994
152-919A-2H-3, 18		85	15								2	69		4				10							
152-919A-2H-4, 50		62	38			38		6	2		25	5	7	4				3					10		
174-1073-1H-1, 10	none given			2		23		14		2	20		20	4	5	5									Austin et al., 1998
174-1073-1H-1, 120	none given			2	1	39		12		4	20		8	1	8										
14-137-3H-2, 90	none given					81	4		5	2		8													

*Other minerals includes opaques, phillipsite, phroxene, hornblende, and others

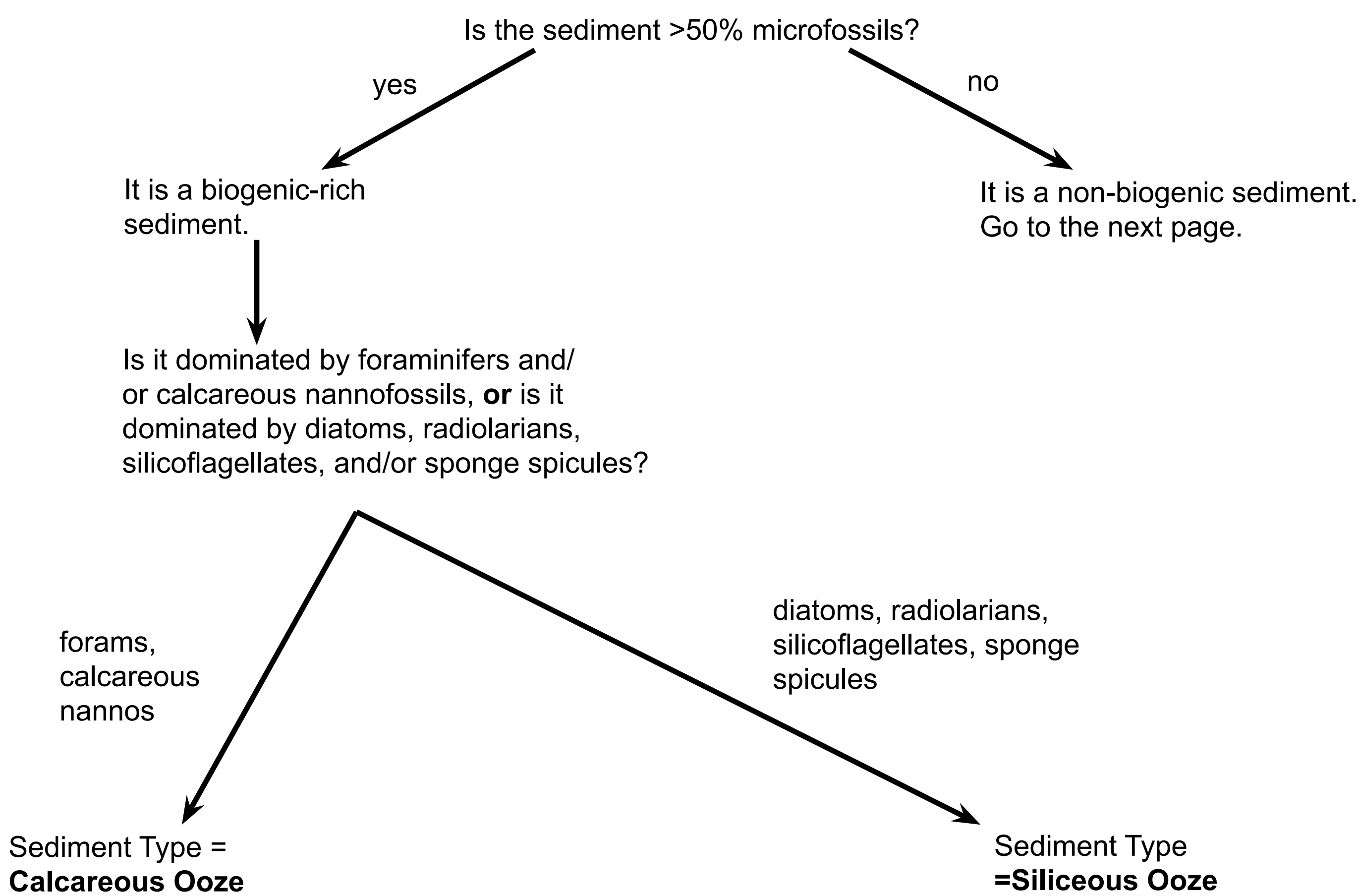
D= dominant, A= abundant, C= common, P = present, R= rare, T = trace

Decision Tree

Notes:

- The decision tree aims to capture end-member sediment types:
  1. **calcareous ooze** (calcareous nannofossils and/or foraminifers)
  2. **siliceous ooze** (diatoms, radiolarians, sponge spicules, and/or silicoflagellates)
  3. **deep sea "red" clays** (may contain siliceous microfossils, fish teeth, Mn-Fe micronodules, and/or volcanic glass)
  4. **deep terrigenous sediment**
  5. **shallow terrigenous sediment**
  6. **glaciomarine sediment**
- In many settings the sediment types can be mixed, so it is possible to have a mix of microfossils and mineral grains. In this case the name could list the main components in order of abundance (most abundant listed last), for example a "siliceous clay", would be mostly clay minerals, but with a large proportion of siliceous microfossils. Be sure to note which component is most abundant and which component(s) are less abundant.
- If there is one microfossil group that dominates the composition, it is also appropriate to be more specific with the name, for example a siliceous ooze that is primarily composed of diatoms, could be more specifically termed a "diatom ooze."
- In any of the sediment types, but especially in biogenic oozes and deep sea ("red") clays, layers of volcanic ash may be distinguishable.

Decision Tree for determining the dominant type of marine sediment based on smear slide data, visual core observations, and site characteristics:



Non-Biogenic Sediment

Is the texture and/or the mineral composition primarily clay (dust-size)?

yes

no

Is the drill site location in a deep basin or is it on (or near) a continental slope/rise?

Go to next page.

Deep basin

Continental slope/rise

Sediment Type = **Red Clay**

(also known as Pelagic Clay and Deep Sea Clay). Additional evidence is a red/brown sediment color, and sometimes black "spots" or nodules in the sediment, which are Mn and Fe mineral precipitants.

Sediment type = **Deep Terrigenous Sediment**

Additional evidence may include fining-upwards sequences, or sequences with sharp bases.

Mixed grain size, primarily non-biogenic sediment

Does the sediment contain isolated pebbles or gravel?

yes

Sediment Type =
Glaciomarine Sediment

no

Is this sediment on the continental shelf or the continental rise?

Continental shelf

Sediment type = **Shallow Terrigenous Sediment** (also known as Neritic Sediment and Margin Sediment). Some margin sediment may contain sea shells (mollusks) and tilted cross-bedding.

Continental rise

Sediment Type = **Deep Terrigenous Sediment** Additional evidence may include fining upward sequences with sharp bases.

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