TSUNAMI & STRATIGRAPHY
MODULE

Table of Content

Vocabulary

Exacavation:

A rectangular hole dug by scientists to see the stratigraphy

GPS:

A system of satellites that can be used by people to find the latitude and longitude of their location on Earth.

Marsh soil / peat:

Soil made of organic matter such as dead leaves and grass.

Soil

Dark upper layer of earth in which plants grow

Stratigraphy:

The study of accumulated sediments

Tephra:

Fragments of rock thrown into the air by volcanic eruption. Tephra is classified into different categories based on the size of the grains:

Name	Size
Ash	< 2 mm
Cinder	2 mm < x < 64 mm
Block or Bomb	> 64 mm

Topography:

Study of the shape of the earth's surface, specifically changes in elevation and the shape of a landscape

Tsunami:

A long-period wave generated by an impulse such as earthquakes, landslides, underwater volcanic eruptions, and meteor impacts

Volcano:

An opening in the earth's surface through which lava and gasses from below the earth's surface escape.

yr BP (years before present):

Date in the years before 1950 (e.g. 50 yr BP is the same as AD 1900).

Background Information

Stratigraphy and the relation between the stratigraphy of different sites allow scientists to identify and date past natural disasters. Stratigraphic layers can record tsunamis, volcanic eruptions, and changes in environment. Using many data points, scientists can estimate the size of past natural disasters based on the area affected by a specific event.

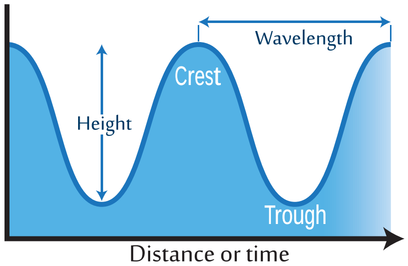
During certain types of volcanic eruptions a mixture of hot gasses, rock fragments, and molten rock are pushed into the atmosphere. The mixture is carried by the prevailing wind. Recent incidents, such as the shut down of airports in Europe due to the eruption of an Icelandic volcano, were due to volcanic particles in the atmosphere. Because of gravity and the cooling, the mixture falls back to earth, creating layers of unconsolidated volcanic rock, called tephra. Typically the largest grains are found near the volcano and the smallest grains are carried further. Tephra is described based on the size of the grains and the chemistry of the rocks. Different volcanoes and often even different eruptions from the same volcano have different ratios of elements in their tephra. Because these layers are widespread and represent a short period of time (hours to weeks), scientists can date these layers and use them to correlate between sites.

Tsunamis are long-period waves generated by some type of impulse such as an earthquake or landslide. They differ from normal wind waves because they move the entire water column even in the deep ocean. When the waves come into shore, they both erode part of the shoreline and deposit sediment over low-lying areas. In the geological record these layers can be identified in areas where sand is not common, such as bogs and marshes. These layers can also contain fragments of marine shell or microscopic marine organisms such as diatoms or foraminifera. These indicate that the sediment originated from the ocean and were transported to the freshwater environment. By counting the number of tsunami deposits in a time period, scientists can find the frequency of tsunami events. By tracing the layers inland scientists can determine the frequency of larger and smaller events.

Tsunami waves compared to wind waves

Wavelength:

- Wind waves: 100 - 200 m
- Tsunami: 200 - 500 km



Velocity:

(both types of waves move slower as they move onto the shore)

- Wind waves: 90 km/hr
- Tsunami: 950 km/hr (as fast as jet planes) in deep water

Period:

(time between two successive waves)

- Wind waves: 5 - 20 sec
- Tsunami: 10 min to 2 hrs

Name: ______________________________

Exercise 1

Plotting topographic profiles

Introduction:

Your goal is to determine how often big tsunamis affect the Kuril Island coasts using the same method that tsunami scientists use.

Exercise 1:

Plotting topographic profiles

Measuring coastal topography is the first step in identifying tsunami deposits and determining how big the tsunamis were. Open the Excel spreadsheet provided on-line or on a CD in the Burke Box. Use Excel to make a graph of the surface of the coastal plain. Distance should be your x-axis and elevation your y-axis; label your axes. Circle the points on your topographic plots where we dug excavations.

How far inland and at what elevation did we dig excavations? (refer to the spreadsheet for the most accurate numbers; look at the profile to get an idea of distance and elevation)

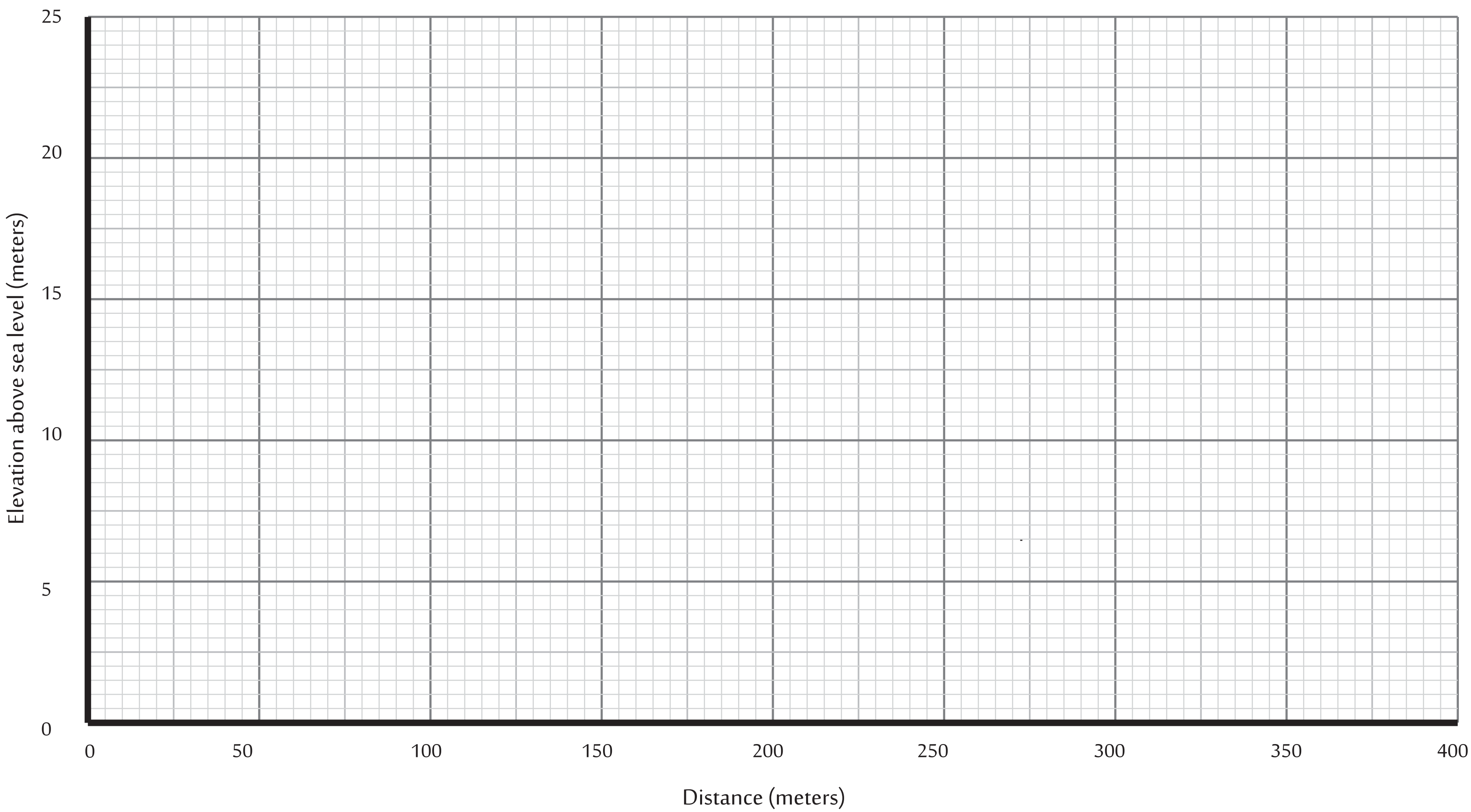
	Site 1	Site 2	Site 3	Site 4
Distance (in meters)				
Elevation (in meters)				

Name: ______________________

Exercise 1

Plotting topographic profiles - Continued

Dushnaya Bay
Simushir Island
Profile 2



Name: ______________________________

Exercise 1

Plotting topographic profiles - Continued

	distance (in meters)	elevation (in meters)	Notes	
1	361	20.0	edge of birch forest, quite flat past here	
2	335	19.1	excavation 102 near here	SITE 4
3	313	18.5		
4	290	17.9		
5	269	17.2		
6	247	17.0	low point	
7	227	17.5	excavation 101	
8	217	18.5		
9	207	19.7	scattered pine shrubs	
10	197	21.4	top of slope	SITE 3
11	191	20.8		
12	183	17.7		
13	182	16.6		
14	179	15.8	step in slope	
15	176	15.1		
16	172	13.1		
17	170	12.6		
18	164	10.1		
19	161	9.0		
20	157	8.1	base of slope, tall flowers above	
21	154	8.0	small ridge	
22	152	7.8		
23	150	7.4	edge of marsh	
24	147	7.2	mid marsh	
25	145	7.4	edge of marsh	
26	144	7.5		
27	141	7.1	edge of marsh	
28	139	7.0	mid marsh	
29	137	7.1	edge of marsh	
30	135	7.1	marshy area	SITE 2
31	130	7.4	[no point 32]	
33	126	8.0	ridge crest	

Name: ______________________________

Exercise 1

Plotting topographic profiles - Continued

34	123	7.3		
35	122	6.7	floated debris, 2006 runup	
36	117	6.6	beach grass starts; people disturbance	
37	114	7.2		
38	111	7.4		
39	108	6.7	trough	
40	104	7.3		
41	101	7.7	ridge crest	
42	98	7.4	people disturbance	
43	95	7.5	excavation near here	
44	92	7.3		
45	91	7.2	edge of ridge	
46	87	4.4	change in slope	
47	84	4.0	trough with short flowers; less beach grass	
48	81	4.6		
49	76	4.9		
50	70	5.4	excavation near here	SITE 1
51	67	3.9		
52	65	3.7	low spot	
53	59	4.4		
54	55	5.1	ridge	
55	53	4.6	beach grass	
56	51	4.5	top edge of scarp; cleaned cliff face for excavation	
57	50	2.8	base of scarp, sandy	
58	42	2.8	top of small berm; a little vegetation	
59	38	2.0		
60	34	1.5		
61	31	1.0	top of stream bank	
62	30	0.4	high tide	
63	26	0.5	stream edge	
64	20	0.6		
65	12	0.7	high point	
66	4	0.4	rock edge	
67	0	0.0	mid-rock outcrop, water level 3:40 PM	
			more rocks about 100 m out to sea	

Name: ______________________________

Exercise 2

Drawing stratigraphic sections

On the template provided and using our written descriptions, draw what we saw in each excavation. Site 1 is already drawn for you to help you get started. Each person in a group should draw one section. Then line the sections up from seaward (site 1) to landward (site 4).

1. How many sand deposits are there in each excavation?

Tsunamis can leave behind sand layers typically less than 25 cm thick.

	Site 1	Site 2	Site 3	Site 4
Number of tsunami deposit				

2. Are there more tsunami deposits at lower or higher excavations?

____

3. Are there more tsunami deposits closer or farther from the ocean?

____

4. What might be the source of other, thicker sand deposits?

____

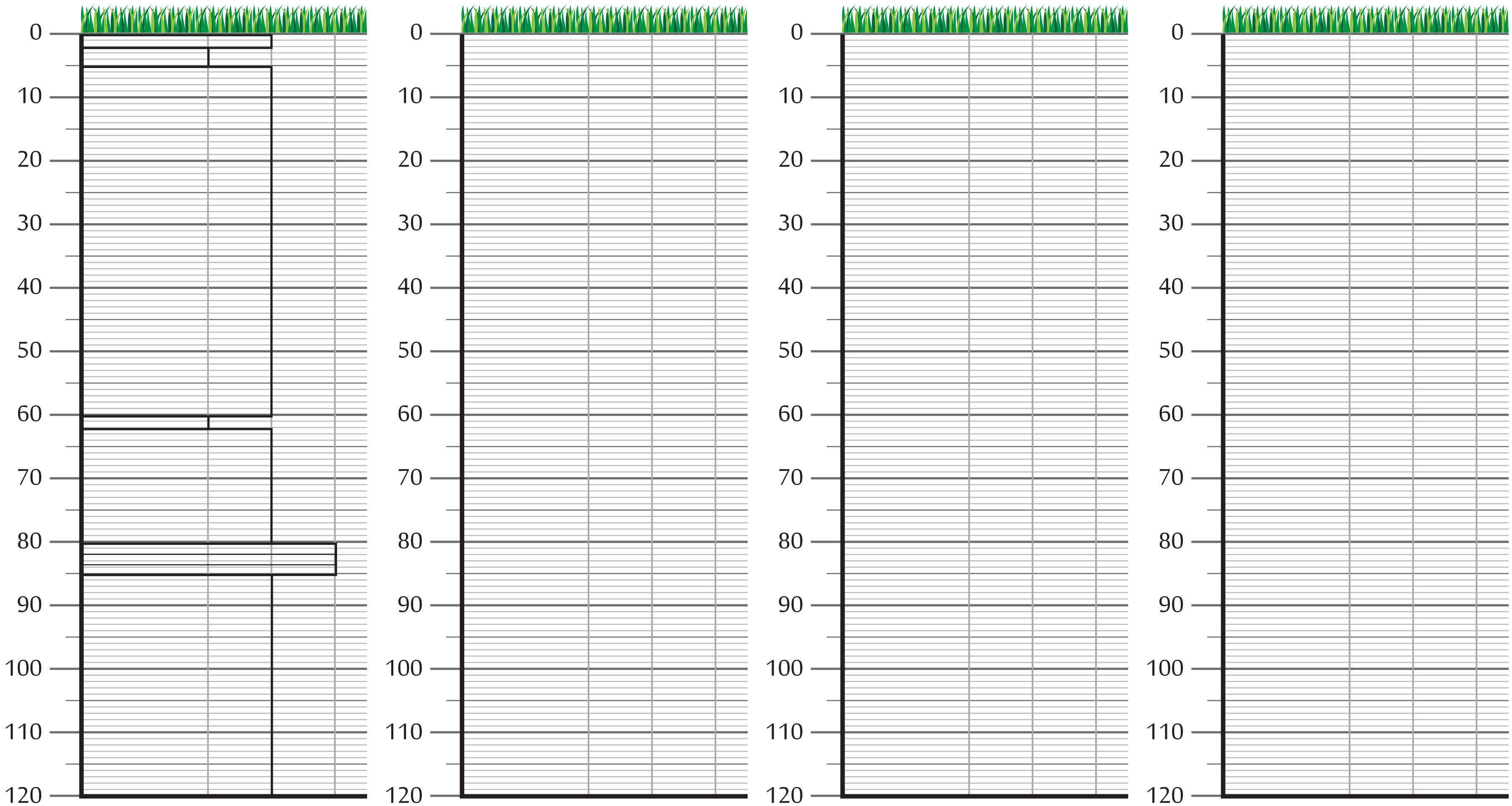
____

Name: ____________________

Exercise 2

Drawing stratigraphic sections - Continued

Site 1 | Site 2 | Site3 | Site 4



Soil / Peat
Sand
Tephra

Soil / Peat	☐
Sand	☐
3 layerd tephra	☐
Angular cinders	☐
Rounded cinders	☐
Yellow-orange sand	☐
Fine gray tephra	☐

Name: ______________________________

Exercise 2

Drawing stratigraphic sections - Continued

Notes from exacavations, Profile 2 (2006 & 2007)

Dushnaya Bay, Simushir Island

Site 1

Excavation 96

Vegetation: beach grass & flowers

Depth (cm)	Description
0-2	gray sand - new in 2007 survey
2-5	soil with roots
5-60	gray sand, top has roots
60-62	soil
62-80	gray sand
80-85	tephra, 3 layers, gray and brown
85-120	sand

Site 2

Excavation 98

Vegetation: moss, sedges, marsh

Depth (cm)	Description
0-4	vegetable mat [soil]
4-6	gray sand
6-13	marsh soil [peat]
13-15	gray sand
15-25	marsh soil [peat]
25-27	gray sand
27-34	tephra, 3 layers, gray and brown
34-40	marsh soil [peat]
40-44	clean gray sand
44-47	marsh soil [peat]
47-49	gray sand
49-51	marsh soil [peat]
51-52	clean sand
52-65	marsh soil [peat] with 2 thin sand layers
65-69	coarse gray cinders, sharp edges
69-76	marsh soil [peat]
76-78	sand
78-84	marsh soil [peat] with 1 thin sand layer
84-86	tephra [volcanic ash] [red and black cinders]
86-90	marsh soil [peat]
90-93	sand
93-94	marsh soil [peat]
94-109	sand
109-111	tephra, fine-grained, gray
111-114	sand [peaty]; sample of wood for dating
114-116	marsh soil [peat], sample for radiocarbon

Name: ______________________________

Exercise 2

Drawing stratigraphic sections - Continued

Site 3

Excavation 100

Vegetation: grasses, flowers, a few pine shrubs

Depth (cm)	Description
0-6	soil with roots
6-10	soil
10-12	gray sand
12-20	tephra, 3 layers, gray & reddish brown
20-24	soil
24-25	gray sand
25-30	coarse gray cinders
30-35	soil with thin sand layer; charcoal sample
35-38	tephra, fine gray and orangish
38-40	soil
40-43	sand
43-44	tephra
44-70	sand
70-80	gray cinders
80-95	sand
95-98	soil
98-115	sand
115-118	tephra, yellow sand

Site 4

Excavation 102

Vegetation: grasses, flowers, shrubs, near birch

Depth (cm)	Description
0-6	soil with roots
6-9	soil, silty gray
9-15	tephra, 3 layers, red-gray and red-brown
15-20	soil with a little sand
20-25	coarse gray cinders, angular grains
25-26	soil
26-28	tephra, fine, medium gray to reddish
28-32	silty soil, possible volcanic ash
32-33	fine cinders, tephra
33-35	sily soil, possible volcanic ash
35-49	gray cinders, clean, smooth grains
49-54	sily soil, possible volcanic ash
54-59	tephra,orange-yellow sand
59-70	soil, silty
70-100	soil, cimpact

Name: ______________________________

Exercise 3

Correlating tephra layers between stratigraphic sections

Write the description from the excavation notes of each tephra layer next to the corresponding layer on your stratigraphic column. Draw a line between layers that have very similar descriptions (similar thicknesses, color, grain size, etc.). These lines represent timelines. We call these tephras marker tephras. Label the tephra with numbers starting with 1 at the topmost marker tephra.

1. How many marker tephras are in the different sites:

	Site 1	Site 2	Site 3	Site 4
Number of marker tephras				

2. The shoreline on this profile has built outward into the sea as time has gone on, so that some land at the seaward sites is younger than the volcanic eruptions that generated some of the tephras.

   How many tsunami deposits are located above each tephra layer in each excavation? If the tephra is not present, leave the space blank.

	Site 1	Site 2	Site 3	Site 4
Above tephra 1				
Above tephra 2				
Above tephra 3				
Above tephra 4				
Above tephra 5				

Name: ______________________________

Exercise 3

Correlating tephra layers between stratigraphic sections

Continued

3. What is the thickness of sediment between each tephra layer in each site?

	Site 1	Site 2	Site 3	Site 4
Above tephra 1				
Between 1 & 2				
Between 2 & 3				
Between 3 & 4				
Between 4 & 5				

4. How do the thickness of sand and soil between tephra layers change as you travel inland and uphill?

5. What might be two reasons for the change in thickness of marshy soil/peat along the profile?

Name: ____________________________

Exercise 4

Adding time to your stratigraphic sections

We just received from the lab the results of radiocarbon dating of organic material for our summer's fieldwork. The charcoal in Site 3 is dated to be 900 yrs BP and the wood in Site 2 is 1100 yrs BP. Your volcanology colleagues have chemically identified the 3-layered tephra as being a 200 yrs BP eruption of the local Prevo volcano and the yellow sandy tephra as being from a gigantic eruption of Medvedzhia Volcano ~2000 yrs BP. Add notes on your stratigraphic sections to indicate the age of all these layers.

About how old is the tephra made of gray cinders?

Name: ______________________________

Exercise 5

Homework

Based on all that you now know about the coastal stratigraphy, you can calculate how often tsunamis affect this region. How many tsunami deposits are located between known dates in your stratigraphy? Write an "X" if there are no sediments in a certain age-range in a site.

1. Wrtie the number of sand layers (tsunami deposit) that are in each site (Write an "X" if there are no sediments in a certain age-range in a site).

Yrs BP	Site 1	Site 2	Site 3	Site 4
in the last 250 yrs		3		
0-1,000				
1,000-2,000				
0-2,000				

2. What is the maximum number of tsunamis per 1000 years we observed? ______________________________
3. What is the maximum number of tsunamis per 2000 years we observed? ______________________________

4. Take the numbers in the chart above, and divide by the time interval to get tsunami frequency: For example, in Site 2, there are three sand layers above the 250-year-old tephra 1 (from Prevo volcano). So the frequency there in that time period was 250 years divided by 3 tsunamis, or about 80 years — one tsunami on average per 83 years.

Frequency of tsunami deposits (years)

Yrs BP	Site 1	Site 2	Site 3	Site 4
in the last 250 yrs		83		
0-1,000				
1,000-2,000				
0-2,000				

5. What is the frequency of tsunamis (total # of tsunami/total time) for this one particular bay:
   - for low-lying areas (Site 2)? 1 tsunami per ________ years
   - for high areas (Site 3)? 1 tsunami per ________ years

Name: ______________________________

Exercise 5

Homework - Continued

6. If the average lifespan of a person is 80 years old, how many tsunami would they see in their lifetime?

7. How does the frequency of tsunamis you calculated from the Kuril Islands compare with the general frequency on the pacific caost of Washington State (1 large tsunami per 500 years)?

8. How long has the low-lying part of the coastal plain existed? Why are there only young tephra in the seaward excavations?

9. Compare the thickness and thickness variations of tephra and of tsunami deposits in your stratigraphic sections. Where do you find the thickest tsunami deposits and why? Why do tsunami deposits vary in thickness more than tephra layers?

Name: ______________________________

Exercise 5

Homework - Continued

10. You are planning to build a community at Dushnaya Bay. Your community will depend on boats to fish for food. How can you use the information from this exercise to help you plan your village? What would you consider when choosing the site of your village? What frequency of tsunamis do you think is acceptable for a community?