Practice Quizzes

Chapter 18: Seismicity and Earth's Interior

1: In P (primary) waves, how do the particles in a rock body move?

at a 45-degree angle to the direction in which the wave travels

in an elliptical pattern

back and forth parallel to the direction in which the wave travels

back and forth at right angles to the direction in which the wave travels

in a circle like sea waves

2: Earthquakes are caused by

convection in the lithosphere

faults in the lower mantle

the focus of magma in the mantle

folding and plastic deformation during mountain building

ruptures that occur where rocks are strained beyond their elastic limits

3: The point on the Earth's surface directly above the place of origin of an earthquake is called the

seismogram

focus

epicenter

seismic zone

seismic point

4: Which seismic wave cannot move through a liquid?

P-waves

T-waves

L-waves

S-waves

X-waves

5: Which of the following are NOT associated with shallow-focus earthquakes?

oceanic spreading ridges

intrusion of magma into a volcano

transform faults

the crest of the oceanic ridge

stable platforms of the continents

6: A liquid outer core in the Earth is indicated by the fact that

S waves will not travel through a liquid and do not travel through the outer core

surface waves cannot pass through the core

P waves do not travel through a liquid and do not travel through the core

all of the above

both S and P waves will not travel through a liquid and do not travel through the core

7: The compositional units of the Earth's interior are

liquid inner core, liquid outer core, asthenosphere, lithosphere

solid inner core, liquid outer core, asthenosphere, lithosphere

liquid inner core, solid outer core, mantle, lithosphere

liquid inner core, solid outer core, lithosphere, crust

solid inner core, liquid outer core, mantle, crust

8: In general, the deepest earthquakes are associated with

mid-ocean ridges

hot spots rising from the core-mantle boundary

convection in the molten core

subduction zones

the San Andreas fault

9: The Moho is the seismic discontinuity at the base of the

lithosphere

crust

upper mantle

mantle

asthenosphere

10: The 1999 earthquake centered near Izmit, in northern Turkey, was related to

a thrust fault

a strike-slip fault

a normal fault at a divergent plate margin

none of the above

Quantitative Problems

Chapter 18: Seismicity and Earth's Interior

Seismic Wave Velocity

The velocity of an S-wave traveling through Earth’s interior is

Vs = (μ/ρ)1/2 where μ = rigidity (or shear modulus) of the rock the wave travels through. This a ratio of shear stress to shear strain. ρ = density of the rock the wave travels through.

1: Calculate the density of the rocks in the upper mantle given that the typical upper mantle seismic wave velocity is 4.7 km/s and its rigidity is 75 gigapascals (remember 1 Pa = kg m-1 s-2) as measured for peridotite in a laboratory.

2: How does this calculation compare with the estimates of mantle density listed on p. 16?

3: Using this equation, describe in words the relationship between seismic wave velocity and rock density.

4: Note that seismic wave velocities increase with depth inside Earth, and so does density. What does this imply about the shear modulus (μ ) as depth increases?

Quantitative Problems

Chapter 17: Plate Tectonics

Convection In Earth’s Interior

One of the principal tenets of plate tectonics is that Earth’s interior convects, that is in flows in response to temperature and density differences. And yet, at the same time, we know that Earth’s mantle is solid and not a liquid. It may be difficult for you to envision that this solid rock is capable of flowing. Careful experiments in the laboratory reveal that even solids can flow given the right conditions. One way to look at this problem of whether or not a certain solid will convect is to construct a ratio of the factors that tend to enhance convection to factors that tend to prevent it. The Rayleigh number is such a dimensionless ratio.

R = (g a ρ T’(d3)) / (h η)

where g = gravitational constant (980 cm/s2)

a = the coefficient of thermal expansion 3 x 10-5 /degree

ρ = density 4.5 g/cm3

T’ = the temperature difference between the top and bottom of a layer

d = the thickness of the layer (cm) 3 x 108 cm (3000 km)

η = viscosity 1021 poise (cm-1.g.s-2)

k = thermal diffusivity 8 x 10-3 cm2 sec-1

Experiments have shown that when this number is greater than 1000 or 2000, then convection will occur. Note, that the higher the temperature difference the more likely the material is to convect; this corresponds with our natural experience at the kitchen stove. Moreover, the thickness of the layer is very critical because this number is raised to the fourth power. Highly viscous materials will not tend to convect.

1: Calculate its Rayleigh number assuming that the only the upper 1000 km or the whole mantle (3000 km) are involved in convection. Use realistic values for the mantle (listed above) and a minimal temperature difference of 1 degree between the upper and lower mantle. Speculate about the meaning of these results for mantle convection.

2: Is the viscosity assumed for the mantle higher or lower than that used for magmas, water, and ice in earlier exercises?

Practice Quizzes

Chapter 17: Plate Tectonics

1: The early (before 1950) concept of continental drift was based on all of the following EXCEPT

evidence of continental glaciation

rock structure and rock type

magnetic reversals

geographic "fit" of continents

the distribution of major coal deposits

2: Paleoclimatic evidence of continental drift includes deposits of

gypsum

desert sandstone

rock salt

glacial deposits

all of the above

3: Which of the following statements concerning patterns of magnetic reversals on the sea floor is NOT correct?

The succession of linear patterns going in either direction out from the crest of the oceanic ridge is similar to that in a dated series of basalts on the continents, starting with the present and going back in time.

They trend perpendicular to the transform faults.

The linear trend of the major patterns cuts across the oceanic ridges.

The patterns are parallel to the oceanic ridges

The linear patterns are symmetrical away from the crest of the oceanic ridges.

4: The youngest rocks of the oceanic crust are found

in the deep trenches

near continental margins

along fracture zones

along the oceanic ridge system

in the abyssal depths of the oceans

5: Sediment on the ocean floor

thickens and thins toward the equator

is approximately the same thickness throughout the ocean basin

is thinnest near the continents

is thickest toward the subduction zone and thin or absent on the ridge

is thickest in the rift valley and thinnest near the trenches

6: Which of the following is NOT a major process at convergent plate margins?

generation of granitic magma

folding and thrust faulting

extrusion of flood basalt

deep-focus earthquakes

mountain building

7: If the continental crust in one tectonic plate collides with the continental crust in another, a common result is

formation of a folded mountain belt

subduction of one of the continents

block faulting of the Basin and Range type

formation of andesitic volcanoes

formation of basaltic volcanism

8: The zone of soft plastic rock beneath the lithosphere is called the

stratosphere

thermosphere

magnetosphere

mantle

asthenosphere

9: The oldest oceanic lithosphere is about

1.75 billion years old

175 million years old

17.5 million years old

1.75 million years old

175,000 years old

10: Slab-pull is the force generated

when an oceanic slab descends under its own weight

gravity forces the slab to slip off the elevated ridge

is the resistance to flow exerted by the asthenosphere

by the buoyancy of hot lithosphere at the ridge

all of the above

11: The magnetic stripes found on the seafloor are the result of symmetrical variations in the concentrations of magnetic minerals.

TRUE

FALSECritical Thinking Web Exercises

Chapter 17: Plate Tectonics

Go to the Paleogeographic Atlas at http://www.geo.arizona.edu/~rees/PGAPhome.html and play the North Atlantic Paleogeography movie. Review the movie several times and take notes about the important plate tectonic events.

1: a. Describe the sequence of events along the eastern margin of the North America.

b. Was it ever a plate boundary? Was it always the same type of plate boundary?

c. When did the northernmost Atlantic Ocean start to form? How?

d. When did South America and North America collide? What geologic evidence of collision is consistent with this computer model?

e. When did South America and North America become separate again? When did they join again with the formation of Central America?

f. Were Africa and South America ever part of the same continent? When did they separate?

g. What plate tectonic event caused the Alps of southern Europe? When did they start to form?

The National Geophysical Data Center (http://www.ngdc.noaa.gov/mgg/image/sedthickv2.png) has a map showing the thickness of sediment in the world ocean. Many of the features of the map can be explained using plate tectonics.

2: a. Why is the sediment so much thicker on the eastern margin of South America than on the western margin of the continent?

b. What causes the great thickness of sediment in the Bengal Fan to the east of India?

c. Why is the sediment so thin in the center of the south Atlantic Ocean?

d. Why is sediment so thin over most of the ocean basins, as compared to continental margins?

Visit the National Geophysical Data Center and examine the Crustal Age Map of the Atlantic (http://www.ngdc.noaa.gov/mgg/ocean\_age/data/2008/ngdc-generated\_images/whole\_world/2008\_age\_of\_oceans\_n1024.jpg)

3: a. Look at the legend. Which color represents the oldest crust? Which color represents the youngest?

b. Where is the youngest oceanic crust found?

c. Where is the oldest crust found? Is there a plate tectonic explanation for its location there?

d. Did the North Atlantic or the South Atlantic start to form first?

e. What part of the Atlantic opened last? What is the evidence? Quantitative Problems

Chapter 19: Divergent Plate Boundaries

Cooling of the Oceanic Lithosphere

1: The elevation of the ocean floor is strongly influenced by its temperature and its age (Figure 19.6). Many observations have shown that old seafloor is much deeper than young seafloor. What explains this correlation?

2: Using the graph in Figure 19.6, about how old would a segment of oceanic crust be if it lies at a depth of 5000 m?

3: Consider the difference between a slow spreading ridge and a fast spreading ridge. How far would this crustal segment be from the ridge if the spreading rate was about 2 cm/y? How far would it be from the ridge if the spreading rate was 10 cm/y?

4: What aspect of seafloor topography do these calculations explain?

Practice Quizzes

Chapter 19: Divergent Plate Boundaries

1: Which of the following is NOT a major process at divergent plate boundaries?

tensional stress

eruption of andesitic lava

normal faulting

fissure eruptions of basaltic magma

shallow focus earthquakes

2: The dominant structures in continental rift zones are

folds and fault systems with small vertical displacements

parallel normal fault systems with large vertical displacements

strike-slip fault systems

erratic fault patterns with small vertical displacements

thrust fault systems with large vertical displacements

3: Based on the volume of lava extruded, the most extensive recent volcanic activity on Earth is associated with

divergent plate margins

Mt. St. Helens and the Cascade Range

transform plate boundaries

convergent plate margins

hot spots

4: The midocean ridge is

a folded mountain belt

a zone where crust plates collide and are up-arched

a zone where plates converge and descend back into the mantle

isolated segments of continental crust

an up-arched segment of the ocean floor split by rifting and transverse fractures

5: The lowest layer in the oceanic crust is

dikes of peridotite

pillow lava

oceanic sediment

sheeted dikes of basalt

gabbro

6: The upper mantle is composed mostly of

pyroxene and olivine

calcite, feldspar, and quartz

feldspar and olivine

quartz, feldspar, and olivine

pyroxene and feldspar

7: Compared to continental crust, oceanic crust is generally

older

thicker

more complexly folded

less dense

poorer in SiO2 and more mafic

8: Rifted continental margins commonly accumulate thick sequences of sediment because the lithosphere cools and subsides as it moves away from the rift.

TRUE

FALSE

9: The formation of the Basin and Range is believed to be the result of

cracking of Earth's crust caused by tidal forces

late motion caused by plate rotation

horizontal compression caused by plate collision

horizontal extension and rifting

a fracture system caused by igneous intrusions

10: Which of the following is NOT important during seafloor metamorphism?

high temperatures along the oceanic ridge

extreme pressure during subduction

hydrothermal alteration involving seawater

fractures and faults in the oceanic crust

black smokers

Critical Thinking Web Exercises

Chapter 19: Divergent Plate Boundaries

Go to the GeoMapApp website (http://www.geomapapp.org/rmbs/PAR\_Movie/mag\_forward.MPG) that shows an animation of seafloor spreading. Play the animation, then repeat the animation with the rewind button, and slowly step through the spreading sequence again. The numbers in the upper left corner of the frame give the age in millions of years.

1: a. What do the differently colored bands represent?

b. Why are they symmetrical about the ridge axis?

c. What is the approximate age of the most recent major magnetic reversal?

d. Which was longer, the most recent normal episode or the preceding reverse polarity epoch?

Go to the Paleogeographic Atlas at http://www.geo.arizona.edu/~rees/PGAPhome.html and play the ""North American Paleogeography"" movie that shows its evolution during the last 250 million years. Review the movie several times and take notes about the important plate tectonic events.

2: a. Which plate is held fixed in this animation?

b. What is the best way to describe the motions of the plates involved? As simple horizontal or as vertical movements or as rotations?

c. What do the different colors represent?

d. What type of plate margin was eastern North America during this time?

e. In relation to North America, where was Africa 250 million years ago? Describe its subsequent movements.

f. List the sequence of events that occurred along the eastern margin of North America.

Make a virtual field excursion through the Oman Ophiolite at http://www.bris.ac.uk/Depts/Geol/vft/oman.html, a site maintained by the University of Bristol in the United Kingdom.

3: a. What are the principle rock types found in the ophiolite?

b. Do they have counterparts to those found on the ocean floor?

c. What caused the hydrothermal alteration of the seafloor rocks? Quantitative Problems

Chapter 20: Transform Plate Boundaries

Rate of Slip on the Alpine Transform Fault

The Alpine Fault of New Zealand is described in the texbook as a classic example of an active continental transform. One of the fundamental characteristics of all transform faults is the rate of slip. To calculate the rate of slip along the Alpine Fault you need to know only two things: how long the transform has been active and how much displacement has occurred.

1: Estimate the total amount of slip on the fault by measuring the distance between the offset ophiolite belts shown in Figure 20.16. [Hint]

2: Calculate the rate (in cm/y) of horizontal movement along the fault. The transform fault appears to have initiated about 38 million years ago.

3: How does this rate compare with typical plate velocities? With movement on the San Andreas transform fault?

4: What would you predict about the number of earthquakes along the Alpine Fault as compared to the San Andreas Fault?

Practice Quizzes

Chapter 20: Transform Plate Boundaries

1: Transform plate boundaries are dominantly

zones of compression

zones of extension

zones of thrusting

zones of shearing

2: The most common type of transform boundary connects which two types of features?

trench to trench

ridge to ridge

ridge to trench

ridge to folded mountains

ridge to volcanic arc

3: Although transform plate boundaries connect convergent and divergent boundaries, lithosphere is NOT \_\_\_\_\_\_\_\_\_at this type of boundary.

prone to earthquakes

created

consumed

created or consumed

4: Shearing along faults at transform plate boundaries produces tectonic breccia and

mylonite

gneiss

granite

conglomerate

5: On the ocean floor, one side of an inactive fracture zone will be higher than the other because

Earth's gravitational pull varies across a transform fault.

one side is hotter than the lithosphere on the other side

earthquakes occur on only one side

compositional differences create crust with different densities on either side of the fracture zone

6: Compression can occur along a continental transform fault where

the trace of the transform fault is not straight

deep (greater than 50 km) earthquakes occur on a regular basis

rapidly subsiding grabens form

it crosses into oceanic crust

7: Magmatic activity along transform plate boundaries characteristically produces

large volumes of andesite magma

large volumes of basalt magma

small, local extrusion of basalt or no volcanism at all

minor granitic intrusions

8: What features are common along a continental transform fault?

rhyolite domes causing damming of streams

andesite composite volcanoes

linear ridges, sag ponds, and offset drainages

low angle faults offsetting river valleys

9: Metamorphism along transform boundaries

results from exceptionally high heat flow related to magmatic intrusions

is produced by high pressure

results from shearing

none of the above

10: Strike-slip faults occur along the entire length of an oceanic fracture zone that cuts the midocean ridge.

TRUE

FALSECritical Thinking Web Exercises

Chapter 20: Transform Plate Boundaries

Go to the website for the Lamont-Doherty Earth Observatory (http://imager.ldeo.columbia.edu/) at Columbia University. Go to the Midocean Ridge Gallery at the GeoMapApp website (http://www.geomapapp.org/gallery/Midoceanridgesgallery.html). The website is affiliated with the Marine Geoscience Data System. Find a map of a ridge-ridge transform fault and fracture zone in the Atlantic or Pacific Ocean.

1: a. Give its name and location.

b. Describe the characteristics of the transform fault zone. Is it marked by a ridge or ridges? By parallel troughs? What happens to the elevation of the plate opposite a truncated ridge?

Go to the website http://www.data.scec.org/significant/landers1992.html#g on the Landers, California earthquake of 1992. Find the simulation of the Landers earthquake. After watching this simulation, answer the following questions.

2: a. On what kind of fault was the Landers earthquake?

b. What do the moving colors in the simulation represent?

c. How deep was the focus of the Landers earthquake?

d. How fast did the zone of rupture move?

e. In what direction did it move?

f. Over what distance could the rupture zone be detected?

g. What was the magnitude of the earthquake?

h. Click on the thumbnails to see the fault scarp in the field and damage to various roads and structures. If this earthquake was so large, why was the ""damage"" so slight?

Find an earthquake hazards map of the United States on the internet using a Google or Bing search engines.

3: a. Explain why earthquakes are so common in Southern California compared to the rest of the country.

b. Are these deep earthquakes? Why or why not?

c. What does this tell us about the temperature-strength relations with increasing depth in the crust?

Quantitative Problems

Chapter 21: Convergent Plate Boundaries

Subduction Zones

The angle of subduction effects many of the basic processes that shape the features and events along a convergent plate margin. But how do we know the angle of any subduction zone when all of the activity takes place at such great depths? One way to determine the configuration of a subduction zone is to look at the distribution of volcanoes and earthquakes. Below you will construct a map and cross section of a subduction zone on a piece of graph paper or with a computerized spread sheet.

1: Plot the locations of these volcanoes and earthquake foci, using the rectangular coordinates given (in kilometers north and kilometers east of the map origin). Label the depth of the earthquakes on the map. What patterns are apparent in these data?

Feature x (km) y (km) Depth (km)

Volcano 1 160 112

Volcano 2 145 70

Volcano 3 123 31

Volcano 4 118 11

Volcano 5 145 90

Earthquake 1 150 65 15

Earthquake 2 80 100 38

Earthquake 3 40 80 10

Earthquake 4 90 80 58

Earthquake 5 130 90 98

Earthquake 6 160 100 130

Earthquake 7 180 60 165

Earthquake 8 120 60 101

Earthquake 9 60 60 37

Earthquake 10 40 40 29

Earthquake 11 60 20 51

Earthquake 12 120 20 125

Earthquake 13 150 30 150

Earthquake 14 160 40 157

Earthquake 15 80 40 62

Earthquake 16 200 10 210

2: Draw contours showing the depth of the earthquakes. Use a contour interval of 20 km depth. At about what depth is the subducting slab below the volcanic arc?

3: What is the angle of subduction (in degrees) of the oceanic lithosphere? [Hint]

4: How long would it take the subducting slab to reach the depth of magma generation? Assume the subduction zone angle you just calculated and a total rate of movement of perpendicular to the trench of 10 cm/y.

Chapter 21: Convergent Plate Boundaries

1: Which of the following is NOT a major process at converging plate margins?

generation of granitic magma

folding and thrust faulting

extrusion of flood basalt

deep-focus earthquakes

mountain building

2: Most composite volcanoes are composed largely of

granite batholiths

thin basaltic lava flows

ash-flow tuff

rhyolite

andesitic lava and pyroclastic rocks

3: Himalayan mountains of Asia are believed to have originated by

large-scale block faulting

collision of the Indian-Australian plate with the mainland of Asia

massive igneous intrusions into this part of the crust

folding of an island arc

vast outpouring of fluid basaltic lavas

4: The major driving force behind explosive volcanic eruptions is

the high density of magma relative to wall rock

the expansion of gas bubbles at low pressure

the failure of the sides of volcanic cones

thermal convection of magma in its subterranean chamber

none of the above

5: As a typical subduction-zone related magma differentiates, the lower temperature fractions of the liquid become progressively

enriched in Mg

depleted in K

enriched in Ca

enriched in Si

6: Which of the following volcanic islands would you predict to be most dangerous to its inhabitants?

Japan

Hawaii

Iceland

7: The oldest continental crust yet found is

from the Rocky Mountains

about 4 billion years old

from the stable platform

all of the above

located in the Appalachian Mountains

8: Consider the origin and evolution of Earth’s continents. Which of the following is correct?

were formed when the Earth as a planet formed

remain about the same size but shift with the moving plates

grow by inflation

grow by accretion

grow and are destroyed by plate tectonics

9: Compared to the continents, the crust of the ocean basins is

older, denser, less folded, more mafic

younger, denser, less folded, more mafic

younger, denser, more folded, more mafic

younger, denser, less folded, less mafic

older, denser, more folded, more mafic

10: What facies of metamorphic rocks are created under low temperature, high pressure conditions?

Greenschist

Blueschist

Granulite

Amphibolite

Zeolite

Critical Thinking Web Exercises

Chapter 22: Hotspots and Mantle Plumes

Using information from the textbook, Google Map, or what is given at this website (VolcanoWorld And the Smithsonian’s Global Volcanism Volcano Search Tool (http://www.volcano.si.edu/search\_volcano.cfm) identify an underwater subduction zone volcano and a volcano related to a hotspot ocean island.

1: Compare the sizes, lava compositions, and internal structures of the two volcanoes.

Examine the topographic map of the seafloor around Hawaii shown here http://topex.ucsd.edu/marine\_topo/jpg\_images/topo7.jpg

2: a. What is the origin of the long topographic swell (light blue) that surrounds the Hawaiian Island chain?

b. Why does the swell end at the southern end of the island chain?

c. Why is there a narrow trough (deep blue) on top of the swell near the island of Hawaii-the southernmost island?

d. Why doesn't the Hawaiian island chain parallel the fracture zones on the floor of the Pacific Ocean?

Visit the U.S. Geological Survey website that describes the earthquakes of Hawaii (http://hvo.wr.usgs.gov/seismic/volcweb/earthquakes/index.php).

3: a. Are earthquakes common in all of the Hawaiian Islands? Explain their distribution.

b. Zoom in on the big island of Hawaii. Where are earthquakes most common on and near the island?

c. How large are they? How deep are they?

d. What causes the earthquakes?

Quantitative Problems

Chapter 22: Hotspots and Mantle Plumes

Isostasy and Uplift at Mantle Plumes

Most mantle plumes are associated with broad domes in the lithosphere. These domes are hundreds of kilometers across, but typically less than two km high. For example, the bulge at the Hawaiian plume is about 1500 km across and nearly 1 km high. Of course, we are not including the extra elevation added by the volcanoes.

What causes the lithosphere to bulge above a mantle plume? There are several interrelated factors that are responsible, including the expansion caused by heat, the buoyancy of the rising plume, and isostatic adjustment. In Chapter 2, you read about how gravity and density differences in Earth’s outer layers combine to create isostatic adjustments. What if a rising plume adds new low density material below normal oceanic lithosphere?

1: Calculate the volumetric expansion of a disk of material in the flattened head of a mantle plume (like the one shown in Figure 22.8). Assume that the constant of thermal expansion of mantle material is 3x10-5/C (a value appropriate for mantle peridotite). Thermal expansion is defined as the change in volume per degree celsius at constant pressure (a = (V2-V1)/V1). Assume that the density of cool mantle is 3.3 g/cm3. Calculate the density of the plume head, if on average it is 200 degrees C warmer than the surrounding mantle.

2: To estimate the amount of isostatic uplift, you need to understand that the concept of isostasy calls upon a “depth of compensation” at which the pressure (P = ρgh) at the base of adjacent columns of rock is equal.

Mathematically, you can describe this situation for two adjacent columns of rock as

P = ρ1gh1 = ρ2gh2 where P = pressure exerted by the overlying rocks (g cm/s2)

ρ1, ρ2 = densities of each column of rock (g/cm3)

h1, h2 = height (or depth of compensation) of each column (cm)

g = gravitational acceleration (980 cm/s2 on Earth)

Imagine a plume that has risen and flattened beneath the ocean floor. Calculate the thickness of the warm plume head assuming it has the density calculated in question 1. Also assume a depth of compensation of 200 km, an uplift of 1 km (decrease in the column of water by 1 km), and the information on thicknesses and densities given below.

Normal Column Plume Column

Density Thickness Density Thickness

g/cm3 km g/cm3 km

Ocean water 1.03 5.0 1.03 4.0

Oceanic crust 2.90 8.0 2.90 8.0

Normal Mantle 3.30 187.0 3.30 ?

Plume Mantle 0 Solved ?

Above

Practice Quizzes

Chapter 22: Hotspots and Mantle Plumes

1: The Columbia Plateau of the Pacific Northwest was formed mainly by

vertical uplift of crust

shallow marine deposition of shale and limestone

composite volcanoes

extensive fissure eruptions of basaltic lavas

ash flows

2: A chain of volcanic islands and seamounts like the Hawaiian chain is believed to result from

volcanic activity associated with the deep trench

volcanic activity along the crest of the mid-oceanic ridge

volcanic activity associated with fracture zones

migration of the sea floor over a hotspot

a line of hot spots in the asthenosphere

3: An example of volcanism related to a mantle plume is

the Aleutian Islands, Alaska

Mt. St. Helens, Washington

Mt. Pelée, Lesser Antilles

Mt. Fuji, Japan

Hawaii

4: Compared to subduction zone magmas, hot spot lavas are

quite water-rich because they form in the ocean basins

water-poor because they form in regions with very little rain fall

water-poor and usually basaltic

water-poor because they lose their water during eruption

water-rich because of extensive fractional crystallization

5: Many geologists theorize that mantle plumes start from

the core-mantle boundary

divergent plate boundaries

the shallow uppermost part of the asthenosphere

the energy generated by the surface movement of the plates

6: Which of the following is INCORRECT? Decompression melting

is a common phenomenon in the mantle

is only found where a hotspot coincides with a divergent plate margin, such as Iceland

occurs when the melting point of a material decreases as pressure decreases

responsible for the generation of magma in mantle plumes

7: Which of the following would you NOT expect to find near a continental hotspot?

Rhyolitic caldera systems

Severe deformation including folding and thrust faulting of the continental crust

Large granitic intrusions

Dike swarms

8: Extensive mantle plume eruptions can make Earth's climate warmer by releasing which volcanic gas?

O2 (oxygen)

CO2 (carbon dioxide)

N2 (nitrogen)

HF (hydrogen fluoride)

H2S (hydrogen sulfide)

9: Which of the following is evidence for mantle plumes?

volcanically active hotspots that do not move with tectonic plates

local zones of high heat flow

geochemical studies of erupted basalt

seismic studies of the mantle

all of the above

10: In a given year, mantle plumes produce more magma than any other tectonic setting on Earth.

TRUE

FALSE

Quantitative Problems

Chapter 23: Tectonics and Landscapes

Uplift and Erosion of Mountain Belts

The development and eventual erosion of mountain belts are fundamental to the development of many continental landscapes, including folded mountain belts, shields, and even mountain ranges in continental rifts. The calculations below are intended to help you understand the rates and processes involved in the development of a mountain belt.

1: Careful GPS (global positioning system) surveys show that the crust below a certain mountain belt at a convergent plate margin is raising at an average rate of 1.4 mm/year. Geologic studies suggest that the deformation and uplift have been going on for about 10 million years. How much uplift (in km) would be accomplished over this period of time?

2: Will the highest peaks in this mountain range lie at this elevation above sea level? Why or why not?

3: Careful measurements of the rate of erosion in the mountain range suggest an erosion rate of about 0.7 mm/y. Estimate about how high the mountain belt would be after 10 million years of combined uplift and erosion.

4: How would you try to estimate the rate of erosion of an ancient mountain belt that is no longer being actively uplifted and eroded?

Practice Quizzes

Chapter 23: Tectonics and Landscapes

1: A portion of the evolution of a folded mountain belt involves establishing an equilibrium between the weight of the rocks in the mountain belt and the density of the material the crust rests upon. Which of the following processes is responsible for establishing this equilibrium?

partial melting of crustal rocks

erosion

magmatic differentiation

isostasy

none of the above

2: The continental shields consist mostly of

metamorphic and igneous rocks

remnants of ancient oceanic crust

fragments of the original crust of the Earth

metamorphosed fragments of the midoceanic ridge

Precambrian sandstone

3: Which of the following is NOT true about a stable platform?

It is composed of sedimentary rocks underlain by the basement complex (shield).

It is considered to be tectonically active.

The sedimentary rocks that compose the stable platform are mainly shallow marine.

It may have numerous broad structural domes and basins.

At times it may be (or may have been) part of the continental shelf.

4: One of the basic systems of landscape development on all continents is

evolution of a fault block mountain range

development of a trellis drainage pattern on folded rocks

formation of deserts

development of mesas and buttes on inclined strata

evolution of the shield from erosion and isostatic adjustments of a mountain belt

5: What causes an inverted valley to form?

folded lava ridges

lava flows extruded on a linear ridge

faulted stream channels

erosion of local lava flows

dissection of high plains

6: The formation of the Basin and Range is believed to be the result of

cracking of the crust caused by tidal forces

motion caused by plate rotation

horizontal compression caused by plate collision

extensional forces and rifting

a fracture system caused by igneous intrusions

7: Natural arches develop in massive sandstone formations as a result of wind erosion.

TRUE

FALSE

8: Continental shields are presently being subjected to mountain-building processes.

TRUE

FALSE

9: Folded mountain belts

represent zones where the crust has been compressed

represent zones of tension in the crust

result from vertical forces

typically form in the interior of continents

are absent in Antarctica

10: The typical landforms of a magmatic arc related to subduction include all of the following EXCEPT

composite volcanoes, cinder cones, and sheets of ash-flow tuff.

collapse calderas filled with lakes

valley glaciers on high peaks

horsts and grabens trending perpendicular to the adjacent trench

Quantitative Problems

Chapter 1: Planet Earth

Density

One of the fundamental characteristics of any planet is its density–a measure of its mass per unit volume. The density of a planet gives us important clues to its composition and structure.

1: Calculate the volume (in cm3) of Earth, assuming the radius of Earth is 6,378 km.

2: Calculate the bulk, or overall, density (usually symbolized with the Greek letter rho-ρ- and given in g/cm3) of Earth, given that its mass is very nearly 6 x 1027grams.

3: How does your result compare with the value given for Earth’s density in the textbook (p. 10 gives the density as 5.55 g/cm3)?

4: If you carefully measure the density of rocks at the surface of Earth, you will find that they range from 2.5 to about 3 g/cm3. What does this observation and the results of your calculations imply about the nature of Earth's interior?

Chapter 1: Planet Earth

1: Earth's atmosphere is unique among the moons and planets in that

it is nitrogen (N2) rich

it has oxygen (O2) rich

it is rich in carbon dioxide because of animal life

it is rich in carbon dioxide because of plant life

it has clouds and storms

2: Which of the following makes Earth unique among the terrestrial planets?

it has an atmosphere

it has an active hydrosphere

it has a lithosphere

it has no meteorite impact craters

it has volcanoes

3: Which of the following planetary bodies has the least number of impact craters on its surface?

Mercury

Mars

the Moon

Earth

4: Continental shields are composed of

ancient rocks of the oceanic ridges

horizontal sedimentary rock

intensely deformed igneous and metamorphic rock

basalt

folded lava rock and sedimentary rock

5: A stable platform is a region characterized by

no vertical crustal movement until recent times

a complete lack of deformed rock at any depth

numerous folds and faults

horizontal sedimentary rocks overlying the basement complex

extensive exposures of igneous and metamorphic rocks

6: Which of the following is NOT true about young, folded mountain belts?

they are commonly associated with volcanic activity

they form as a result of horizontal stresses

they typically occur near and parallel to continental margins

they form as a result of vertical stress in the crust

they are long, linear zones made of rock which has been deformed and intruded by molten rock

7: Continental crust

is composed mostly of low density "granitic" rock

is part of the upper mantle

drifts through the lithosphere

is about 5 km thick

is made of the same kind of rocks as the oceanic crust

8: Up-arched segments of the ocean floor, split by rifting and transverse fractures, are the

mid-oceanic ridges

abyssal hills

deep sea trenches

seamounts and guyots

submarine canyons

9: The lithosphere is

the outermost solid shell of Earth

a layer above the asthenosphere

a rigid layer that varies from 10 to 300 km thick

in motion

all of the above

10: The difference in elevation of Earth's continents and ocean basins is caused by a fundamental difference in

crustal strength

crustal composition and density

extent of crustal deformation

age

Quantitative Problems

Chapter 2: Geologic Systems

Magnitude of the Hydrologic System

It may be difficult to imagine the volume of water on Earth that is involved in the constant circulation system we call the hydrologic system. The total amount of water on Earth is about 1.35 billion cubic kilometers (or somewhere around 1020 gallons of water). How much water is that? A few simple calculations may help you put this in huge number in perspective and help you see where most of the water resides.

1: The table below shows the percentage of water in each of the major reservoirs on Earth. It may surprise you that there is more water in the pore spaces in rocks than there is in streams and lakes. Calculate the volume of water in each subdivision.

Reservoir Percent Volume (km3)

Ocean 97

Icecaps and Glaciers 2.2

Groundwater 0.7

Lakes and Streams 0.013

Soil Moisture 0.0045

Atmospheric Vapor 0.0009

[Hint]

2: Now to help you see just how much water this is, for each reservoir calculate how deep the water would be if it were spread uniformly over the entire surface of a completely smooth Earth. [Hint]

Quantitative Problems

Chapter 3: Minerals

Calculation of Density

For identifying minerals, density (ρ) is one of the more diagnostic features. However, it is easy to confuse density with mass (m) or weight. Just because a large sample weighs more than a small sample of another mineral does not mean that it is denser. You need to develop a feel for density so that you can estimate it and contrast it with the mass of a sample.

1: Use the following measurements to calculate the densities of ten mineral samples. Do the densities correspond with those listed in Table 3.3 of your text?

Sample Mineral Mass (g) Volume (cm3) Density (g/cm3)

1 quartz 10.0 3.7

2 quartz 54.2 20

3 olivine 2.2

1 quartz 40.5 11.9

4 olivine 84.5 24.3

5 pyroxene 5.2 1.6

6 pyroxene 78.3 23.7

7 plagioclase 10.0 3.7

8 plagioclase 59.8 22.1

9 plagioclase 91.3 33.8

10 galena 55.6 7.3

[Hint]

2: Which two of these minerals would be hardest to tell apart based only on their densities?

3: Calculate the volume of quartz in a particular specimen, if you know it weighs 2.34 kg.

4: Assume this sample is a cube and give its dimensions in centimeters. [Hint]

Quantitative Problems

Chapter 4: Igneous rocks

Viscosities of Magmas

You already know that the viscosity of a magma is one of its most fundamental features, controlling for example the type of intrusion, the style of eruption, and thickness and the flow rate of a lava on the surface. As you will discover in future exercises, viscosity also controls the deposition of sedimentary particles, the convection of the mantle or of magma chambers, the flow properties of ice and other fluids. Thus, understanding viscosity is very important, even for a beginning geologist.

But what exactly is viscosity and how is it measured? In the text, we used the term nonquantitatively to describe the resistance to flow of a fluid. Thus, basaltic magmas are relatively fluid and have low viscosities and rhyolitic magmas flow only sluggishly and have high viscosities. Viscosity (η) is a substance’s internal resistance to flow when a shear stress is applied to it. It is measured in units called poises, where 1 poise = 1 g cm-1 s-1.

Viscosity of magma is not a single number. As a rule silica-rich magmas are more viscous than silica-poor mafic magmas. Moreover, magmas (and most other) become more viscous as they cool. In addition, even the rate of shearing effects the viscosity. Nonetheless, some simple relationships between the velocity of a fluid flowing down hill and the viscosity of the fluid have been discovered experimentally.

v = (ρgh2 sinα)/3η

where v = velocity of flow (cm/s)

ρ = density of fluid (g/cm3)

g = acceleration of gravity (980 cm s-2)

h = thickness of the flow (cm)

α= the angle of the slope (degrees)

η = viscosity of the lava (poise–g cm-1 s-1)

From this equation, you can see that the velocity is faster for denser lavas, for thicker lavas, and for those on steep slopes, and for those with low viscosities.

1: Use this equation to calculate the velocity of basalt, andesite, and rhyolite lava flows moving down the side of a volcano whose slopes are 7 degrees measured up from the horizontal.

Density Thickness Viscosity Velocity Velocity

ρ (g/cm3) h (m) η (poise) cm/s km/h

Basalt 3.0 3 2 x 104

Andesite 2.7 10 5 x 106

Rhyolite 2.3 30 1 x 108

[Hint]

2: For a given volume of lava erupted, which type of lava flow will probably cover a larger area? Why?

Quantitative Problems

Chapter 5: Sedimentary Rocks

Stokes Settling Velocities

The settling of particles through fluids is an important geologic process in many geologic systems. Crystals settle in magmas, particles settle in flowing streams, or through the static ocean. We can better understand the controls on this process using an equation called Stokes Law.

The motion of a settling particle is controlled by gravity and viscous forces resisting its downward movement. Consider a spherical grain of radius r and density ρ1 falling through a liquid of density ρ2 and viscosity η. The velocity of fall v is given by Stokes Law

v = 2/9(r2 (ρ1 - ρ2)g)/η

As you can see from this equation, the settling velocity of a mineral fragment sinking in water is essentially a function of its weight or size. If the settling velocity (v) is much less than the velocity of stream flow, the particle will travel far downstream before it reaches the river’s bed. Coarse grains for which v is large, travel shorter distances before settling to the floor of the river. Moreover, a grain of sediment will be suspended in a moving river if the settling velocity is less than the velocity of turbulent upward moving currents found in a flowing stream.

1: Calculate the settling velocities of five different grains of quartz in water. Assume the density of quartz is 2.7 g/cm3 and the density of liquid water is 1.0 g/cm3. Gravitational acceleration (g) is 980 cm/sec2. Assume the viscosity of water is 1 x 10-2 g/(cm s) and that the grains are spherical. (Tabular flakes of mica or clays will settle at slower velocities than spheres.)

Radius (cm) Settling Velocity (cm/sec)

Grain 1 0.0001 (clay)

Grain 2 0.001 (silt)

Grain 3 0.01 (fine sand)

Grain 4 0.1 (coarse sand)

Grain 5 1.0 (pebble)

2: How do the settling velocities compare to the upward component of velocity in a typical turbulent stream? [Hint]

3: Using the information from Stokes Law, why do grains of magnetite or of gold settle out in different parts of a stream than quartz grains, even if they are of the same size?

4: It is important to note that Stokes' Law is valid only for fine sand to clay-sized particles (less than 0.2 mm in diameter). In fact, in experiments, particles larger than about 0.2 mm settle much slower than predicted by Stokes' Law. Can you think of a reason why larger grains might settle more slowly than predicted?

Quantitative Problems

Chapter 6: Metamorphic Rocks

Pressure

In geology, we are commonly interested in the pressure exerted on a rock found deep inside the Earth. For example, many metamorphic reactions occur when a particular mineral or group of minerals find themselves at a pressure which exceeds their stability range.

Pressure is the force exerted on an area.

P = F/A where P = pressure

F = force

A = area (in m2)

1: What is the major source of pressure on a rock buried deep in the crust?

2: Consider two igneous rocks buried at a depth of 10 km. One inside the Earth and one in the much smaller Moon. Is the pressure on these two rocks the same? Why or why not?

3: Consider two sedimentary rocks buried at the same depth on Earth. One rock is overlain by unconsolidated layers of sand and silt. The other is overlain by massive gabbro. Is the pressure on these two rocks the same? Why or why not?

4: You should now realize that pressure is proportional to depth, gravitational acceleration, and density of the overlying rocks. Now formulate an equation you could use to calculate lithostatic pressure–that is the pressure caused by the overlying rocks. Start with the equation for P given above and make justifiable substitutions to arrive at an equation that describes pressure as a simple function of depth, gravitational acceleration, and density. [Hint]

5: Use the equation you just derived to calculate the pressure on a rock at depths of 1, 5, 10 and 30 km depth. Assume the density of the overlying rock is that of granite (2.7 g/cm3= 2700 kg/m3). Calculate the pressure in pascals (kgm/ s2) and in kilobars (1 kilobar = 108 pascals and 1 bar is about the same as the pressure of the atmosphere at sea level Force is equal to mass times acceleration). Round your answer to the nearest tenth of a kb.

Quantitative Problems

Chapter 7: Structure of Rock Bodies

Geometry of Dipping Beds

An important bed of coal dips at an angle of 20 degrees. Where the bed crops out at the surface, the coal has been mined out. You are considering the feasibility of mining it underground. You have acquired the necessary permits and permissions to open a mine 2 km (measured perpendicular to the strike direction) away from the surface outcrops.

1: How deep will you have to drill a vertical hole to reach the top of the coal bed? Assume that the surface is horizontal and that the dip and strike of the bed are constant. [Hint]

Quantitative Problems

Chapter 8: Geologic Time

Calculating a Radiometric Age from a Mineral Analysis

An equation that relates the half life of a radioactive element to the elapsed time has been derived through experiment and theory.

t = (t1/2 /0.693) ln((D/P) +1)

where t = age of mineral in years

t1/2 = half life of radioactive element “P”

D = Number of atoms of stable daughter isotope

P = Number of atoms of radioactive parent isotope

This expression clearly shows that the age of a mineral is directly proportional to the ratio of radiogenic daughter isotopes to the parent isotopes, as found in the mineral today. The more daughter isotopes, the older the rock.

1: Using the half-life of 87Rb (rubidium) given in the text (Table 8.1), calculate the age of a muscovite grain separated from a granite that contains 1020 atoms of 87Sr (strontium) formed by decay and 50 x 1020 atoms of the parent isotope 87Rb.

2: What assumptions are inherent in this calculation?

3: Would you be able to date this mineral using 14C? Why or why not?

Quantitative Problems

Chapter 9: The Atmosphere-Ocean System

Melting of the Antarctic Ice Sheet

One of the threats of global warming is that the ice sheets on the continents might melt and release the stored water back into the ocean. This would considerably raise sea level and drown many low-lying areas including many of the largest cities.

1: Estimate the change in sea level caused by complete melting of the Antarctic ice sheet. In the absence of a measurement of the true area of Antarctica, approximate the area as a semicircle with a radius of 2,500 km. The average thickness of the ice is about 3 km (Figure 14.20). Calculate the height of a dam that would need to be built along the present shoreline to prevent inundation. (Ignore the slight density differences between ice and liquid water and assume that Antarctica rebounds to sea level after the ice is removed.) [Hint]

2: The ocean doesn't cover the entire Earth.

Quantitative Problems

Chapter 10: Weathering

Chemical Reactions During Weathering

The common iron sulfide mineral pyrite is unstable when exposed to oxygen-rich surface waters.

1: Write a balanced chemical reaction between reactants (pyrite - FeS2, water - H2O, oxygen dissolved in water - O2) and products (limonite - Fe(OH)3 and sulfuric acid - H2SO4). [Hint]

2: What is the charge (valence) on the iron ions in pyrite (FeS2) if each sulfur ion has a charge of +1? [Hint]

3: What is the charge on the iron ions in the limonite (Fe(OH)3, assuming oxygen has -2 charge and hydrogen +1 charge?

4: What happened to the iron in this chemical reaction?

5: Like many other weathering reactions, one of the products is an insoluble reddish mineral (limonite - Fe(OH)3) and the other is a highly soluble acid (sulfuric acid - H2SO4). Knowing this, what do you think the water is like that leaks out of a stack of mine tailings that contain abundant pyrite?

Quantitative Problems

Chapter 11: Slope Systems

Stability of a Block on a Slope

Slope stability is best understood by considering the driving forces and the resisting forces. Let us consider the case of a block on a hillside like that in Figure 11.1. The principal driving force is the force of gravity represented by the weight (W) of the block. The weight can be calculated indirectly if the volume and mass of the block are known.

W = ρg V

where ρ = density in kg/m3 (1000 x g/cm3)

g = gravitational acceleration (9.80 m/s2)

V = volume in m3

The weight force acts as if it were at the very center of the object (not the base as indicated schematically in Figure 11.1). However, only a fraction of this force is directed downhill as a driving force. From trigonometry you should be able to see that this downhill force is

F = W sinθ where θ = angle of the slope in degrees

(Other driving forces may accompany this force. Temporary changes in weight may result if rain water is absorbed by the rock. Or the expansion of freezing water might push the block downhill.)

Resisting forces include the force of static friction (fs). This force depends on the force perpendicular to the hillside and upon the nature of the materials in the slope and in the block, including changes if the materials become wet or dry. Thus,

fs = μ W cos θ

where μ = coefficient of static friction

W cos θ = force perpendicular to the sloping surface

Another resisting force is the force of cohesion (fc) between the block and the hillside This force is directly proportional to the area of contact (A) between the block and the slope.

fc = c A

where c = cohesion stress in pascals (1 Pa = kg m-1s-2)

A = area of contact in m2

To keep the block from sliding downhill, the resisting forces (fs + fc) must equal or exceed the driving force F. Therefore, a simple safety factor (SF) against sliding is the ratio between the resisting forces and the driving forces.

SF = resisting forces/driving forces

= (fs + fc)/F

or

SF = (μ W cos θ + cA)/ (W sin θ)

If the safety factor is less than 1, then the resisting forces are less than the driving force and the block should slide down hill.

1: A rectangular block of sandstone with a density of 2,500 kg/m3 (2.5 g/cm3) sits on a 20 degree slope underlain with shale. The base of the block is 15 m by 10 m and it is 3 m thick. Experience shows that the slab will slide if even very slightly disturbed. What is the weight of the block?

2: What is the downhill component of this force? [Hint]

3: Measurements indicate that the cohesion stress between the block and the hillside is small, on the order of 5,000 Pa. Assume this value and calculate the cohesion force.

4: Using these results, calculate the coefficient of static friction for this block. [Hint]

5: What would the coefficient of static friction be if you neglected the cohesion force?

6: Perhaps you noticed that if you neglect the cohesion force, the SF equation reduces to SF = (μ W cos ?)/ (W sin ?) = (μ cos ? )/ ( sin ?) = μ / tan ? In other words, if the tangent of the slope angle (?) is larger than the coefficient of friction (μ) the slope should fail, because SF < 1. To simplify this relation even further, the coefficient of friction of some slope material is sometimes converted to an angular representation by defining the angle of internal friction (φ) μ = tan φ Using this definition and replacing it in the simplified formulation of SF gives SF = tan φ / tan θ You can thus see that if the angle of internal friction (φ) exceeds the angle of the slope (θ), then the slope should fail. Use this simplification and the results from the other questions to estimate the angle of internal friction–the angle at which failure will occur. Does ignoring the cohesive force change the result much?

Quantitative Problems

Chapter 12: River Systems

Sediment Load

One of the fundamental characteristics of a river system is the amount of sediment that it is carrying. It is easy to think that a river is just moving water. A quick calculation will help you visualize just how much sediment a river may carry.

A river 30 m wide, 8 m deep, and flowing at 4 m/s empties into a reservoir behind a large dam. Careful sampling of the river as it enters the reservoir shows that it carries an average sediment load (suspended and bed load) of 3 g per kilogram of water (0.3%). Naturally, the sediment load varies with the seasons and an annual average helps to account for this variation. Where the river exits the floodgates in the dam there is essentially no sediment load.

1: How many metric tons (1,000 kg) of sediment are deposited in the reservoir in one day? In one year? [Hint]

Quantitative Problems

Chapter 13: Groundwater Systems

Darcy’s Law and the Flow of Groundwater

The flow of groundwater through an aquifer is important in many practical applications, including the maintenance of safe municipal water supplies, disposal of liquid wastes, contamination of aquifers from surface waters, to name only a few. A few simple equations can be used to help you better understand the flow of groundwater.

Consider an aquifer with an inclined water table that is tapped by two wells separated by a horizontal distance (l) of 2 km. There is a difference in the height (h) of the water table found in the two wells of about 100 m. Water will tend to flow down the slope in the water table from one well to the next. The rate at which it will flow will depend not only on the slope (h/l = hydraulic gradient) but also on the ability of the aquifer to transmit water. If it is highly permeable with many interconnected pores the water will flow readily, if not the water flows slowly. This property is called the hydraulic conductivity (k). Laboratory experiments with different types of sands have shown a simple relationship between these parameters. Historically, Darcy’s Law has been formulated as follows and is commonly used to describe the rate of groundwater flow.

v = k (h/l) where v = velocity of groundwater flow in m/s

k = hydraulic conductivity or coefficient of permeability in m/s

h = vertical drop of the water table in m

l = horizontal distance in m

Written in this way, different fluids, as a consequence of their different viscosities, have different hydraulic conductivities. Thus, different values would be used for k if you were considering water and petroleum flowing through the same rocks.

1: Calculate the rate of groundwater flow through the sloping aquifer described above. Find the Darcy speed for the six different types of materials listed below.

2: How do these velocities compare with the velocity of overland stream flow?

3: Do you think the flow will be turbulent?

4: How long (years) would it take for contaminated water injected into the up gradient well to reach the second (down gradient) well? Make an estimate for each material.

Quantitative Problems

Chapter 14: Glacier Systems

Turbulent and Laminar Flow of Fluids

Obviously the flow of glacial ice is very different from that of liquid water. The characteristics of flow govern how the glacier will reshape the landscape as it erodes and transports sediment. For example, almost all rivers flow turbulently, rather than with smooth steady streamlines of laminar flow. In laminar flow, the planes of flow are nearly parallel to one another and nearly parallel to the surface the fluid flows over. In turbulent flow, the flow paths are torturous, sinuous, and bear no simple relationship to the solid surface of the bed. Turbulent flows will erode and transport sediment in suspension and cause saltation to occur. Laminar flows will not cause saltation.

One way to tell if a certain flow is laminar or turbulent is to calculate a dimensionless ratio called the Reynolds Number (Re). It is defined as follows:

Re = Rvρ/ η where R = hydraulic radius or layer thickness (cm)

v = velocity of the moving fluid (cm/s)

ρ = density of the fluid (g/cm3)

η = viscosity of the fluid (g cm-1 s-1)

The factors on the top of the ratio favor turbulence whereas viscosity tends to dampen turbulence. Experiments in the laboratory with different fluids, tells us that if the Reynolds number exceeds a value of 1000 to 2000, fluid flow is turbulent.

1: Given the following information for ice, liquid water, air, and a rhyolite lava, calculate the Reynolds number for each flow and determine whether or not the flow is likely to be turbulent. Use the condition that Re>1000 as the threshold for turbulent flow.

2: Do the predictions from your calculations agree with what you see in the real world? Explain.

Quantitative Problems

Chapter 15: Shoreline Systems

Wave Velocities

The velocity at which a wave (the energy and not the particles in the medium) moves is related to the depth of the water and the wavelength. Experiments have shown that

v2 = (gL/2π) tanh (2πd/L)

where v = velocity of the wave crest (m/s)

g = acceleration of gravity (9.8 m/s2)

L = wavelength (m)

d = depth of water (m)

tanh = hyperbolic trigonometric function

1: Estimate the velocity of a wave along a straight stretch of shoreline where the wavelength is 30 m and the depth of the water is 5 m.

2: Using a constant wavelength of 30 m, construct a graph showing the calculated wave velocity (x-axis) versus depth (y-axis). Do the calculations over the range 0.1 m to 50 m depth. What is the effect of depth on the wave velocity?

3: Estimate the depth of the sea floor along a straight stretch of shoreline where the wave velocity is 8 m/s and the wavelength is 30 m. [Hint]

4: How does this quantitative relationship help explain wave refraction? [Hint]

Quantitative Problems

Chapter 16: Eolian Systems

Flow of Wind and Transport of Sand

The principles that govern the transport of sediment by the wind are essentially the same as those for running water. However, the viscosity (1.8 x 10-4 g cm-1 s-1 at 20 degrees C) and density of air (1.35 x 10-3 g/cm3)are vastly different than those of water. In addition, wind velocities are commonly higher than stream velocities. Therefore, the onset of turbulence (described by Re > 1000) and the Stokes settling velocities of particles are very different for windblown particles than for clasts carried by a stream.

1: A strong wind is blowing with a steady velocity of 50 km/h. Will the wind flow be turbulent or smooth and laminar at this velocity? Assume a thickness of the flowing layer of only 2 cm–this is where most sand transport occurs in eolian systems.

The Reynolds Number (Re) is defined as

Re = Rvρ/ η

where R = hydraulic radius or layer thickness (cm)

v = velocity of the moving fluid (cm/s)

ρ = density of the fluid (g/cm3)

η = viscosity of the fluid (g cm-1 s-1)

Experiments in the laboratory with different fluids, tells us that if this dimensionless ratio exceeds a value of about 1000, fluid flow will be turbulent.

2: Use Stokes Law to calculate the settling velocity of medium sand (diameter 0.3 mm) made of quartz (density = 2.7 g/cm3) through still air. [Hint]

3: How does this compare with the settling velocity of a quartz grain of the same size in water? Why?

4: To be transported in suspension, a particle’s settling velocity must be less than that of the upward velocity component of the turbulent fluid carrying it. Will this sand grain be suspended in the wind described above, if the upward velocity is 1/5 that of the forward velocity?

5: Given this result, describe how this sand grain behaves in this steady wind.