

Name: _____

Student number: _____

University of Ottawa
Department of Earth Sciences

GEO 1111
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EXAM 2

March 2th, 2016

2:30 to 3:50 pm

INSTRUCTIONS

1. **No cellphones or calculators** or other electronic devices allowed.
2. Please turn off cellphones, laptops, tablets, etc. and store them out of sight.
3. Please write your name on all pages of the exam.
3. Answer Part 1 using the Scantron sheet. Answer Part 2 on the exam, in the spaces provided.
4. On the **Scantron sheet**,
 - write the **colour** of your exam (green, blue, yellow or white) in the top right corner,
 - write your **name** in the top right corner, and
 - write your **name (again)** by shading in the **bubbles**.

PART 1. Multiple choice questions (15 points)

Each question in this section has one correct answer. Please mark it on the scantron sheet.

1. Which arrives second during an **earthquake**?
 - a) P-waves
 - b) S-waves**
 - c) Surface waves
 - d) None of the above

2. Which cause most **damage** during an earthquake?
 - a) P-waves
 - b) S-waves
 - c) Surface waves**
 - d) None of the above

3. What is required to locate the **epicenter** of an earthquake?
 - a) The P-S interval
 - b) The P-S interval measured at two locations
 - c) The P-S interval measured at three locations**
 - d) None of the above

4. The **P-wave shadow zone** is generated by
 - a) attenuation of the P-waves by the solid inner core.
 - b) attenuation of the P-waves by the liquid outer core.
 - c) refraction of the P-waves as they pass through the core.**
 - d) reflection of the P-waves off the inner core.

5. Weak, **late P-waves** in the P-wave shadow zone are likely generated by
 - a) attenuation of the P-waves by the solid inner core.
 - b) attenuation of the P-waves by the liquid outer core.
 - c) refraction of the P-waves by the core.
 - d) reflection of the P-waves off the inner core.**

6. The **Moho discontinuity** demarcates
 - a) the core–mantle boundary.
 - b) the base of the crust.**
 - c) the base of the lithosphere.
 - d) the boundary between the inner and outer core.

7. Which mineral will likely **weather** most rapidly?
 - a) Quartz
 - b) K feldspar
 - c) Olivine**
 - d) They will all weather at the same rate.

8. The relatively low **competence** of flowing water can cause
- sediment sorting in rivers.
 - downstream fining in rivers.
 - rivers to deliver more mud to the ocean than gravel.
 - All of the above**
9. **Coal** and **evaporites** are
- paleoclimate indicators.
 - less abundant than siliciclastic and carbonate rocks.
 - generally not composed of clastic particles.
 - All of the above**
10. The three main types of **siliciclastic rock** are
- mud, sand and gravel.
 - mudstone, sandstone and gravelstone.
 - claystone, sandstone and gravelstone.
 - mudstone, sandstone and conglomerate.**
11. Generation of a **metamorphic rock** typically involves
- chemical alteration.
 - solid-state recrystallization.
 - changes in mineralogy and texture.
 - All of the above**
12. **Metallic mineral deposits** are
- often associated with magma that forms igneous rock.**
 - destroyed during cooling and crystallization of the magma.
 - only observed in metamorphic rocks.
 - most abundant in sedimentary rocks.
13. **Diamonds** are formed
- in ultramafic rocks.**
 - in conglomerates.
 - in sedimentary rocks.
 - in metamorphic rocks.
14. **Placer gold** deposits are formed
- by volcanic activity.
 - when gold is concentrated by flowing water.**
 - by metamorphism.
 - in the earth's mantle.
15. **Hydrothermal ore** deposits
- are associated with igneous activity.
 - are deposited as sulphide minerals.
 - are precipitates of metals that were originally dissolved in sea water.
 - A, B and C are correct.**

PART 2. Short-answer questions (25 points)

Answer the questions below in the spaces provided.

1. What two things are needed to determine the magnitude of an earthquake on the **Richter scale**? (2 points)

From Lecture 8, slide 10

“**Two things** on a seismometer printout are used to determine the magnitude of an earthquake on the Richter scale: (1) the amplitude of largest seismic wave (**maximum amplitude**) recorded, and (2) the distance of the seismometer to the epicenter (determined from **P-S time interval**).”

2. Explain why the **speed** of seismic waves increases with depth in the solid Earth. (1 point)

Answer: Because **rigidity** increases with depth.

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From Lecture 8, slide 15

“The deeper a seismic wave travels through the solid Earth, the faster it travels. Why? Because seismic velocity increases with the rigidity of a solid, and rigidity increases with depth (pressure). **Rigidity** is a measure of how difficult a solid is to shear (see **shear modulus (μ)**, below) and how difficult it is to compress (see **bulk modulus (K)**, below.) S-waves travel faster through solids with higher shear moduli, whereas P-waves travel faster through solids with higher bulk moduli and shear moduli (see equations below). By contrast, increases in **density** reduce seismic velocity of both P- and S-waves. Because density increases with depth in the Earth, rigidity must therefore also increase, and it must do so at a faster rate.”

$$P\text{-wave velocity} \propto K, \mu, 1/\rho$$

$$S\text{-wave velocity} \propto \mu, 1/\rho$$

K = bulk modulus = compressive force/deformation \rightarrow a measure of how hard a solid is to compress

μ = shear modulus = shear stress/deformation \rightarrow a measure of how hard a solid is to shear

ρ = density

3. P-waves travel through the center of the Earth, whereas **S-waves** do not. Why? (2 points)

Answer

- Award 1.5 points for something like “Because the outer core is **liquid**.”
- Award the additional 0.5 point if the student provides details, something akin to “P-waves travel through liquids because liquids rebound elastically to compression. By contrast, S-waves cannot travel through liquids because liquids do not rebound elastically when sheared; rather, they deform permanently.”

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From Lecture 8, slide 21

“Remember, compressional waves like P-waves and sound waves travel through fluids because fluids rebound elastically to compression. By contrast, shear waves like **S-waves** are not

transmitted by fluids because fluids deform permanently when sheared, the shear being dissipated as turbulence and, ultimately, heat.”

4. What three factors promote **mantle convection** ? (3 points) (Hint: All three are in the numerator of the Rayleigh number.)

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From Lecture 9, slide 12

“Studies of thermal convection in the lab (by Lord Rayleigh, among others) have established a parameter, the **Rayleigh number (R_A)**, that indicates whether or not convection will occur in a fluid that is being heated from below. Convection occurs when $R_A > 2000$.

Numerator = Variables that promote convection

Denominator = Variables that hinder convection

$$R_A = [\alpha \Delta T g h^3] / [\eta \kappa]$$

where

α = coefficient of thermal expansion

ΔT = temperature contrast between top and bottom

g = gravitational acceleration

h = thickness

η = viscosity

κ = thermal conductivity

*a measure of how much an object expands with increasing temperature

**a measure of how quickly heat diffuses through a material

When approximate values for these variables are plugged in for the mantle, R_A comes out to somewhere close to 1 million! The mantle must therefore be convecting.

In short, despite its high viscosity (which hinders flow, and thus convection), the mantle must convect because (1) it is very thick (large h ...harder for heat to diffuse away...helps maintain that requisite density imbalance), (2) it is very poor at conducting heat (low κ ...helps maintain that requisite density imbalance), and (3) the temperature contrast between its bottom and top (ΔT) is substantial (again, which helps maintain the requisite density imbalance).”

5. Discuss the **processes** by which magma is generated at spreading ridges, volcanic island arcs¹, and continental arcs², and explain how this affects **magma composition** at these three locations (6 points)

¹ Oceanic–oceanic convergent plate boundaries

² Oceanic–continental convergent plate boundaries

Answer

- Spreading ridges (2 points) → Award 1.5/2 if students mention decompression melting, and award them the remaining 0.5 if they mention partial melting and explain why mafic melts are generated there (see below).
- Volcanic island arcs (2 points) → Award students 1.5/2 if they mention flux melting, and award them the remaining 0.5 if they mention partial melting and explain why mafic to intermediate melts are generated there (see below).
- Continental island arcs (2 points) → Award students 1.5/2 if they mention flux melting, and award them the remaining 0.5 if they mention partial melting and explain why mafic to felsic melts are generated there (see below).

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From Lecture 11, slides 33 to 35

“A) Mid-oceanic ridges

Decompression causes partial melting of mantle (decompression melting); little fractionation (short time in magma chamber); mafic magma produced as a result”

B) Volcanic island arc

Volatiles lower the melting T of mantle, causing it to partially melt (flux melting); more fractionation than (A) (longer time in magma chamber); mafic to intermediate magma produced as a result

C) Continental arc

Volatiles lower the melting T of mantle, causing it to partially melt (flux melting); fractionation can be significant (long time in magma chamber due to thick continental crust); also, contamination with continental crust possible; mafic to felsic magmas produced as a result”

6. What is **viscosity**, why does it differ between mafic and felsic magmas, and how does this impact the intensity of eruptions in mafic versus felsic volcanic systems? (6 points)

Answer

- Viscosity is a measure of the resistance of a fluid to flow (i.e., resistance of a fluid to shearing) (2 points)
- Mafic magmas are less viscous than felsic magmas because they have (1) lower silica contents and (2) generally higher temperatures. (2 points)
- Because of the lower viscosity of their magmas, mafic systems produce volcanoes that are less eruptive than felsic systems. (2 points)

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Lecture 11, slides 27 to 30

“Mafic and felsic magmas have very different physical properties. The **viscosity** (resistance to flow) of a magma is a function of temperature, silica content and volatile content.

↑ temperature → ↓ viscosity

↑ silica content → ↑ viscosity

↑ volatiles → ↓ viscosity

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Because of this, mafic and felsic magmas erupt very differently, and generate different types of volcanoes...

...MAFIC *Less explosive eruptions* INTERMEDIATE/FELSIC *Explosive eruptions*"

7. (a) Describe the 3 key steps in mineral deposit formation (3 points). (b) Give two examples of types of ore deposits that follow this formation model (2 points).

- (a) 1. Source of the metal or element of interest. 2. A mechanism to transport the element.
3. A mechanism to trap and concentrate the element to much higher concentrations than in the surrounding rock.
- (b) Examples 1. magmatic fluids in an intruding pluton. 2. Hydrothermal fluids. 3. Gravitational settling to form placer deposits (lots of other examples too)