Earth Sciences 083F **<u>Plate Tectonics Exercises</u>**

Plate tectonics is a model for the dynamic behaviour of Earth's lithosphere. Outlining stable areas of lithosphere are narrow zones (plate boundaries) in which most of the world's earthquakes occur. Earthquakes occur as the result of movement in response to stress, both in the crust and the mantle of the earth.

Three kinds of movement account for earthquakes in the crust: compression, which results in rocks being faulted above or below other rocks along a plane and increases the thickness of the lithosphere; tension which results in thinning of the lithosphere and exposure of rocks that had been under a fault plane; and horizontal movement of plates past each other along nearly vertical fault planes.

Rocks of the crust reflect where they were formed and the processes by which they were formed. Another way of looking at this is that rock-forming processes occur in association with particular tectonic environments.

<u>Igneous Rocks</u>

Igneous rocks are formed by crystallisation from magma as it cools. Rock of this class that are composed of mineral grains that are entirely visible finished cooling within the crust. Other rocks (both those containing minerals that are too small to see with the naked eye and those that combine visible and invisible grains) are formed at or on the earth's surface. The phaneritic, felsic igneous rock ***granite*** is commonly formed in association with subduction zones where increased thickness and high temperatures cause partial melting of the deformed materials (via hydration melting). It is recognised by the dominance of light-coloured minerals such as quartz, orthoclase, and sodium-rich plagioclase, with smaller amounts of dark coloured minerals such as amphibole and biotite. All of the grains are visible to the naked eye. The aphanitic, mafic igneous rock ***basalt*** is associated with rifting of oceanic lithosphere (i.e. sea-floor spreading) and extrusion of molten rock sourced from the mantle. The smallest grains are too fine to see with the naked eye. The tone is dark. The rock generally has an earthy appearance and is opaque. Bubbles or "vesicles" are usually round or oval shaped in this rock.

<u>Sedimentary Rocks</u>

Sedimentary rocks are mostly formed at the earth's surface due to the precipitation and deposition of dissolved minerals in seawater (i.e. chemical sedimentary rocks such as salt) or fragments of pre-existing rock/mineral grains carried by water, wind or ice. Those rocks composed of fragments (i.e. clastic sedimentary rocks), are found in areas where rivers, glaciers and wind have been able to transport these bits from high ground to the lower elevations at which deposition occurs. This mostly occurs on and adjacent to continental land masses where they form "**clastic sedimentary wedges.**" **Conglomerate** is a clastic sedimentary rock composed of rounded pebble-sized and sand-sized grain. It is deposited in rivers and beach environments. **Sandstone** is a clastic sedimentary rock composed of sand and silt-sized grains. It can be deposited in a desert, river, beach, or nearshore environment. **Shale** is a clastic sedimentary rock composed of clay-sized particles and may contain fossils. Shales represent quiet water. This usually translates into “deep and far from shore”.

Biogenic sedimentary rocks are those formed by remains of organisms. Significant amounts of biogenic sediments mostly composed of calcium carbonate skeletal remains (e.g., seashells) can accumulate in clear-water depositional environments at the seaward edge of a clastic wedge where clastic input is low. Such an accumulation can form a broad, shelf-like feature called a “**carbonate platform.**” Reefs commonly develop on such platforms. Depending on the organisms present and the degree to which sediments are agitated by waves and currents, the biogenic sediment in carbonate platforms can range in character from lime mud to solid reef frameworks of fossiliferous limestone. For our purposes, f**ossiliferous limestone**, composed entirely (or at least to an obvious extent) of calcitic skeletal remains of once-living organisms can be considered to be indicative of a carbonate platform setting.

Metamorphic Rocks

Metamorphic rocks are formed by physical “changes in form” to earlier rocks brought about by increasd temperature and, in most cases, increased pressure. This involves the recrystallisation of pre-existing minerals, as well as the formation of new minerals from those that become unstable due to the elevated temperature or pressure. ***Contact metamorphism*** occurs due to simple heating under fairly uniform pressures (e.g. in rocks surrounding intrusive igneous bodies) whereas ***regional metamorphism*** occurs due to the heat and pressure induced by the lithospheric thickening at the edges of converging plates.

Contact metamorphism can occur anywhere that magma rises, including both convergent boundaries and divergent boundaries (rift zones); in either case, rocks formed by this process do not show foliation due to the more or less uniform application of pressure during their formation. ***Regional metamorphic rocks*** are easily identified by their foliated textures, provided that the dark-coloured platy and/or elongate mineral grains are present; if such grains are not present, as in the case of marble and quartzite, the rock may well have a **non-foliated** (**granoblastic**) texture. In other words, when platy minerals are not present, field relationships must be considered. If the granoblastic rock is interlayered with foliated rocks, it can be assumed to record is regional metamorphism.

Foliated rocks are defined by the type of foliation they possess. Recall: ***Slate*** has a slaty cleavage; ***Phyllite*** has *phyllitic* foliation; ***Schist*** has a *schistose* foliation; and ***Gneiss*** has a *gneissic* foliation and *compositional banding*.

There is a connection between metamorphic rocks and their precursors (i.e. the rocks that have undergone metamorphism). During metamorphism, the overall chemistry of the rock changes only a little, except where metasomatism (introduction or depletion of chemical elements by fluid flow) occurs. The “classic” foliated metamorphic rocks ***slate, phyllite, schist*** and ***gneiss*** commonly form from earlier shale, but can also form from intermediate to felsic volcanic rocks if the elements necessary for the formation of minerals in these particular rocks are present in the original (precursor) rock.

Plate Movement

Rates of movement in centimetres per year can be calculated for lithospheric plates by converting kilometres to centimetres and then dividing by the length of time in years.

For example: given a distance of 2,546 kilometres that has been travelled in 200,000,000 years, we can determine the rate by converting the distance into centimetres. There are 1000 metres in one kilometre and 100 centimetres in one metre. So there are 100,000 centimetres in one kilometre. The distance in our example is 2,546 km x 100,000 cm/km = 254,600,000 centimetres.

The rate of movement is simply this distance divided by the amount of time involved.. That is: 254,600,000 cm / 200,000,000 yrs. We can simplify this by deleting five of the zeros from both the top and bottom of this fraction (in other words take out a factor of 100,000 from both parts), so 254,6~~00,000~~ cm / 200,0~~00,000~~ yrs = 2546 cm / 2000 yr. So we finally arrive at a rate of movement of 2,546 cm / 2,000 yr, which reduces to 1.273 centimetres per year.

ES083f Exercises **Name ________________________**

Student #_____________________

The west coast of sub-Saharan Africa was formed due to rifting 160 million years ago. The city of Londji, in Cameroon is now at 3^o N, 10^oE and Recife, Brazil is now at 8^oN, 35^oW. One hundred, sixty million years ago, the land under these cities was on opposite sides of a rift that was only a few kilometres wide.

1) If the Atlantic Ocean opened up to a distance of 5,005 km during 160,000,000 years, what is the average rate of spreading in centimetres per year (show your calculations as in the example above: (3)

Calculations:

Final answer (in centimetres) to 3 decimal places: __________________________

To the left of room 123 in Biological and Geological Sciences Building is a case containing the four-stage diagram that accompanies this page. You will also find a set of rocks which you will be expected to identify.

2) On figure 1, mark "**A**" where basalt might form from magma. (1)
3) On figure 2, mark "**B**" in two places where conglomerate would be deposited. (2)
4) On figure 2, mark "**C**" where shale would be deposited (1)
5) On figure 2, using a pencil or pen, **shade in the area** where regional metamorphism would be expected to occur. (1)
6) On figure 2, mark "**D** where granite would be formed. (1)
7) On figure 3, mark "**E** where schist would be formed (1)
9) On figure 4, mark "**F** where limestone would be deposited. (1)

Optional exercise: Match the rock types mentioned in questions 2 – 4 and 6 -9 with the specimens shown in the case. You will not be graded on this identification, but you are encouraged to remember what these rocks look like for future discussions in class.

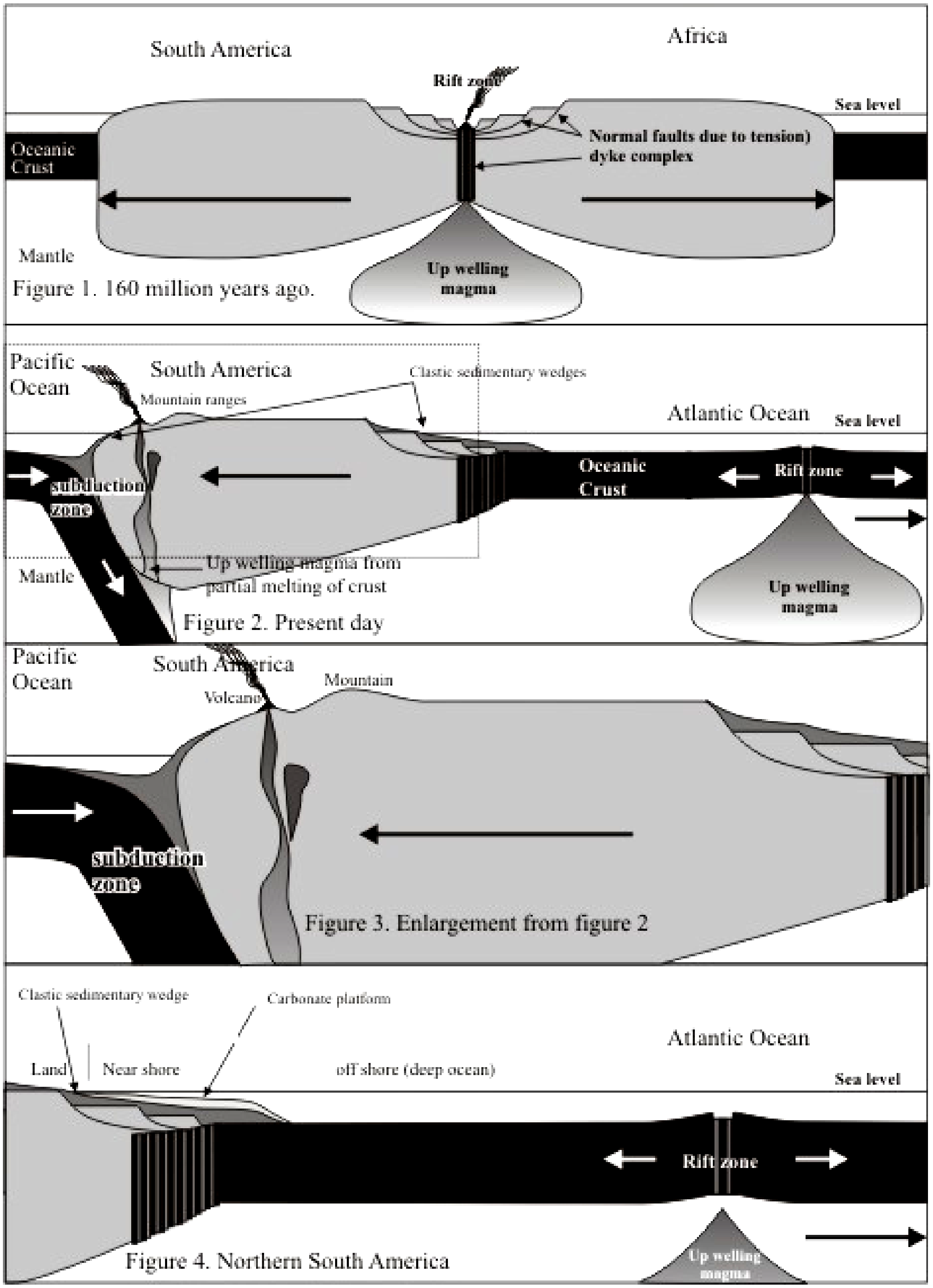
10) Fossil coral reefs about 350 million years and older can be found in the Rocky Mountains of Alberta. Answer the following two questions in the space provided:

a) What does this say about the climate (in terms of temperature) and former latitude of Alberta (relative to the north pole) 350 million years ago ? (2)

b) How can the model of plate tectonics account for the occurrence of ancient reefs (which must have formed in the sea) high up in the present-day Rocky Mountains.? (2)

11) Complete the following table by providing the specimen numbers of the rock types corresponding to the names below (these are the rock types mentioned in questions 2-4 and 6-9) (6)

Rock Name	Specimen Number (*e.g. I-4, S-2, etc.*)
basalt	
conglomerate	
shale	
granite	
schist	
limestone	



Four stage diagram for questions 2 to 9. Note that the term "clastic sedimentary wedge" refers to where clastic sediments (gravel, sand, silt and mud) are deposited. The term "carbonate platform" applies to where calcite (and/or) dolomite are deposited in abundance.