GES1004 Biophysical Environment of Singapore

Part 0 Introduction

1. There are 5 main components of the biophysical environment. Namely, they are the **lithosphere**, the **hydrosphere**, the **atmosphere**, the **biosphere**, and the **anthrosphere**.

2. To study the biophysical environment, we need to learn geology, geography, topography, biological sciences, environmental sciences, and social sciences.

Part 1 Rocks and Plate Tectonics

1. There are mainly 3 types of rocks on the earth, **igneous** (**intrusive** and **extrusive**), **sedimentary** and **metamorphic**.

2. Internal structure of earth: **atmosphere** (exosphere, thermosphere, mesosphere, stratosphere and troposphere), **crust** (oceanic crust and continental crust), **mantle** (upper mantle and mantle), and **core** (outer core - liquid and inner core - solid).

3. The boundary surface between crust and upper mantle is called **Mohorovicic discontinuity**. Crust forms the lithosphere (100km) of the earth, while the upper mantle is considered to be the asthenosphere (250km) of the earth (low-velocity zone). The boundary surface between mantle and core is called **Gutenberg discontinuity**.

4. Structural components of the lithosphere: African Plate, Austral-Indian Plate, Eurasian Plate, Pacific Plate, Nazca Plate, South American Plate.

5. Evidence for Continental Drift (Alfred Wegener): continental fit, rock sequences, mountain ranges, glacial deposits and striations, fossil existence, palaeomagnetism & Curie point. Due to so many geologic evidences, a unifying theory called **Plate Tectonics** have been developed based on **Continental Drift**.

6. There are 3 types of plate boundaries. Namely, they are **divergent**, **convergent** and **transform**. Thus, dipping earthquake zone, Benioff zone and subduction zone always come together. For instance, the average rate of motion is 0-20cm/year. Singapore is moving about *3.5cm/year to the east*.

1) Divergent boundary: **rift valley**, **narrow sea**, **coastal mountain** range and crests of **oceanic ridge**s;

2) Convergent boundary: 3 types, oceanic-oceanic boundary (one plate will subduct and form a **volcanic arc**, the other one will form an **oceanic trench** and **volcano**es), oceanic-continental boundary (the oceanic plate will subduct, the continental plate will form an **oceanic trench** and **volcano**es) and continental-continental boundary (neither will subduct and they will form an **interior mountain chain**);

3) Transform boundary: Change the type of motions between plates, will form large **faults**.

7. Driving mechanism of Plate Tectonics: (major) convective heat system, (minor) gravity-driven system (slab-pull + ridge-push).

Part 2 Geology & Formation of Rocks and Minerals

0. The geology of Singapore should study along with the geology of Peninsular Malaysia and that of Johor Batholith, to help us get a big picture of its history and formation.

1. Stratigraphic belts of Peninsular Malaysia: **Eastern Belt** (270-250 Ma, Andean-type granite – subduction, hornblende, biotite), **Central Belt** (250-230 Ma), and **Western Belt** (220-200 Ma, Himalayan-type granite – collision, muscovite). The boundary of central belt and eastern belt is the

result of oceanic-continental convergent motion, while that of central belt and western belt is the result of continental-continental convergent motion. B-R suture zone is the remaining part of a mid-oceanic ridge.

2. Distribution of rocks in Singapore: **gabbro** (central, small area), **granite** (central, large area), **Jurong formation** (west part), **old alluvium** (east part), **recent alluvium & land-fill** (surrounding area).

3. There used to be high mountains and volcanoes in Singapore. However, they are hard to be seen now due to erosion. Sentosa used to be a lake. The erosion process helps the Jurong formation and old alluvium.

4. Rocks & minerals: minerals have definite chemical composition and only contain inorganic substance; rocks do not have specific chemical composition and may also contain organics.

1) Minerals: **quartz**, **muscovite**, **pyrite**, **K-feldspar**, **silver**, etc.

2) Rocks: igneous (**granite** – Andean-type biotite and Himalayan-type muscovite, **gabbro** – white plagioclase and black pyroxene, **Andesite lava** – plagioclase, quartz and hornblende, and **Rhyolite lava**), sedimentary (**conglomerate**, breccia, **sandstone**, siltstone, **mudstone** and **claystone**), and metamorphic.

5. Usages of rocks: granite (crushed for concrete aggregate, polished for facing stone), gabbro (polished for floor stone), lava (used in construction of roads and buildings), sandstone (esplanade facing stone).

6. The color of flood water indicates the particles inside. White milky water means **kaolinite** clay particles, while red/brown milky water means **limonite**, **hematite** and **gibbsite** clay particles.

Part 3 Climate & Weather in Singapore

1. Climate & Weather: **climate** is the average and variations of weathering conditions prevailing in an area in a very long period (as long as 30 years); **weather** is the state of atmosphere at a particular place and time, including temperature, pressure, wind, humidity and rain. For instance, Singapore is classifies as **tropical rainforest climate** (1.5°N, no distinguishable seasons).

2. Pressure zone: **inter-tropical convergence zone** (ITCZ), **subtropical high pressure** zone, **subpolar low pressure** zone and **polar high pressure** zone.

3. Wind zone: **trades** zone (northeast for Northern Hemisphere and southeast for Southern Hemisphere), **westerlies** zone and **polar** zone (eastern).

4. The "seasonal" change of climate in Singapore is controlled by the movement of ITCZ. From December to March, ITCZ moves to the north and brings **northeasterly monsoon** due to Siberia high pressure; from June to September, ITCZ moves to the south and brings **southwesterly monsoon** due to oceanic high pressure. In addition, the inter-monsoons also affect the climate. The result is: Singapore is the **wettest in December** and is **hazy during August**.

5. Orographic rain: Rain cloud formation requires **moist air** and a **lifting process**. The latter can be obtained by condensation, turbulence, mass ascent (convection) and orographic ascent. Due to high hills like Bukit Timah, there is **more rain in the center and north** of Singapore.

6. Atmospheric irregularity: **La Nina** years (cooler and wetter) and **El Nino** years (warmer and drier).

7. Urban irregularity: **head island** effect, 4.5°C difference at midnight and during the day, difference between CBD and northern part.

8. Cloud classification:

1) By cloud base: high clouds (>6km), medium clouds (2-6km) and low clouds (<2km);

2) By form and shape: **cumulus** (putty heaped, early afternoon), **stratus** (layer) and **cirrus** (feathery, early morning);

3) More types: **cumulonimbus** (late afternoon), **anvil** (late afternoon), **cirrocumulus** (mid-morning), **cirrostratus** (early morning and mid-morning), **altocumulus** (mid-morning), **altostratus**, **stratocumulus** and **nimbostratus**;

4) Result: Singapore is often *thundery and wet in the afternoons*.

9. Special weathering phenomena: **Squall**s, **gust front**s, **water spout**s, **double rainbow**s, lightnings, thunders, flash floods, etc.

Part 4 Topography and Morphology of Singapore

1. Weathering effects: **physical** (or mechanical) weathering, **chemical** weathering, and **biological** weathering.

2. Highest elevation in Singapore is 164m at Bukit Timah Hill, the average is 15m, the median is 12m.

3. Morphological units: assembly of slope elements which have more or less common character.

1) **Hills**: > 90m, made up of gabbro and granite;

2) **Hills and valleys**: found over old alluvium, *3 types* – HVs1 (steep high relief, > 30m), HVs2 (steep low relief, <30m) and HVg2 (gentle low relief, 15-24m);

3) **Ridges and valleys**: found over Jurong formation, ridges with hard sandstones and valleys with soft mudstones, *2 types* – RVs1 (steep high ridges and narrow steep valleys, > 46m) and RVs2 (steep low ridges and variable valleys, < 30m);

4) **Plains**: < 3m, *2 types* – Plain P (recent deposited at large estuaries) and Plain Pf (costal lowlands);

5) **Valleys**: distinct round or flat-bottomed valley, associated with major streams.

4. The **distribution of morphological units** is related to the geology of Singapore.

5. Dip **slope failure**s happen both in nature and artificially (re-grading, cut and fill). Remedial slopes are stabilized by vegetation, concrete piles, terracing and concrete geogrid. Notice that hard sandstone ridges have the steepest slopes. Slope failure often happens after a wetter NE monsoon.

6. Ground composition: **bedrock** (the unaltered rock below the regolith), **regolith** (the loose un-consolidated rock) and **soil** (the loose surface layer of earth that supports the growth of vegetation).

7. Soil profile & horizons: **soil profile** is the sequence of layers of soils in a vertical cross section through the soil; **horizon**s are the distinctive layers of soils.

8. Typical soil profile: **O** (fresh to partly decomposed organic matters), **A** (dark-colored mineral soil with humus), **E** (lighter-colored zone of leaching of clay, iron and aluminum), **B** (zone of accumulation of clay, iron and aluminum) and **C** (relatively un-weathered unconsolidated minerals).

9. Soil composition: **solid** (inorganic and organic materials), **liquid** (soil solution) and **gas** (atmospheric gases and those liberated by biological activities and chemical reactions).

10. Soil properties: **physical properties** (color, bulk density, texture, structure and compaction), **chemical properties** (nutrients, cation exchange capacity, colloid and pH) and **biological properties**.

11. Soil classification: gelisols, **histosols**, spodosols, andisols, **oxisols** (on old alluvium), vertisols, aridisols, **ultisols** (on Bukit Timah granite and Gombak Gabbro), mollisols, alfisols, **inceptisols** (on Jurong Formation & sandstone ridges), and **entisols** (on Pulau Tekong landfill).

12. Role of soil: vegetation growth, horticulture, catchment protection, reclaimed land, slope protection.

13. Characteristics of soils in Singapore: **mainly from quartz and very little feldspar**, mostly **sand/clay-sized** particles, aggregated with igneous rocks, quite **high water permeability**, oxidized and acidic soil, low cation exchange capacity, **poor nutrient** and bad fertility.

14. Soil erosion & urbanization stages in Singapore: initial **undisturbed forest** (soil erosion in natural reserves), intermediate stage of **urban construction** (soil erosion in construction sites) and **fully urbanized region** (soil erosion in urban areas).

15. The combined effects of soil erosion, soil creep and a Sumatran Squall will promote slope failures.

16. Reducing soil erosion: proper urban design (minimal modification), management of engineered landscape (vegetation, geogrids and pearl grass), and people's awareness.

Part 5 Climate Change & Sea Level

1. Evidence for past climate systems: early human records, **geomorphology**, geological records (fossils), and **ice core**s.

2. Climate change: the variation of the earth's **global or regional climate**s over time, i.e., changes in the variability or average state of the atmosphere over decades to millions of years.

3. Causes of ice ages: **plate tectonics**, orbital parameters – Milankovitch cycles (**eccentricity**, **axial tilt** and **precession**) – change of insolation.

4. Global warming: In the past 1000 years, showing a "**hockey stick**" rise; in the past 150 years, a two-step increase of 0.8°C; since 1999, no apparent increase (El Nino and La Nina years, volcanic eruptions).

5. Temperature & Greenhouse gases: sometimes **temperature rises before CO_2 rises**.

1) If CO_2 level doubles, the direct effect is the temperature increase of 1.1°C. However, people debate about the **feedback** effect of CO_2 level and evaporation. The majority believe in amplification, thus the observed temperature increase is 3.3°C; however, the minority believe in dampening, which is 0.55°C;

2) **Iris effect**: more evaporation, more water vapor, more cloud, more reflection, climate cooling;

3) Based on no changes in emission, Singapore will be **3°C hotter** in next 100 years.

6. History of sea level changing: 2.58-0.78 Ma, -40m, **old alluvium** deposited; 2-1 Ma, **braided river** channels; 1 Ma, -40m, rivers feeding into **Lake Temasek**; 135,000 years, -130m, last 2nd glacial maximum, Singapore is 300km away from the sea; 125,000 years, +5m, last 2nd interglacial, **Pulau Tekong** formation and mangrove; 50,000 years, -50m, human arrived in Australia; <8500 years, -35m, **recent alluvium** & **Kallang formation**; since 1880, global sea level rises at **3mm/year**.

7. Cause of sea level rise: **thermal expansion** (30%), glacier melting (30%) and ice sheet melting (25%).

8. Sea level in the future:

1) Sea level at Singapore is rising at **7mm/year**. Projection: **24-65mm and 2.7-4.2°C** in 100 years;

2) Potential effects: increased flooding, coastal land loss, water resource scarcity, public health danger, heat stress, increased energy demand, and impacts on biodiversity;

3) Adaption measures: in 1992, reclamation land is 125cm high; in 2011, it is 225cm high.

9. Singapore's biggest natural resource is its **biophysical environment**. Singapore owes its economic wealth to climate change and sea level rise.