105 Chapter 3 Review Notes

- The eruption of any liquid substance from beneath the surface of a planetary body, that then flows out and cools/solidifies as a layer on the surface (whether as ash, cinders, or lava flows) is considered to be *volcanism*
    - "Volcanism can be defined as the processes associated with the transfer of molten material (magma), associated volatiles and any suspended load of crystallized material, from the interior of a planetary body to its surface" (M&G – your textbook)
- Magma must first be generated, by a melting process, for volcanism to be possible. This can happen in various ways:
    - Temperature rise
        - Impact
        - Tidal heating
        - Radiogenic heating
    - Decompression (pressure-release) melting
        - Rising of mantle "plumes" (hot, more buoyant rock) to shallow depths
            - Hotspot volcanism (like Hawaii, Iceland, Yellowstone)
        - Tensional stretching and thinning of crust at divergent boundaries
            - Mid-oceanic ridge basaltic volcanism
            - East African Rift volcanoes
    - Hydration-induced (adding water) melting
        - Volcanoes along convergent plate boundaries
            - Volcanic arcs along edges of continents (Andes, Cascades, Kamchatcka)
            - Island arcs in oceans (Japan, Philippines, Lesser Antilles)
- Partial melting:
    - "The incomplete melting of a parent material that characteristically produces a melt whose chemical composition is different from that of its parent"
    - Produces *mafic* (basaltic) magma from *ultramafic* (olivine-rich) mantle rock in asthenosphere – ***<u>BASALT</u>*** **IS WHAT IS PRODUCED BY PARTIAL MELTING OF THE MANTLE OF A DIFFERENTIATED ROCKY PLANET**
    - Produces more silica-rich *intermediate* and *felsic* magmas from originally *mafic* (basaltic) melts
    - Occurs because different minerals melt at a variety of temperatures that span hundreds of °C
    - Once ~5% melting has occurred, it can rise toward lower pressure conditions at the surface of a planet
- Partial melting of peridotite (rock in Earth's mantle) or similar materials will produce a *basaltic* composition
    - Basalt differs from the original meteoritic ("chondritic") composition of the bulk Earth (and, presumably, the other inner planets) by being *enriched* in certain elements, and *depleted* in others
        - Elements that tend to resist migrating into any melt are "compatible" and will stay behind when partial melting occurs

        (e.g., they will remain in the mantle) and will be found in erupted lavas in lower than chondritic amounts
            - MgO, Fe_2O_3, Cr, Ni, Zn
        - Elements that tend to separate from the solid materials and concentrate in the melts are "incompatible" and will be found in erupted lavas in higher than chondritic amounts
            - SiO_2, Al_2O_3, CaO, Na_2O, K_2O, Ba, Ti, K, Th, Zr, U
    - The higher the proportion of partial melt (and thus, the higher the T), the more the magma will resemble the parent material that is melting
    - Small degrees of partial melting will produce magmas that are the most different from their parent materials
- Komatiites are most "primitive" (parent-like) lavas on Earth; erupted early in Earth's history when it was hotter inside
    - basalts are more "evolved"; andesites still more so, and rhyolites the most evolved (highest in SiO_2, Al_2O_3, Na_2O, K_2O)
    - Basalts are common (apparently) to all terrestrial planets where volcanism has occurred
    - Earth has retained heat longer, and has plenty of water, allowing melts to form at lower temperatures, over longer timeframes of planetary history, and to produce more evolved (less primitive) compositions
- Earth's volcanic styles:
    - Effusive
        - Calm eruption of long thin flows of fairly fluid lavas (basalts) that produce broad, gently sloping ***shield*** volcanoes (~1100-1200°C)
        - Calm eruption of shorter, thicker flows of pastier lavas (andesite) that pile up closer to the eruption site (the "vent"), and can combine with ash layers to form steep-sided ***stratocone*** ("composite cone") volcanoes (~1000°C)
        - Rare, calm eruption of glass, extremely thick and pasty ***domes*** of high-silica lavas (rhyolite and obsidian) – (as cool as 700°C)
        - Largest-volume eruptions on Earth are extremely rare *flood basalt* eruptions
    - Explosive
        - High in volatiles (gases) like water vapor, carbon dioxide, sulfur dioxide, etc.
        - Erupt violently, typically sending lots of pyroclastic materials (especially ***ash*** and ***pumice***) high into the atmosphere
        - Typical of high silica (more evolved) magmas like andesite and especially ***rhyolite***
        - The more silica and the more gas/volatiles present, the more explosive the eruption is likely to be
        - The more explosive the eruption, the smaller the pyroclastic fragments will be
            - Volcanic spatter and bombs are ~10s to 100s of cm across
            - Cinders are ~mms to 1 cm across
            - Ash is ~µms across (dust-sized)

        - Extreme differentiation over billions of years and the abundance of liquid water in and on the Earth have allowed highly evolved magmas to be formed on Earth, but perhaps nowhere else in the solar system
        - Ash columns can collapse when they cool and produce *pyroclastic flows* that spread out downslope for up to hundreds of kilometers
        - The largest of these eruptions, called *supereruptions* can drastically affect global climate, and may have contributed to extinction events during Earth's history
- Surface conditions on planets affect eruption styles and the emplacement of lava flows and pyroclastic (e.g., ash) deposits
    - Higher gravity allows lava of a given viscosity (runny vs. pasty) to flow downhill over lower slopes, with thinner flows
    - Lower atmospheric pressure will allow more explosive force due to bubble production and expansion from lavas with a given amount of volatile content
    - Absence of an atmosphere will prevent asymmetric ashfall produced by winds
    - Lower gravity will allow explosive deposits to spread out over a larger area, and will decrease the average thickness of the deposit
        - Lunar pyroclastic deposits are very thin veneers spread over large areas; on Earth, ashflows can be hundreds of meters thick near the vent areas and gradually thin with distance
    - Surface temperatures can lead to more rapid cooling (lower T's) or slower cooling (higher T's) of lava flows; Venus' surface temperature can almost halt the crystallization of the lowest temperature lavas, allowing them to flow for thousands of kilometers, as evidenced by extremely long channels (up to 6800 km long!)
- Cryovolcanism involves the eruption of low-T fluids (like water, methane, nitrogen) which can freeze into flows on cold surfaces, particularly in the outer solar system. Satellites of the gas giants, particularly at Saturn and beyond, show some evidence of this process
- Volcanic features on Earth and the other terrestrial bodies:
    - Lava flows (Earth, Moon, Venus, Mars, Io, Mercury?, Europa?, Ganymede?, Enceladus?, Triton?, Other icy moons?, Vesta?)
    - Shield volcanoes (Earth, Venus, Mars, Io)
    - Flood basalt lavas, often filling large depressions (Earth, Moon, Mars, Venus, Mercury?, Io?)
    - Pyroclastic deposits (Earth, Moon ("dark mantle craters"), Mars (probably), Io, Triton)
    - Small cones (Earth – cinder cones, Venus, Mars (probably), Io?)
    - Stratocones (Earth)
    - Volcanic domes (Earth, Venus, Moon?)
    - Caldera craters (Earth, Venus?, Mars, Io, Moon?, Triton?)