Chapter 9

29) *What is the longest-lasting source responsible for geological activity?*
b. Radioactive decay. After an atom decays, particles from the initial atom spray into the surrounding material increasing the temperature of a planetary interior. Sunlight would have to penetrate the Earth's crust to warm the interior, therefore radioactive decay is more efficient at heating Earth's surface than sunlight. The half-life for radioactive decay can be billions of years, therefore occur for a long time compared to accretion of material, which only occurs for approximately a hundred million years.

31) *Which of a planet's fundamental properties has the greatest effect on its level of volcanic and tectonic activity?*
a. size. Since radioactive decay is the longest lasting source of geologic activity, it stands to reason the more material that a planet has to decay (i.e. the more massive the planet is) the more geologically active a planet is. However, the larger the surface area (surface area $= 4\pi \mathrm{r}^2$) of planet the more efficiently the planet is able to cool. Since the mass is related to the volume ($[4/3]\pi \mathrm{r}^3$), both the cooling and heating of the planet are related to the size of the planet. Taking the ratio of cooling compared to heating or surface area to volume ($\cancel{4\pi}4^{\cancel{2}}/\cancel{4\pi}\mathrm{r}^{\cancel{3}}/3 = 3/\mathrm{r}$) one is able to see that the larger the planet the more geological activity the planet will have.

55) *In daylight, Earth's surface absorbs about 400 watts per square meter. Earth's internal radioactivity produces a total of 30 trillion watts that leak out through our planet's entire surface. Calculate the amount of heat from radioactive decay that flows outward though each square meter of Earth's surface (your answer should have units of watts per square meter). Compare quantitatively to solar heating, and comment on why internal heating drives geological activity.*
The Earth is roughly spherical, so one is able to approximate the surface area as $4\pi \mathrm{r}^2$. Assuming all of the heat created from radioactive decay is emitted from the Earth from its surface uniformly, then the amount of energy per second per square meter is the total energy produced in radio active decay divided by the surface area of Earth (30×10^{13} watts/ $4\pi \mathrm{r}^2_{\mathrm{Earth}}$). Therefore, 0.06 watts per square meter are given off through Earth's crust from radioactive decay in the core. This means the Sun's contribution to the surface temperature is 7,000 times (400./0.06) that of Earth's core. However, the surface area near the core of the Earth is much less than at the crust, therefore radioactive decay is more efficient at heating the interior than the crust. This drives convection cells and creates hot spots, which keeps the mantel molten and geological activity present on Earth.

56) *Typical motion of one plate relative to another is 1 centimeter per year. At this rate, how long would it take for two continents 3000 kilometers apart to collide? What are the global consequences of motion like this?*
Assuming the plates are moving towards each other at constant rate of 1 centimeter per second per year, then the time to collision is distance divided by rate. Converting the rate to kilometers, it would take 300 Million years for the plates to collide (i.e. 1.0 centimeter = 0.00001 kilometers or 10^{-5} kilometers, so 3000 kilometers/10^{-5} kilometers/year = 3×10^8

years = 300 Million years). This process is called continental drift. Continental drift causes the continents to rearrange their orientation with respect to each other. Therefore, the continental patterns seen on Earth's surface will change over time. In fact, there is evidence that at one time all of Earth's continents were together in one "supercontinent".

Chapter 10
33) *Which terrestrial world has the most atmosphere?*
a. Venus. The atmosphere of Venus is so thick that only radio waves are able to penetrate the clouds to observe the surface. The high reflectivity of the atmosphere of Venus (75%) is partially due to the thickness of its atmosphere.

57) *What is the total mass of Earth's atmosphere? You may use the fact that 1 bar is the pressure exerted by 10,000 kilograms pushing down on a square meter in Earth's gravity. Remember that every square meter of Earth experiences this pressure from the atmosphere above it. Alternatively you may start with the English unit value for pressure of 14.7 pounds per square inch and covert to kilograms for your final answer. Remember that the surface area of a sphere of radius r is* $4\pi r^2$.
Pressure is the force per unit area. The force due to gravity is mass multiplied by gravitational acceleration. A bar has units of 10,000 kilograms per square meter in Earth's gravity, therefore multiplying a bar by the surface area of Earth ($4\pi r^2$), which has units of square meters, the total mass of Earth's atmosphere is 5.1×10^{18}kg. Alternatively, one could multiply the 14.7 lbs per square inch by the Earth's surface area in inches then convert from pounds to kg by multiplying by 0.45. This gives an Earth atmosphere mass of 5.3×10^{18}kg.

58) *By assuming 0% and 100% reflectivity (respectively), find the maximum and minimum possible "no greenhouse" temperatures for a planet at 1 AU. What reflectivity would be necessary to keep the average temperature exactly at the freezing point? Compare to Earth's actual reflectivity in Table 10.2.*
From Mathematical Insight 10.1 the temperature of a planet with no greenhouse effect is 280K multiplied by $\left(\frac{1-reflectivity}{d^2}\right)^{\frac{1}{4}}$. Immediately, one is able to drop the $\frac{1}{d^2}$ term, since the distance to the planet is 1 AU and 1 to any power is 1. Zero and one hundred percent reflectivity means the fraction of light reflected is 0.0 and 1.0 respectively. Therefore, solving 1-reflectivity for zero and one hundred percent reflectivity is one and zero respectively. The fourth root of one is one, therefore with zero percent reflectivity the temperature of the planet is 280K. The fourth root of zero is zero, so a planet that reflects all of its sunlight will have 0K according this equation. However, the planet will not be 0K or what is called absolute zero because of internal heating and the sunlight reflecting of the atmosphere will bump the atoms giving them kinetic energy or heat.
Zero Celsius is the temperature where water freezes. The conversion from the Celsius to Kelvin temperature scale is that the Kelvin temperature is 273K plus the Celsius temperature. To find the reflectivity needed to keep a planet at one AU at the freezing temperature of water one needs to solve the above equation for reflectivity with the temperature with no greenhouse effect set to 273K (i.e. $273K = 280K[1\text{-reflectivity}]^{\frac{1}{4}}$).

Dividing both sides by 280K and taking that quantity the the fourth power gives one minus the reflectivity ($[270K/280K]^4$ = 1-reflectivity). Finally, rearranging terms reflectivity is one minus $[273K/280K]^4$ giving a reflectivity of 0.10 or 10%. This is approximately a third of the reflectivity of Earth's atmosphere (29%), so Earth should be cooler than the freezing point of water based on reflectivity alone. Fortunately, the Earth has greenhouse gases, which traps the sunlight keeping the Earth warm.