E



A

R

T

H



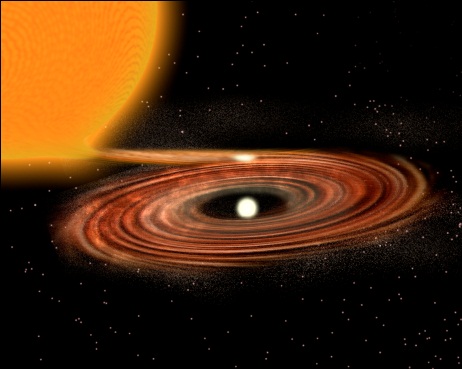
‘

S

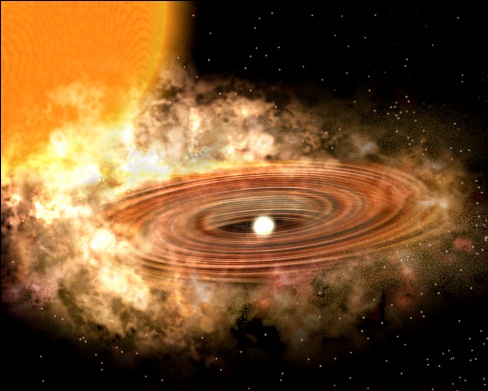
F O R M A T I O N

**Formation of the Earth**

* The sun and planets, along with satellites (moons), Asteroids, and comets, all formed from a huge mass of dust and gas called a **Nebula.**
* Under the influence of **Gravity** (force of attraction) this nebula collapsed inward. As the volume of dust and gas shrank in size, its **density** increased and the **temperature** rose proportionally.
* The sun used up most of the material of the nebula; what little remained went into making the rest of the solar system.
* If we went back in time to around 5 b/y ago (B= billion/ Y= years) and we observed our forming solar system, we would see a very big glowing star –our sun, and a large flat ring of material extending outward from the sun’s equator. From this ring of material the rest of the solar system would form (our only interest is in the formation of just one planet –earth; our discussion thus will be limited to just our planet.)
* **Accretion** is the process of growth from external sources.
* This process describes how the earth formed from a speck of dust, to a planet with a diameter of 7,927 miles: the diagrams below illustrate this process.



* **A**. As the particles are revolving around the sun in the big ring, the particles collided with other particles and stick together, thus getting bigger.
* **B.** Now the clumps of particles are somewhat bigger so that more matter is accreted with each collision.



* **C.** At this stage the growing proto- earth is now a few hundred miles in diameter, and is getting warm.



* **D.** Now the proto- earth is a few thousands of miles in diameter. The meteor bombardment is very intense, and the proto- earth is getting very hot.
* **E.** At this point the proto- earth is so hot it totally liquefied. This allows the many different materials with their different densities to seek their own level: heavy, dense materials sink to the middle, while light materials rise to the top.
* This process is called **Differentiation.**
* **F.** Toward the end of the accretion process, many large meteors slam into the planet making large basins.
* **G.** By **4.6 B/Y** the earth has finally formed a permanent hard crust which is totally covered with various size craters.



**Sources of Heat**

* As the earth was growing in size, by accretion, it was getting hotter. There were three sources of heat that played big roles at various times during the formation:

- Accretional heat

- Compressional heat

- Radioactive heat

**Accretional Heat**

* During the period of meteor bombardment, when chunks of rock are impacting on the surface at 15 m p s, besides making a huge crater, a tremendous amount of energy is transferred to the earth in the form of heat. If you multiply this by thousands of impacts each day over tens of millions of years then you may start to understand the tremendous amount of energy that was transferred to growing the earth.

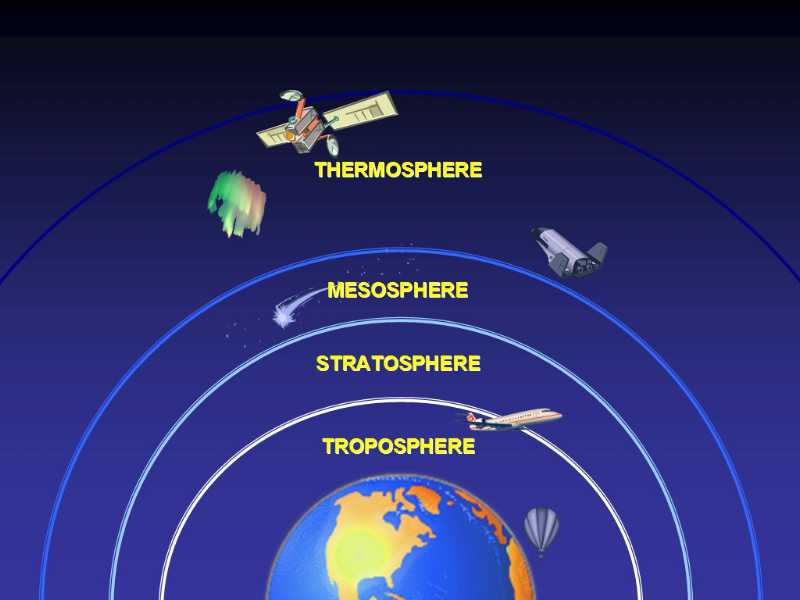
**Compressional Heat**

* As more and more material accreted to the proto- earth the weight of the overlying material pushes inwards, it makes the material denser and then raises the heat.

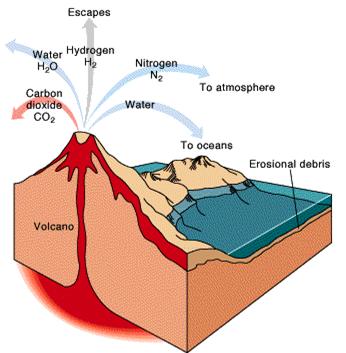
**Radioactive Heat**

* As unstable elements (isotopes) decay and become stable they generate heat within the confined area within the crust. As the isotopes give off sub-atomic particles they collide with other atoms nearby and get them moving faster- thus hotter.
* Another way of expressing heat would be atomic motion.
* The temperature of the nebula as we start the formation process is about -457\* F
* The temperature of the earth’s interior today is **11,000\* F**; it was much hotter billions of years ago.
* So as we started this process at the temperature of almost absolute zero, and we end the process with temperatures of tens of thousands of degrees.
* If we were bigger we would also be hotter.
* Our sun has a mass that is 334,000 times that of the earth, it has a core temperature of 25,000,000\* F.

**Origin of the Atmosphere**



* When the earth finally developed a hard, permanent crust, the internal heat could not now escape easily. The interior thus got hotter.
* The liquid rock that makes up the earths is made up of many different elements – each one of these elements has a different melting point.
* As the internal temperature rose, more and more elements were being forced to change their state of matter again, now into gas.
* As some of the liquid changes to gas, it becomes less dense, and it rises through the liquid trying to find places in the crust through it can escape. This process is known as **outgassing.**



* Many of the gasses coming from the earth’s interior were building- up around the planet, held there by the earth’s gravity, and becoming a permanent envelope surrounding the planet.
* The early atmosphere would be totally alien to us today; breathing it would kill you. Besides large amounts of water vapor and carbon dioxide, other gasses present were methane (CH4); ammonia (NH3); various sulfur mixes; etc.
* The early atmosphere had no free oxygen (O2). It was not until much later that oxygen would gradually accumulate as a result photosynthesis.
* Over time the atmosphere has gradually been modified by:

1. **Chemical Reactions-** Like when oxygen combined with iron to produce red colored rocks; or when CO2 combined with water to make a weak carbonic acid which in turned became part of the rock forming process.
2. **Photochemical Reactions-** When ultra-violet rays from the sun break – down such gas molecules like ammonia (NH3) in which the hydrogen escapes but the nitrogen is heavy enough to be held by the earth’s gravity.

* Today’s atmosphere is made- up of 78% nitrogen; 21% oxygen; and 1% other gases (CO2 today is less than 1%)

**Origin of the oceans**



-The origin of water that would eventually form our oceans came from two sources:

* **Rocks--** Probably about 80% of the water in the oceans today came from the rocks themselves. There is actually a large amount of water locked- up within the original rock material. This can be demonstrated by heating a meteor and observing how much water is given off.
* **Comets—**Balls of frozen water and some rock material. As the earth was accreting, comets would have been part of the material striking the proto- earth.

-The process which liberated the water was outgassing, as described previously.

-From 4.6 B/Y to 4 B/Y the earth would have been totally covered with a thick envelope of gases. The surface of the earth would have radiated lots of heat. At the top of the clouds the water vapor would have condensed into raindrops and started to fall. However, the heat from the surface would cause the drops to evaporate high up in the sky. As the earth’s surface continued to cool, the droplets would get closer to the surface. It took about 600 M/Y for the surface to cool down enough so that the water could finally reach the surface and be evaporated.

-It must have then rained for hundreds of years. When finally most of the water vapor had collected onto the surface, we got a surface that was totally aquatic--- water covered the entire surface at a depth of about 10,000 ft.

**Continental Formation**

* The continents eventually formed by a volcanic processes which involved large outpourings of liquid rock from the interior
* When you change the state of matter of something, like a rock, you will cause it to expand. In the confined space of the interior, this causes pressure which must be relieved.