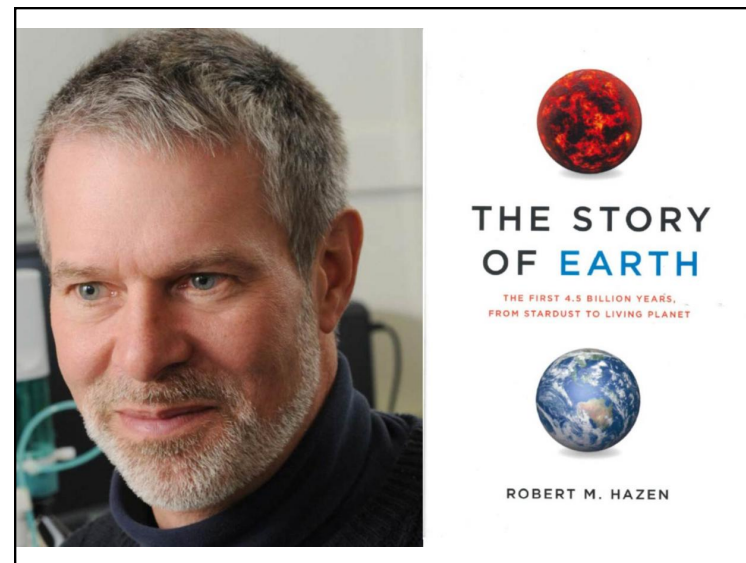


EXPLAIN

1. Origins of Earth & Atmosphere



Whoosh!

- Time and Space originated in a silent "Big Bang" 13.7 billion years ago
- Inflation, expansion, & cooling
- "Quark soup" condensed into protons, neutrons, electrons, and photons in a microsecond
- Too hot for atoms for 380,000 years!
- Combination of protons & electrons to form Hydrogen atoms released flooded the universe with gamma rays
- This is now redshifted to form the Cosmic Microwave Background

Galaxies

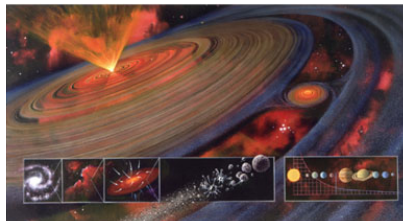
- Accretion
- Disks
- Spiral arms
- Star formation
- Dust

Stardust

- Fusion and elements
- Hydrogen to Helium ... to carbon and oxygen!
- Supernovas and a dozen “Ur-Minerals”
- Chemistry

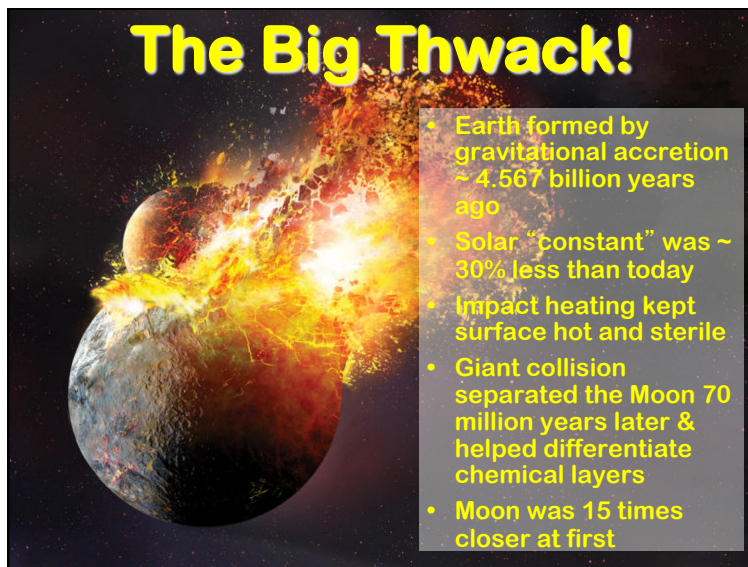


Solar System Origins

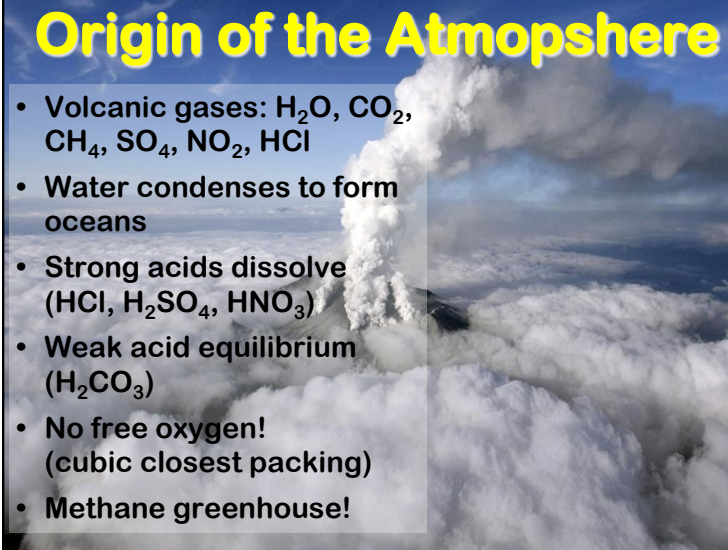
- Gravitational **collapse**
 - Self-gravitating Hydrogen
 - Swirling **dust of Ur-Minerals**
 - Volatiles: H, C, & O -> H₂O and CO₂
 - **Heating, hydration, & oxidation** of Ur-Minerals to form about 50 primordial minerals
 - Accretion, collisions, & vertical **differentiation**
 - Metallic cores, rocky mantles, organic gunk
- 

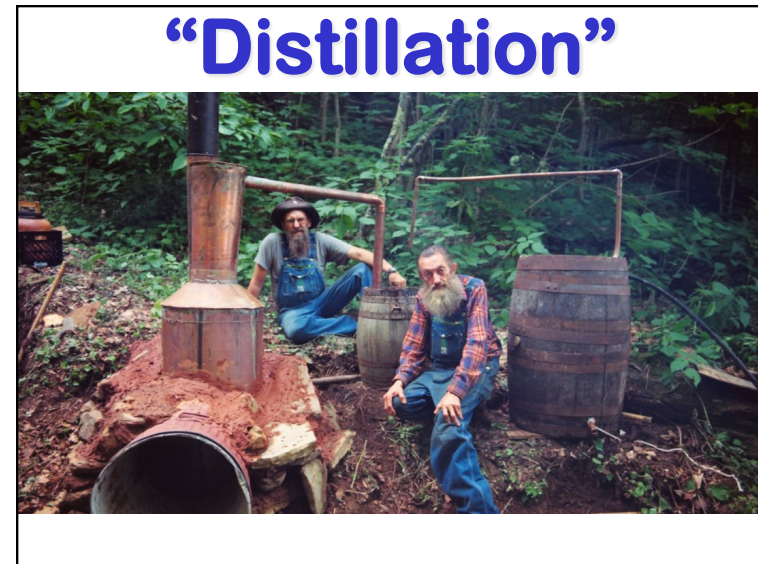
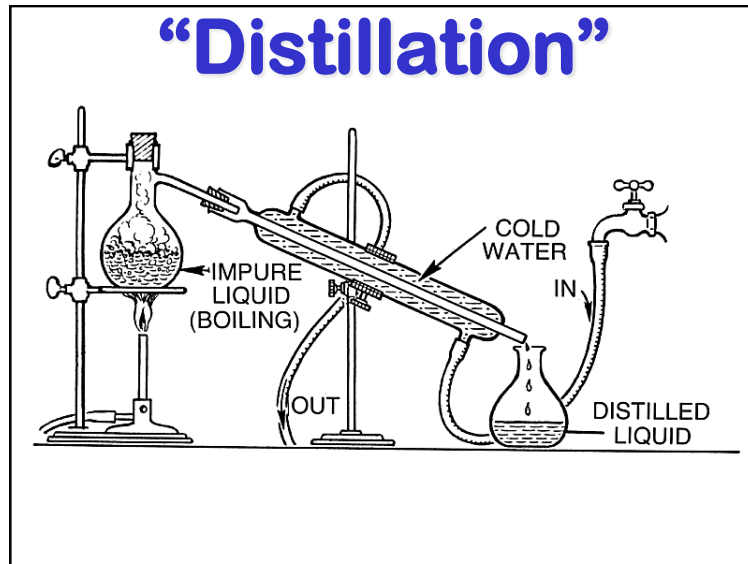
The Big Thwack!

- Earth formed by gravitational accretion ~ 4.567 billion years ago
- Solar “constant” was ~ 30% less than today
- Impact heating kept surface hot and sterile
- Giant collision separated the Moon 70 million years later & helped differentiate chemical layers
- Moon was 15 times closer at first



Origin of the Atmosphere

- Volcanic gases: H₂O, CO₂, CH₄, SO₄, NO₂, HCl
 - Water condenses to form oceans
 - Strong acids dissolve (HCl, H₂SO₄, HNO₃)
 - Weak acid equilibrium (H₂CO₃)
 - No free oxygen! (cubic closest packing)
 - Methane greenhouse!
- 



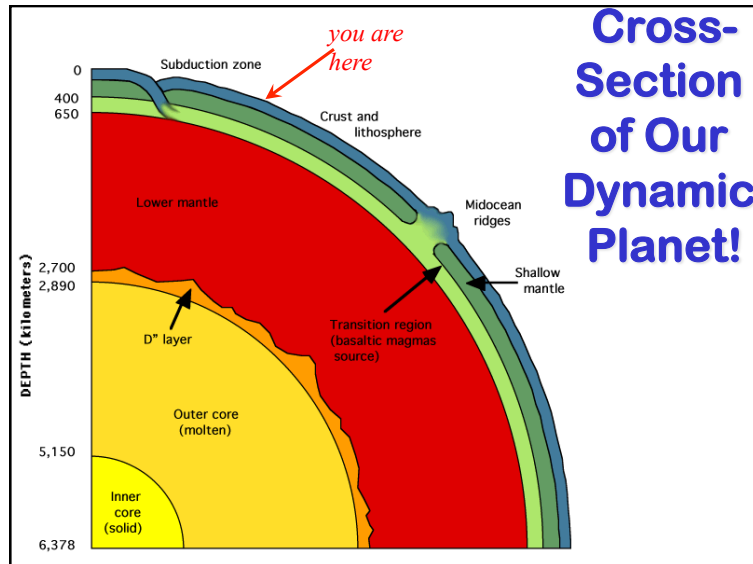
Mineral Evolution!

- Ur mineral dust & presolar grains to asteroids & comets
- A few hundred minerals in early Earth
- 5000 minerals today
- Role of water
- Role of life!

Geologic Time

ERA	PERIOD	AGE (millions of years)	EPOCH	MAJOR GEOLOGICAL AND PALEONTOLOGICAL EVENTS
Phanerozoic	Cenozoic	Quaternary	Holocene	Himalayan Mountain-building
			Pleistocene	
	Tertiary		Pliocene	Alpine Mountain-building
			Miocene	
			Oligocene	
			Eocene	
			Palaeocene	
	Mesozoic	Cretaceous	136	First stages of Rocky Mountains
			190	
225				
Triassic		280	Breakup of Pangaea – opening of Atlantic	
		320		
		345		
		395		
Paleozoic	Carboniferous	430	Consolidation of continents to form super-continent of Pangaea	
		500		
		570		
		570		
Precambrian	Proterozoic	2300	First abundant shelled invertebrates	
		2800		
	Archean	4600		Abundant iron formations
		4700		

- Precambrian, and then everything else! *(It's always down there)*
- “Primary, Secondary, Tertiary”
- Fossils told this story



Early Life

- 1) Formation of Oceans (H₂O)
- 2) Abundance of Carbon Dioxide
- 3) Sunlight
- 4) Still no life! But...
 - Lots of Energy (Lightning, UV)
 - Volcanic Bombardment
 - Anoxic
 - Origin of life?
 - Organic Soup

Rise of Oxygen

- Marine photosynthesis evolved at least 2.3 billion years ago (half the age of the Earth)
- CO₂ + H₂O + Sunlight = Release of **free O₂**
- When living things die, organic matter is decomposed (oxidized) back to CO₂
- No net change in CO₂ or O₂ if this happens!
- Slow, steady burial of reduced organic material led to steady increase of O₂
- **O₂ levels increased dramatically around 2.25 billion years ago**, allowed ozone layer, land plants, more complex life forms

glaciation
breakdown of CH₄
oxidative weathering
nutrients
ozone
decreased UV flux
atm. O₂
aerobic respiration
ozone!
ocean oxygenic photosynthesis
organic C burial

Time Scales

- **Billions of Years:**
 - Sun heats up
 - CO₂ goes down
- **Millions of Years:**
 - “Geologic thermostat”
 - Regulation by plate tectonics
- **Thousands of Years:**
 - Periodic changes in Earth’s orbit
 - Ice sheets grow and shrink

2.0 Ga: First eukaryotes
1.8 Ga: Cambrian explosion
1.5 Ga: First vertebrate land animals
1.0 Ga: First dinosaurs
0.5 Ga: First mammals
0.2 Ga: First flowering plants
0.1 Ga: First modern humans
0.05 Ga: First modern humans
0.01 Ga: First modern humans
0.001 Ga: First modern humans

