

## ORIGINS OF THE OCEANS AND LIFE



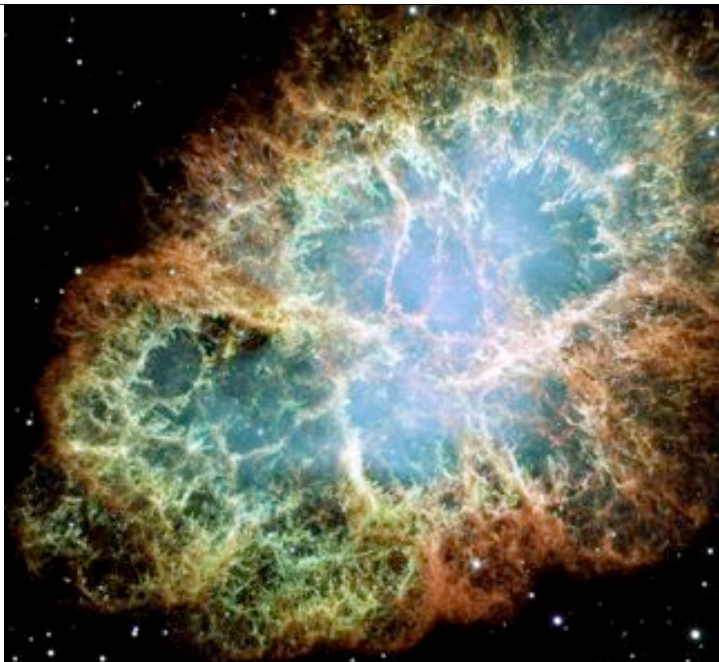
### Origins of the Ocean & Life

- ☺ deep time
- ☺ comet vs. volcanic
- ☺ Martian water
- ☺ Iron-sulfide hypothesis
- ☺ Stanley Miller
- ☺ stromatolites



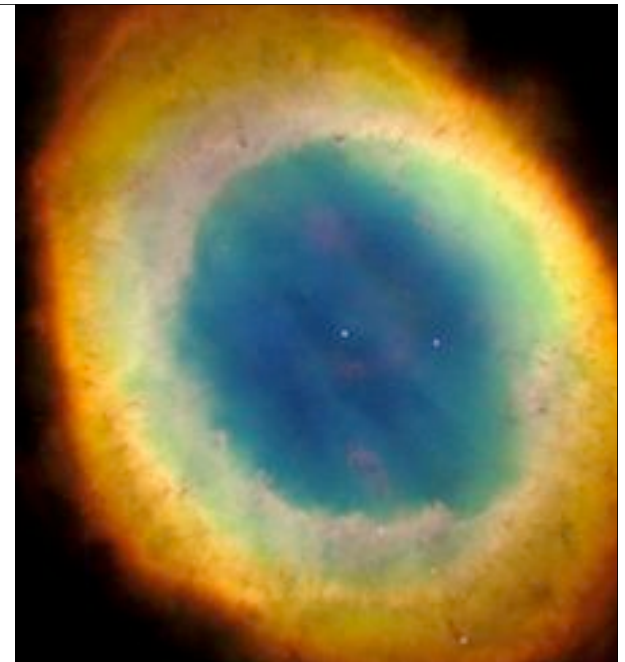
**Deep  
Time**

**13.7 Ga**



**Deep Time**

**13.7 --> 12.7 Ga**



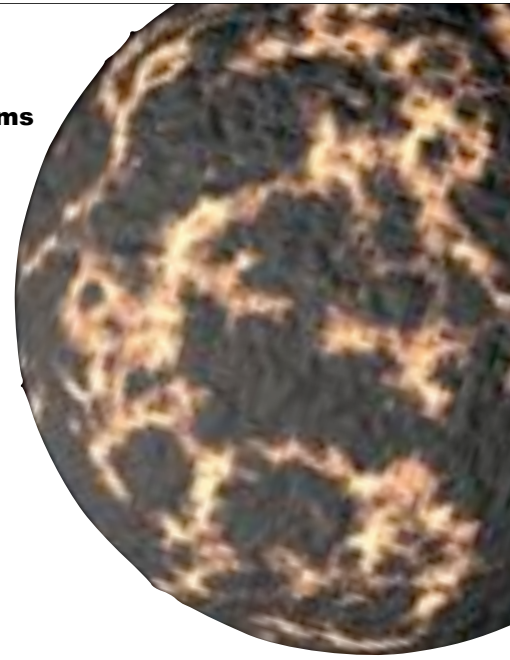
**Deep Time**

**~4.6 Ga  
solar system**



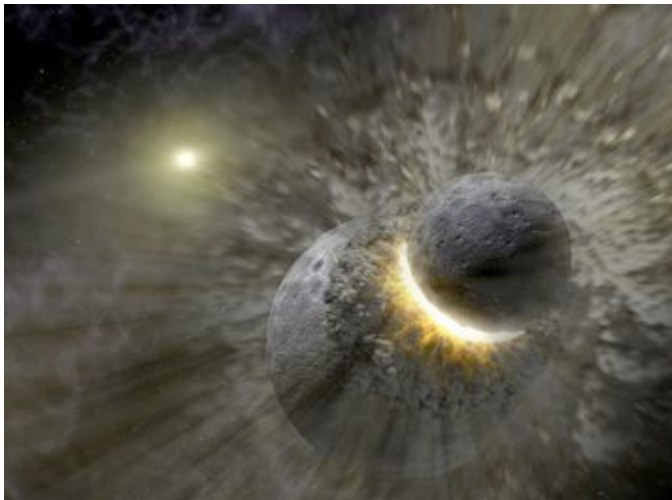
**Deep Time**

**4.54 ±1% Ga Earth forms**



**Deep Time**

**~4.510 Ga collision w/planetoid  
creates moon**



**A Young, Cool Earth**

**zircons =  $ZrSiO_4$   
4.404 Ga, Jack Hills**

**4.4 Ga cool Earth  
4.35 Ga oceans**



## Origin of the Ocean

where did all that water come from?

competing ideas:

1. volcanic outgassing
2. comets



Comet Hale-Bopp  
(Courtesy Ian Griffin,  
Brevard Community College)



## Outgassing Theory

exsolution



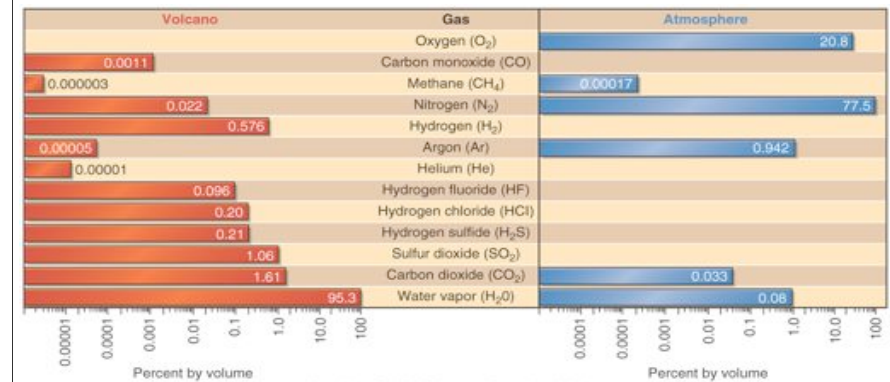
as magma rises, ↓ pressure  
↓ pressure = gases exsolving

## Exsolution

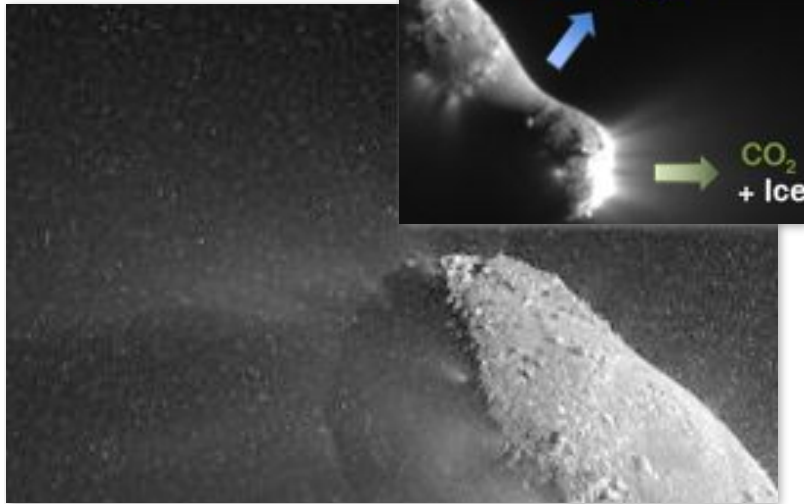


## Volcanic Outgassing

- 79% H<sub>2</sub>O
- 15% SO<sub>2</sub>
- 3% CO
- trace H<sub>2</sub>S, HCl, HF, H<sub>2</sub>



## Comet Theory



isotopes

## Isotopes

elements  
different # of neutrons

same chemistry  
different mass

## Oxygen-16 (8 protons, 8 neutrons)

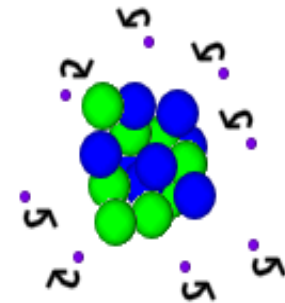
● Proton      ● Electron  
● Neutron

oxygen defined by 8 protons  
if 9 protons, then it's F

oxygen can have 8, 9, 10  
neutrons

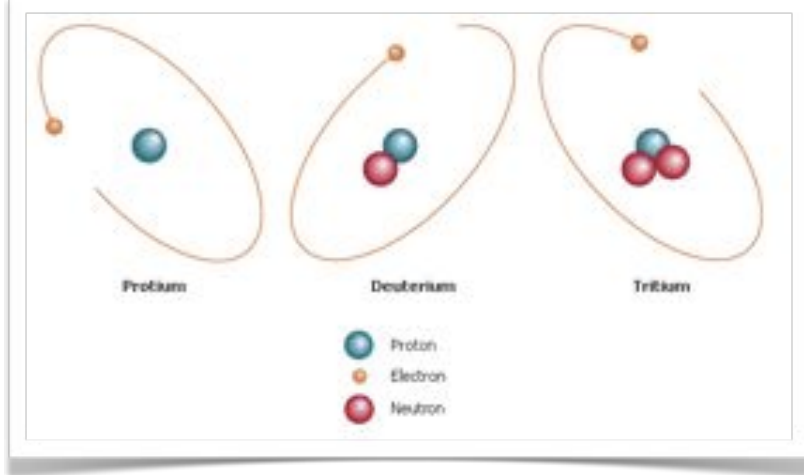
$O^{16}$  = normal

$O^{17}$ ,  $O^{18}$  = isotopes



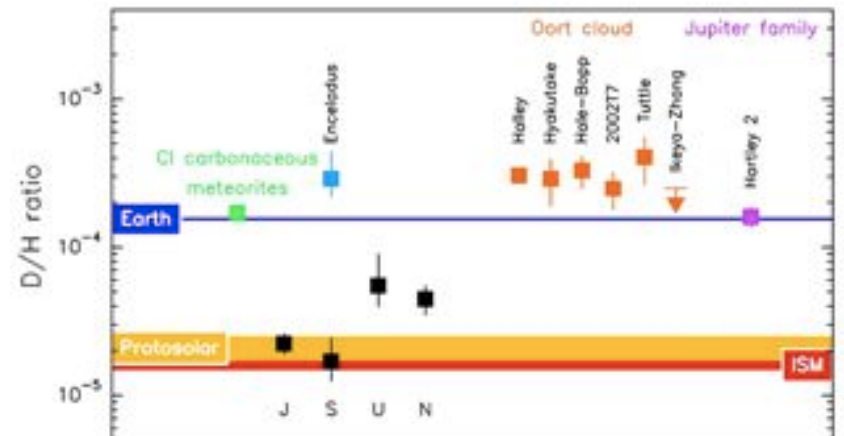
## Comet Theory

deuterium vs. hydrogen, D/H

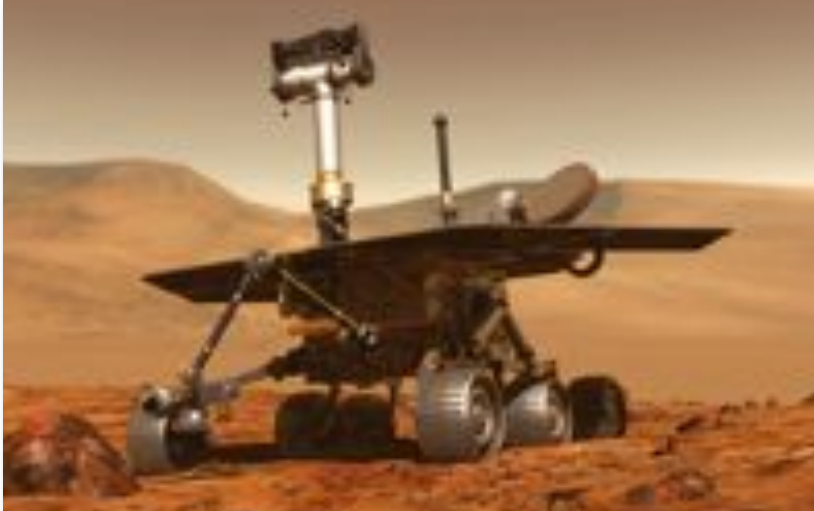


## Comet Theory

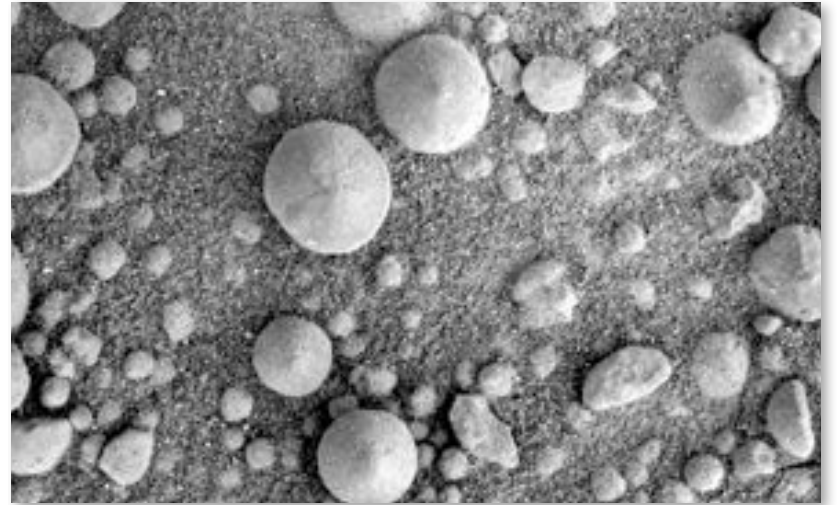
deuterium vs. hydrogen, D/H



**Martian Water**  
**Spirit & Opportunity (June, July 2003)**

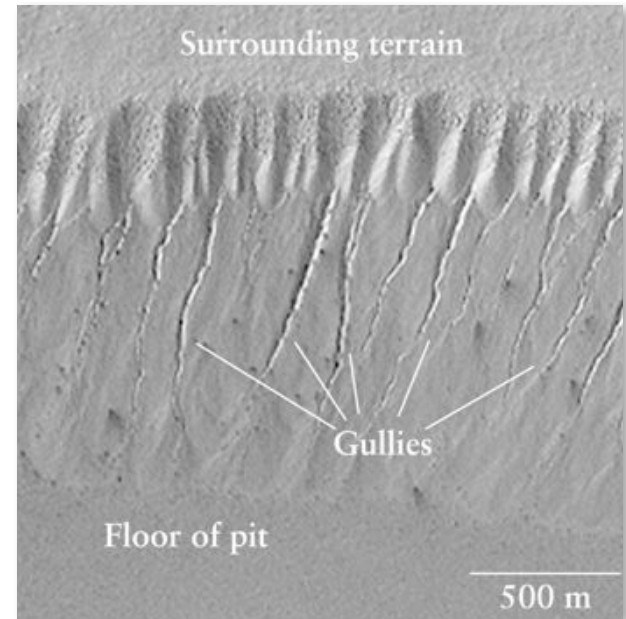
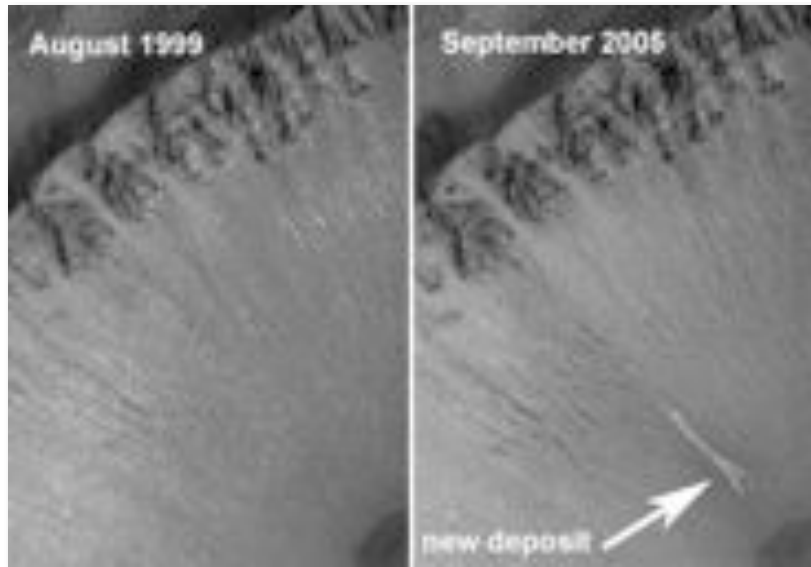


**“Blueberries”**  
**hematite**



**Cross-bedding**





**Mars had water**

**shallow oceans**

**sed structures**  
**topographic features**

**blueberries**  
**mineral jarosite**

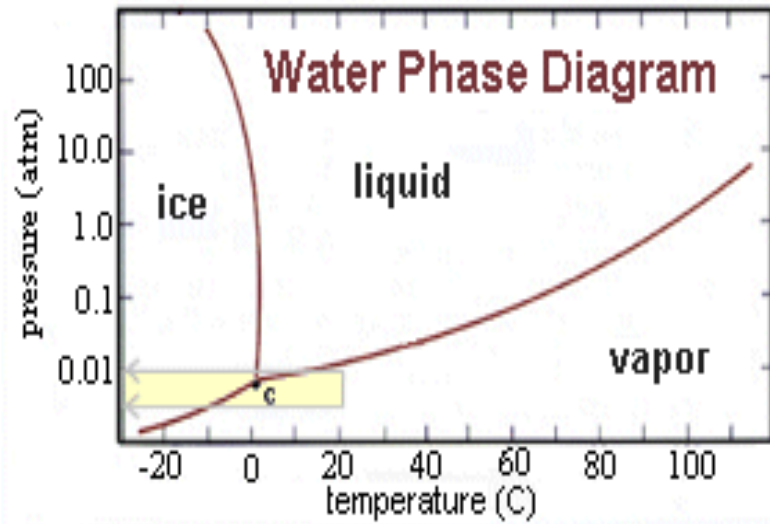


**Mars today**

**low atmospheric pressure**  
**1/100th Earth**

**low temps**  
**27°C to -143°C**

**Triple-Point "Trap"  
sublimation**

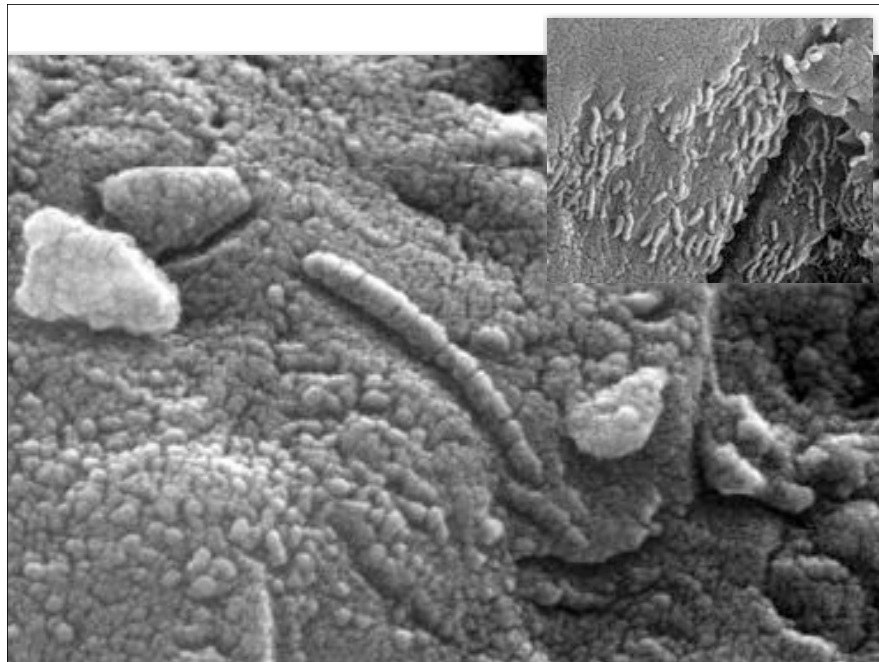
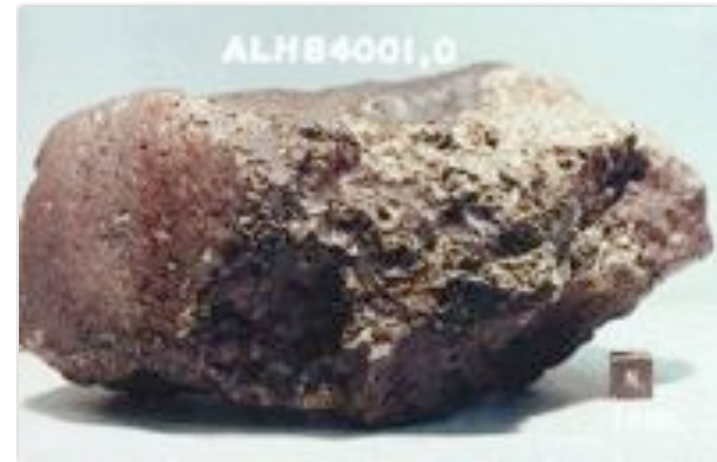


**Why do we care?**

**ALH 84001**

**found Dec 1984**

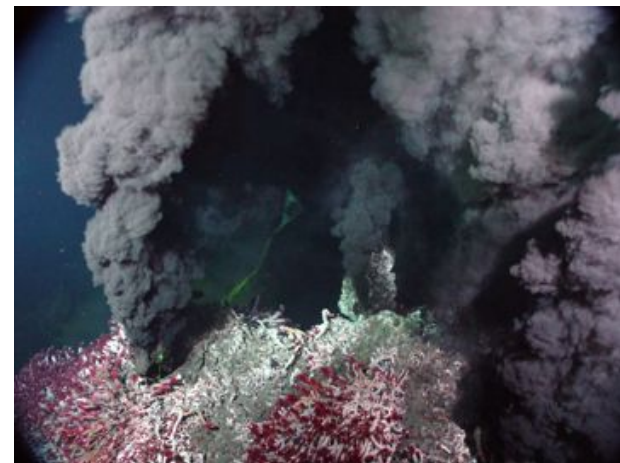
**lava flow, 4.5 Ga**

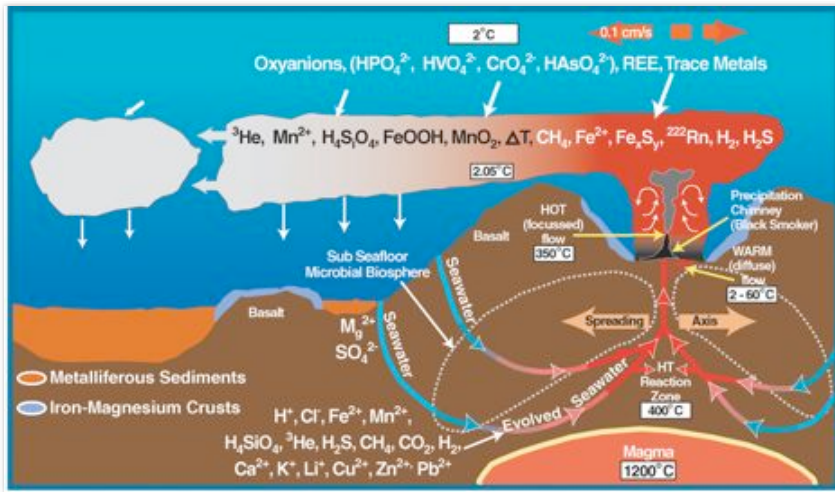


**How might life have started?**

**water**

**hydrothermal vents**

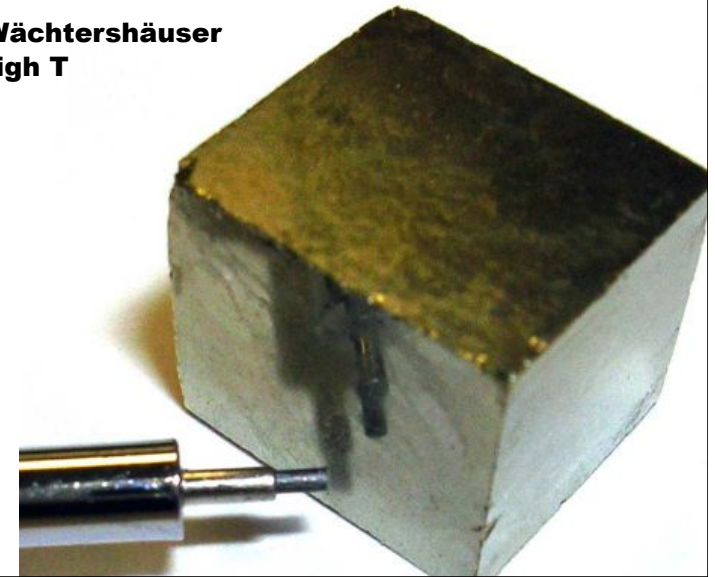




## The Iron-Sulfide Hypothesis

Günter Wächtershäuser  
high P, high T

pyrite



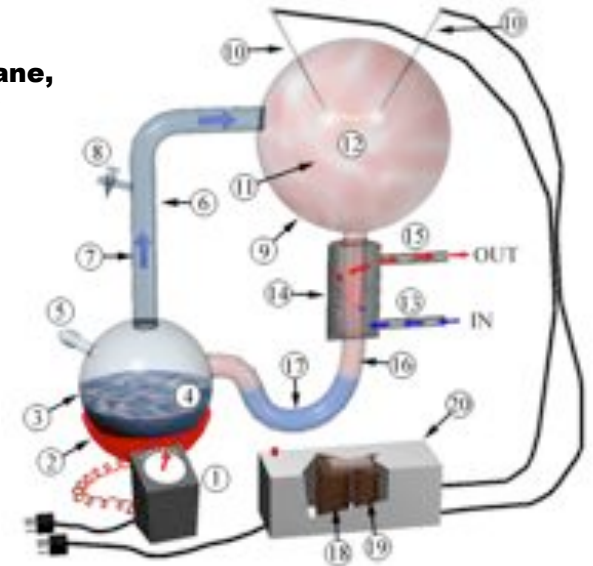
## Hydrothermal vents rich in iron-sulfides



## The Stanley Miller Experiment 1953

hydrogen, methane,  
ammonia, water

amino acids



### 2011 Re-analysis



22 new amino acids

### Oldest Rocks

**Acasta Gneiss, Greenland**  
4.03 Ga

unconfirmed 4.28 Ga



### Earliest Life?

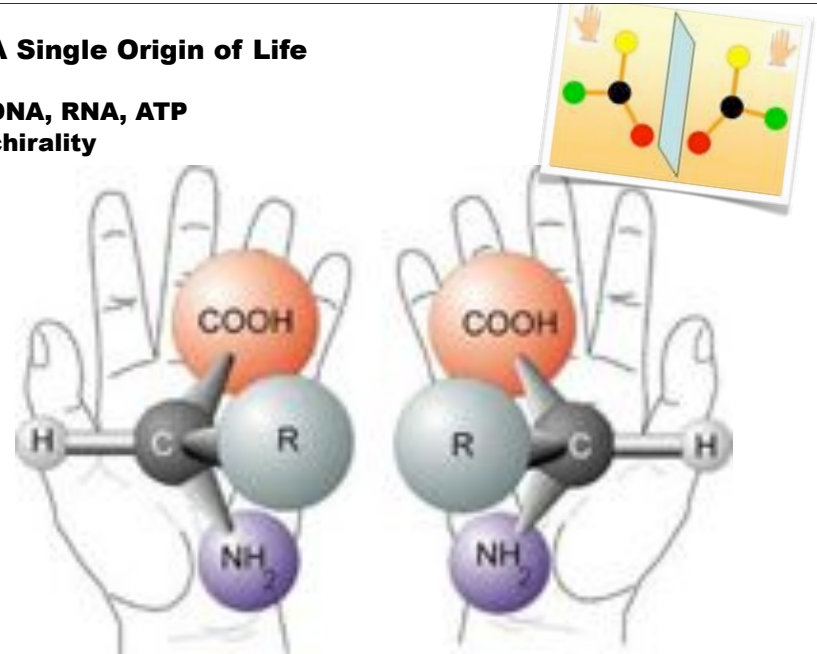
3.85 Ga Akilia Island, Greenland

carbon microspherules  
living things prefer C<sup>12</sup> over C<sup>13</sup>



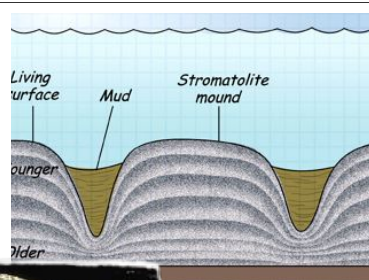
### A Single Origin of Life

DNA, RNA, ATP  
chirality



## Stromatolites, 3.5 Ga

photosynthetic bacteria  
oxygen as waste



geologist imagines



## Wrapup

