Picture credit: Reuben Reyes University of Texas at Austin

On the composition of putative oceans on early Venus

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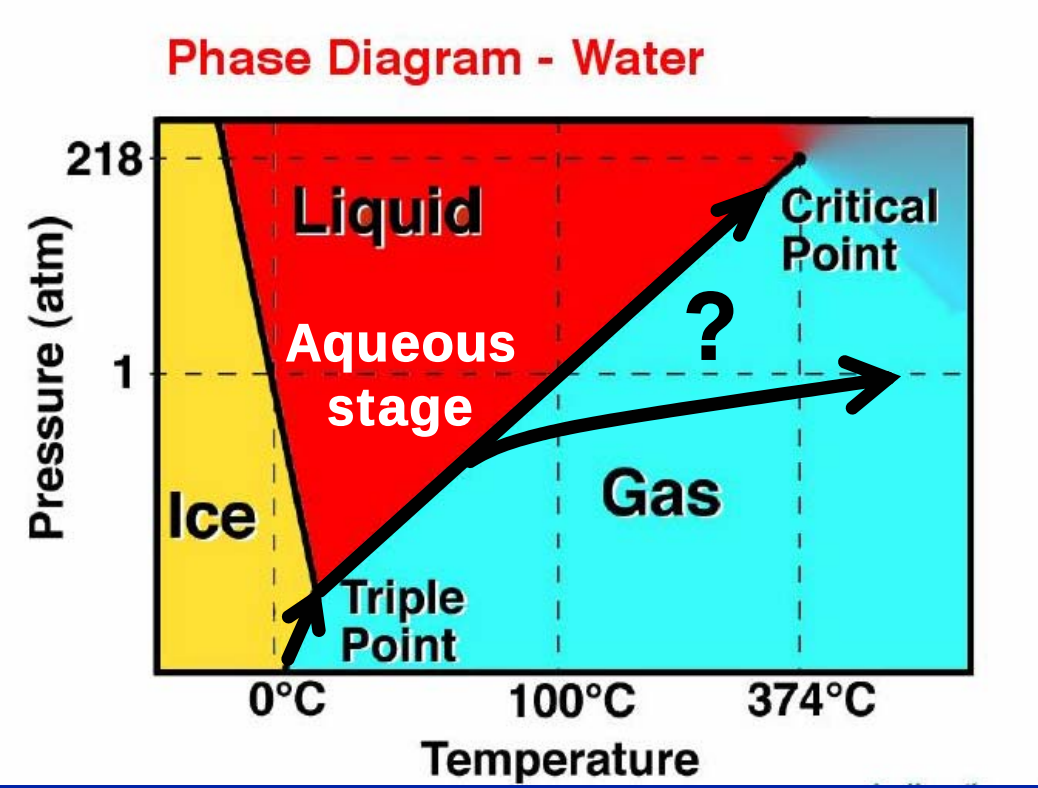
If Venus had an ocean, can we observe signs of that ocean?

Geochemistry of early water-rock interactions as a clue for

- atmospheric chemistry and physics
- sediments and evaporites
- rock alteration
- igneous processes
- tectonics and solid state geophysics



- Evolution toward critical point
- Warm/hot ocean
- Water-saturated atmosphere
- Consumption of liquid water
  - hydration
  - dissociation
  - evaporation

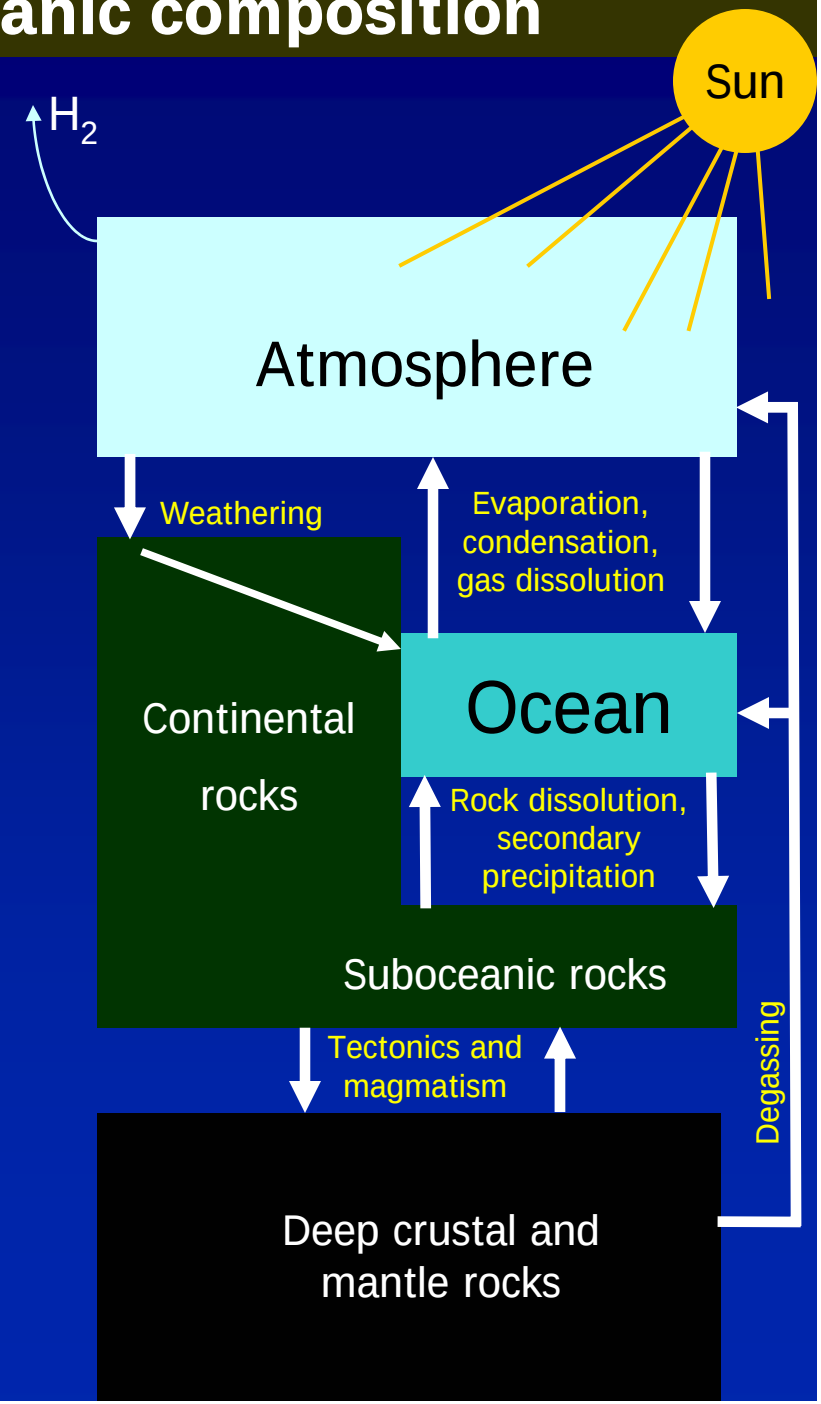
- Amount of H_2O
- Amount of volatiles (Cl, S, C, N)

} **Mass balance**

- Surface temperature and pressure

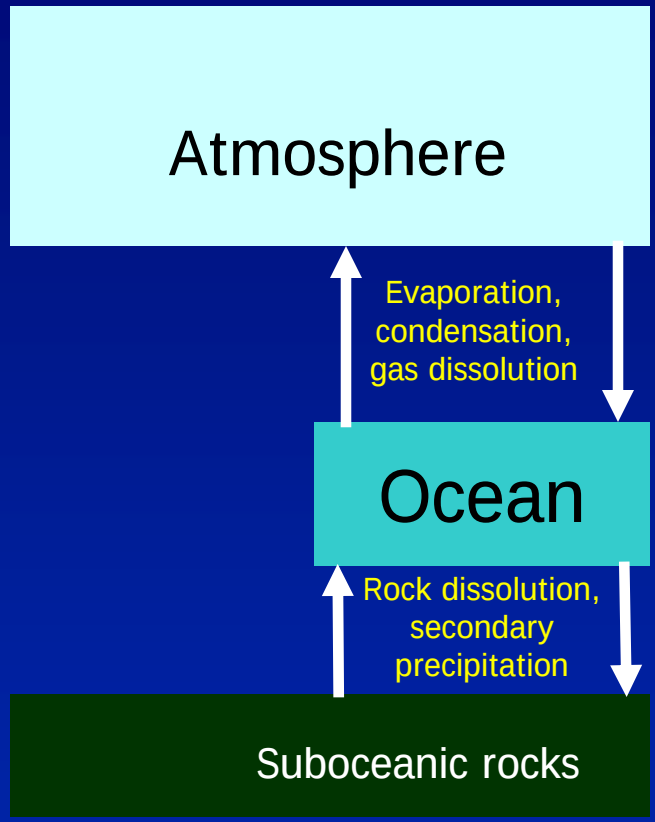
Processes affected oceanic composition

- Evolution of solar luminosity
- The greenhouse effect
- Atmosphere-ocean partitioning
- Dissolution of rocks
- Secondary precipitation
- H_2 escape
- Mantle/impact degassing
- Tectonics/resurfacing



A simplified model

- ~~Evolution of solar luminosity~~
- ~~The greenhouse effect~~
- Atmosphere-ocean partitioning
- Dissolution of rocks
- Secondary precipitation
- ~~H_2 escape~~
- ~~Mantle/impact degassing~~
- ~~Tectonics/resurfacing~~



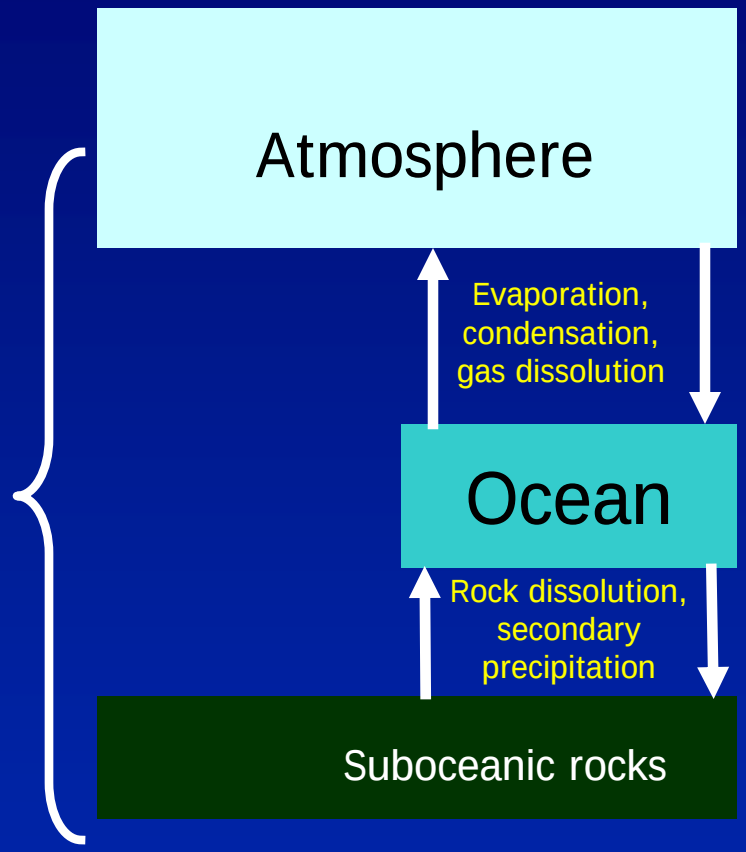
Assumed chemical equilibrium in the atmosphere-ocean-rock system

Our initial model for oceanic composition

Calculation of chemical equilibrium

in closed gas-water-basalt system

O-H-C-S-Cl-N-Na-K-Mg-Fe-Ca-Si-Al



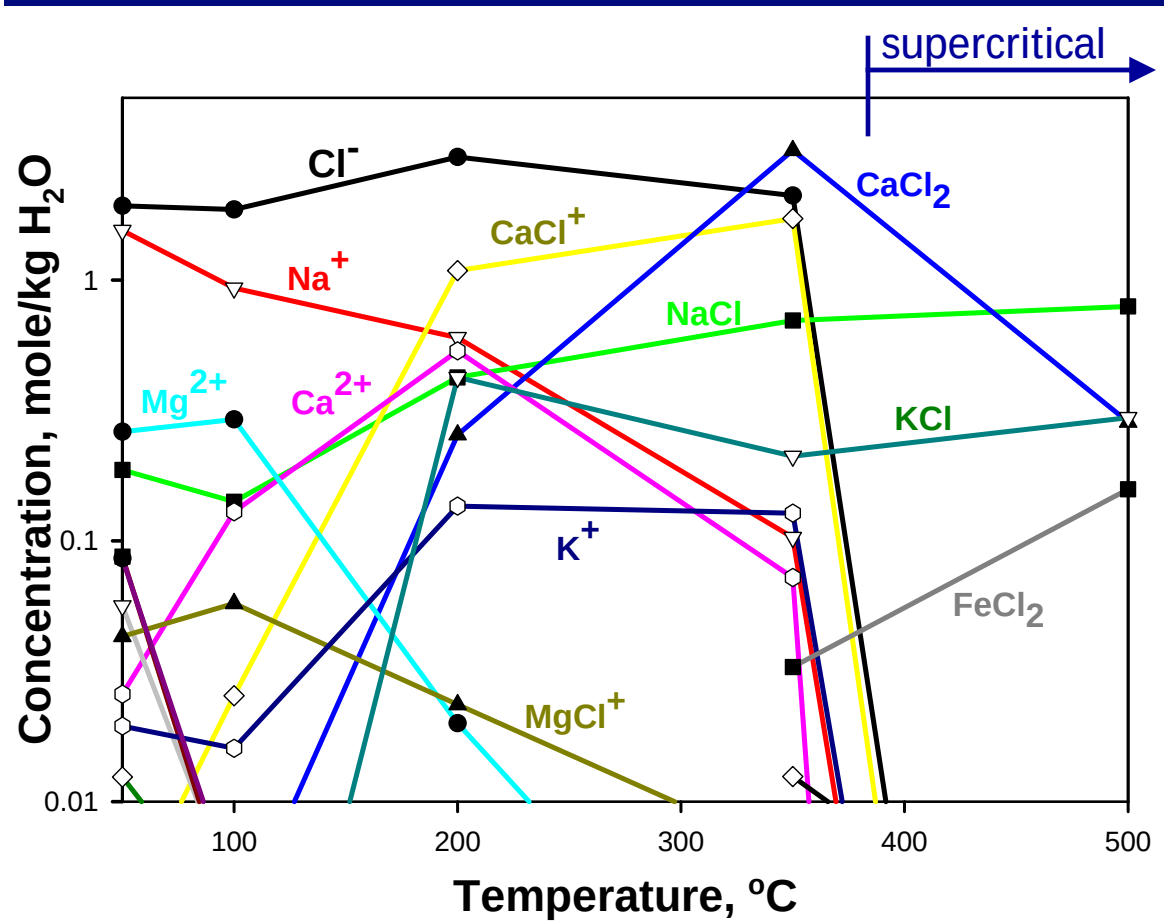
Output data

- Oceanic composition, pH
- Mineralogy of altered rock/sediments
- Atmospheric composition

- All CO_2 and N_2 are degassed
- S and Cl are from Earth's data
- 1 km thick ocean, variable basalt layer

Results: Oceanic water composition

- Oceanic water is a $NaCl$-$CaCl_2$ solution



Oceanic evolution

Why?

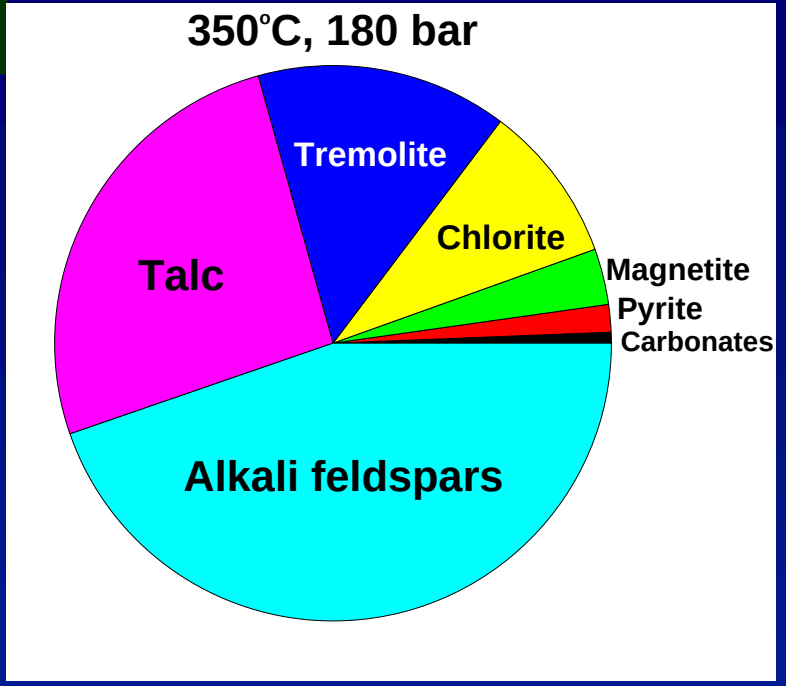
- Large Cl mass
- Cl accumulates in the aqueous phase
- Limited amounts of secondary Na-Ca minerals
- Mg is in dolomite and phyllosilicates
- S is in sulfate and sulfide minerals

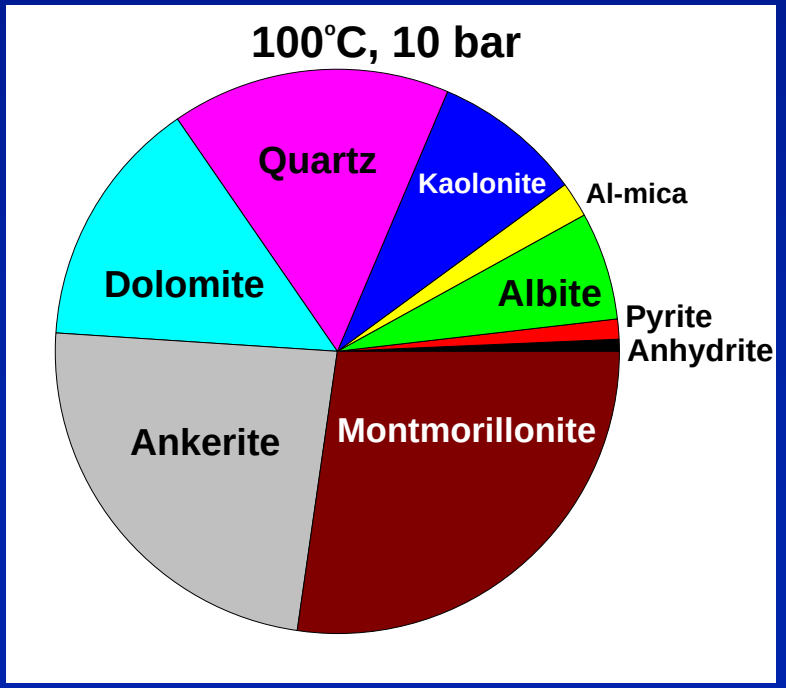
- ~ neutral pH, no trapping of atmospheric CO_2 in a “soda ocean”

Results: Secondary mineralogy

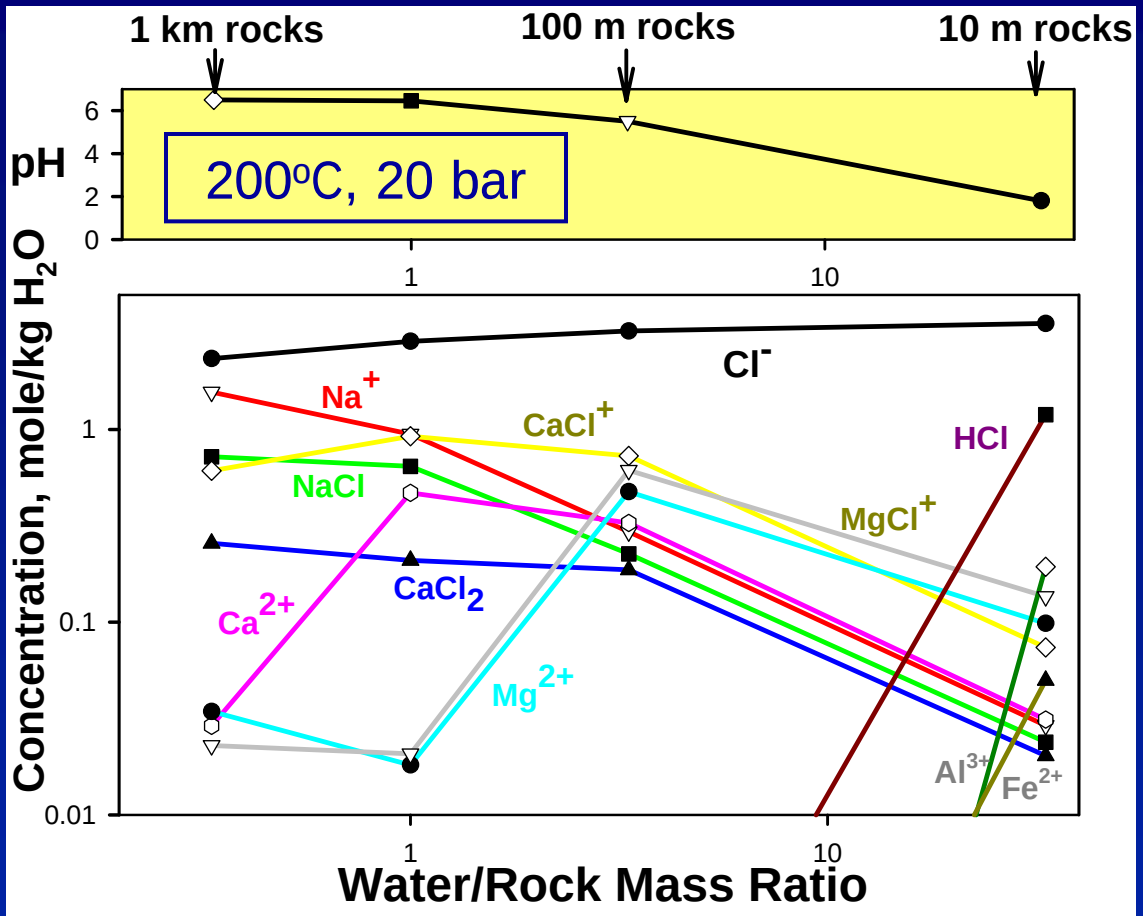
- Phyllosilicates
  - clay minerals, micas
  - amphliboles (tremolite)
  - talc
- Carbonates
  - dolomite
  - ankerite
  - calcite
- Quartz
- Na-K feldspars
- Anhydrite
- Pyrite
- Hematite/magnetite

- Evaporites: $NaCl + CaCl_2$

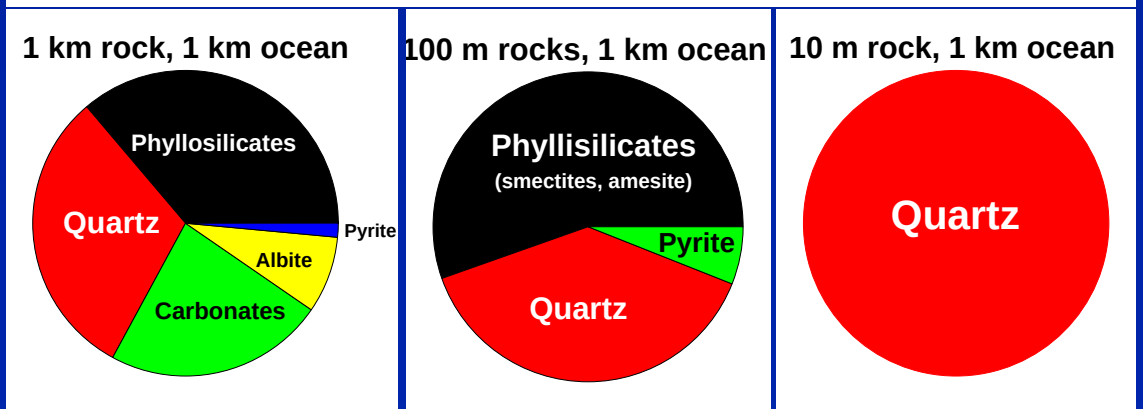


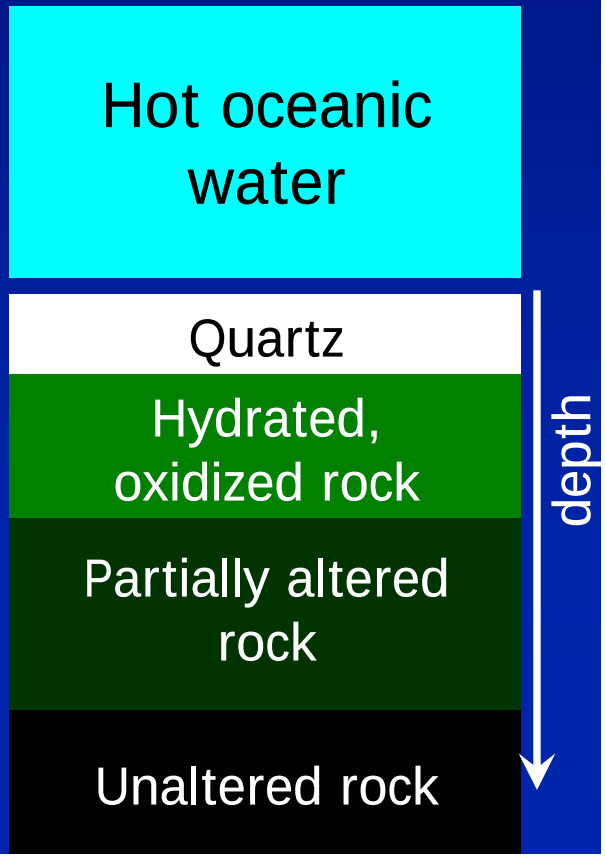


Effects of water to (permeable) rock ratio



- An acid ocean over impermeable rocks (not realistic)
- Quartz-rich formations: continents and oceans

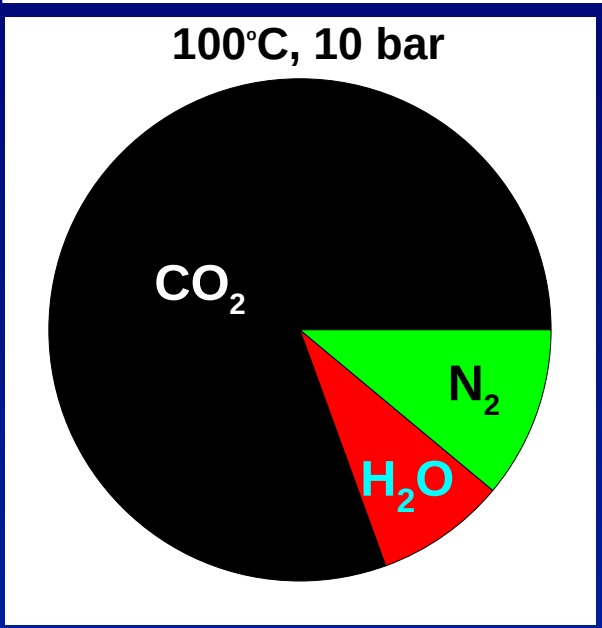




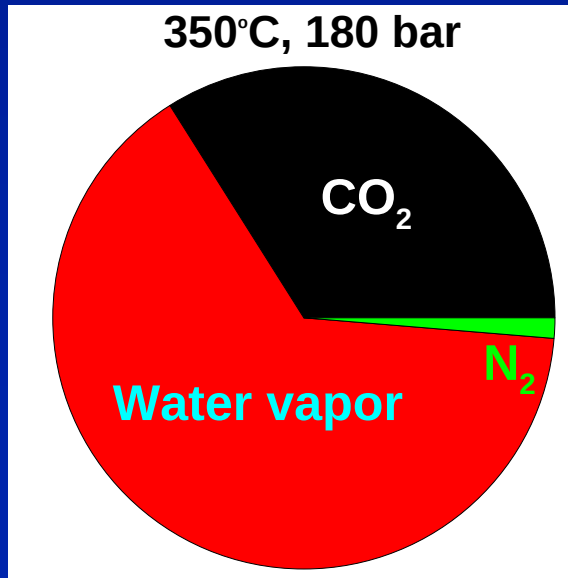
Results: Atmospheric composition

The atmosphere mainly consists of CO_2, H_2O and N_2

- CO_2, ~0.3-0.9 (volume fraction)
- H_2O, ~0.01-0.6
- N_2, ~0.02-0.15



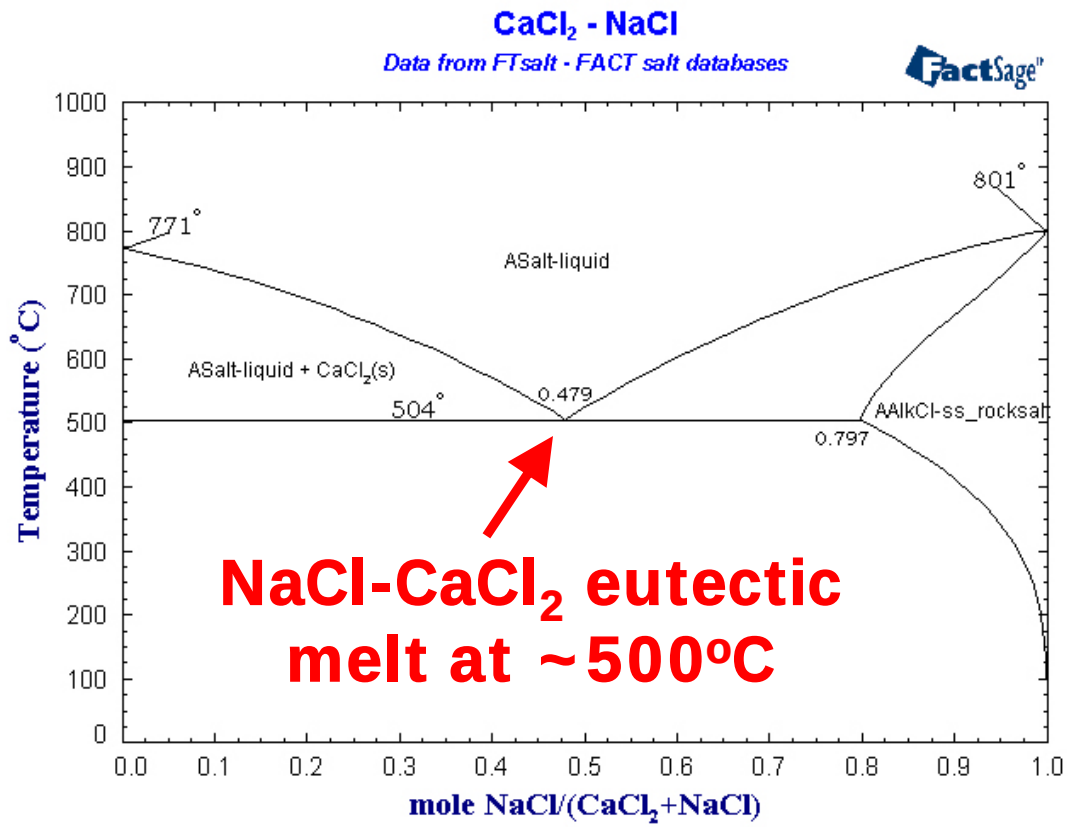
- High temperature corresponds to high H_2O
- Low water/rock ratio corresponds to low CO_2 (CO_2 goes to carbonates)
- Some CH_4 at low *W*/*R* ratios (?)



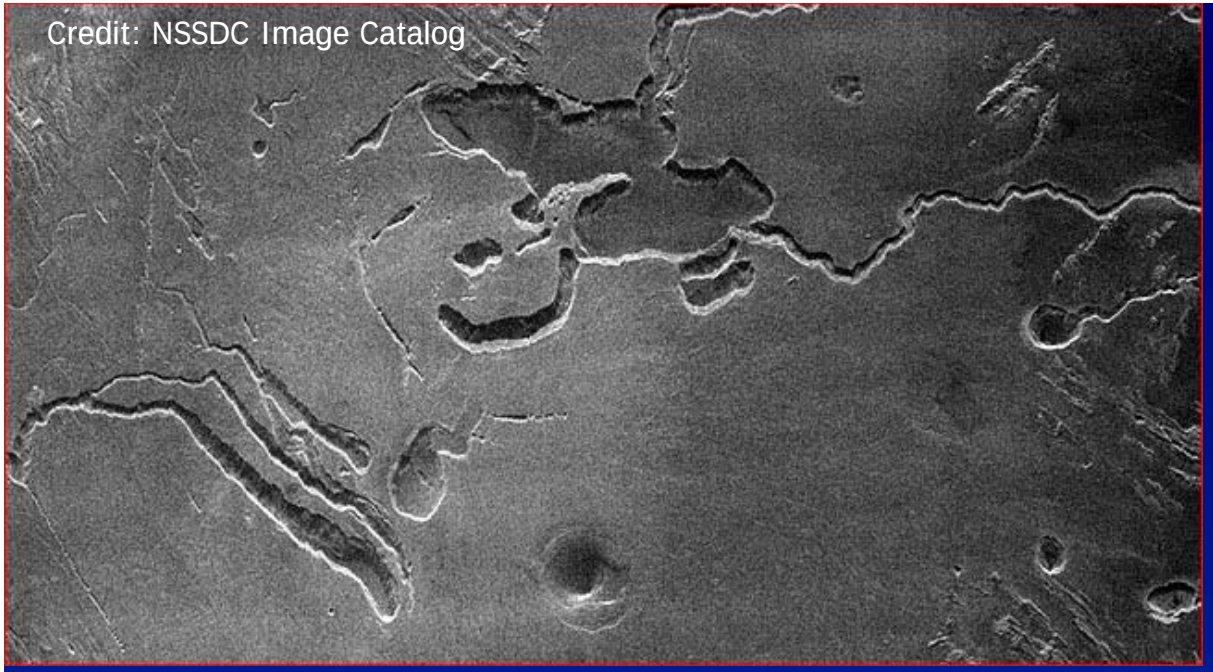
Implications for subsequent Venus' history and exploration

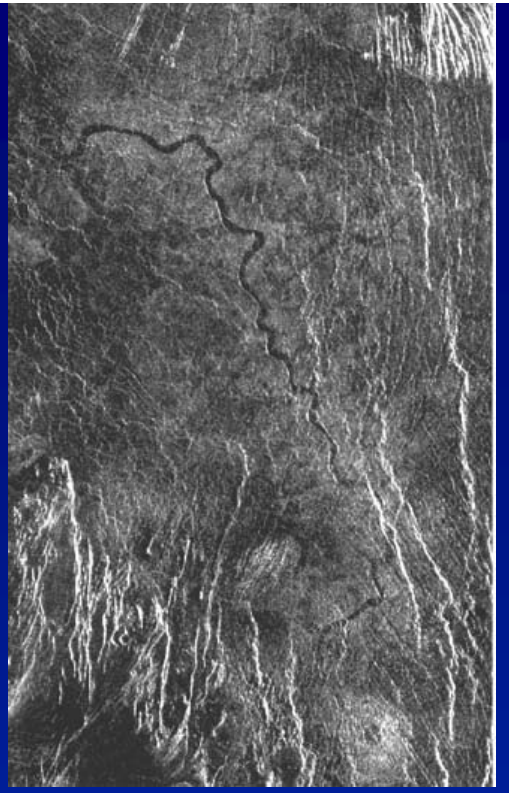
- Ocean evaporation, salt precipitation, rock dehydration/decarbonation
- Metamorphic carbonates (quartz-wollastonite-calcite buffer ?)
- Anhydrite-pyrite-Fe-oxides as buffer of atmospheric S and fO_2
- Anatexis of SiO_2-rich, partially hydrated, and Na-, Cl-bearing rocks
- Formation of felsic and alkaline rocks

Low-temperature chloride melts in today's Venus' crust



- NaCl-$CaCl_2$ eutectic at ~580°C
- +KCl, +NaBr, LiCl, $MgCl_2$ ...
- Melted salts at near subsurface
- Convection; "hydrology"
- Heat transfer by salt melts
- Lowering rock melting T
- Alteration/erosion by salt melts
- Chloride channels and outflows





Magellan radar image of “lava” channels north of Ovda Regio.
Lo Shen Valles, a system of channels and **large collapsed source areas**.

- Collapsed areas, outflows, and channels could have formed by low-temperature chloride melts
- High-albedo coronas
- No need for komatiites, sulfate and Na-carbonate high-temp. melts
- Follow the chlorides!