Mercury

- Distance from Sun (average) = 0.387 × (Earth-Sun)

Revolves around Sun once every 87.969 days
Rotates on its axis once every 58.6 days
i.e. $1\frac{1}{2}$ rotations on axis per orbit around Sun.

Does not keep same face towards Sun always.
Sunrise to Sunset is 176 days

Temperature when sunlit up to 600°F
When dark down to -250°F

- Mariner 10 (March 1974) → surface features very similar to Moon's, heavy cratering, fewer/smaller "maria" regions but those it has resemble Moon's (wrinkle ridges, etc.)

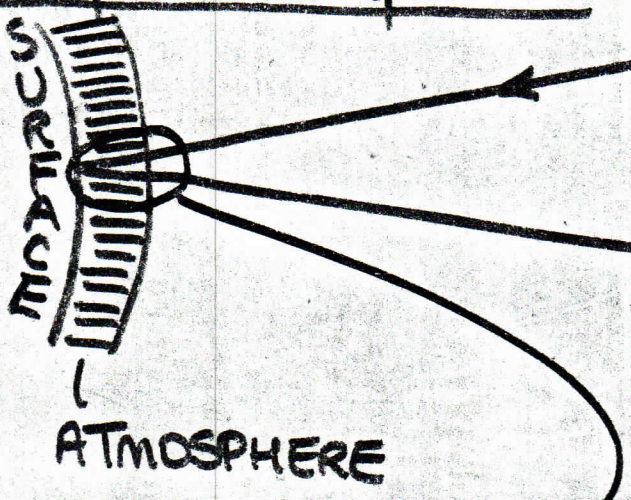
Atmosphere ~ 10^{-11} Earth's
Transient capture of solar atmosphere?
Outgassing of surface rocks?

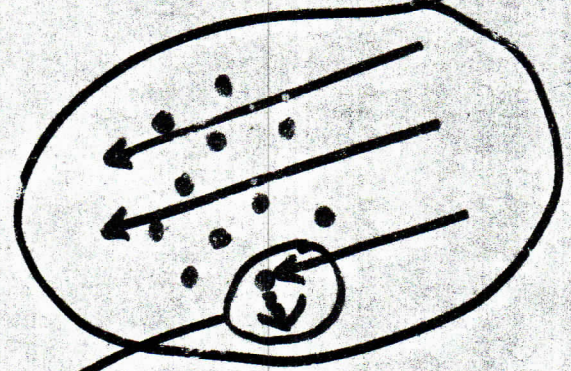
GENERAL SIMILARITY TO MOON, EXCEPT FOR HIGHER MEAN DENSITY

- (Mercury 5.5 × water, Moon 3.3 × water)

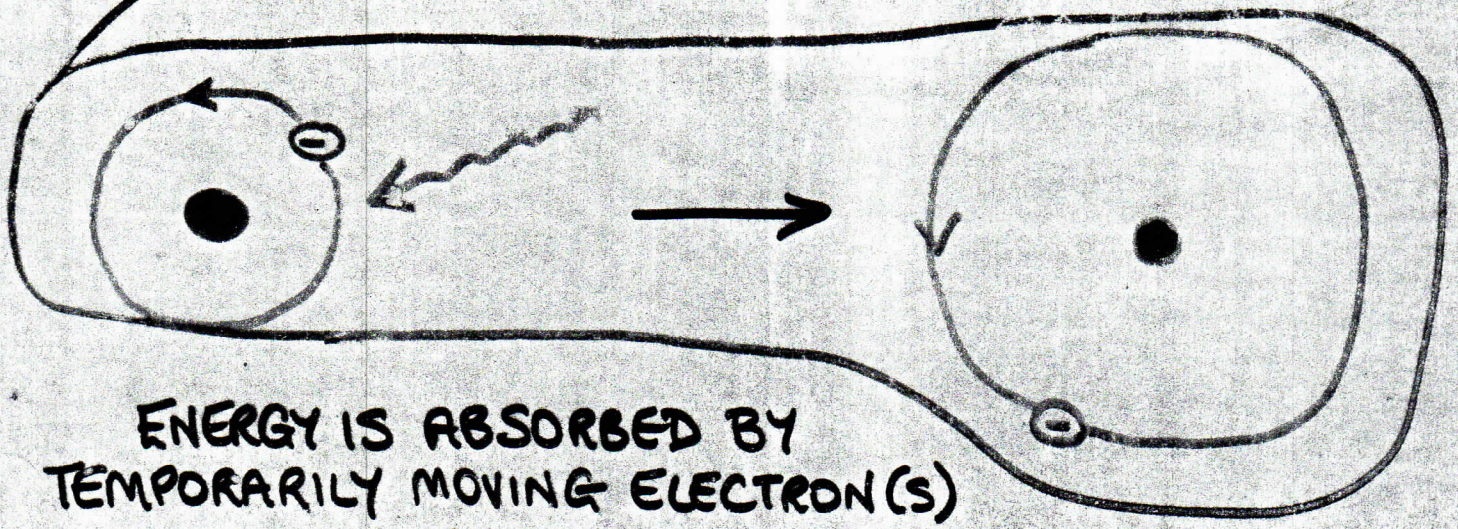
REMOTE SENSING OF PLANETARY ENVIRONMENTS

1) <u>Atmospheric Composition</u> – Reflected Sunlight Spectrum

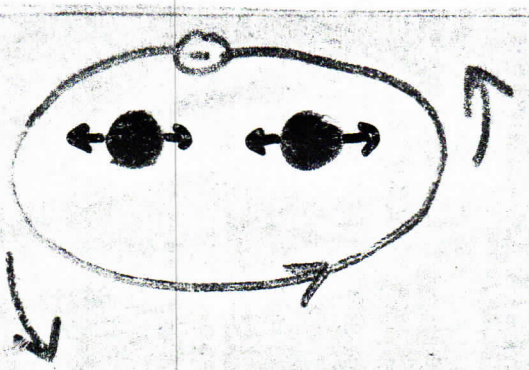




ATOMS AND MOLECULES IN ATMOSPHERE ABSORB ENERGY FROM ARRIVING SUNLIGHT, THEN RE-EMIT IN <u>RANDOM</u> DIRECTION UNRELATED TO ARRIVAL DIRECTION



ENERGY IS ABSORBED BY TEMPORARILY MOVING ELECTRON(S) INTO NEW ORBITS AROUND NUCLEI OF ATOMS OR MOLECULES, OR BY MAKING MOLECULES SPIN OR VIBRATE.



VIBRATING
SPINNING
} MOLECULE

ONLY CERTAIN DISCRETE AMOUNTS OF ENERGY (QUANTA) CAN BE ABSORBED BY GIVEN TYPE OF ATOM OR MOLECULE.

"ALLOWED" QUANTA ARE DETERMINED BY ELECTRICAL FORCES IN ATOM OR MOLECULE, SO ARE DIFFERENT FOR DIFFERENT CHEMICAL CONSTITUENTS OF ATMOSPHERE.

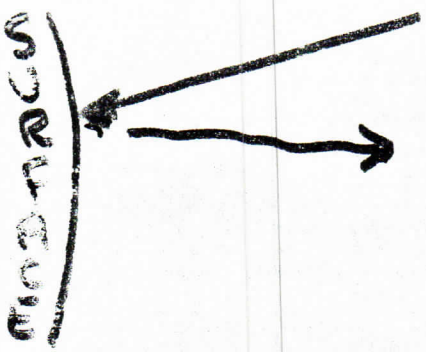
GIVEN ENERGY QUANTUM CORRESPONDS TO GIVEN WAVELENGTH IN ARRIVING RADIATION

WHICH WAVELENGTHS ARE MISSING FROM RADIATION REFLECTED BACK TO DETECTOR?

COMPARISON WITH LABORATORY STUDIES OF ABSORPTION → IDENTIFICATION OF CHEMICAL CONSTITUENTS OF ATMOSPHERE.

REMOTE SENSING (CONT'D)

2) Surface Temperature — Emission from Surface



SUNLIGHT REACHING SOLID SURFACE ABSORBED BY MOLECULES THERE.

RADIATION (INFRARED) EMITTED BY SURFACE HEATED BY SUNLIGHT OR FROM WITHIN (e.g. RADIOACTIVITY)

IN DENSE MATERIALS, QUANTA WHICH CAN BE ABSORBED ARE DETERMINED BY INTERACTIONS BETWEEN NEIGHBOURING MOLECULES, AS WELL AS BY INTERNAL FORCES WITHIN MOLECULES.

IN SUFFICIENTLY DENSE MATTER, INTERACTIONS DOMINATE AND ABSORBED ENERGY CAN BE SHARED AMONG MOLECULES.

DISTRIBUTION OF ENERGY WITH WAVELENGTH IN RE-RADIATED ENERGY THEN DETERMINED BY TEMPERATURE OF MATTER AND NOT BY CHEMICAL COMPOSITION.

MEASURE ENERGY EMITTED FROM SURFACE AT DIFFERENT WAVELENGTHS → SURFACE TEMPERATURE.

Mars

- Mars-Sun distance = 1.52 × Earth-Sun distance
  Mass = 0.12 Earth mass
  Density = 3.97 × water
  "Day" = $24^h\ 37^m\ 22^s.6$
  "Year" = 1.88 Earth Years
  Axis Tilt = 24°

Seasonal cycle. Growth/recession of polar caps
Light/dark areas of planet vary in size.

Early 20th-Century, late 19th-Century observers → "canals"

- Mariner Spacecraft:- Cratered terrain
  Craters appear eroded.
  Polar caps solid CO_2 ice (mainly)
  Atmosphere ~ 1% Earth's in density
  ~ 90% CO_2 in composition
  Planet-wide dust storms (seasonal)
  Huge volcanoes, e.g. 70,000-ft Nix Olympica
  300 miles across base
  Great Rift Valley 3000 miles long
  Features resembling dry river beds
  Average surface temperature -30°F

- Interpretation of planet environment greatly modified by Mariner spacecraft data.

Venus

- Venus-Sun distance = 0.723 x (Earth-Sun)

Venus mass = 0.815 Earth mass

Venus surface area = 0.91 Earth surface area

Venus volume = 0.86 Earth volume

Venus density = 0.945 Earth density

Surface gravity = 0.9 Earth surface gravity

Receives ~ 2 x Earth's supply of solar radiation
But reflects twice as much as Earth does.

- Earth's "twin" ?

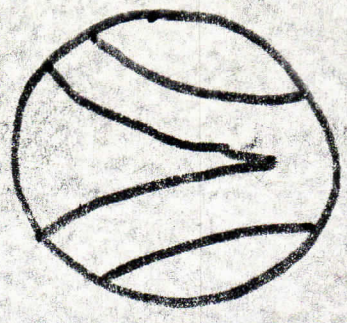
December 1970 VENERA 7 (USSR) landed
February 1974 MARINER 10 (USA) flew by

Atmosphere 100 x Earth atmospheric pressure
90-95% Carbon dioxide
Trace water, oxygen, hydrogen (solar?)

Surface temperature above 700°F !

Upper levels of atmosphere rotate ~ 60 x faster than surface of planet !

- Spiral pattern in cloud deck: —



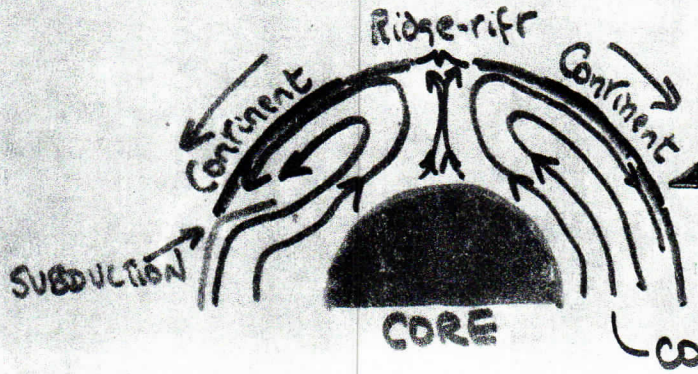
Earth

Radius 6370 km Overall average density 5.5x water

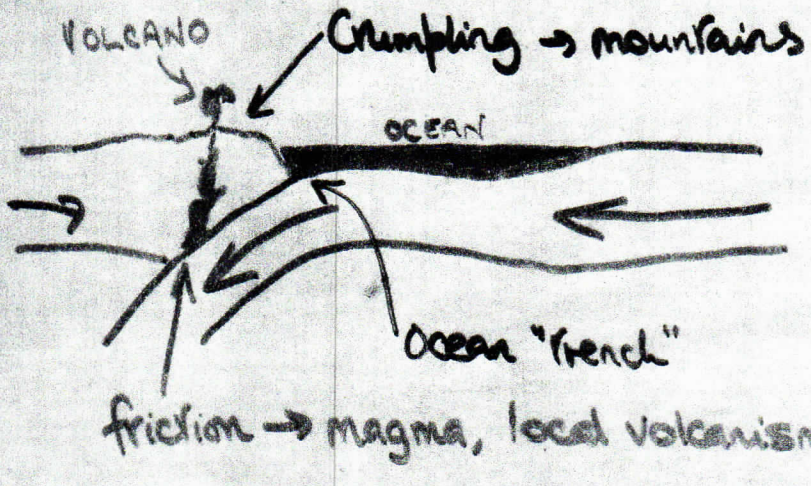
Liquid Core radius 3400 km (from seismic wave propagation)

Below ~100 km depth, rock is soft.
Upper 100km broken into CONTINENTAL PLATES.

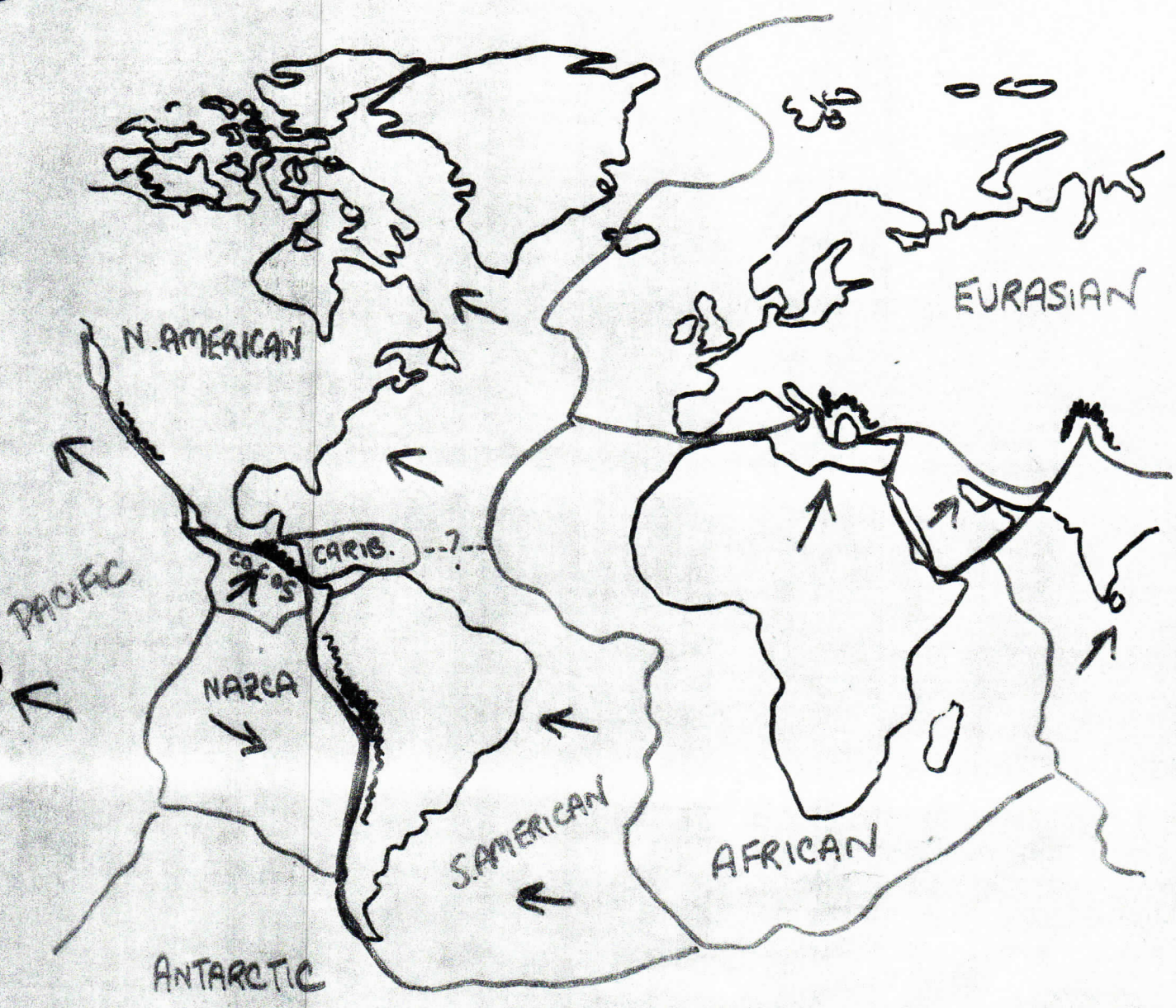
Convection in soft rock (MANTLE) moves continental plates relative to one another.



Average density of surface material ~ 2.6 x water
Inner must be denser – liquid iron/nickel?



Meeting of plates at subduction zone



Movements of Earth's crustal plates relative to Eurasian plate, around Atlantic and Mediterranean

Note areas of great earthquake activity:

- CENTRAL AMERICA
- CHILE
- CALIFORNIA
- YUGOSLAVIA – TURKEY
- NORTHERN INDIA

} plate boundaries

GASES ESCAPING FROM EARTH VOLCANOES NOW.

Water vapour ~ 75% → oceans

Carbon dioxide ~ 12% → ?

Sulphur dioxide

Nitrogen

Traces of:-

Carbon monoxide

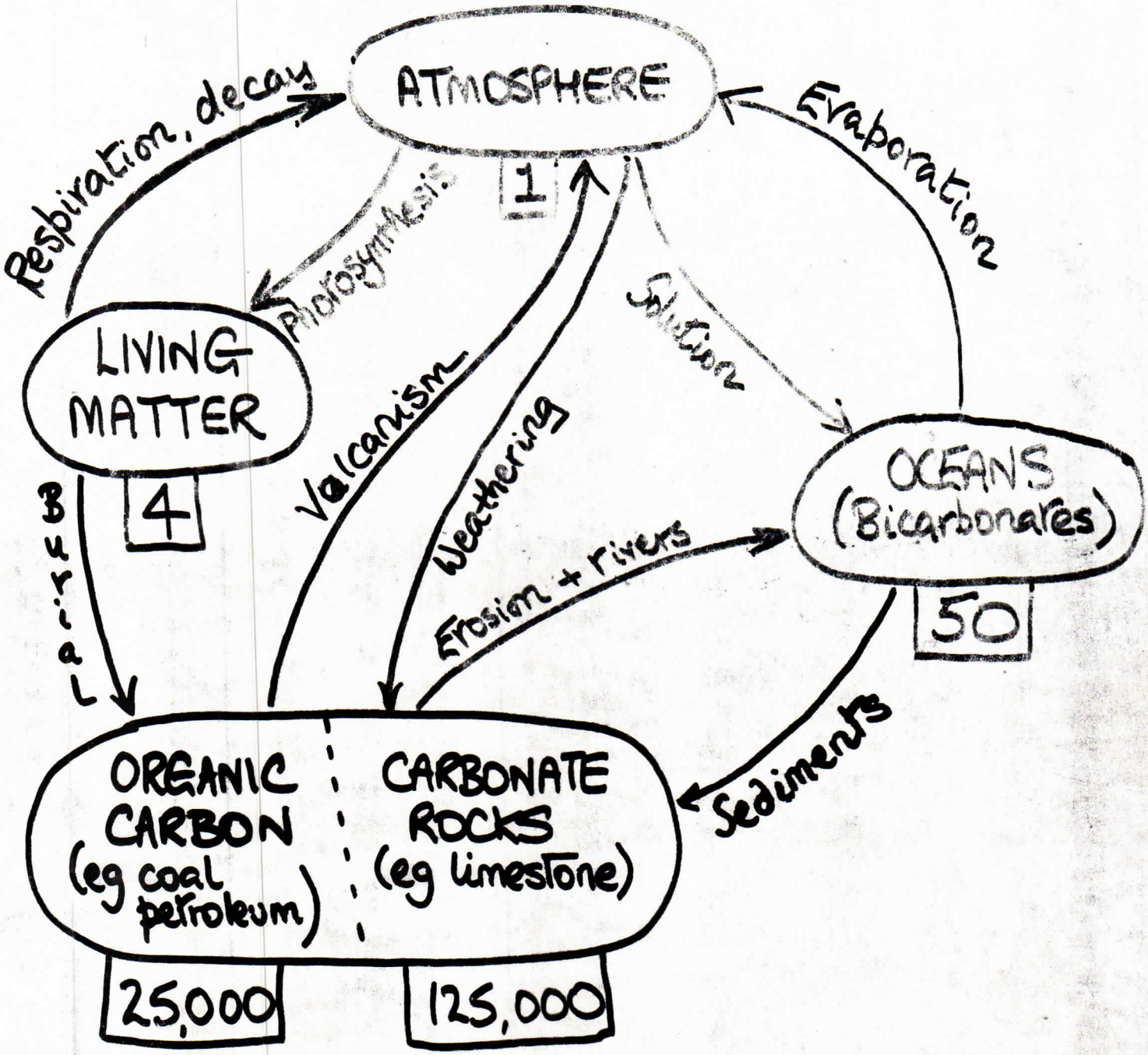
Hydrogen

Argon

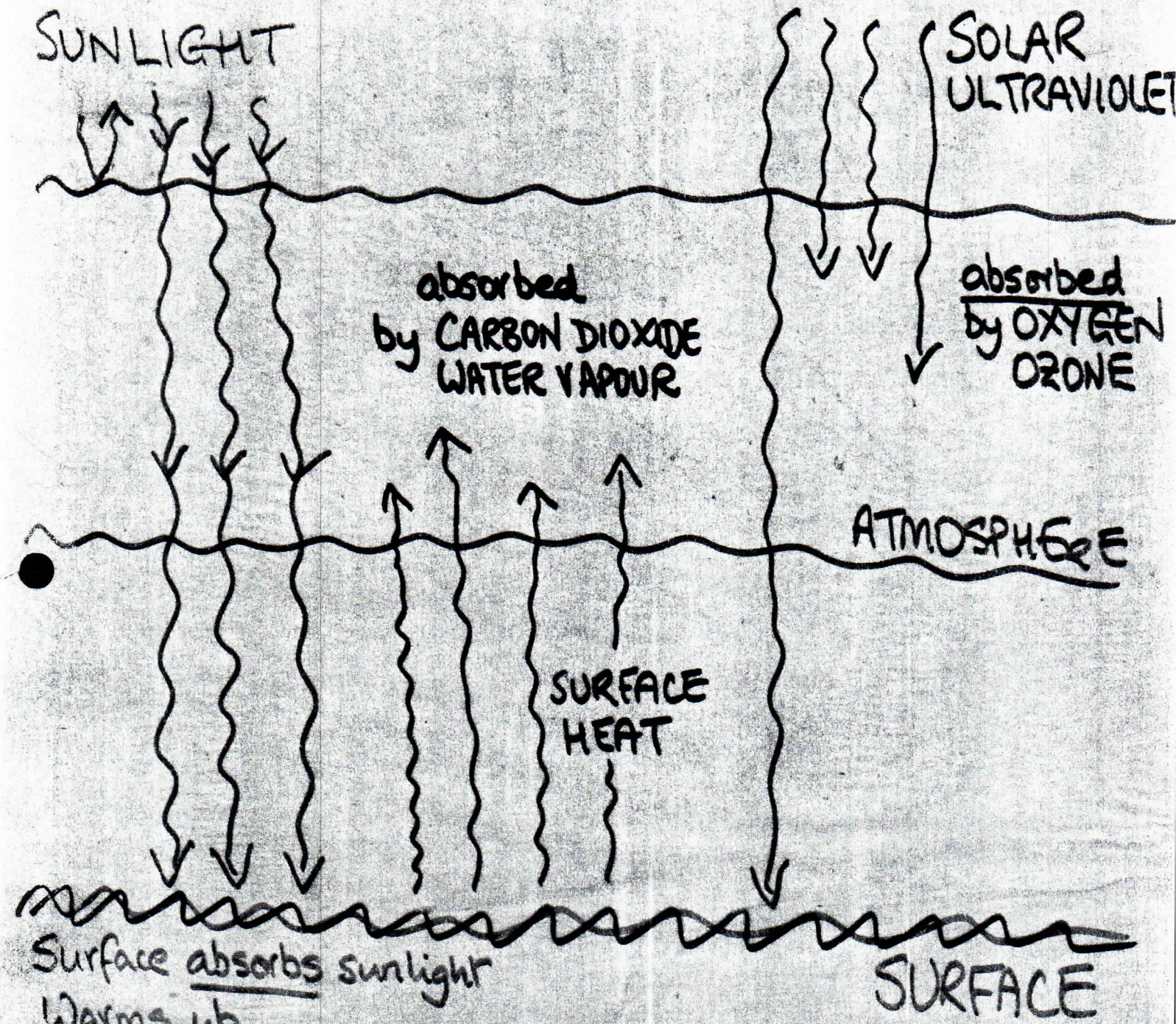
Chlorine

Explains why <u>nitrogen</u> more abundant than heavier <u>neon</u> in Earth atmosphere — nitrogen more chemically reactive, dissolved in interior fluid Earth; neon inert, escaped.

CARBON DIOXIDE CYCLE ON EARTH



The "Greenhouse" Effect



Surface absorbs sunlight

Warms up

Reradiates infrared (heat) radiation

Environmental Balance of Earth and Venus

1. Similar conditions of aggregation, volcanism.
   Similar initial atmospheres, mainly H_2O, CO_2.
   BUT: Venus somewhat hotter than Earth because closer to Sun.

2. Chemical weathering of surface rocks
   SILICATE ROCKS + CO_2 → CARBONATE ROCKS
   e.g. granite — e.g. limestone, marble
   Proceeds better on Earth, removes atmospheric CO_2 on Earth, reducing "greenhouse effect" and cooling Earth.

3. Water condenses into oceans on cooler Earth.
   CO_2 on Earth can now dissolve in surface water.
   Erosion → salts in oceans → combine with CO_2 from atmosphere → bicarbonates
   Removes more atmospheric CO_2 on Earth
   Removal of CO_2 and H_2O further reduces "greenhouse"

4. life evolves in watery environment of Earth.
   Plant life: SUNLIGHT + CO_2 + H_2O → ORGANIC MATTER + O_2
   Replaces atmospheric CO_2 on Earth with O_2 (oxygen)
   O_2 and O_3 (ozone) absorb solar ultraviolet, reducing heat input to Earth and reducing dissociation of H_2O by ultraviolet.

ALL DEPLETE CO_2 IN EARTH ATMOSPHERE
COOL EARTH RELATIVE TO VENUS

Environmental Balance of Mars

Differences from Earth and Venus:-

1. SMALLER PLANET
   - heated less and cooled more rapidly
   - less atmosphere produced by volcanism
   - easier escape of very light gases
2. FURTHER FROM SUN
   - cooler environment at all times.

CARBON DIOXIDE AND WATER COULD FREEZE OUT AT POLES → POLAR CAPS
→ THINNER ATMOSPHERE, EASIER ESCAPE.

If volcanism stopped long ago, replenishment of escaped atmosphere no longer possible.

Solar ultraviolet steadily dissociates water vapour into hydrogen and oxygen → escape.

MARS MAY HAVE BEEN MORE "EARTHLIKE"
(denser atmosphere, "greenhouse" → milder temperatures liquid water, etc. IN PAST ?)

The Seven "Ages" of An Inner Planet

after W.M. Kaula, Icarus, vol. 26, No 1, p. 1. September 1975

1. Condensation
   - Formation of solid grains from interstellar cloud
   - Collapse to disk
2. Planetesimal interactions
   - Aggregation into ~100km bodies (planetesimals)
   - Heating by collisions. Loss of volatile materials
3. Formation
   - Accretion onto biggest planetesimals → planets
   - Heating by accretion
4. Vigorous volcanism and outgassing
   - Separation of iron cores
   - Radioactive heating.
   - Large-scale exhalation of gases → atmospheres
5. Plate tectonics
   - Crust formed but broken into moving plates
   - Outgassing through weak spots.
   - Recycling of material to interior at plate boundaries
6. Terminal Volcanism
   - Plate motion stops
   - Final volcanism at weak areas → large volcanic piles
7. Quiescence
   - Thick crust, no volcanism
   - Only deep activity.

MOON, MERCURY	7	ESTIMATES of stages reached to date by various solar-system objects
MARS	6½ - 7 ?	
EARTH	5	
VENUS	4 - 5 ?	

The Seven Ages of a Planet

Our System is a stage
And both the Sun and planets merely players.
They had their birth and'll have their fiery end.
A planet in its time plays many parts,
Its acts being seven ages. The first of these
Is condensation: dust grains drifting to
The nebula plane in chondrite clods. And then
The planetesimals: breaking sometimes, but
Mostly growing, though the Sun's hot breath blows gas
Away. And then formation: sweeping up
The bodies in its way, in fierce infalls
To bring them full convective vigor, too hot
For crust to form, though iron may sink and seas
Outgas, by radioactive energy driven.
And then comes plate tectonics: cooling leads
To lithosphere, with many marginal breaks.
Convective thrusts a crust create in belts
Complex. But heating slows; the sixth age shifts
Into the final volcanism: no
More lithospheric spreading, only vents
For magma, Nix Olympica or mare
To surface, ending fractionation. Last scene
That ends this history is quiescence: time
Sans melt, sans plates, sans almost everything.

William M. Kaula
(Professor of Geophysics, UCLA)