Life in our Solar System?

- Carl Sagan was fond of saying that extraordinary claims require extraordinary proof.
- Finding life elsewhere would certainly be extraordinary.
- We have only suggestive just-so stories. Intriguing, but that’s all it is.

Speculations on Life Elsewhere in our own Solar System

- Anywhere near the surface of the earth (10 km?) where there's a living to be made doing chemistry, there are microbes there doing it.
- In deep mines, bacteria and archea have been found in the pores in rocks, doing sulfur and metal chemistry.
- They probably migrated from near-surface conditions on earth.
- There is subsurface water on Mars, and there once was an earth-like climate (3.5 Gyr ago).
- This is suggestive but not "extraordinary proof"

- Much of what follows is from a recent Sky and Telescope article “The Martian Underground” (posted on the website at RichardJEdgar.github.io) by Javier Barbuzano. Sky & Tel, Jan 2020, p35

- There are as many cells in the deep biosphere as there are on the surface of the earth.

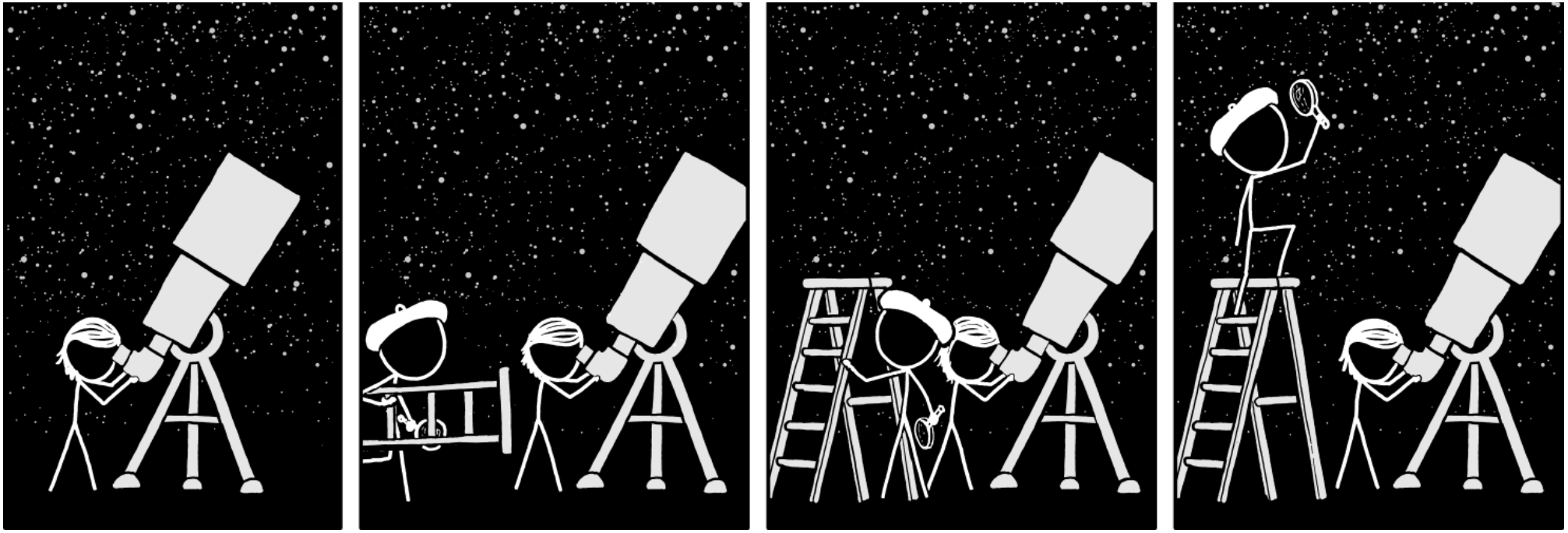
- Life is abundant at mid-ocean ridges, with microbes feeding from the chemistry brought up from the earth’s interior. Larger animals have these microbes internally feeding them.

- Microbes are also found in the pores of rocks deep underground.

- Uranium, etc. decays, splitting water molecules, and microbes can use the hydrogen to do reduction/oxidation reactions with sulfates.

- *Serpentinization* reacts iron-rich minerals with water to liberate hydrogen. This sometimes reacts with carbon (with microbial help in some cases) to make methane, CH_4, which is also food for microbes (fuel plus a carbon source).

- Life exists in a wide variety of temperature and pressure, salinity, etc. Some Archea are known as *extremophiles*, for the extreme environments in which they can survive.

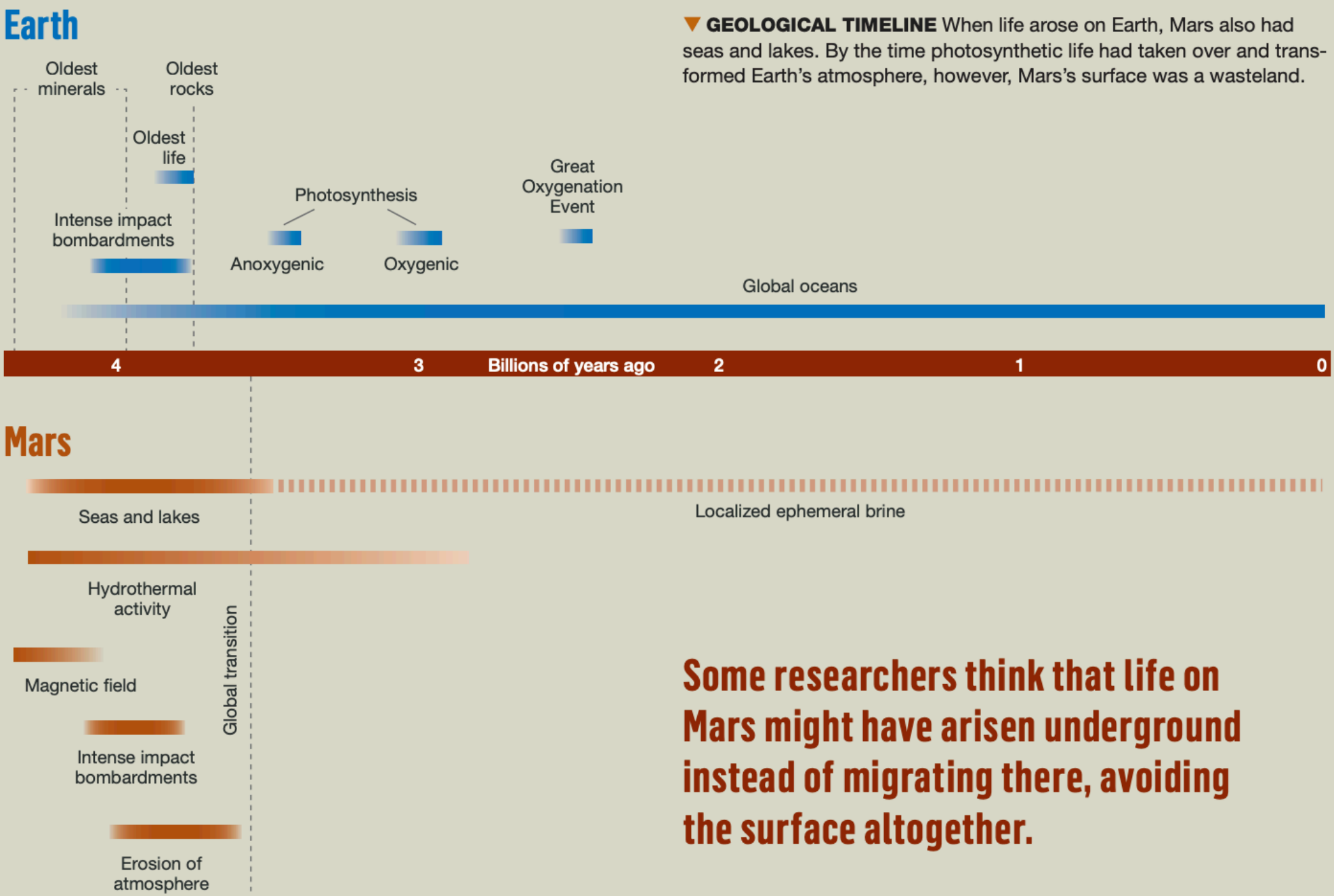


“Astrobiology is held back by the fact that we’re all too nervous to try to balance on the ladder while holding an expensive microscope.”

https://xkcd.com/1522/

What about Mars?

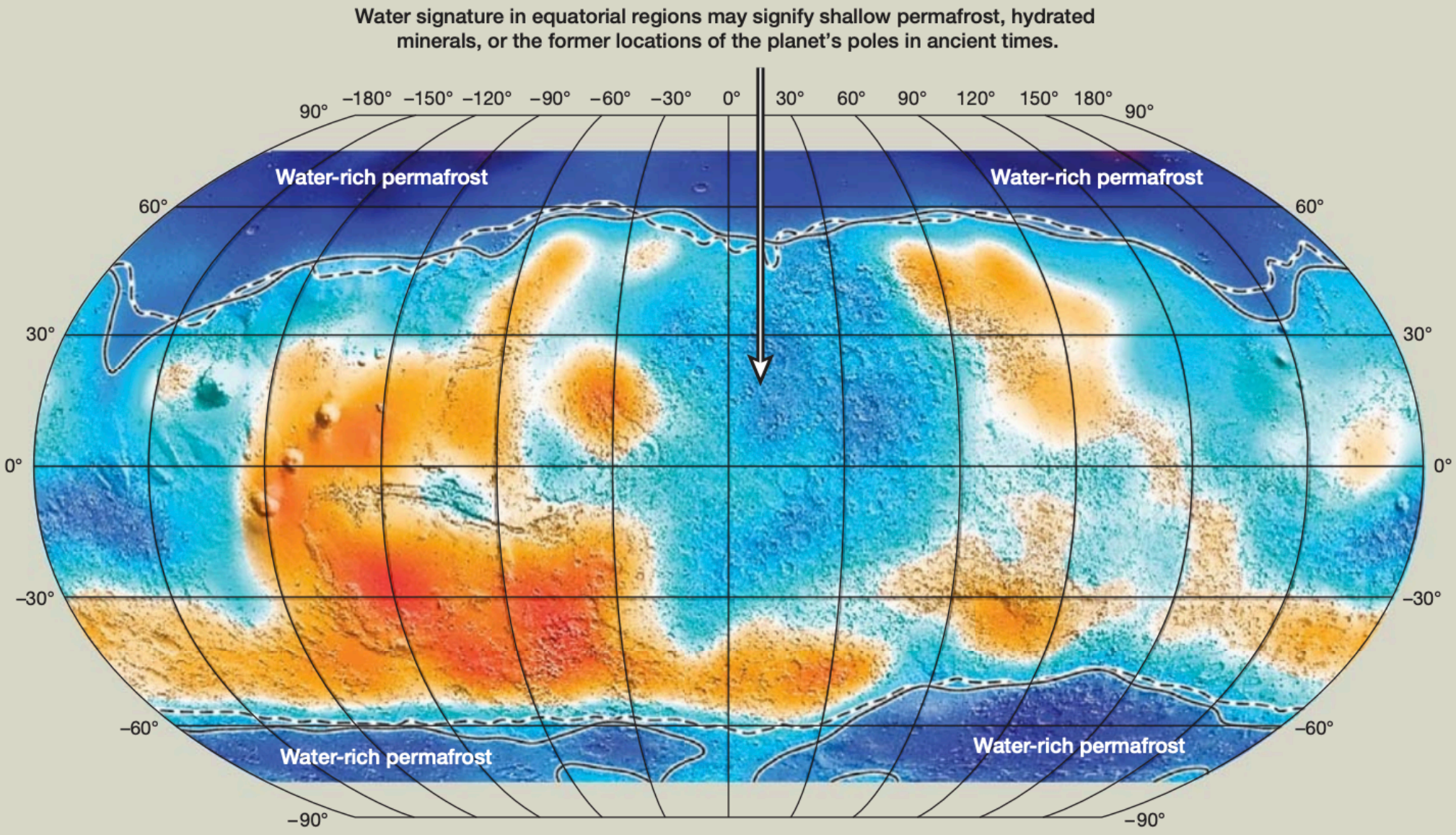
- In its first billion years or so, Mars had many earth-like features.
  - global magnetic field: failed when the core solidified about 4 Gyr ago
  - thicker atmosphere. ablated by the sun when the magnetic field faded.
  - running and standing surface water: seas, lakes, rivers, perhaps an ocean in the north. boiled or froze when the pressure got too low.
  - geothermal activity
  - Subsurface brines still exist.

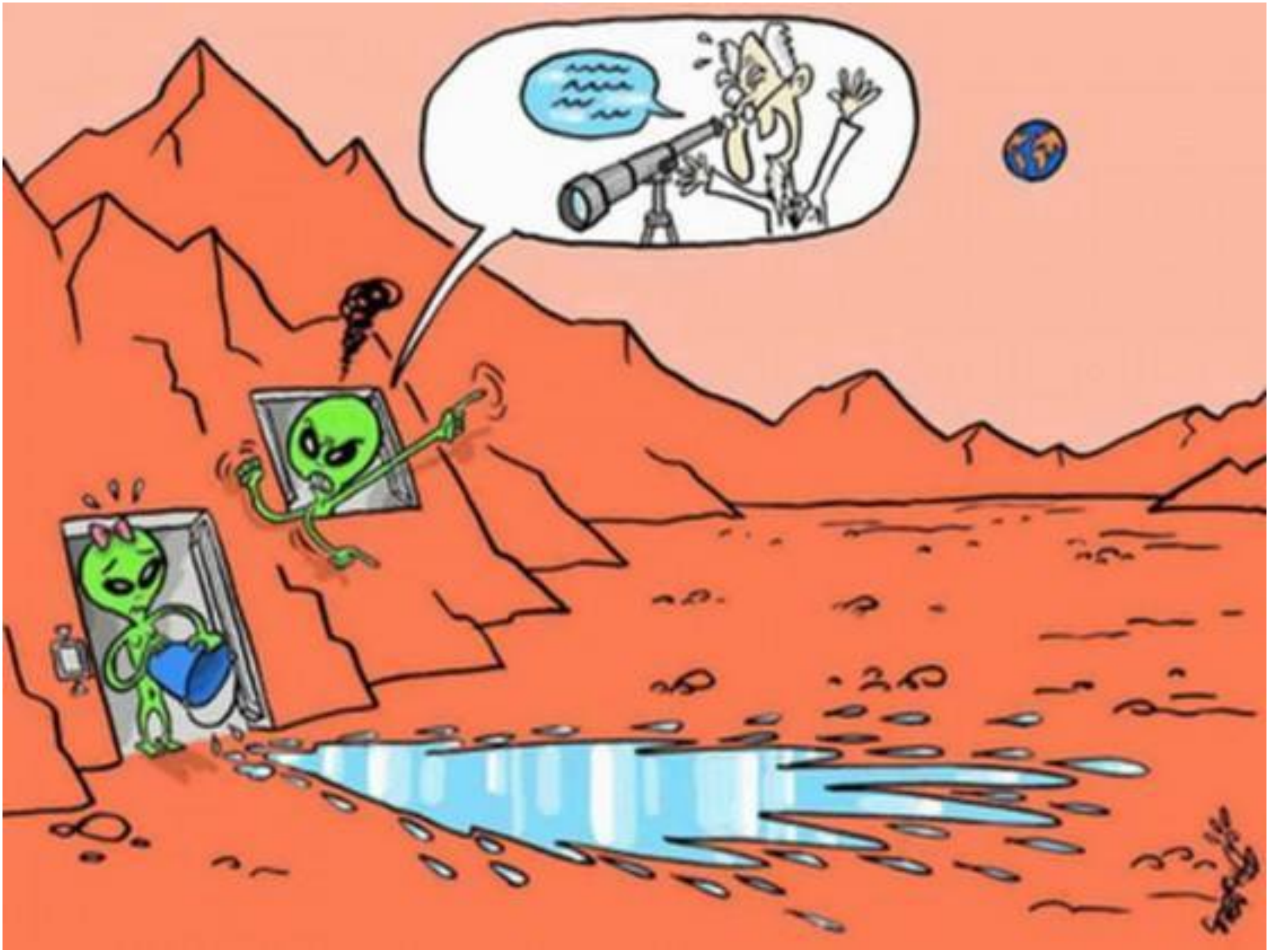


▼ **GEOLOGICAL TIMELINE** When life arose on Earth, Mars also had seas and lakes. By the time photosynthetic life had taken over and transformed Earth's atmosphere, however, Mars's surface was a wasteland.

Some researchers think that life on Mars might have arisen underground instead of migrating there, avoiding the surface altogether.

▼ **UNDERGROUND WATER** This map from the ExoMars Trace Gas Orbiter shows hydrogen's distribution (bluer colors mean more hydrogen) in the uppermost meter of Mars's surface. Hydrogen might indicate water, water absorbed into the surface, or minerals formed in water.





In Situ measurements

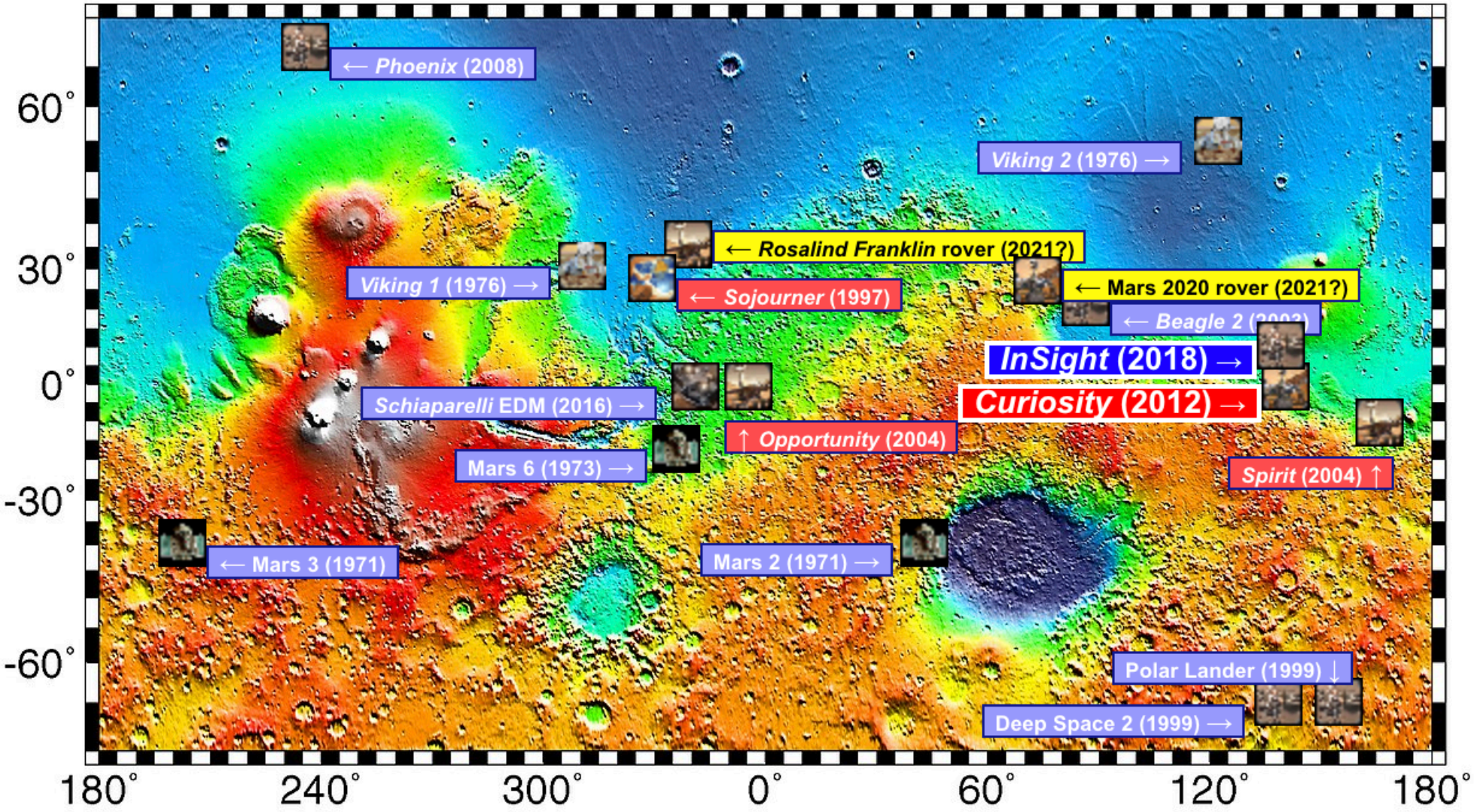
- Two Viking landers (built by Martin Marietta) soft-landed in 1976, and survived for years on the surface

- 15 kg worth of miniature chemistry lab equipment with four instruments. Three returned negative results, but one claimed positive results.

- The results may be explained as inorganic chemical reactions in the Martian regolith (soil); e.g. H_2O_2

- This view is softening with the discovery of water ice not all that far down below the surface at the landing sites.

- No organic compounds were found in the soil. ***But*** dry valleys in Antarctica on earth also have no organics in the soil, yet still have microbes inside the rocks.



- Mars is completely inhabited by alien robots.

- Lesson learned: searching for life is hard.

- Subsequent landers and rovers have looked at geology, especially evidence for surface water, geologic activity, and the like.

- There's another rover mission scheduled to launch this summer, Mars 2020. It includes gathering samples for subsequent return; search for organics molecules; and a small helicopter scout craft.

Ocean Worlds

- A number of moons in the outer solar system have icy surfaces and sub-surface oceans of liquid water.
  - At Jupiter, Europa, Ganymede and Callisto
  - At Saturn, Titan and Enceledus
  - At Neptune, Triton.
  - Possibly Pluto?
- Titan also has a N_2 atmosphere with earth-like pressure, but very cold temperatures (90 K)

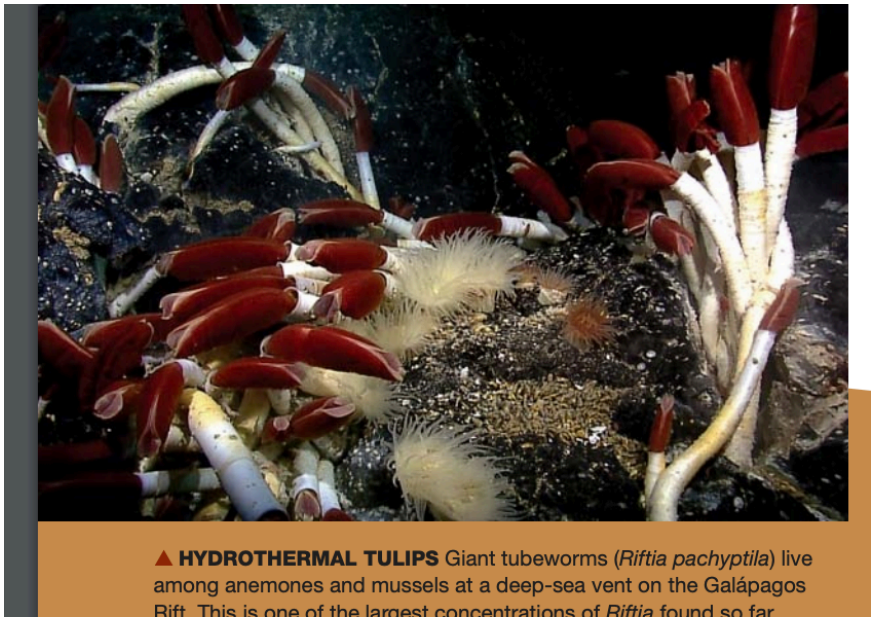
- Life is abundant on earth at mid-ocean ridges, where hot chemical-laden water comes up from the earth's interior.

- The Jupiter moons may be heated by tidal action (The inner big moon Io is strongly volcanic), suggesting sub-ocean heat transfer like earth's mid-ocean ridges.

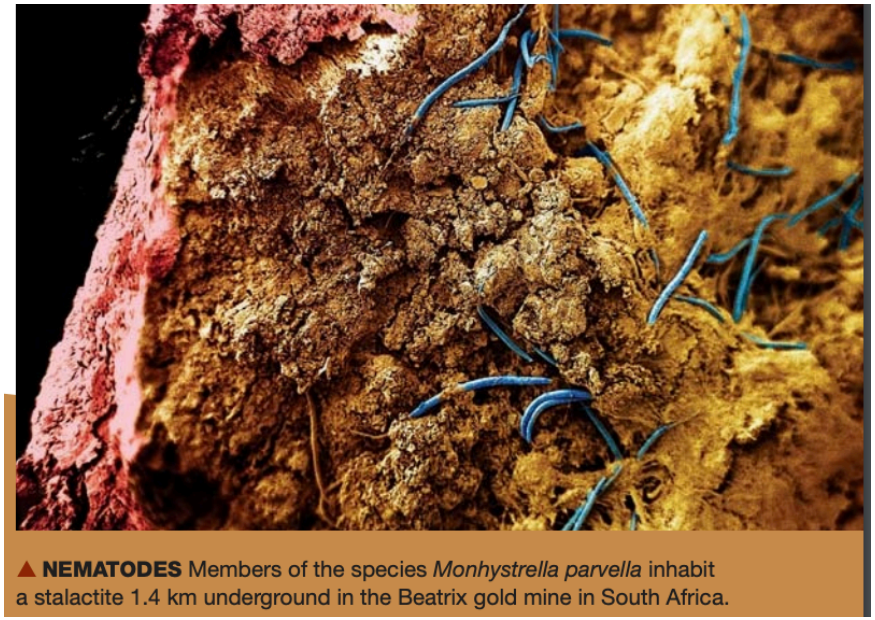
- Enceledus has obvious geyser activity at the south pole. Europa apparently has weaker geysers. Sampling the geyser plumes might turn up organics if there's life down there.

- ESA is sending the Jupiter Icy Moons Explorer (JUICE) to explore Europa and friends. NASA will send the Europa Clipper to do multiple flybys.

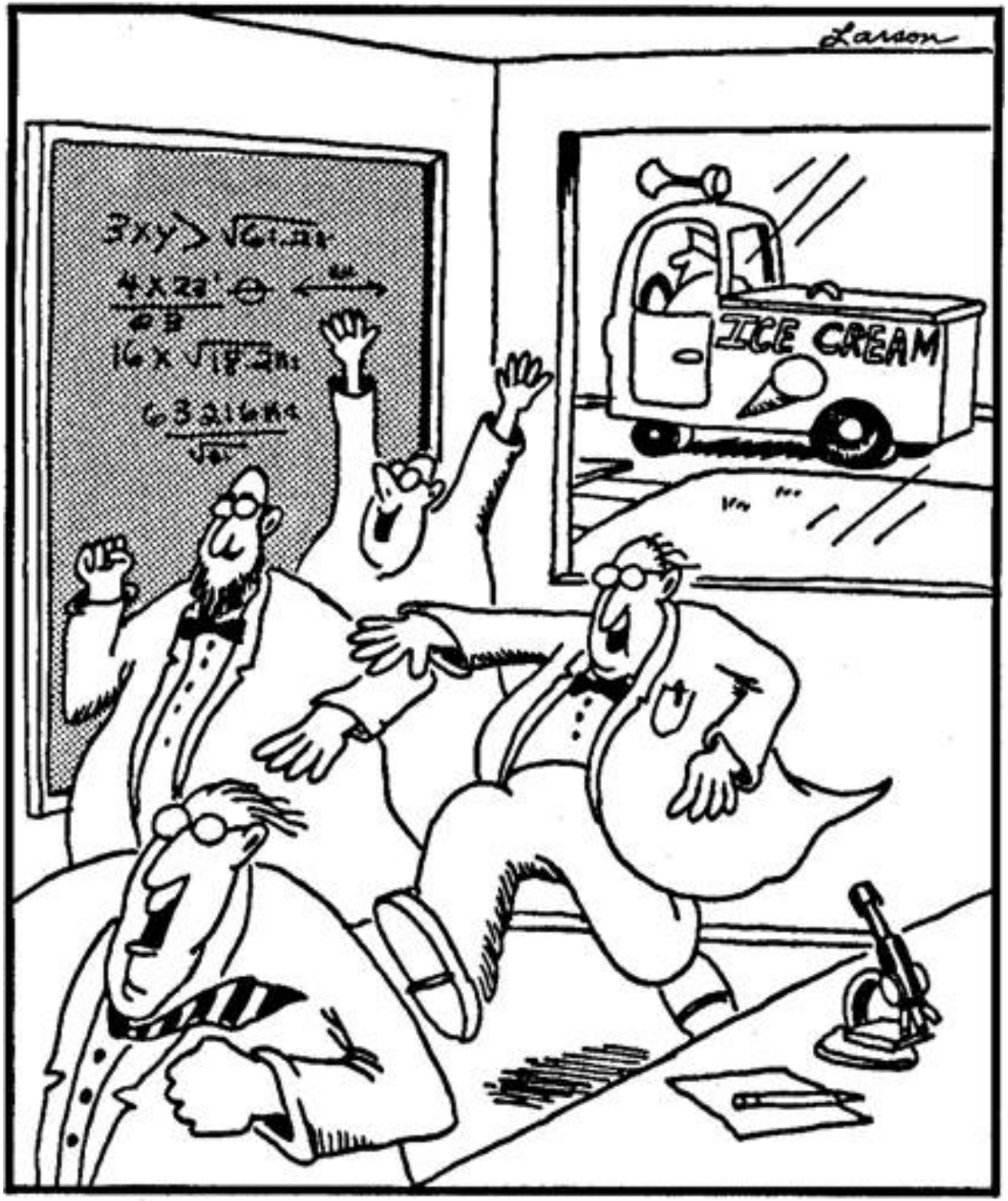
- A few examples of mid-ocean ridge life on earth
- There's a research group at Woods Hole Oceanographic Institution researching just this topic:
- https://oceanworlds.whoi.edu/



▲ **HYDROTHERMAL TULIPS** Giant tubeworms (*Riftia pachyptila*) live among anemones and mussels at a deep-sea vent on the Galápagos Rift. This is one of the largest concentrations of *Riftia* found so far



▲ **NEMATODES** Members of the species *Monhystrella parvella* inhabit a stalactite 1.4 km underground in the Beatrix gold mine in South Africa.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