

Ocean Acidification back to basic(s)

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Rising CO₂ levels

probably cause climatic change

BUT

certainly cause Ocean Acidification

What can we do about it?

If a solution is too acid one can

- Add a base
or
- Remove the acid

That is what Nature has been doing during
the past 4.6 billion years

HOW?

- Nature adds the base by the weathering of basic silicates
- Nature removes the carbonic acid by converting it to organic carbon

Weathering

- Weathering means the neutralization of an acid by the reaction with rocks, always in the presence of liquid water.

CO₂; the short and the long cycle

- Reactions of CO₂ in and out of biomass, in and out of the atmosphere, and in and out of the oceans are all part of the short cycle.

Time scale years to tens of years; ***the CO₂ remains in the biosphere.***

- CO₂ degassing of the Earth, reaction with rocks, transport as bicarbonate solutions to the oceans, followed by precipitation of carbonate sediments form the long cycle

Time scale thousands to many millions of years; ***the CO₂ is permanently removed from the biosphere.***

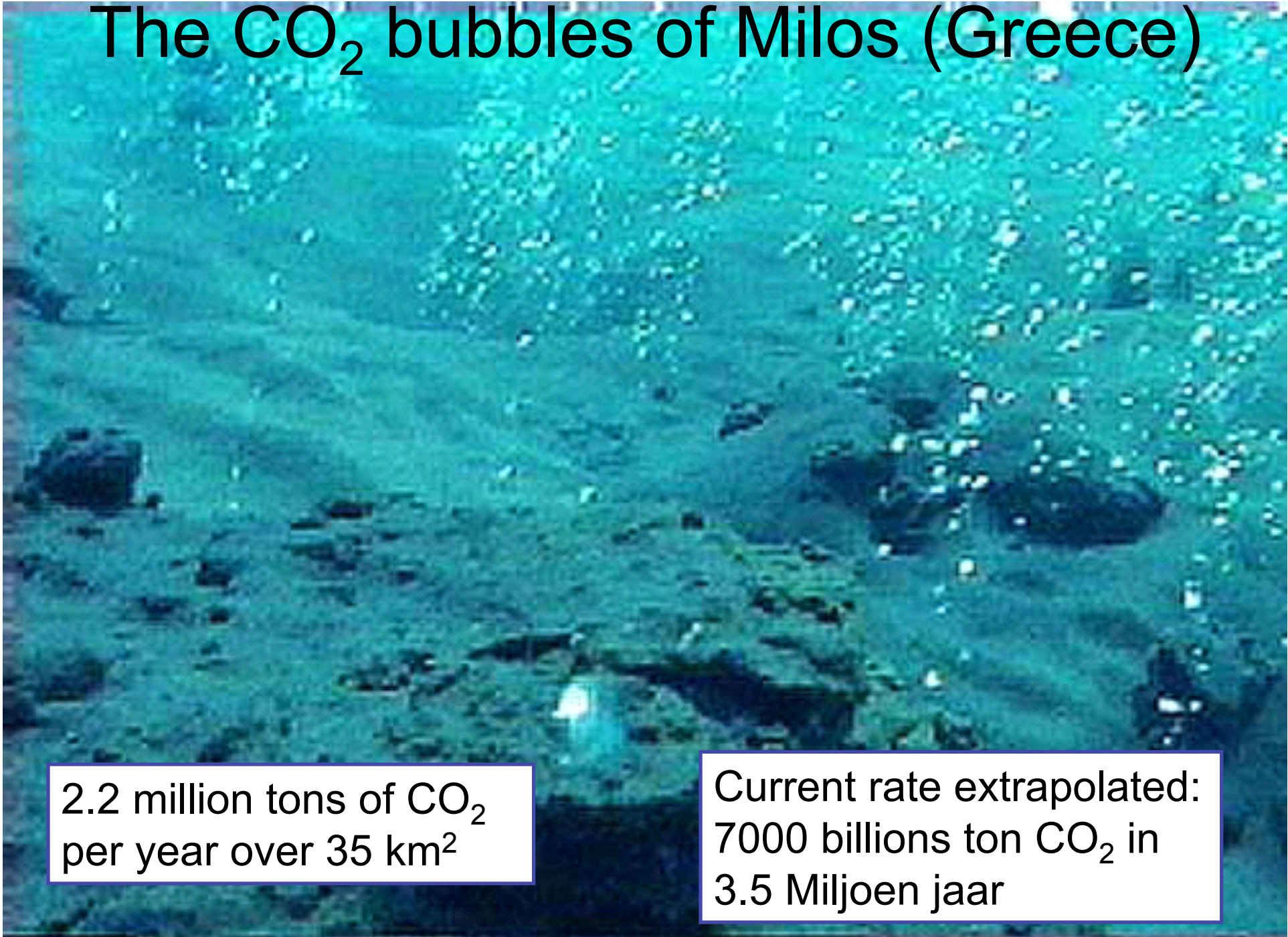
This is how CO2 is stored



Or this way



The CO₂ bubbles of Milos (Greece)



2.2 million tons of CO₂
per year over 35 km²

Current rate extrapolated:
7000 billions ton CO₂ in
3.5 Miljoen jaar

A balance lost

- Input of CO₂ by degassing of the Earth was more or less balanced by the weathering of silicates, *UNTIL ..*
- ***WE*** started to burn fossil fuels, then the balance was lost, and CO₂ levels in the atmosphere are steeply rising.

Now most of the CO₂ comes this way



A simple solution

- If the input is increasing, we must increase the output as well to restore the balance.

This can be done as follows:

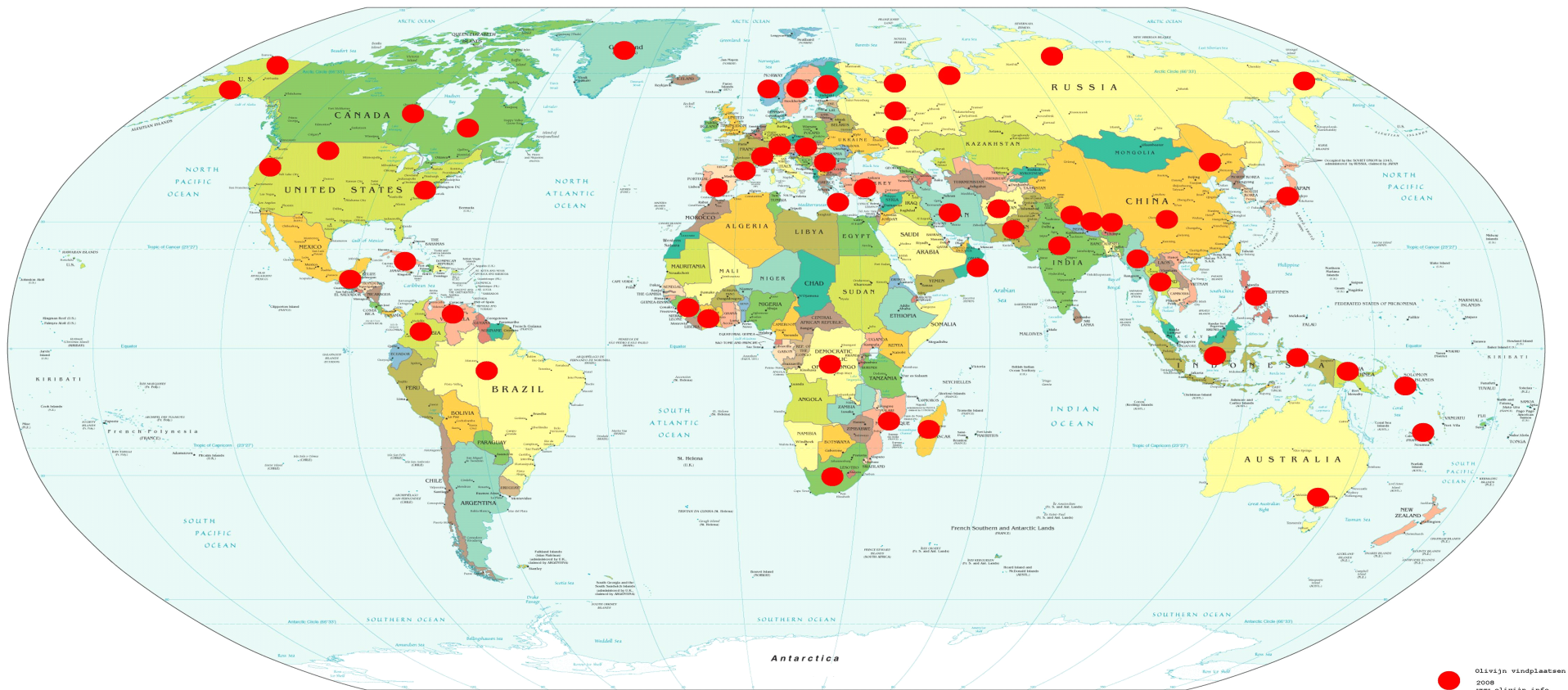
1. Select an abundant material that weathers fast
2. Mine it and mill it
3. Spread the powder over fields and beaches.

(then sit back and let Nature do the work)

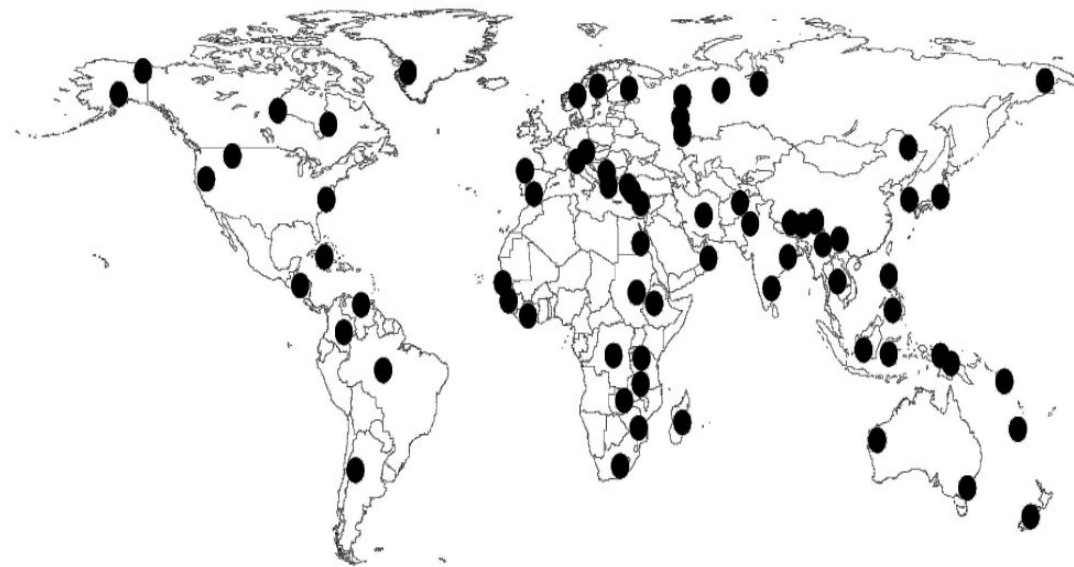
Best candidates OLIVINE and SERPENTINE

- These minerals are found in large massifs near the Earth's surface in many countries on all continents.
- Can be mined in large open pit mines, strategically located to limit transport distances to the points of use.

What is olivine, and where is it found?

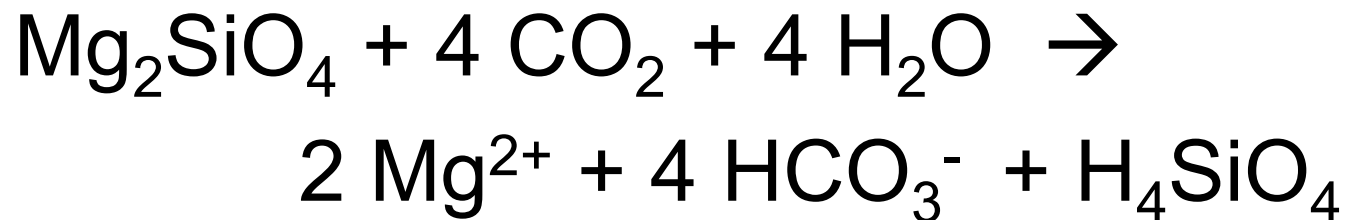


Some major olivine massifs. One dot in a country often means many dunites

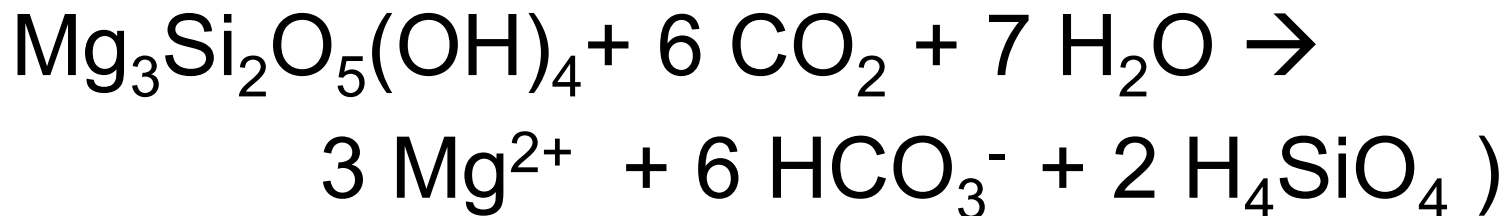


How can they capture CO₂?

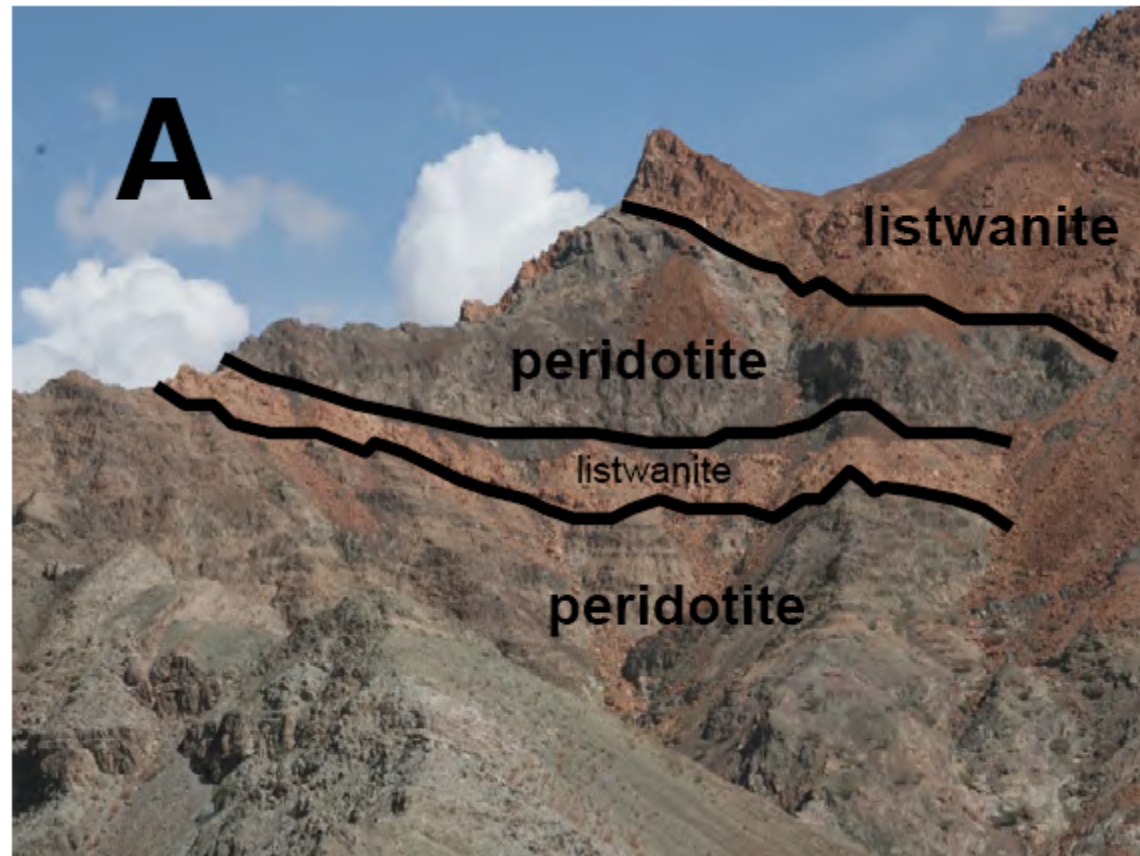
- By the following reaction
for olivine:



for serpentine:



This gigantic rock mass represents
only 1 week of the world's CO₂
emission!



Does olivine weather fast enough?

- Extrapolation from laboratory observations shows that it is very slow
- Observations in nature on the contrary show that weathering proceeds fast enough

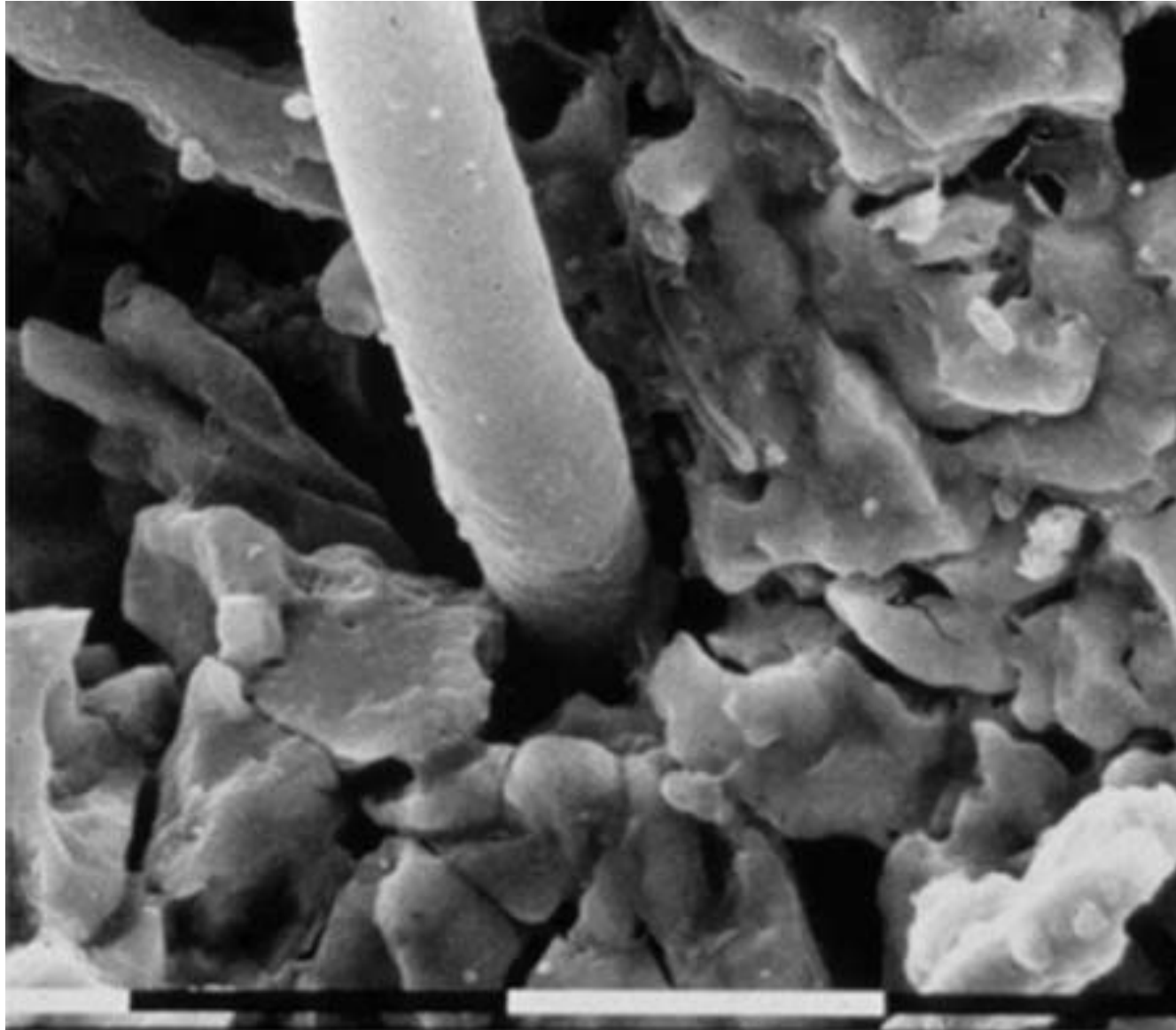
Natural aids for weathering

- Bare rocks: lichens release oxalic acid
- Minerals in soils: mycorrhizal fungi release malic acid, oxalic acid and a whole range of other organic acids which attack minerals
- Olivine on beaches: are quickly rounded and abraded in the surf, and then react fast
- Olivine on tidal flats: weathering in the guts of lugworms is very fast

Lichens secrete oxalic acid



Mycorrhizal fungi eat rocks



What happens to olivine on the beach? Before shaking, the grains are rough and angular



After 10 days of shaking, the grains are rounded and smooth



Left before, right after 10 days shaking



The lugworm digests minerals fast



What does it cost?

- Mining **and** milling of bulk rocks in open pit mines cost about 6 Euro per ton.
- We can limit transport costs to a similar amount, which means 12 Euro per ton of crushed olivine at the point of use.
- 1 ton olivine captures 1.25 ton of CO₂, so the costs per ton of CO₂ become around 10 Euro per ton (other technologies to capture CO₂ cost around 100 Euro per ton)

A bright yellow rectangular sign with a white border is mounted on a wooden post. The sign features the text "THERE IS NO PLANET B" in large, bold, black, sans-serif capital letters. The sign is positioned on the deck of a boat, with wooden beams and ropes visible in the background. The boat is docked in a harbor, with buildings and water visible in the distance.

**THERE
IS NO
PLANET B**

Thank you for your attention