Let the Earth help us to save the Earth

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What has saved the Earth and provided the conditions for life?

- Annual CO2 emission of volcanoes is around 300 million tons a year
- 300 million tons multiplied by 4.5 x 10 billion years is a huge number. If all that CO2 had stayed in the atmosphere, the Earth would be covered by a heavy blanket of CO2 with a pressure of ~100 bars, and there would be no life on Earth.
- As there is life (look around you), there must also be a process that has removed almost all that CO2 and stored it safely

That process is weathering

- Weathering is the reaction between a mineral and water + CO_2.
- Example: $Mg_2SiO_4 + 4\ CO_2 + 4\ H_2O \rightarrow$

  $2\ Mg^{2+} + 4\ HCO_3^- + H_4SiO_4$
- Those magnesium bicarbonate solutions are carried by rivers to the sea, and in the sea corals, shellfish and plankton convert that to solid carbonates

Olivine against climate change and ocean acidification

Without the weathering of basic silicates, the Earth would have been unlivable, with a CO_2 pressure of 100 bars in its atmosphere and a surface temperature of 500 degrees centigrade

On Earth, Nature has prevented that horror scenario

- Since the origin of the Earth, CO2 and water have reacted with basic silicates (a process called weathering). By this reaction CO2 has been converted to bicarbonate solutions.
- These are carried by rivers to the sea, where corals, shellfish and plankton convert them to limestones and dolomites, the ultimate storage rooms of CO2.
- Carbonate rocks contain a million times more CO2 than the atmosphere, the oceans and the biosphere together.

So if you walk in the Dolomites

Or sail along the Cliffs of Dover

Or make an exotic tour in China

You stand face to face with Nature's stores of CO2

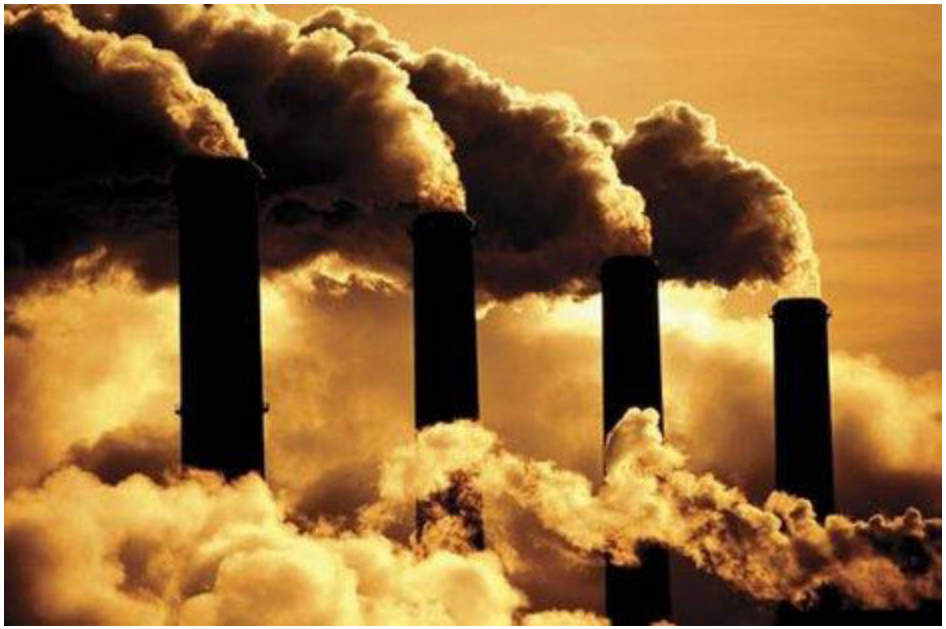
- Carbonate rocks contain one million times more CO2 than the oceans, the atmosphere and the biosphere together

Natural variation of the CO2 content of the atmosphere

- We know that there have been variations in the past of the CO2 concentration in the atmosphere.
- These were caused by variations in volcanic activity, and by the extent of basic rock-types exposed at the surface. It is estimated that volcanoes emit about 300 million tons of CO2 each year.
- Weathering, and removal of CO2 has an inbuilt feedback system. When the CO2 level is high, the waters become more acidic, and weathering is faster, and when the CO2 level is low, the rate of weathering is also reduced.

CO_2 belletjes komen uit de zeebodem bij Milos/Griekenland

But these days most CO2 comes like this



The olivine option can be used in many of our activities

- These include, the addition of olivine to biodigesters to increase methane production, phytomining of nickel, cultivating diatoms for the production of biodiesel, olivine sand for beach suppletions, using the surf to crush and abrade olivine grit to counteract ocean acidification, treating the air inside schools and offices suffering from the sick-building syndrome, fire fighting with serpentine slurries, and many more

Increasing rice production by adding olivine

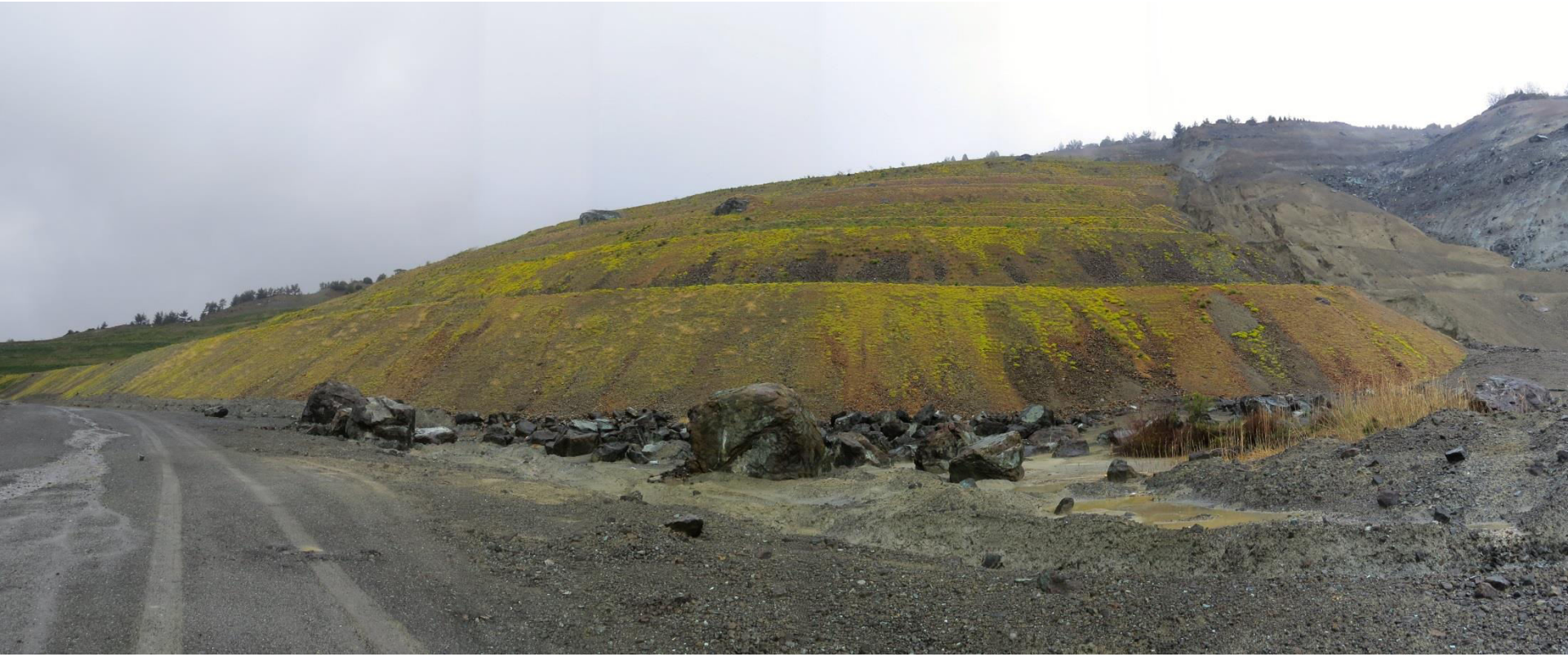
Effect of olivine on rice paddies

- When olivine is spread over rice paddies, the effect on CO2 capture is easy to measure. Water samples can be taken at the point where the water comes in a paddy that is treated with olivine, and also at the drainage point, where that water leaves the paddy. The difference in composition and pH tells about the amount of CO2 that has been captured. By following the rice production in paddies with and without olivine spreading, its effect on rice production can be measured directly.

Phytomining of nickel

- The mining and ore dressing of nickel is expensive, both in terms of energy as well as pollution.
- Olivine rocks (and their soils) are richer in nickel than most rocks.
- Some plants (nickel hyperaccumulators) can extract nickel very efficiently from such soils, and store it in their tissues.

Alyssum with yellow flowers on the tailings of a former asbestos mine on Cyprus



And this is what an individual nickel-hungry *Alyssum* looks like

Nickel farming; does it pay?

- When such plants are harvested at the end of the growing season, dried and burnt, their ash contains up to 10% of nickel, **much richer than the richest nickel ore.**
- You save energy (= reduce emissions of CO2), and provide employment and income for poor farmers

Why did I tell you this?

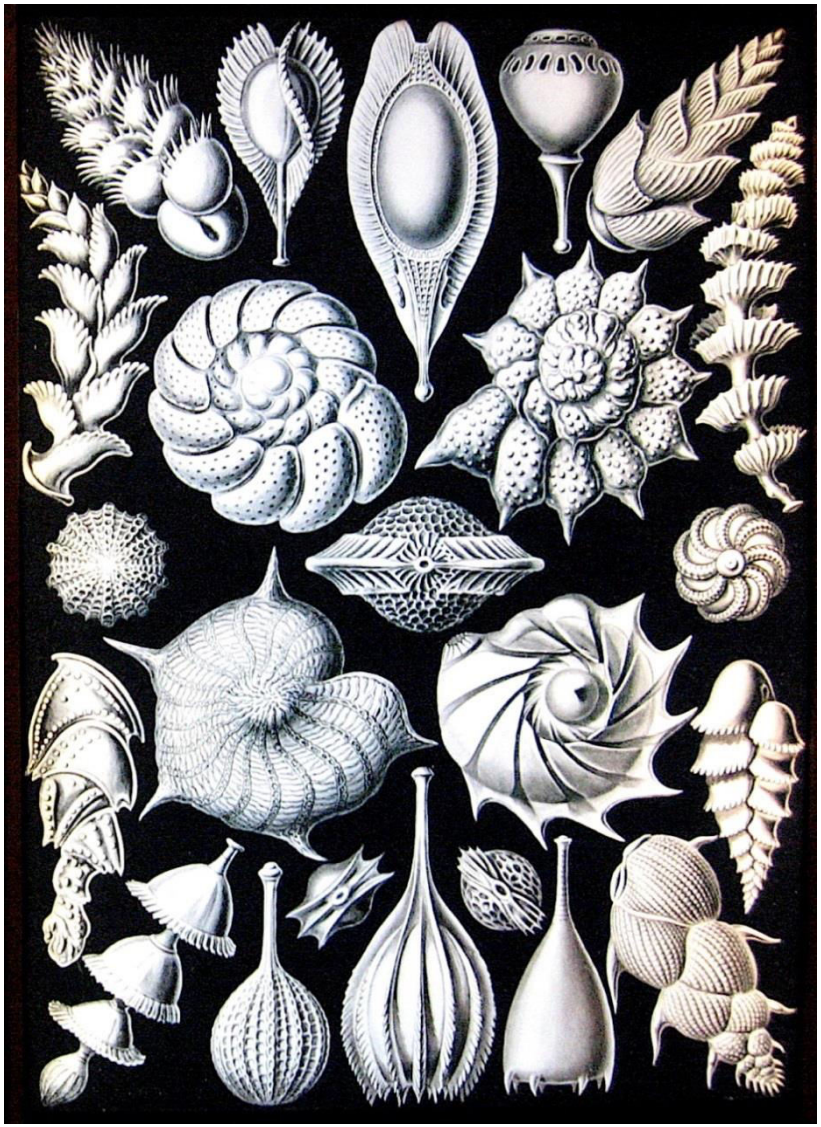
- Nickel mining and ore processing cost a lot of energy, and are quite polluting
- Plants are environmentally friendlier and we save large CO2 emissions.
- You might call it geo DE-engineering.

Biodiesel from Diatoms?

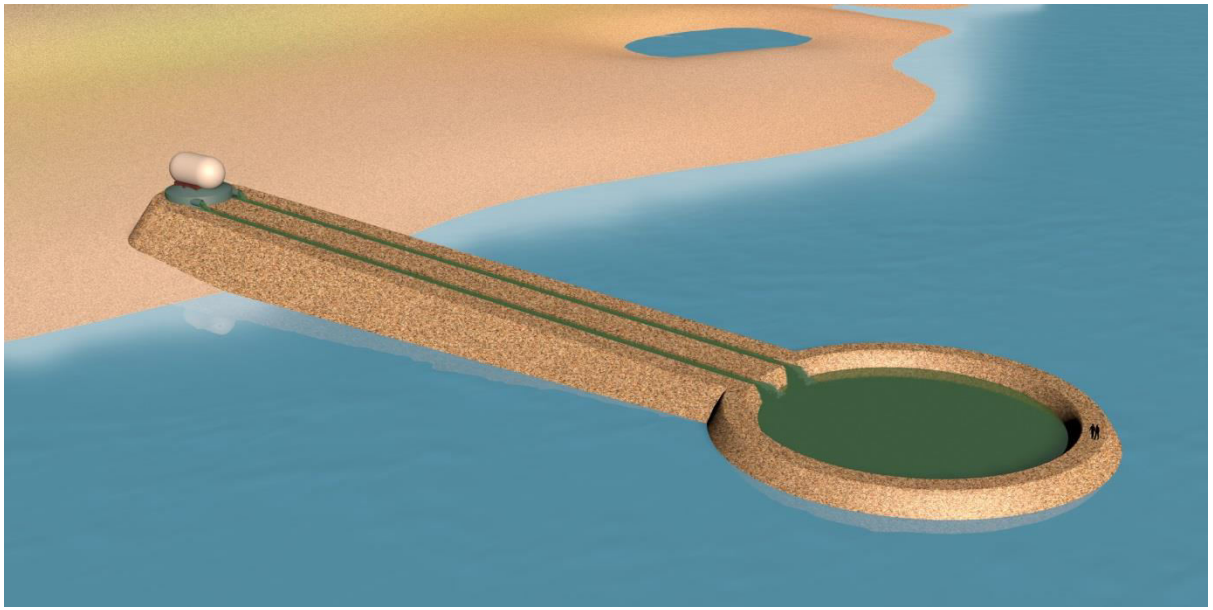
- Diatoms multiply fast, but they need silica, because they have a silica skeleton
- We are setting up a diatom farm in Qatar to test the possibility to cultivate diatoms (they contain 50% of fatty acids by weight) and use them as a marine source of biofuel.
- Land-based biofuel crops occupy large areas, require irrigation water and fertilizers, and this wasteful use of the resources of the Earth should be phased out.

These diatoms thrive in the mine pit lake of a former asbestos mine in Canada

Diatoms often construct beautiful silica skeletons



But … no silica, no diatoms



An olivine reactor + a diatom pond

The normal weathering reaction of olivine, the most common mineral of the Earth

$$Mg_2SiO_4 + 4\ CO_2 + 4\ H_2O \rightarrow 2Mg^{2+} + 4\ HCO_3^- + H_4SiO_4$$

Our analyses of spring waters in dunite massifs have confirmed that this is the normal weathering equation.

So we use the weathering of olivine to provide silica, an important nutrient for diatoms, and bicarbonate for their photosynthesis, also at night, by using underwater LED lighting

Forest fires cause the second largest CO_2 emission

Quenching forest fires with a serpentine slurry?

- When you sprinkle a serpentine slurry on a burning material, the fire is immediately stopped.
- The serpentine breaks down, and produces a thin glassy impermeable layer on the burning material.
- Oxygen cannot reach the inflammable material, and inflammable gases can no longer leave the burning wood.
- Interestingly, this glassy material reacts very fast with rainwater and CO2 after the fire, so part of the CO2 emission of the fire is compensated.

Olivine powder in biodigesters

- Biogas produced in digesters has an approximate composition of 2/3 methane and 1/3 CO_2, + traces of H_2S. For a higher quality, it is necessary to reduce the CO_2 content and to remove the H_2S.
- When olivine powder is added, the iron content of the olivine reacts with H_2S and transforms it into (non-smelling) iron sulfides.
- Because olivine raises the pH of the digester, more CO_2 is dissolved in the digestate (the liquid in the digester).
- The fayalite (the iron part of the olivine) reacts with CO_2 and water, and generates MORE methane, according to
- $6\ Fe_2SiO_4 + CO_2 + 14\ H_2O \rightarrow 4\ Fe_3O_4 + \mathbf{CH_4} + 6\ H_4SiO_4$
- *So, no foul smell, a better quality and increased production of biogas, and capture of CO_2 in the digestate*

Nature has (again) preceded us

- This methane generation is also known in nature. Some famous examples are the “YANARTASI” (the rock that always burns) in Turkey, and los Fuegos eternos (the eternal fires) in the Philippines.
- The Yanartasi is on a mountain slope facing the Mediterranean. Nearby on the coast is an ancient Greek city called Olympos. You can still visit the ruins of that city. Already 3000 years ago they organized games in which the boys of the city had to run up the mountain with a torch, which they had to lit on the methane flames. The boy who was first to return in the city with a burning torch was the winner.
- Would that be the origin of the Olympic torch?

The flames of the Yanartasi by night

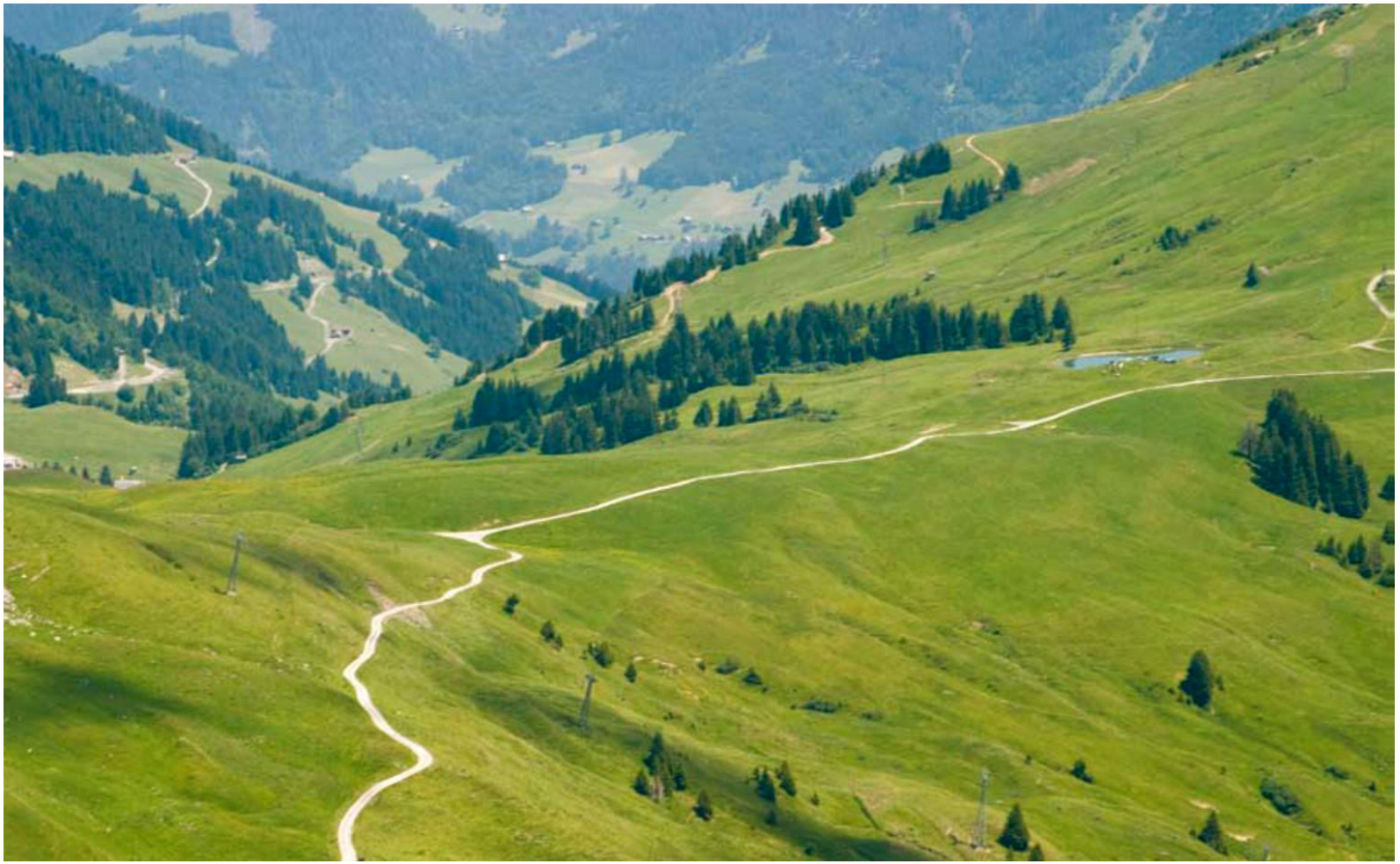
Olivine grit in the surf; at the start rough surface, angular habit

After 10 days in a modest imitation surf, round and smooth

Left before, right after 10 days shaking

We have one gigantic advantage over all other solutions for CO2 reduction

- We use the same mechanism that has kept the CO2 levels of the atmosphere within bounds for the past 4.5 billion years.
- It is highly unlikely that this process would all of a sudden start to cause problems when we use it against climate change and ocean acidification.



This is my reactor !