Let the earth help us to save the earth

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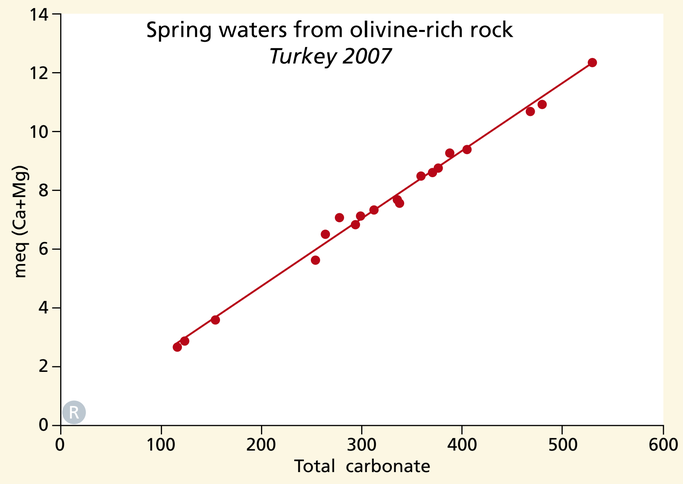
Climate change has become a global issue. Massive sequestration of CO_2 can be achieved by the enhancement of the natural process of chemical weathering. This is a sustainable method. It is

- cheaper
- more efficient in terms of energy and cost
- it captures carbon dioxide that is already emitted to the atmosphere

It can be carried out with standard mining and milling technology. It involves the use of olivine, the most widespread silicate in the world. The Earth's mantle is dominated by olivine, and huge slabs of olivine-rich rocks have been pushed up into the Earth's crust, and are now exposed at the surface.
It weathers easily when in contact with CO_2 and water, according to

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

This means that 140 gram of olivine will sequester 176 gram of CO_2. This is unambiguously proven by the close correlation between the sum of Mg- and Ca- ions and CO_2, as found in spring waters from several Turkish massifs of olivine rocks.



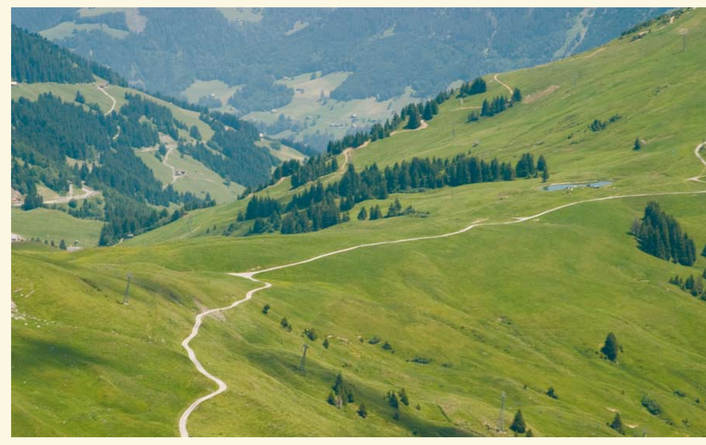
Concentration in meq [Ca^{2+} + Mg^{2+}] in spring waters versus total carbon as mg CO_2. ® composition of rain water.

In pre-industrial times the CO_2 that escaped from the mantle was roughly balanced by the CO_2 sequestered by chemical weathering. This used to keep the CO_2 level in the atmosphere reasonably constant. The rapid combustion of fossil fuel, however, causes atmospheric CO_2 to rise. Chemical weathering, followed by carbonate precipitation in the oceans, cannot keep pace with the increased input. Weathering is a surface process, which proceeds slowly in the case of solid rocks. To speed it up, we must increase the reactant surface by grinding. We propose, therefore, to restore the balance by mining large volumes of olivine, grind it, and spread it over the surface of the Earth.

The volume of olivine to sequester all carbon dioxide produced annually from fossil fuels is ~7 km^3. In comparison, the volume of concrete poured every year is 6 km^3. The largest open pit mines in the world have volumes around 20 km^3. So the proposed operation is large, but doable, certainly if it is distributed over several tens of olivine mines on different continents. To remove1 billion tons of CO_2, 0.5% of the land surface (just over 5 % of Siberia) should be covered by a 0.4 mm thick layer of olivine grains, preferably by mixing them with fertilizers before spreading.

Costs

The grain size of the olivine is important, both in reactivity and in cost. If olivine has a grain size of ~100µ, the weathering reaction will take in the order of one year under favorable conditions of high humidity and temperature. Grinding to 100 micron costs about 1.65 Euro/ton, but for finer sizes the cost increases exponentially. The cost per ton of ground olivine in the port of destination is about 23 Euro per ton, including transport and handling. Most olivine mines are located in high-wage countries. When olivine mines become larger, and are located in lower-wage countries, and transport is reduced, the cost may drop to less than 10 Euro per ton of CO_2 sequestered. Even in our approach, the sustainable removal of all CO_2 produced will cost several hundred billion Euros annually, a huge sum, but well below the cost of other removal schemes presently under discussion.
One should leave CO_2 removal to nature (with a little help from us), and not try to carry it out in large (energy-consuming) industrial autoclaves. The interface between the atmosphere and the solid Earth itself is a giant but gentle reactor.



The surface of the Earth, a giant but gentle reactor

Flexibility

To remove more CO_2, one can use a larger surface area, make the olivine layer thicker, or use also beaches and the high energy tidal zones. When olivine reacts with sea water, the added alkalinity counteracts the danger of acidification of the oceans.

Preferred location

The current option is underground disposal of the CO_2 from the stack gases of power plants. This CCS (carbon capture and storage) will add 30% to the cost of electric energy. We do not require the expensive capture and cleaning of CO_2 produced by power plants. All molecules of CO_2 are equal. One should look for the cheapest way and the best location to remove it, and avoid complicated technologies and long transport for such large amounts of olivine.

To capture as many molecules of CO_2 from the atmosphere in a sustainable way, and as cheaply as possible, we should:
Mine olivine in wet tropical countries (Central Africa, South America, Southeast Asia).
Grind the olivine and spread it in the wider surroundings of these mines, thus combining 3 major advantages:

- **Rapid chemical weathering under wet tropical conditions**
- **Low wages (+ new employment opportunities in developing countries)**
- **Limited transport costs**

Let the Earth help us save the Earth cheaply and energy efficient, by removing the CO_2 from the atmosphere and undo the harm already done.

Geosciences

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