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Natural and Enhanced Weathering of Basic Rocks: An Effective Process to reach Net-zero Emissions

Willem Langenberg, University of Alberta

Summary

Presently, the global Carbon Capture and Storage (CCS) goal is to store 6 GT CO_2 per year (13% of yearly emissions) at a cost of $0.6 trillion per year, while 25.6 GT are stored by vegetation, soils, and oceans at no cost. As well, the storage potential of natural and enhanced weathering of basic rocks is estimated at 100,000 to 250,000 GT CO_2.

The natural uptake of CO_2 by vegetation, soil and oceans and the natural and enhanced weathering of basic rocks (mineral carbonation) are more efficient processes than CCS. Thus, it would be beneficial if Canada increased funding for research on the uptake of CO_2 by vegetation, soil, and water and the natural and enhanced weathering of basic rocks.

Method

The present atmosphere contains 27,965 GT of CO_2 (762 GT Carbon), of which 605 GT (165 GT Carbon) was added by humans burning fossil fuels since the industrial revolution (Figure 1).

Today, annual CO_2 emissions are from several sources. Burning fossil fuels produces 34 GT (9.3 GT Carbon). Forest fires and other burning adds 5.9 GT (1.6 GT Carbon). The exhalation of CO_2 by 8 billion animals (including 7 billion humans) produces another 7.2 GT. The eruption of volcanoes produces 0.5 GT each year. These numbers add up to a total of 47.5 GT CO_2 emissions per year.

Of these 47.5 GT CO_2 emissions, 13.3 GT (28%) is taken up by vegetation and soil, and 12.3 GT (26%) is absorbed in the oceans. This leaves 21.9 GT (46%) in the atmosphere, which is known as the cause of the climate change crisis.

Emission Reduction

The Paris Accord states that emissions must be reduced to net-zero by 2050, and emissions need to be reduced to 50% from 1990 emission levels by 2030. This means that Canada's yearly 587 MT emissions need to be reduced by 363 MT/year to reach 224 GT, which is 50% of the 1990 emissions.

The four main methods to achieve CO_2 emission reduction considered are:

1. The natural uptake of CO_2 by vegetation, soil, and oceans
2. Natural weathering of basic rocks
3. Enhanced weathering of basic rocks
4. Carbon Capture and Storage (CCS)

The efficiency of reducing CO_2 emissions will be compared according to how much CO_2 is reduced by each of these strategies, the risk and cost to do so, and Canada's required emissions reduction according to the Paris Accord.

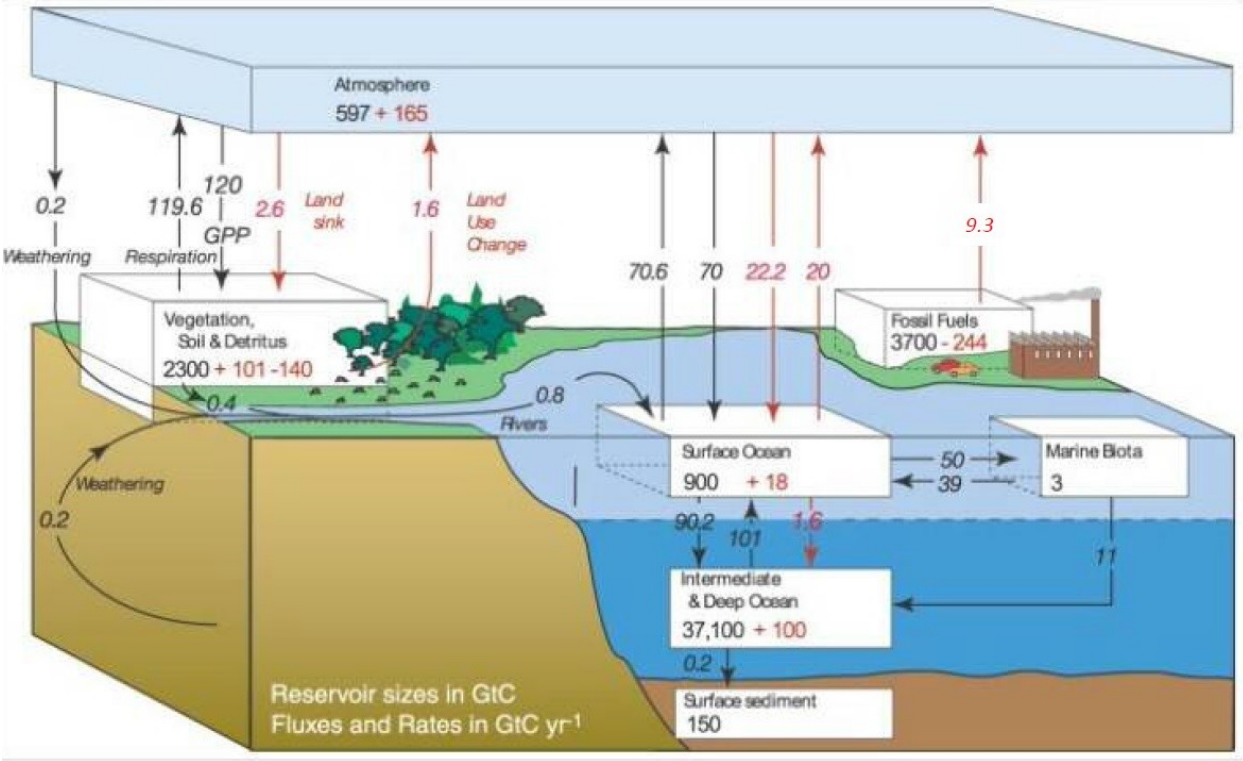

Figure 1. The natural rock cycle with emissions and reservoirs expressed in total carbon (1 T Carbon equals 3.7 T CO_2). Figure and data from Global Monitoring Laboratory.

Natural Uptake of CO_2

The reduction CO_2 emissions through the natural uptake of these emissions by vegetation and soils, and the natural absorption of them by the oceans is effective in reducing CO_2 emissions. The implementation of this process is basically risk free. The financial cost is the cost of planting vegetation, especially trees.

Natural weathering of basic rocks

Natural weathering involves the formation of stable carbonates by the reaction of CO_2 with naturally occurring oxides or rocks of magnesium, iron, and calcium. It mainly uses the most common mineral on earth, olivine, and its related product serpentine (Schuiling, 2018). This process proceeds relatively slowly. The yearly global amounts of CO_2 uptake need to be determined. This process basically has no risk and has minimal financial cost.

Enhanced weathering of basic rocks

Enhanced weathering or mineral carbonation is a process that accelerates the natural geological process of rock weathering. It involves the quicker formation of stable carbonates by mining and crushing of olivine and serpentine bearing (ultra-basic) rocks and exposing them to CO_2 (Hamilton *et al.*, 2020). The storage potential of enhanced weathering of basic rocks (mineral carbonation) is estimated at 100,000 to 250,000 GT CO_2. The risk is the environmental damage caused by mining. The cost of removing 1 tonne of CO_2 by enhanced weathering is about $15, whereas it is about $100 using CCS (Schuiling, 2018).

Carbon Capture and Storage (CCS)

Carbon capture and storage (CCS) is the process of capturing CO_2 before it enters the atmosphere, transporting it, and storing it under high pressure.

Every year 1.2 MT CO_2 is captured and stored by the Shell Quest project. This is an exceptional engineering feat of which Canada can be proud. Globally, governments are considering permanent CCS of possibly 6 GT of CO_2 per year. However, this amount is unfortunately only 13% of the yearly emissions.

CCS is wrongly called geological storage because there is no natural geological process that captures low pressure CO_2 (a deadly chemical) and then stores it at high pressure in depleted gas fields or saline aquifers. It is generally accepted that the present oil and gas resources represent about 10% of what was generated and stored over geologic time by a natural process known as petroleum generation. This is the process by which solid organic matter present in source rocks is transformed into liquid or gaseous hydrocarbons. Petroleum generation starts in natural conditions at temperatures around 70-80°C, which frequently corresponds to burial depth of 2.5-3 km, depending on the geothermal gradient. Then it migrates to either a reservoir or leaks out to the surface.

Since it is known that during hydrocarbon generation and migration, a certain amount of petroleum produced leaks out, it can be deduced that there is the potential risk that 90% of the stored CO_2 through CCS will leak out in the future.

The cost of storing 6 GT per year is about $0.6 trillion per year, assuming a cost of $100/tonne.

Consequently, CCS only stores a relatively small amount of CO_2, and it is potentially unsafe, expensive, and for these reasons ineffective. Considering these concerns about CCS, the other processes previously mentioned deserve more attention and financial commitments.

Conclusions

Presently, the global CCS goal is to store 6 GT CO_2 per year (13% of yearly emissions) at a large cost, while 25.6 GT are stored for free by vegetation, soil and oceans. As well, the storage potential of natural and enhanced weathering of basic rocks is estimated at 100,000 to 250,000 GT CO_2.

Permanent storage projects such as the Shell Quest and Weyburn projects cannot be considered proven effective technology. Furthermore, the significant amount of money needed for CCS ultimately may be wasted on such projects (Langenberg, 2010).

Large amounts of money have already been spent on CCS, and there is a strong lobby to spend more on it in the future (see IPCC Special Report on Global Warming of 1.5°C from 2018).

The reduction of 363 MT of CO_2 emission per year for Canada by 2030 is difficult to achieve. Reaching the goal of zero emissions by 2050 is even more difficult. To rely on only one means of reducing emissions, and one that has not been proven to be reliable, safe, and cost-effective, is shortsighted.

For these reasons, Canada needs to increase funding for research on other processes that are more efficient, effective, and financially viable, such as the uptake of CO_2 by vegetation, soils,

and water, and the natural geological processes of CO_2 capture by weathering (mineral carbonation).

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