New NETWORKS, Part 4 – Peridotite & Soil

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1. Introduction

You have heard of the Extraterrestrial, what about the Subterranean:

Mantle Rocks are minerals that normally only exist in Earth's Mantle, a layer that is normally starts 4 miles below the surface, and extends to almost 2,000 miles below the surface. Thus it makes up 67% of the mass of Earth.[1] The main image for this post shows the Earth's layers.

Rocks in this layer normally stay in this layer, but in a few locations they rise to the surface. That is the case with peridotite. From this reference:[2]

Mantle peridotite is composed largely of the minerals olivine [$(Mg,Fe)_2SiO_4$] and pyroxene [$(Ca,Mg,Fe)_2Si_2O_6$], which react with H_2O and CO_2 near the Earth's surface to form hydrous silicates (serpentine), Fe-oxides (magnetite), and carbonates (calcite, magnesite, and dolomite).

Note the "CO_2" in the above description. In normal weathering this results in veins of the materials that come from the above-described reactions in the peridotite, and over time the reactions slow down (see the image to the right.). The veins are mainly magnesite.

Thus even though there are huge deposits of peridotite above ground, it would need to be mined and pulverized to completely absorb the CO_2. Not very efficient, even if the resulting minerals might be marginally useful. But there is another way that might very efficient, and is capable of storing huge amounts of CO_2. We will cover this in section 2.

If Mantle Rocks might be thought of as an exotic material, soil is definitely not. It's everywhere: in our yards, forests, deserts, plains mountains, everywhere. We will talk about a particular type of soil, that which is used for agriculture (it too is pretty common). This soil probably has the capability to store more CO_2 than peridotite if we modify our farming practices to do so. However the clock is running on this opportunity. We've almost waited too long. You may have noticed that there has been extensive flooding in the Midwest and Southeast. This is an early effect of climate change (I've written on this recently, see the link below).

https://energycentral.com/c/ec/stuck

The extensive flooding washes away a large percentage of agricultural soil.

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[1] Wikipedia article on "Earth's Mantle," https://en.wikipedia.org/wiki/Earth's_mantle

[2] Peter B. Kelemen, Lamont–Doherty Earth Observatory, Columbia University and Jűrg Matter, University of Southampton, England, "In situ carbonation of peridotite for CO_2 storage," September 22, 2008, https://www.pnas.org/content/pnas/105/45/17295.full.pdf

Section 3 will cover the potential and process to sequester large amounts of CO_2 in soil.

Both of the articles that triggered the initial research for the two sections below came from an amazing issue (July of this year) of Scientific American. This will be referenced below, but this reference is for the print issue, and thus there will be no link. If you are interested in Negative Emissions Technology (the NET in this posts title), you might consider calling (800) 333-1199 to order this issue.

2. Peridotite

The Scientific American article referenced here[3] focuses on huge peridotite deposits in Oman. I would suggest that we will need to find deposits a bit closer to home. Fortunately there are deposits in "*Alaska, Canada, California… and other places*." In the first subsection below we will deal with the process the team of scientists is developing which is place-independent, and in the last subsection below, we will deal with the "nearby places" issue.

2.1. The Process

The team leaders that are developing and testing the process described herein include Dr. Peter B. Kelemen and Dr. Juerg M. Matter (see reference 2 above).

Dr. Kelemen and his associates estimate that these large deposits could store a billion tons of CO_2 per cubic km of rock per year. The first process is obtaining the CO_2. I covered what may be the current state-of-the-art process for doing that in the earlier post linked below, section 3.1.

https://energycentral.com/c/ec/tough-love-–-part-2

Initially "obtaining the CO_2" will be from emitters (like gas-fired power plants). Eventually as processes are improved this might evolve to air-capture.

However the process that this subsection covers is sequestering the CO_2 for a very long time (like maybe forever?). This, of course, leads to another question: how do we pulverize rock, easily, and leave it in place. Fortunately this has been solved by petroleum drillers – frack it.

There is another problem with this process, it is really slow at ambient conditions. Fortunately this and the prior problem has the same solution – deep underground. In several years of dogged research, this team discovered the process described below:

…Other equipment would pressurize the gas and send it down a borehole. At 1,000 to 3,000 meters down, the gas would be mixed with water (injected through a separate pipe), and the water with dissolved CO_2 would be released into the surrounding mantle rocks. The water would seep through the rock's pores, eventually reaching a second hole as much as 1,000 meters away that would act as a return chimney. The water, depleted of CO_2 would rise back to the surface, where more gas could be concentrated in it again.

Rock temperatures three kilometers down are about 100 degrees C. That heat would accelerate the reactions. Additional heat generated by the reactions themselves would help drive the circulation of warmed water back up the chimneys.

In 2020 Kelemen and Paukert Vankeuren published calculations suggesting that pumping water containing mildly elevated concentrations of $C0_2$ down to three kilometers

[3] Douglas Fox, Scientific American, July 2021, Page 45, "The Carbon Rocks of Oman,"

could accelerate mineralization by many thousands of times. At that rate a single injection well could capture up to 50,000 tons or CO_2 a year- similar to the amount or the gas being absorbed naturally in all of Oman-under an area or ground about the size of nine soccer fields. Over 10 years that well could capture half a million tons of CO_2.

We still have one problem to solve – how do we frack the mantel rocks that are thousands of meters below the surface. The good news is the team had already solved it and didn't realize it. The materials that result from reactions that occur at depth occupy 20 to 60% more volume that the original materials did. Modeling by Kelemen suggested that these expansions could exert 2,900 atmospheres (over 40,000 psi). This would drive initial cracks deeper and deeper into the subsurface rocks.

In order to verify this, seismic monitoring was performed in boreholes that had been filled with water. In a month the monitors recorded hundreds of micro-earthquakes. Apparently each resulted from cracking in the mantel rocks driven by natural CO_2 saturated into the water. The government in Oman has approved a limited project to test the sequestration. About the time you read this, injection of water saturated with CO_2 and containing a tracer chemical will start testing this project. If they expand it to a full-scale project, they will use salt-water from the Persian Gulf to avoid consuming fresh water, which is in short supply in Oman.

2.2. Nearby Places

Peridotite is really a family of minerals rather than a specific one. Deposits of this mineral frequently contain major chromium and nickel ores. In tracking down major deposits, the first I encountered was the [4]Josephine Peridotite, in Northwestern California and Southwestern Oregon. A map of this area is on the next page. This is the largest peridotite deposit in the U.S.

Alaska has significant deposits of peridotite. I found a couple through the sites below.

https://pubs.usgs.gov/pp/1170a/report.pdf

https://mrdata.usgs.gov/sim3340/show-sim3340.php?seq=D195&src=EA002_129&f=html

Montana has significant kimberlite deposits, and this is a form of peridotite. Note that kimberlite also hosts several types of gem stones (most famously in South Africa).

The link below contains information on gemstones in Montana kimberlite / peridotite.

https://pubs.usgs.gov/bul/1604/report.pdf

Canada also has significant deposits of peridotite. See link below.

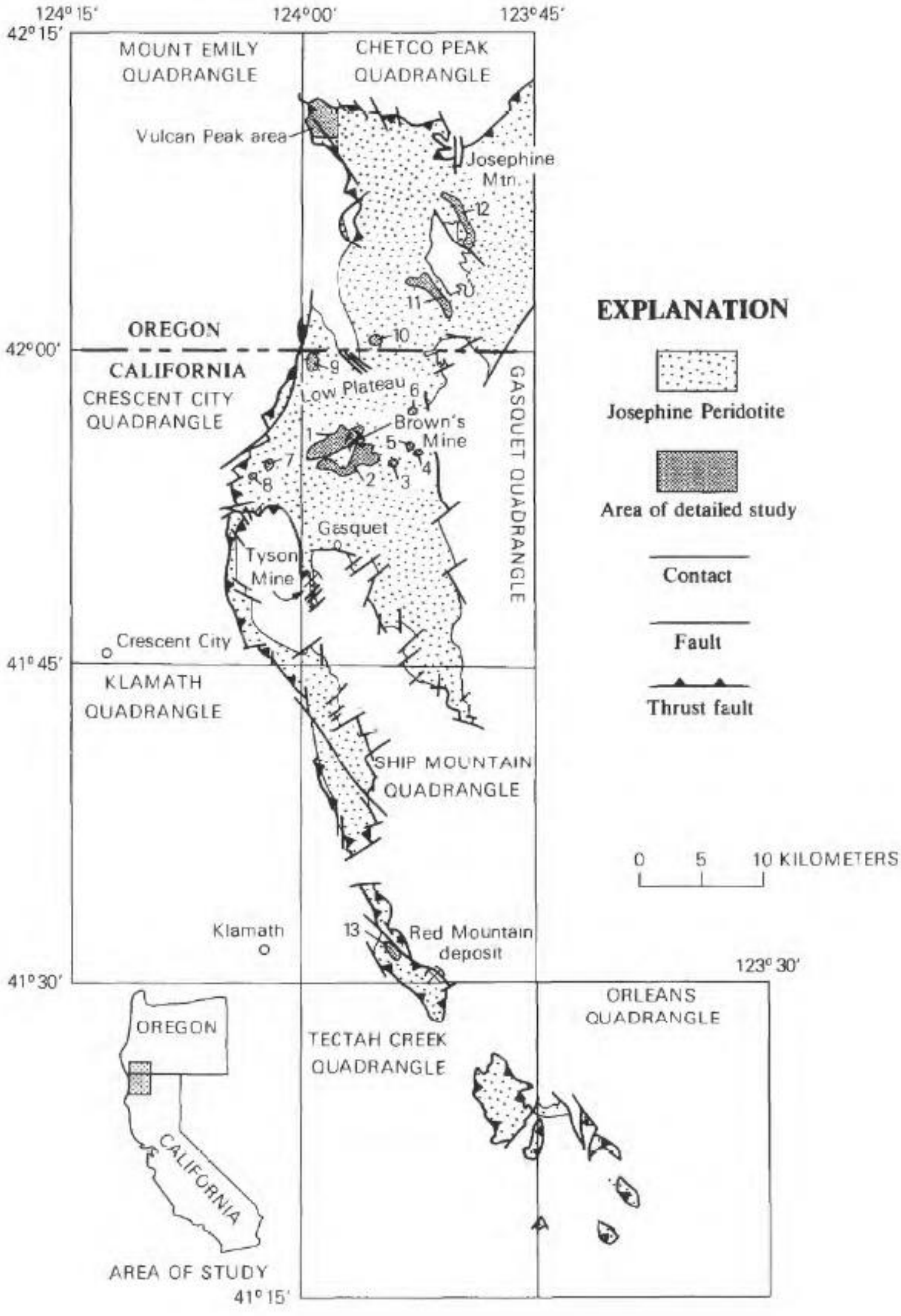
https://thediggings.com/mines/usgs10069194

I found another site at the Webster Peridotite Deposit in North Carolina. Go through the link below for more information.

https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10025907

The following other states have significant chromium mining, and these are typically in peridotite deposits: Colorado, Idaho, Maryland, Oklahoma and Pennsylvania.

[4] U.S. Geological Survey Bulletin 1546 A-D, "Geological and Geophysical Studies of Chromite Deposits in the Josephine Peridotite, Northwestern California and Southwestern Oregon," https://pubs.usgs.gov/bul/1546a-d/report.pdf



3. Soil

Although soil is an excellent place to sequester carbon, including CO_2, that isn't the main issue we need to deal with. Mankind has been doing an excellent job of destroying agricultural soil and its nutrients for the last 200 years. In many places we are nearly running out of it. No soil = no food = no humans. Of course that will solve the problem of soil depletion.

The above problem may be self-solving, but we need to hope that our agro-scientists and most of our leaders and economists see this problem coming and move to solve it, and I believe they will. Below are some examples of our destructive practices and how we might remedy them. Oh yes, and the remedies will sequester huge amounts of CO_2 if used worldwide.

3.1. The Midwest

The words below are from the source referenced here.[5]

Geologically speaking, I grew up in a small farm town on the Des Moines lobe, a huge tongue-shaped remnant of glacial activity that reaches south across central Iowa. All around us were mollisols with a deep A-horizon — a type of rich black topsoil visible in farm fields for miles in every direction… Yet when I was very young, I surely must have met old people — relatives from northwest Iowa — whose elders had helped break the prairie in the late 19th century…

You hear many different numbers regarding that black Iowa soil. It's often repeated that the topsoil — the nutrient-rich A horizon — was some 14 to 16 inches deep when the prairie was first broken, a fantastic depth of fertility… By the mid-1970s — roughly a century after the prairie was broken — it was reported that, in places, half of that topsoil had already been lost to erosion from wind and runoff. There was a lot of talk about soil conservation, of course — about contour plowing and set-aside programs that paid farmers to keep marginal land out of cultivation. Yet year by year, the soil loss went on. There were also large-scale erosion events, like the floods of 2008 and 2013, in which parts of Iowa lost in a week what experts maintained was a sustainable yearly loss: 5 tons of soil per acre.

Author's Comment: I'm an energy systems engineer, not an agro-scientist, but I have talked to many farmers, and all of them complain about the marginal economics of growing crops. Although sustainable agriculture (briefly described above) tends to have a lower yield in the short term, in a longer time horizon it will preserve and enhance the soils, which will enhance the yield. However it is difficult for many farmers to see past this year's cash flow. I would opine that the State and/or Federal Governments need to step in here, as they have frequently in the past, to assist farmers.

In late February, three geoscientists from the University of Massachusetts — Evan Thaler, Isaac Larsen, and Qian Yu — published a paper called, "The extent of soil loss across the U.S. Corn Belt." Using high-definition satellite imagery, a recent soil carbon index, and soil spectral data, they were able to show that across the Corn Belt — which includes all of Iowa and parts of Minnesota, Wisconsin, North Dakota, South Dakota, Missouri, Illinois, and Indiana — A-horizon soil was essentially no longer present on convex slopes. What they found on those slopes was B-horizon soil — subsoil in other words, with minimal fertility, which is only exposed after A-horizon soil has been removed. What does that look like? The paper includes a satellite photo of a bare field near Clear Lake, Iowa. The low areas in the field are medium to dark brown — an

[5] Verlyn Klinkenborg, Yale Environment 360, "How the Loss of Soil Is Sacrificing America's Natural Heritage," March 1, 2021, https://e360.yale.edu/features/how-the-loss-of-soil-is-sacrificing-americas-natural-heritage

indicator of A-horizon soil. But the high spots are tan and beige — the color of B-horizon soil. By calculating the exposure of B-horizon soils across the region, the scientists were able to estimate the overall loss of A-horizon soil.

The number they arrived at is shocking. "We predict," they wrote, "[that] the A-horizon has been completely removed from 35±11% of the cultivated area of the Corn Belt." Plus or minus 11 percent is a large range of uncertainty. But its meaning is plain. At best, 24 percent of the topsoil in the Corn Belt has been completely removed by farming. At worst, 46 percent has been lost.

3.2. California

Although there are many smaller areas, the largest agricultural region in California is the large Central Valley, consisting of the Sacramento Valley to the north and the San Joaquin Valley to the south. This area grows an amazing amount of food crops. *San Joaquin soils today also support growth of an abundant variety of irrigated crops including almonds, pistachios, figs, grapes, oranges and wheat.*[6]

California remained the leading state in cash farm receipts in 2019 with combined commodities representing over 13 percent of the U.S. total. California's leading crops remained fruits, nuts and vegetables.

California accounts for 40 percent of all organic production in the U.S. and organic sales continue to grow in the state. In 2019, sales of organic products in California totaled more than $10.4 billion, which represents an increase of 3.5 percent from 2018…[7]

California's top 20 crop and livestock commodities accounted for $42.6 billion in value in 2019. Eleven commodities exceeded $1 billion in value in 2019…

3.2.1. The Soil

The first characteristic in a San Joaquin soil that people notice is a distinctive soil horizon (layer) known as a duripan to soil scientists and generally as "hardpan" to many people. It is extremely hard and it can be chipped with mechanical means or through use of a pick or very strong, heavy shovel… [6]

Typically, San Joaquin soils have a brown to reddish brown surface or surface soil horizon with a loam (a combination of sand, silt, and clay) texture that has an accumulation of organic matter. The next underlying horizon is similar in soil texture to the surface horizons; however it does not have an accumulation of organic matter…This horizon rests on a brown or reddish brown clay or clay loam horizon that has a distinctive prismatic structure (soil broken up into pillar like structures) with cracks between the prisms. This horizon, with a dramatic increase in clay which restricts root and water penetration, is about 15 to 30 inches from the surface of the soil. Finally, the fourth horizon is the brown to reddish brown silica cemented duripan. The duripan has an abrupt upper boundary at a depth of 20 to 40 inches and is impervious to roots and water. The duripan often continues to a depth of 60 inches or more…

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[6] Kerry Arroues, Dr. Gordon Huntington, Dr. Roy Shlemon, Philip Smith, Soil Science Society of America, San Joaquin Series, California State Soil, https://www.soils4teachers.org/files/s4t/k12outreach/ca-state-soil-booklet.pdf

[7] California Department of Food and Agriculture, "California Agricultural Statistics Review, 2019 – 2020," https://www.cdfa.ca.gov/Statistics/PDFs/2020_Ag_Stats_Review.pdf

Over the last century many San Joaquin soils utilized for agricultural crops were significantly modified to increase rooting depth and increase water infiltration into the soil. Modification of the soil usually began by leveling the soil which was closely followed by deep ripping the soil and modification of the claypan and duripan horizons. Partial sticks of dynamite were even used for a time to break up the duripan before planting trees…

The soil was even more significantly altered in the decades that followed by use of larger and larger tractors pulling slip plows.

Authors Comment: The key point in the above is that much of the San Joaquin Valley soil that exists now is totally man-made. A century ago the original farmers found the soil totally incompatible with the crops that they needed to grow (nut and fruit trees, vineyards and seasonal crops). Thus they modified it extensively. When you get out of the valley into the foothills the soils are much like the Midwest – mainly grasslands, although these are now being repurposed into host nut and fruit trees and vineyards.

Modification of the soil accomplished the intended purpose by increasing the root zone and water infiltration into the soil. It also permanently disrupted the natural ecology of these areas…

In recent decades it has been recognized that natural, relatively unmodified environments with unique features have value and can be preserved in some areas. These preserves and conservancies have allowed future generations to see what past landscapes of San Joaquin soil looked like before they were modified.

Authors Comment: This is amazing – I could not find anything on problems with the soils in California other than an attitude. Like: "If there is something wrong with our soils, dammit, fix it!" This is what I call the California Attitude. The big problem with our soil right now is too little moisture. This is a big problem, but it is being worked on (now you know why we are so serious about climate change). Also we have found a way to monetize just about anything that sequesters CO_2, it's described and linked below.

Carbon Offsets: *Offsets are financial instruments that are used by the California Cap and Trade Program and other similar programs. In this paper we will review the types of offsets, offset protocols and offset verification.*

https://energycentral.com/c/cp/carbon-offsets

California carbon offsets can be applicable to any CO_2 reduction project in the U.S., or even Canada. This allows, for instance, a project to enhance the soil in Iowa, and thus sequester more CO_2 to be paid for this project (lots of requirements – read the above linked post). This is reasonable, because we all share the same atmosphere.

In California we do have a significant number of seasonal crops. See the table below. I count roughly $8 Billion value of seasonal crops in 2019.

Top 20 Commodities in California for 2017-2019

Commodity	2017 $1,000	2018 $1,000	2019 $1,000
Milk and Cream	6,561,720	6,371,017	7,340,707
Almonds (shelled)	5,603,950	5,602,500	6,094,440
Grapes	5,847,966	6,260,348	5,411,688
Miscellaneous crops	4,088,169	4,273,231	4,286,518
Cattle & Calves	2,647,838	3,189,177	3,064,300
Berries, All Strawberries	2,530,903	2,086,077	2,221,320
Pistachios	1,014,507	2,615,550	1,938,800
Lettuce, All	3,017,377	1,786,564	1,824,435
Walnuts	1,568,700	916,650	1,286,410
Floriculture	1,171,900	1,215,997	1,215,997
Tomatoes, All	1,075,824	1,197,642	1,174,395
Rice	699,401	780,221	896,790
Broilers	936,565	965,340	843,036
Carrots, All	638,482	655,479	810,007
Hay, All	770,399	765,878	787,135
Broccoli	850,183	679,405	786,354
Tangerines	532,038	556,024	735,564
Oranges, All	888,331	1,093,052	670,529
Lemons	717,746	681,564	644,002
Other animals/products	501,789	552,965	552,960

On an average of once a week, I drive through San Joaquin County's main agricultural areas (driving from my primary home in Livermore to my Mountain Home in the Sierras). In addition to the above, I also see significant plantings of corn, onions, melons, wheat and pumpkins (among the mostly almond orchards and vineyards). This area is capable of growing three or four seasonal plantings a year. It's difficult to tell if they are leaving any fields fallow or with just cover crops. However, since this is some of the most valuable farm-land in the country, I expect the farmers are otherwise taking good care of their soil.

I'm guessing at some point in the future, as the cost of offsets rise, farmers will be taking advantage of them, and trading some production for cash-payments. I'm sure there will be some innovative use of lands in all states.