Atmospheric Greenhouse Gas Reduction Through Deep Ocean Carbon Sequestration “DOCS”

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Abstract

The United Nations, Intergovernmental Panel on Climate Change, Assessment Report 6 (UN IPCC AR6) dated August 7th 2021 describes the urgency of reducing atmospheric greenhouse gasses, carbon dioxide (CO2) in particular, and methane (CH4) in order to limit global warming to a survivable level. AR6 identifies the tight connection between the world's Gross Domestic Product and anthropogenic fossil fuel consumption that has resulted in the buildup of CO2. It also describes how and why it is going to become more difficult to achieve the desired goals as we get closer to those goals with the present available technologies. The options for fighting global warming are limited, difficult to implement, and with few good options, the decisions that are being made under these circumstances, are of concern. Rather than focusing on the difficult task of eliminating 100% of anthropogenic atmospheric greenhouse gas emissions, the focus herein is on eliminating ≈7% of the atmospheric greenhouse gasses emitted by microbes, and decomposition including wildfires, every year to achieve net zero emissions for our planet.

Introduction

The United Nations, Intergovernmental Panel on Climate Change, Assessment Report 6 (UN IPCC AR6)[1] dated August 7th 2021 describes the urgency of reducing atmospheric greenhouse gasses, carbon dioxide (CO_2) in particular, and methane (CH_4) in order to limit global warming to a survivable level. AR6 identifies the tight connection between the world's Gross Domestic Product and anthropogenic fossil fuel consumption that has resulted in the buildup of CO_2. It also describes how and why it is going to become more difficult to achieve the desired goals as we get closer to those goals with the present available technologies. The options for fighting global warming are limited, difficult to implement, and with few good options, the decisions that are being made under these circumstances, are of concern. Rather than focusing on the difficult task of eliminating 100% of anthropogenic atmospheric greenhouse gas emissions, the focus herein is on eliminating ≈7% of the atmospheric greenhouse gasses emitted by microbes, and decomposition including wildfires, every year to achieve net zero emissions for our planet.

Fast Carbon Cycles

Carbon cycles are described in many ways. It includes carbon that makes its way to a tectonic plate subduction zone, becomes a diamond and never makes it back to the surface of the planet. Here the focus is on annual carbon cycles as described in Figure 1. Figure 1 is from the Doe/SC-108 Carbon Cycling and Biosequestration Report[2] from a March 2008 Workshop. The information from the report that is critical to the arguments presented here including the following as illustrated in Figure 1:

- 9GT/yr Anthropogenic Carbon Emissions-
- 60GT/yr Microbial Respiration and Decomposition (from the land)
- 90GT/yr Respiration and Decomposition (from the sea)

Also pertenant to the discussion is the following statement found in the "*Key Biological Carbon Cycling Research Areas"* section of the report[2] under the description of a Biological Pump

- "Carbon in the deep ocean is effectively sequestered because it can remain there for thousands to millions of years due to the slow vertical mixing of ocean water. The process that results in transferring organic carbon into the deep ocean and sediments is known as the biological pump."

Considering the UN IPCC report and the information in the above paragraph, getting rid of 100% of the anthropogenic carbon emissions (9GT C→33GT CO_2) would be a very difficult if not impossible, and very invasive effort while getting rid of 6% of nature's land based and ocean based emissions ($60GT_{Land}$ + $90GT_{Sea}$→550GT CO_2) might be relatively easy to accomplish. This discussion explores a method of accomplishing the reduction of nature's CO_2 emissions to offset anthropogenic CO_2 accumulation with minimal effect on "business as usual."

Background

Humans have been burning significant amounts of fossil fuel since the start of the industrial revolution (≈ year 1820). The reason we have been burning fossil fuel which increasing Earth's atmospheric CO_2 is simple. We needed the energy to increase industrial productivity and improve our way of life. Most of the needed energy came from fossil fuels, coal, gas and oil. Figure 2 is a plot of world's Gross Domestic Product (GDP) and the associated anthropogenic CO_2 emissions for the year. The GDP curve is plotted from United Nations (UN) and later the International Monetary Fund (IMF) data tracking the estimated world's GDP.

Having a high GDP is a good thing, but the resulting increase in atmospheric CO_2 is the primary driver of Global Warming. In response to this, there are countries that are actively reducing their CO_2 emissions, including the European Union (EU), the United Kingdom (UK) and the United States (US) while others are increasing their CO_2 emissions including China and India. A July 25th, 2021 article[5] published by "The Guardian" stated that *"A key group of leading G20 nations is committed to climate targets that would lead to disastrous global warming, scientists have warned. They say China, Russia, Brazil and Australia all have energy policies associated with 5°C rises in atmospheric temperatures, a heating hike that would bring devastation to much of the planet."*

A number of solutions have been developed for controlling atmospheric CO_2 levels, the top contenders have been forms of Carbon Capture and Storage (CCS) including Direct Air Capture (DAC) and for both CCS and DAC, the storage of CO_2. Great progress has been made with CCS but there are limits. An article in *Renew Economy* [14] stated "*The world's biggest project to capture and store carbon dioxide isn't working like it should, highlighting the challenges oil companies face in tackling their greenhouse gas emissions.*" The CCS operation at the Chevron Corp. Gorgon liquefied natural gas export plant in Australia missed a local government target to inject captured carbon dioxide underground.

Deep Ocean Carbon Sequestration (Docs)

The effort described herein is focused on reducing the atmospheric CO_2 emissions from the 150GT of carbon (550GT CO_2) emitted by microbes and decomposition annually and storing about 12GT of carbon (44GT of CO_2 Equivalent) at the bottom of the ocean. The goal will be to decrease the level of atmospheric CO_2 by more than 4GT per year while increasing the carbon concentration in the deep ocean by about 1% per century. This world wide effort herein will be called "Deep Ocean Carbon Sequestration" or "DOCS".

All organic matter is carbon based and it is relatively easy to capture compared to atmospheric CO_2. An 8% reduction in worldwide microbial respiration and degradation CO_2 output will make the Earth carbon negative. This, in turn, is expected to reduce Global Warming and get our planet back to a more ideal temperature range without severely curtailing anthropogenic activity.

Some of the needed biosequestration of the carbon in organic matter can be accomplished through simple means, including waterlogging organic matter at sea and letting it sink down to the deep ocean. The size of the problem is about 38GT/a of anthropogenic CO_2 and for that, a more active human involvement is likely to be needed to bring biosequestration of the carbon in organic matter up to the needed level.

Hydrous Pyrolysis

Hydrous Pyrolysis of organic matter can separate carbons and/or hydrocarbons from organic matter. It would take thousands of large, high energy consuming, super pressure cookers, as big as barns and operating at very high pressures to make a significant dent in the ≈1400GT of excess atmospheric CO_2 that has accumulated over the last 200 years as a result of anthropogenic CO_2 emissions. It is a huge job, but DOCS could be a significant component of a plan that could accomplish a carbon negative Earth and do it without a massive change on our daily lives or strangling the world's GDP.

Pyrolysis is the decomposition of organic matter by heating it in the absence of oxygen. Unlike fire or other forms of combustion that exhaust CO_2, pyrolysis releases little or no CO_2 due to the lack of oxygen. Any organic matter can be a source of raw material for pyrolysis including vegetation, animals and their byproducts, garbage, sewerage, household plastics, even you and me. The byproducts of pyrolysis very depending on how the pyrolysis is accomplished but typically include:

- Char- a Fuel – Similar to powdered coal it is carbon separated from the organic matter
- Gas - a Fuel – Similar to natural gas containing propane, ethane, butane, etc.
- Oil – a Fuel – Something like sweet crude oil.

The char is a solid and can be stored away so that it is not cycled back into the atmosphere for a very long time. The char, gas and oil can be processed into the fuels we used in our daily lives but it will be "Net Zero" fuel and not "fossil" fuels, since they are not from a fossil source.

For reducing atmospheric CO_2, pyrolysis of organic matter in this plan will be done on very large quantities of organic matter underwater to achieve the needed decomposition. This requires very high temperatures, very high pressures, and a massive source of carbon free energy to make a dent in the atmospheric CO_2 buildup over the past 200 years. Also, there is a need to store the char that is where it will not be disturbed for millions of years.

HYDOTHERMAL VENTS

Hydrothermal vents in the deep ocean were first photographed off Equator's Galapagos Islands in 1976s. Since then over 720 hydrothermal vent fields have been identified and are listed in the InterRidge Vents Database 3.4[8]. Figure 3 is a map showing the spreading rates of known hydrothermal vent fields. There are about six times as many hydrothermal vent fields as there are stars in the figure. Most of the vent fields are located along the 60,000km long Mid-Ocean Ridge. Some of the areas where there are no stars are tectonic plate subduction zones.

Typically the magma chambers which can supply the energy for the needed coalification process is closest to the ocean floor near the fastest spreading tectonic plate boundaries. Speed is relative and in this case the Mid-Atlantic Ridge is slowly spreading at 0.2cm/yr. while in the South Pacific the tectonic plates are spreading at a very fast 1.4cm/yr.

The energy released naturally at hydrothermal vent fields falls well short of the energy required for a pyrolysis effort that can reduce the level of atmospheric CO2 to levels of a century ago but the vent fields are areas where excess energy is being released.

HYDROTHERMAL BOREHOLE VENTS (HBV) (Patent Pending)

The energy stored in the magma chambers below hydrothermal vent fields is more than enough to power the needed decarbonization. It is basically carbon free energy that can power the process and the ocean bottom below the mid-ocean ridge is a great place to leave the carbon loaded char that emanates from the process. The carbon char will piles up, and likely form coal seams that won't reach a continental plate subduction zone for millions of years.

The energy emitting from the 1200°C magma chambers can be tapped using techniques commonly used for offshore oil exploration and shown in Figure 4. When the dill bit of Figure 4 is actively drilling as in Figure 5a, high pressure water is pumped through the drill bit shaft at rate that will force the ground up rock out of the borehole. This also cools the drill bit as the temperature increases as the drill bit gets closer to the1200°C lava chamber.

Once the borehole is drilled as shown in Figure 5a, a liner is added as shown in Figure 5b when needed to prevent the walls of the borehole from collapsing.   The output from the bore hole at the ocean floor as shown in Figure 5d will be separated from the input plumbing. From that point, the hot water is likely to be stored for used on demand, piped into a hydrothermal borehole vent (HBV) oven as shown in Figure 6, or brought to the surface for use high pressure steam to drive turbines.

Figure 6 us a HBV oven with a municipal garbage barge feeding organic matter into the HBV oven through a Sea Silo capable of holding multiple day's refuge while it is waiting to be processed into char.

Figure 7 is a graph of the approximate pressure at depths below the ocean's surface as well as the approximate state of the water.   The values are approximate because fresh water is lighter than salt water, brine is heavier to than salt water, and deep water is compressed due to the high pressure.   Below the boiling point curve it will be hot water and to the right of the boiling point curve it will be steam. In the lower right corner of the chart the water will be supercritical where there is no difference between water and steam, the density is about 1/3 that of the surrounding water, and the supercritical water is a solvent capable of penetrating pores rocks.

Figure 8 depicts a typical HBV oven at the bottom of the ocean with the borehole drilled near the 1200°C magma chamber and the char being discharged down the side of mid-ocean ridge accumulating in the deep ocean reactive sediment of Figure 1.

Under the wide ranging set of processing conditions anticipated for the HBV hydrous pyrolysis, a wide range of organic and some inorganic matter can be broken down while optimizing the output of char being adding to the bottom of the ocean. The gas and oil produced during the hydrous pyrolysis process will be brought to the surface avoiding water pollution and processed into carbon neutral fuel. The char can also be brought to the surface and burned as fuel should that become advantageous but it would defeat the goal of lowering atmosphere CO_2 concentrations.

The volume of organic matter needed to be run through pyrolysis to achieve the goal of negative carbon emissions for the planet is enormous. The municipal waste operation of Figure 6 is attractive because the organic matter is already being collected, the cost of obtaining land for a land fill operation is rising, the release of methane from landfills would no longer be a problem, and for some municipalities the operation will provide a cost savings. Unfortunately, municipal waste is expected to solve about 1% or 2% of the anthropogenic atmospheric CO_2 accumulation problem. For the rest of effort, many industrial sized operation will be need

Docs Processing Centers

Much of the high volume work will be done on processing centers like that shown in Figure 9.   The Processing Centers and pellet factories that supply wood pellets to electric power generating facilities will, in some case, be competing for the same organic matter. Unlike the pellet processing facilities, the hydrothermal borehole vent Processing Centers are not likely to have any neighbors nearby since the depth required for the process is not likely to be found near shore.

There are examples of large volumes of organic matter being transported to manufacturing facilities like the 120 Benson Log Rafts[9] of Figure 10 assembled in the Columbia River and delivered to the Benson Saw Mill in San Diego between 1906 and 1941. The larger Benson Log Rafts contained 19,000m^3 of lumber and would sequester the carbon equivalent of about 16 Mega Ton of atmospheric CO_2 once it is processed. This is more than the average daily anthropogenic CO_2 emissions for the USA. There is a log corral on the right side of Figure 9, the processing center, to hold log or bamboo rafts waiting to be processed.

SUPPORTTING ORGANIC MATTER SORCES

For an operation of the size needed to work, support for the production of organic matter is likely to be required. When looking at the 60GT of carbon from land that ends up as atmospheric CO_2, per Figure 1, a compelling argument can be made that the available organic material can be improved if droughts and the associated wildfires can be reduced. It may be possible to generate rainclouds[10] over large bodies of water, similar to Marine Cloud Brightening[11] but the nimbostratus rain clouds will move inland to drought stricken areas and provide drought relief.

There are massive amounts of forest litter in wilderness areas that could feed the carbon sequestration effort. All of forest litter is at elevations above the sea making it a downhill transport but, no-road transport systems[10] are needed to move the organic matter efficient.

The use of fire for land clearing of the Earth's jungles and forests to make way for corps is common and devastating to the environment but if the organic material were run through the coalification process instead of being burned, it would improve the atmospheric CO2 problem since the new crops will pull more carbon from the atmosphere.

From the sea, phytoplankton, seaweed, algae blooms, kelp forests, organic matter in the Sargasso Sea, even the Asian carp that have invaded the Chicago River could become sources of organic matter for the coalification effort. The work being done by Running Tide[11] from Portland Maine on cultivating organic matter at sea might prove to be the primary sources of organic matter for a DOCS Processing Centers of Figure 6 and/or Figure 9.

TROPICAL FOCUS

The cost of transporting organic matter to the processing site is a significant part of the cost in terms of both dollars expended and CO_2 emissions generated during transportation. Municipal waste disposal requirements are expected to result in processing centers near population centers. Large scale organic matter sources will be required to meet the goal of bring down atmospheric CO_2 levels using HBV coalification. The northern hemisphere has more land mass and vegetation than the southern hemisphere. The Tropics and Subtropics have more than half the half the Earth's organic matter and a longer growing season than the temperate zones.

Reforestation and afforestation are promoted as ways of absorbing atmospheric carbon through photosynthesis for tens or hundreds of years. Organic matter run through the coalification process and secured at the bottom of the ocean will likely be there for millions of years. When looking at organic matter plantations, bamboo generates about 4 times more organic matter per acre than with conifer forests[11] and bamboo is ready to harvest much faster than trees giving bamboo an order of magnitude advantage over trees when it comes to cultivating organic matter for the coalification process. Also, bamboo is a grass and after clearcutting a bamboo stand, the roots will put out shoot to regrow the stand.

The HBV coalification process is expected to be a 24/7 operation 365 days a year. On any ocean there will be storms that will interrupt the operations. The relative consistency and predictability of weather in the tropics is expected to less disruptive than that of the North Atlantic or North Pacific with their winter storms.

For the reasons mentioned above, the majority of the HBV coalification efforts will be located in the tropics. One of the effects of a tropical processing location will be a significantly increased in investments and employment in developing nations, many of which are located in the tropics. This will be paid for by the developed nations with large fuel dependent economies.

CARBON COMMODITY CIRCULAR ECONOMY

The creation of the system described herein will require financing. Much of the initial work will rely on the petroleum industry which has drill ships, semisubmersible platforms, engineers and workers skilled in the art, and management teams in place. They are involved in the technology, the transportation, the economy, and would benefit from the stabilization of the energy market.

A stable *Carbon Commodity Circular Economy* with negative anthropogenic CO_2 emissions could emerge from this effort. A tax could be added at the well head or mine entrance to cover the costs of removing about 110% of the CO_2 equivalent for the fossil fuel being removed. Most nations are likely to support such an effort, but not all. For those countries that don't want to open their books or don't have the capacity in place to provide such information, Import/Export Tariffs[13] can be imposed in a manner that would encourage participation of such countries as has recently been suggested by some EU countries[13].

Conclusions

The author has been actively involved in this environmental effort for the past few years. The information offered herein contains much conjecture and there are patents pending. This is a premature concept and much work needs to be done before the system could be considered a success. The UN IPCC Report, AR6 and the grim images it invokes has resulted in the early publishing of this concept. If this effort is successful, global warming would be a thing of the past, the economy could go back to being driven by financial results, and the World GDP would not be restricted by greenhouse gas emissions.

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Figures

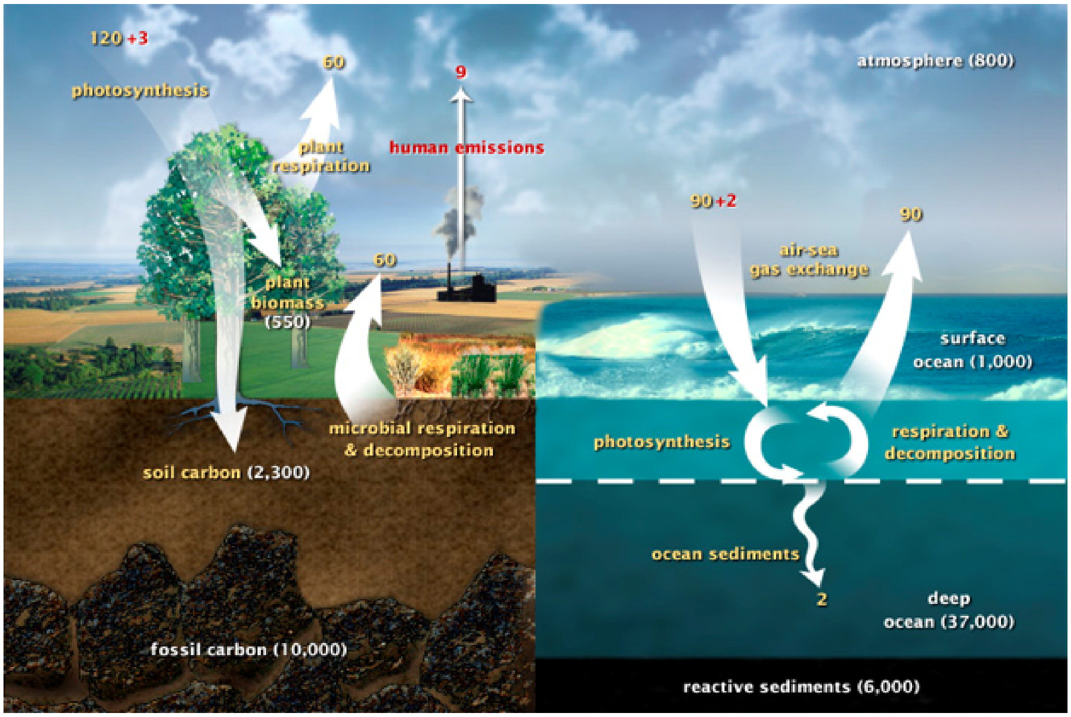

Figure 1

Fast Carbon Cycle2. This diagram of the fast carbon cycle shows the movement of carbon between land, atmosphere, and oceans. Yellow numbers are natural fluxes, and red are human contributions in gigatons of carbon per year. White numbers indicate stored carbon.

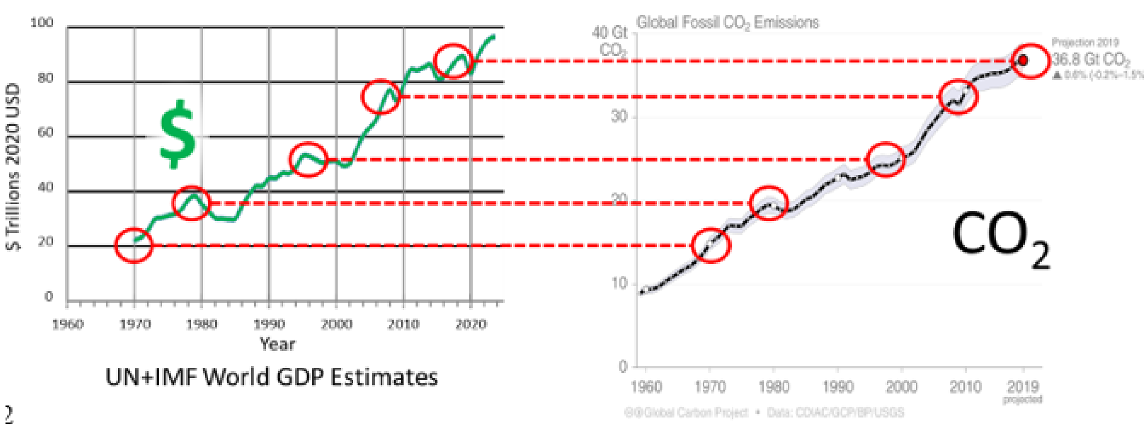

Figure 2

A Comparison of the world's Gross Domestic Product (GDP)3 and Global Fossil CO2 Emissions4

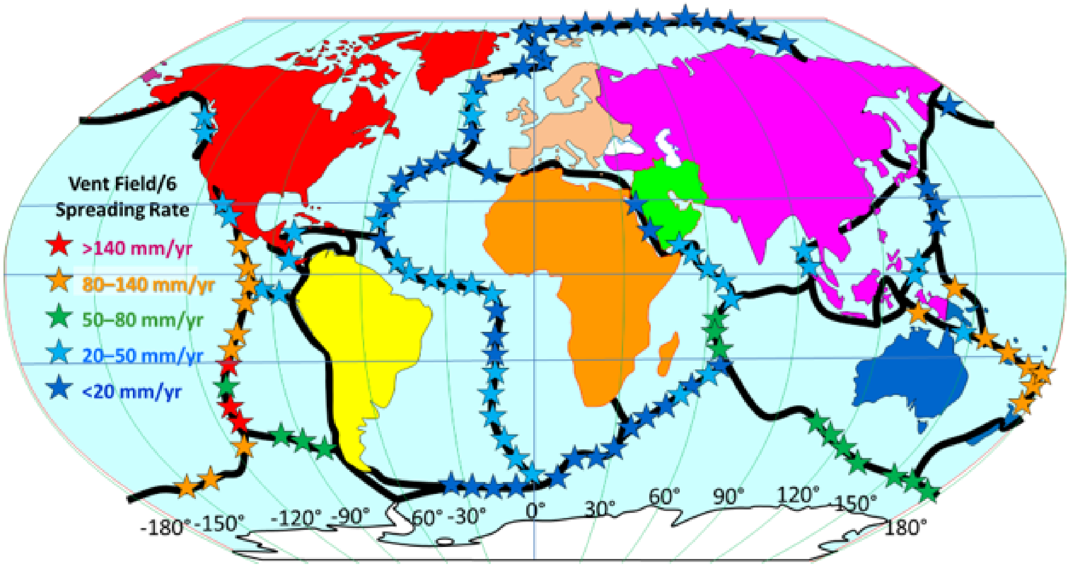

Figure 3

Hydrothermal Vent Field Spreading Rates

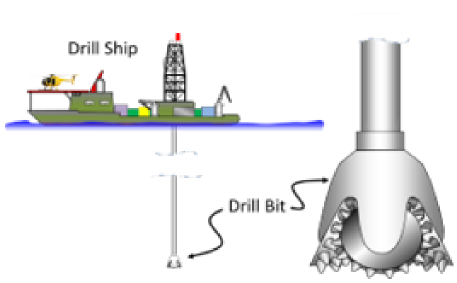

Figure 4

A Typical Deep Water Drilling Equipment

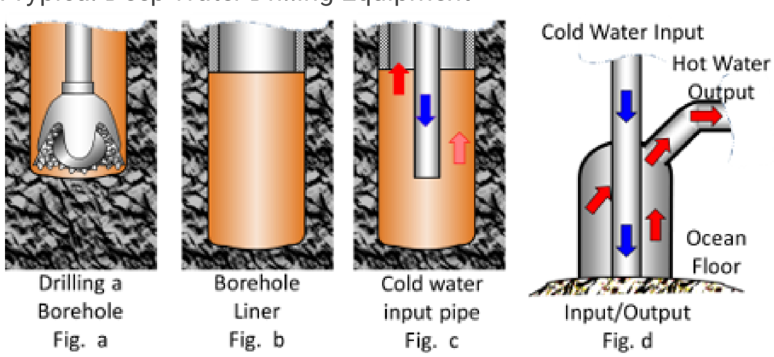

Figure 5

Construction of a Hydrothermal Borehole Vent

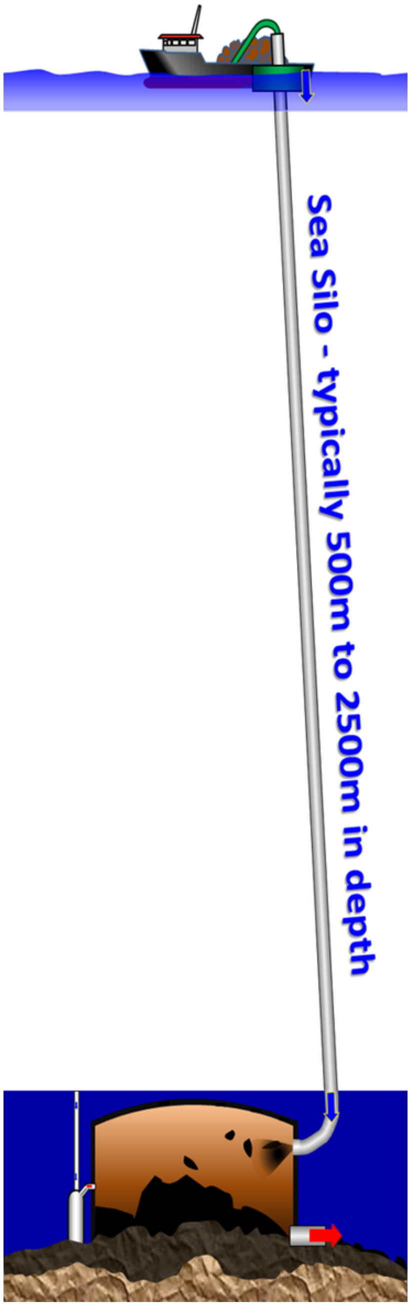

Figure 6

Hydrothermal Borehole Processing Oven

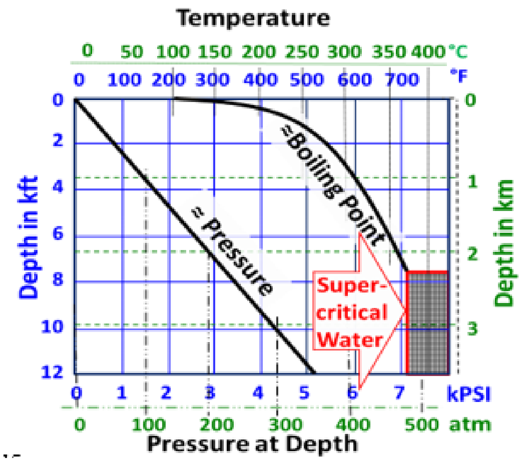

Figure 7

Typical Pressure and Water State vs Ocean Depth

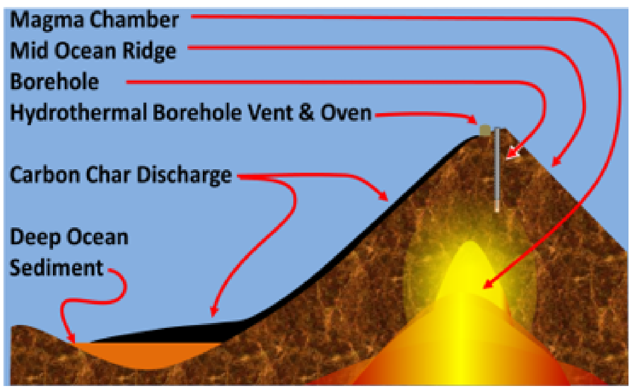

Figure 8

Hydrothermal Borehole Vent Oven Operation

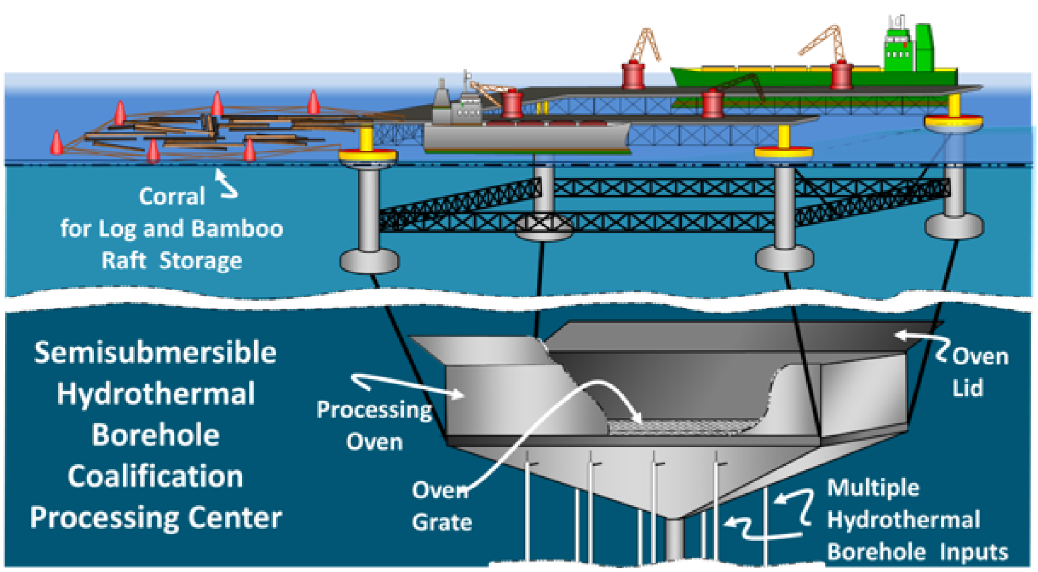

Figure 9

Large Mid-Ocean Ridge DOCS Processing Center

Figure 10

Benson Log Rafts