Inquiry into geosequestration technology

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Geo-sequestrated CO2 as a renewable resource.

Dear committee,

A perceived **potential risk** of geo-sequestration technology is that of carbon dioxide escaping. Currently the **science underpinning geo-sequestration technology** expects the CO2 to remain unchanged for thousands of years where sequestrated. This is supported by the fact that CO2 is a relatively inert species that is not readily reduced. CO2 is the “end-of-the-line” for modern industrial and energy economies. That’s why we what to bury the stuff – there’s simply little or no use for it.

The current geo-sequestration model provides for no further **economic benefits** to be gained once the CO2 is in the ground. Indeed monies will need to be spent monitoring the sequestration. It can be argued that these monies, however small, are non-trivial if a compound interest formula is applied over the vast time scales proposed. Even if the risk of CO2 escaping to the atmosphere is negligible, which I believe it is, there will always be a perceived risk, at least politically, that it will escape - a very easy catastrophic picture to paint by opponents. Most punters just don’t know about or trust the long experience of the petroleum industry in dealing with and using CO2 underground. So there are both ongoing financial and political costs to geo-sequestration. At some point governments will most likely be burdened with these long term liabilities. And the CO2 will always still be there – or will it?

Recent research [1] has looked at the role that indigenous deep subsurface microbes might play in disturbing the sequestrated CO2 over long time scales. Microbes might reduce the CO2 to methane. (methane is a more powerful greenhouse gas than CO2 which might then escape). But it’s also possible that other co-habiting microbes may oxidize this methane back to CO2 forming a harmless steady state ecosystem [2]. This second aspect, together with the slow rate at which this might occur, if at all, is probably why microbial activity has not figured in **the science underpinning geo-sequestration technology**, at least not publicly. But dismissing this issue or putting it off to the never-never isn’t really dealing with it. Knowledge of deep subsurface microbes has only been around for about 15 years or so. A very early stage of knowledge relative to the eons of proposed CO2 sequestration. It appears that these microbes are very old, very tough, and very resourceful [3].

“The extent to which subsurface microbial communities will play a role in the long-term fate of CO2 is not known and it may depend upon numerous factors including the abundance, diversity and relative proportions of autotrophic to heterotrophic organisms in the community, the abundance of potential electron donors (e.g. H2, acetate and fermenters), the formation of a separate gas phase in the aquifer, the ambient temperature and pressure.” ; T.C. Onstott [1].

MINING THE REDUCING POTENTIAL OF THE EARTH’S CRUST

I propose a solution to the above liabilities whereby artificial hydrothermal vent [4] systems are constructed beneath continental saline aquifers (see attached figure) to *support and stimulate* deep subsurface microbial communities that would reduce geosequestrated CO2 to methane according to equation (1) utilizing energy and materials derived from fluid-rock reactions. This methane could then be re-burnt at the surface and the resulting CO2 resequestrated thereby creating a carbon neutral renewable energy[1].

$$(1) \qquad CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Igneous rocks, including Australia’s hot dry rock (HDR) granites, are formed from the solidification of molten magma. These rocks form part of the Earth’s crust which is ca. 40km thick for continental Australia. Importantly these rocks have not seen the light of day – literally. They have not been weathered, as sedimentary rocks have, to become relatively oxidized. Equation (2) nominally depicts this weathering process.

$$(2) \qquad 2Fe + O_2 \rightarrow 2FeO + \text{energy}$$

Formed from magma in the absence of oxygen Australia’s hot dry rock (HDR) granites are in a relatively reduced state. These rocks are therefore a vast source of potential energy if only it could be extracted (mined). So far only the *heat* energy contained in these rocks has been seen as potential source of energy - that is HDR geothermal. I propose a method of extracting the *chemical* energy or reducing potential from these rocks.

HDR Geothermal

Currently Geodynamics is involved with the commercial exploitation of HDR resources in Australia. Briefly, Hot Dry Rock Geothermal technology (HDRG) involves drilling a borehole into hot dry granites to a depth of ca. 3-5kmbls (kilometers below land surface) at sites where temperatures range around 300°C at these depths. Water is then pumped into the well at great pressure. This hydraulically fractures the rock below the bore casing increasing its permeability (the ability of rocks to transmit fluids) by ca.1000000 times. This then forms the HDRG reservoir (see figure 1). Two or more production boreholes are then drilled at the periphery of this reservoir (ca. 500m radius) that allows superheated water to rise to the surface. The heat from this fluid is transferred to a second liquid and then returned down the injection well traveling back to the reservoir where it is reheated and the process continued. Importantly this fluid is in a closed loop. This means that dissolved gases and minerals in the fluid are not allowed to escape into the atmosphere or precipitate, respectively. The dissolved gases include hydrogen sulfide (H2S), carbon dioxide (CO2), and a small amount of hydrogen (H2). See below. If the dissolved minerals were allowed to precipitate they would form blockages or plaques in the pipes that would need to be removed.

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[1] Subject to drilling technology accessing greater and greater crust depth.

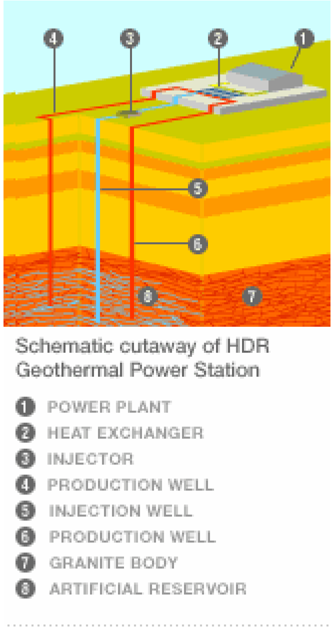


Figure 1: HDRG reservoir (heat exchanger). Source: www.geodynamics.com.au

Hydrothermal Vents

Submarine hydrothermal systems (see figure 2) are similar to surface geothermal springs such as those at Yellowstone National Park. They are usually associated with underlain, newly formed, hot igneous rock or magma that is near the deep seafloor. These areas are often at the junction of tectonic plates. The heat from these rocks drive convective fluid circulation that pulls saline water down into the rock where fluid-rock reactions occur. The resulting superheated fluid has dissolved gases and minerals that rise up through a ‘chimney’ exiting at the seafloor. These “black smokers” have inhabited organisms that derive a living from the chemical energy contained in this fluid.

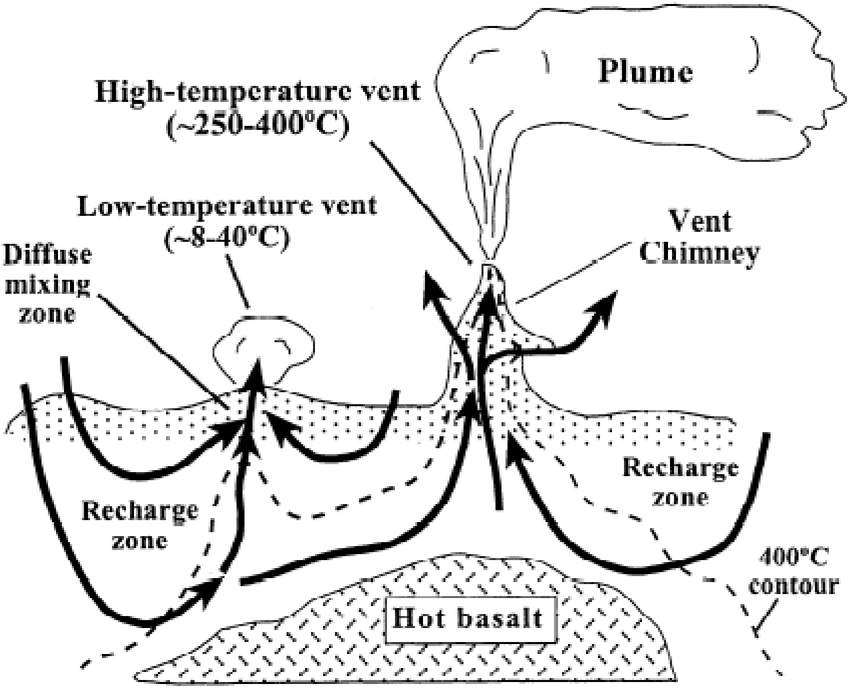


Figure 2: A submarine hydrothermal vent system. Source: McCollom 1999.

My Invention

My invention relates to the discovery that a HDRG system and a hydrothermal vent system are thermochemically equivalent. They both cycle water through relatively reduced hot igneous rock where fluid-rock reactions oxidize the rock producing a reducing fluid that has dissolved gases and minerals. These materials provide chemical energy to inhabited ecosystems in the case of seafloor hydrothermal vents and present an engineering problem for HDR. The major differences between them are that with closed-loop HDRG 1: the saturated fluid is returned back under ground and 2: no new oxidants, such as O2 or CO2, are added to the system. This is an engineering solution that effectively halts the fluid-rock reactions for HDRG. HDRG systems are design to extract heat from the rocks not chemicals.

I propose “transposing” the three boreholes of a HDRG system to a position below a saline aquifer that has a geo-sequestrated CO2 phase or ‘atmosphere’ partitioned above an oxidized (with CO2 not O2) aqueous saline phase. Instead of the fluid exiting at the surface as it would with conventional HDRG systems or the ocean floor as with hydrothermal vents, it would exit at the bottom of the aquifer ‘ocean’. The heat differential between the saline aquifer and hot rock reservoir below it induces convective fluid circulation, drawing saline water down the ‘injection well’ into the reservoir. The heated fluid then rises buoyantly back via ‘production wells’ exiting at the aquifer floor. This would *increase* the flux of “microbial power [1]”. Dissolved hydrogen (H2) would partition into the organic phase. This would allow unsaturated water to dissolve more gas as it re-circulates back down into the hot rock and then cycle back up the vent. Hydrogen partitioned in the organic phase would inhibit methanotrophs (methane eating microbes) if present. The organic phase would act as a substrate and product reservoir for methanogenesis. The high solubility of CO2 in aqueous relative to methane allows for the partitioning of the product away from the microbes in aqueous driving the reaction kinetics in the forward direction and the accumulation of methane.

The Chemistry

Hydrothermal vent systems have been modeled [6] for putative oceans on Europa. The model predicts that fluid-rock reactions for igneous rocks produce dissolved hydrogen H2(aq) that can support methanogenesis (microbial production of methane) for temperatures below 350 ° C. For an oxidizing ocean with dissolved CO2 the relative concentrations of dissolved gases in the returned fluid are shown in figure 3.

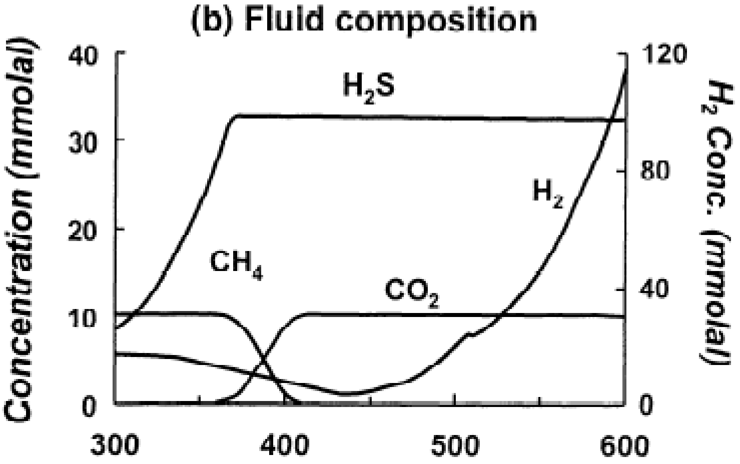


Figure 3: Dissolved gases after fluid-rock reactions. Source: McCollom 1999.

In theory Australia’s hot dry rocks should give a similar result. I notice that the gaseous content of current HDRG system fluid is consistent with McCollom’s model. The limited availability of new oxidants and the diffusiveness of H2 should be taken into account with closed-loop HDRG.

I notice that the trial of CO2 sequestration in the Otway basin is near prospective geo-thermal energy regions [5]. At 2km depth there might be geology suitable for drilling beneath the aquifer to create a stable sub-aquifer hydrothermal vent system. (See enclosed figure)

Deliberately disturbing a sequestration site in this way may seem like anathema to current philosophy but may indeed provide a **potential** renewable **environmental and economic benefit.** With my model, a combination of current geo-sequestration and geothermal philosophy, Australia’s vast saline aquifer resources could serve as renewable powerhouses beyond the depletion of our fossil fuels. Atmospheric CO2 could be put back in the ground with this model just as well as coal CO2. Australia could export this service to carbon trading participants from the E.U.

Please consider.

Luke Gale

1: T.C. Onstott, *“Impact of CO_2 Injections on Deep Subsurface Microbial Ecosystems and Potential Ramifications for the Surface Biosphere”* in Carbon dioxide capture for storage in deep geologic formations : results from the CO2 capture project. v. 2. Geologic storage of carbon dioxide with monitoring and verification / edited by Sally M. Benson; pp1217-1249. Amsterdam ; Oxford : Elsevier, 2005.

2:Kotelnikova S., “*Microbial production and oxidation of methane in deep subsurface”* Earth-Science Reviews, Volume 58, Number 3, October 2002, pp. 367-395(29)

3: Chapelle FH, O'Neill K, Bradley PM, Methe BA, Ciufo SA, Knobel LL, Lovley DR. “*A hydrogen-based subsurface microbial community dominated by methanogens*.” Nature. 2002 Jan 17; 415(6869):312-5.

4: en.wikipedia.org/wiki/Hydrothermal_vent

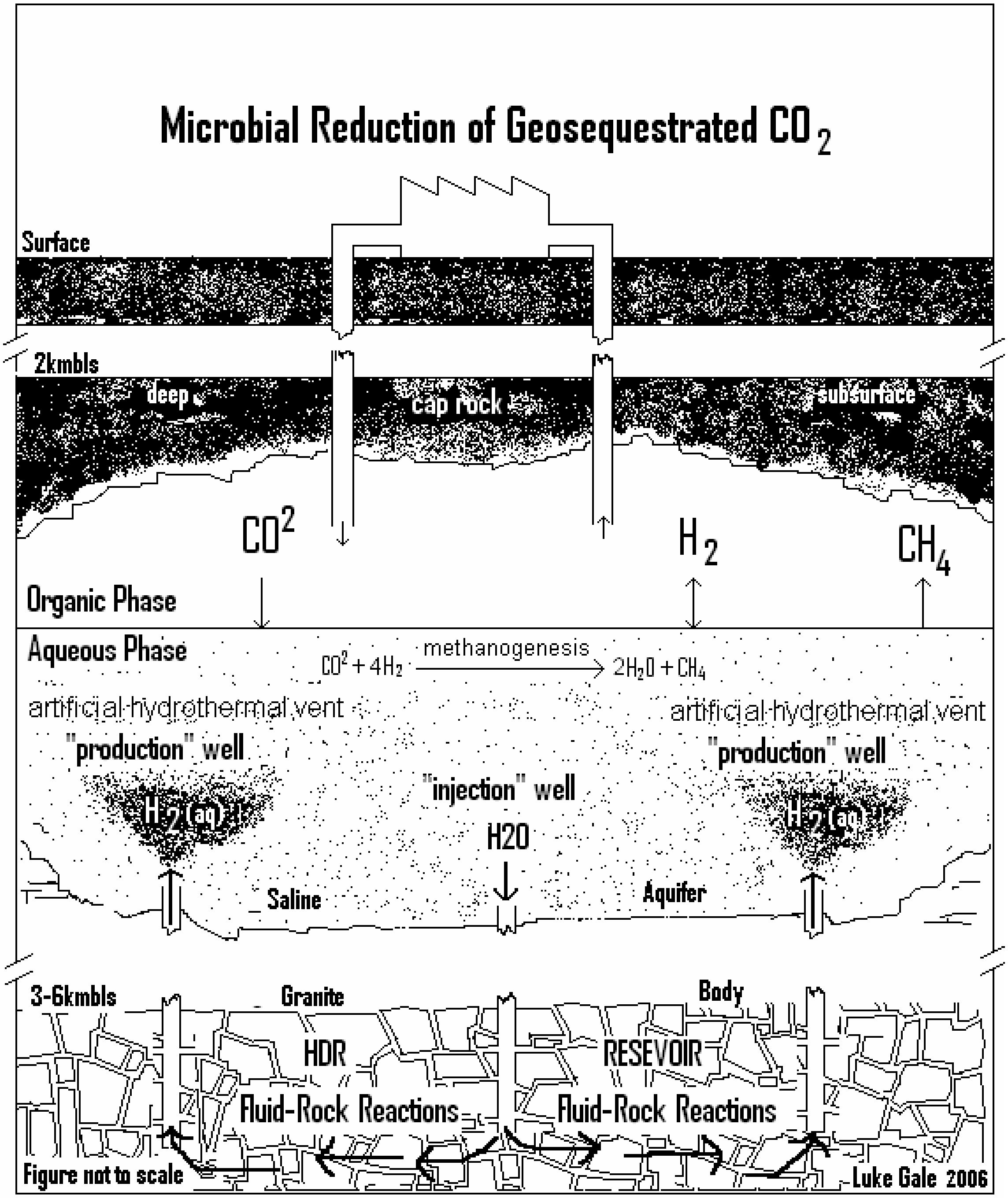
5: www.geothermal-resources.com.au/project_crower.html

6: McCollom, T. M., *“Methanogenesis as a potential source of chemical energy for primary biomass production by autotrophic organisms in hydrothermal systems on Europa”,* Journal of Geophysical Research, v. 104, No. E12, p. 30,729 (1999).

Further Refs:

Freund et al, *“Hydrogen in Rocks: An Energy Source for Deep Microbial Communities”* ASTROBIOLOGY Volume 2, Number 1, 2002, pp83-92

Stevens & McKinley, *“Abiotic Controls on H2 Production from Basalt-Water Reactions and Implications for Aquifer Biogeochemistry”,* Environ. Sci. Technol. 2000, 34, 826-831


Microbial Reduction of Geosequestrated CO 2
Surface
2kmbls
deep
cap rock
subsurface
CO2
H 2
CH4
Organic Phase
Aqueous Phase
CO2 + 4H2 methanogenesis 2H2O + CH4
artificial hydrothermal vent
"production" well
artificial hydrothermal vent
"production" well
"injection" well
H2(aq)
H20
H2(aq)
Saline
Aquifer
3-6kmbls
Granite
Body
HDR
RESEVOIR
Fluid-Rock Reactions
Fluid-Rock Reactions
Figure not to scale
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