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Hydrothermal dynamics on environmental problems using the aspect of earth science

N. YAMASAKI*, Y. YAMASAKI, K. TOHJI, N. TSUCHIYA, T. HASHIDA, K. IOKU
Graduate School of Environmental Studies, Tohoku University, Aoba 20, Sendai 80-8579
E-mail: yamasaki@mail.kankyo.tohoku.ac.jp

In order to establish a sustainable society, with practical material recycling, it is appropriate to focus on a range of guiding "Earth Principles", including the character and application of hydrothermal processes. In this paper, it is demonstrated that information obtained from the study of fundamental Earth Principles can be used to inspire the development of new methods for material recycling, such as the following:

(1) Hydrothermal hot-pressing processes, simulating the formation of sedimentary rock sequences, can be used for the solidification of toxic and hazardous materials.
(2) Organic materials could be formed from CO_2 under hydrothermal conditions (using Fe and Ni metals, and low valence Fe oxides), at temperature and pressure conditions consistent with a subduction (tectonic) setting, such as (under Japan) where the Pacific Plate sinks beneath the (Eurasian) continental plate.
(3) Diamond-structured carbon may be formed from toxic chlorinated hydrocarbon, in very high pressure regions of the Earth, and at high alkaline hydrothermal conditions, where magma formation may occur.
(4) High temperature dry steam in rock fractures (at near critical conditions — i.e. below saturated vapor pressure, but relatively high pressure) is not only a source/carrier of noble metals, including gold, silver and copper, but also ceramic materials, silica and alumina. Its laboratory simulation may also be a guide for the formation of thin layer silicate ceramics on metal plates (e.g. SUS-304 nickel alloy).
(5) To design an underground boiler in hot dry rock, non-equilibrium dissolution and deposition hydrothermal processes may be studied using a tube reactor, which simulates fluid flow and temperature gradients in fractured hot rock.

1. Introduction [1]

Fig. 1 shows a reaction media of aqueous solution under hydrothermal conditions.

Every chemical reaction generally existences among from terminal reaction such as the ionic complex decomposition: Formation of AgCl ($AgNO_3$ + NaCl) to radical reaction (burning of organic compound by oxygen). Characteristics of water are multi-power of reaction media and its selectivity by control of P-T condition and kinds and concentration of solute. The great recycling of water-CO_2 is shown in Fig. 2. In order to consider the global environmental problems, these two figures are useful and the research subject can be easily selected by using these figures. The five research topics have been described in the abstract.

*Author to whom all correspondence should be addressed.

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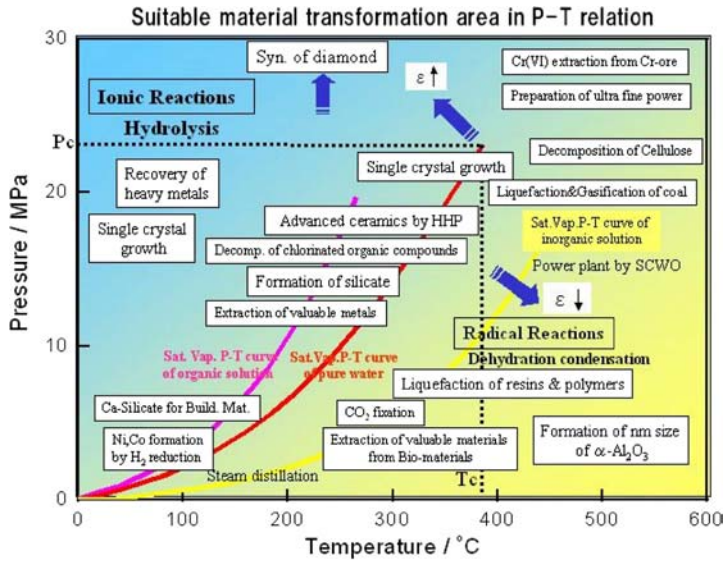

Figure 1 P-T Relation as Reaction Media.

Fig. 2 shows a great recycling of carbon and water containing silica and alumina.

In order to dissolve of environmental problem, these big recycle must be considered. The sedimentary process on ocean bottom and the sinking zone of ocean plate under Eurasian continental plate is a most interesting spot such as large energy stock, strong reductive conditions, containing sea water. In this zone, natural gas as alkane compounds, diamond may be formed from carbonate (CO_2).

2. Hydrothermal hot-pressing processes, simulating the formation of sedimentary rock sequences, can be used for the solidification of toxic and hazardous materials [2–10]

The typically natural sedimentary rocks are limestone and chert. These are formed from living thing. The chert is forms from the skeletone of diatom and other organic component of diatom is CH_2O. This CH_2O decomposed by CO_2 remove under the conditions of sea water and

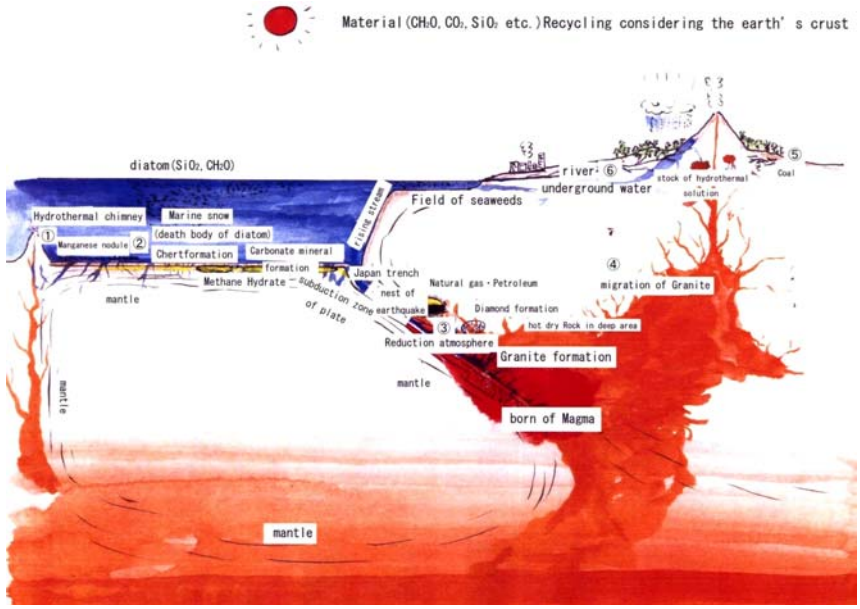

Figure 2 Great recycling of Water-Carbon Dioxide containing earth cluster.

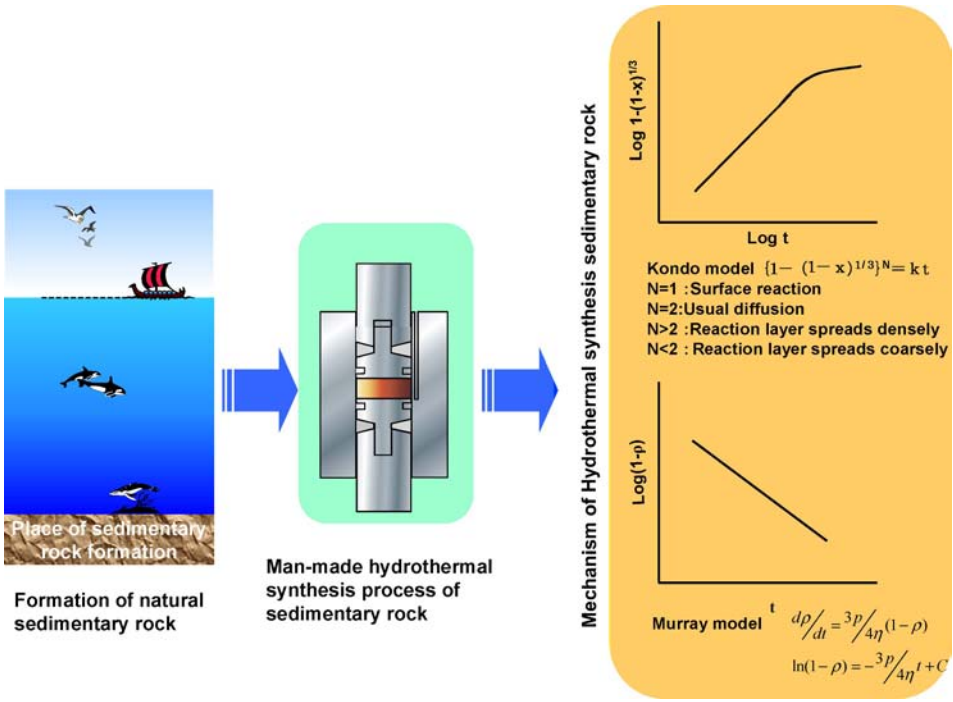

Figure 3 Simulation of sedimentary process using HHP process.

to form the carbonate as Ca, Mg salts. The powder and small amount of water is kneaded and set in the cylinder as shown in Fig. 3. By compressing by piston with top and bottom, and heating by outside heater, then the powder is formed to compact body. The water existence in powder released during compression but PTFE resin among piston and push rod prevent the water leakage. These processes are the simulation of sedimentary process for extremely short time. Using these technologies, we have been attempt following applications:

1) Solidification and Immobilization of various radioactive waste in the simulated chert formation,
2) Solidification of calcium carbonate (waste treatment of shell and oyster shell),
3) Porous and tough calcium phosphate as implant materials,
4) Solidification of incineration ash
5) Solidification of waste glass for building materials.

3. Organic materials could be formed from CO_2 under hydrothermal conditions (using Fe and Ni metals, and low valence Fe oxides), at temperature and pressure conditions consistent with a subduction (tectonic) setting, such as (under Japan) where the Pacific Plate sinks beneath the (Eurasian) continental plate [4–12]

Fig. 4 shows a hydrothermal reduction from CO_2 and $NaHCO_3$. These results may reproduce the simulation in the plate sinking zone and show easily change to organic compounds from CO_2. Many industry releasing CO_2 are side in ocean, and so if the piping of CO_2 can be introduce to Japan deep, easily sink with sea water and to change the carbon (diamond), natural gas and petroleum state.

4. Diamond-structured carbon may be formed from toxic chlorinated hydrocarbon, in very high pressure regions of the Earth, and at high alkaline hydrothermal conditions, where magma formation may occur [13]

The synthesis of diamond under hydrothermal conditions has been attempted. The process using chemical reaction (carbonation by condensation polymerization) is our

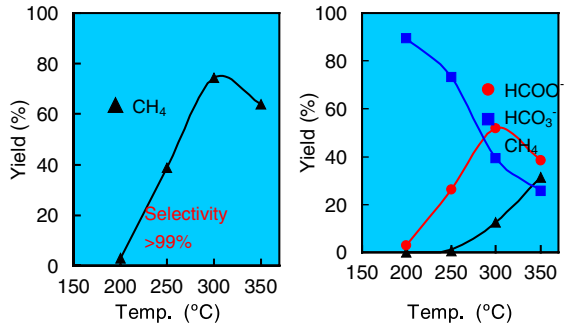

Figure 4 Hydrothermal reduction from CO_2 and Na_2CO_3 with Ni catalyzer.

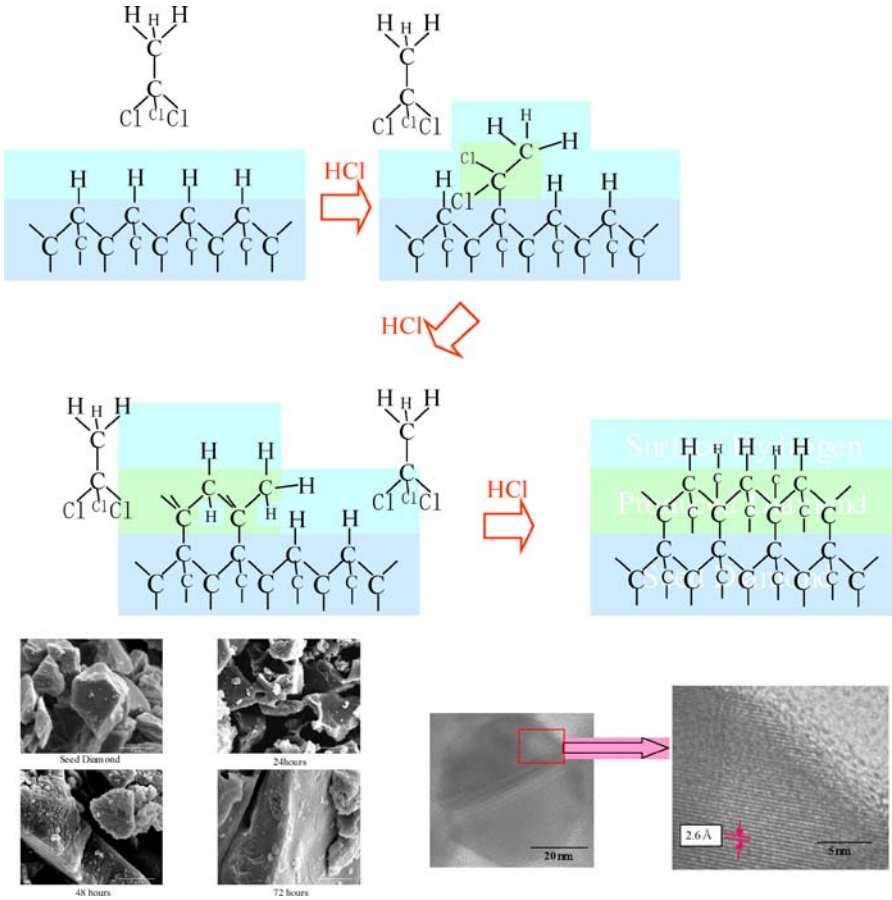

Figure 5 Reaction mechanism and images of SEM and TEM.

original view point as shown in top of Fig. 5. The SEM and TEM images are added in this Fig. 5. The four SEM images are starting diamond and products of 24 h reaction, of 48 h and 72 h and under conditions of 573 K, 0.7 GPa. The products after 24 h estimated by Raman spectrometry and X-ray micro diffraction pattern. The TEM of lattice image (under right figure) shows the same parameter of diamond. For further conformation of the diamond formation, the hydrated C-BN was used instead of hydrated diamond. Fig. 6 shows the Raman spectra of then. The products on C-BN show a SP^3 bond of diamond. These conditions are migration zone under continental plate and melting and formation zone of initial magma.

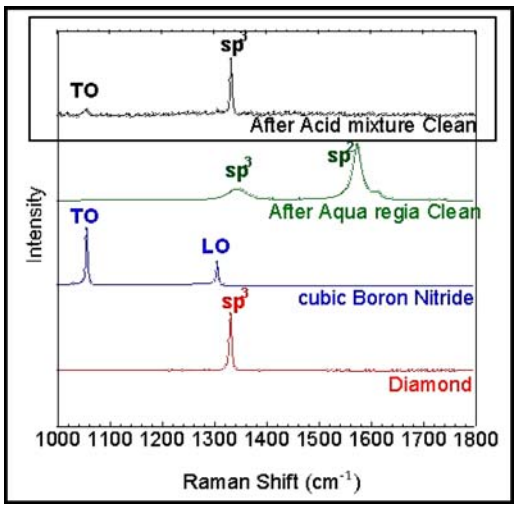

Figure 6 Raman Spectra of deposition carbon on c-BN.

5. High temperature dry steam in rock fractures (at near critical conditions — i.e. below saturated vapor pressure, but relatively high pressure) is not only a source/carrier of noble metals, including gold, silver and copper, but also ceramic materials, silica and alumina. Its laboratory simulation, as shown in Fig. 7, may also be a guide for the formation of thin layer silicate ceramics on metal plates (e.g. SUS-304 nickel alloy) [4–16]

These results may make new image. That is, when the dry steam flow up during crack from deep crust, these dry steam containing silicate bring some metals and to form many ores. In general, it was believed that the metal or mineral can not dissolve in steam. However these

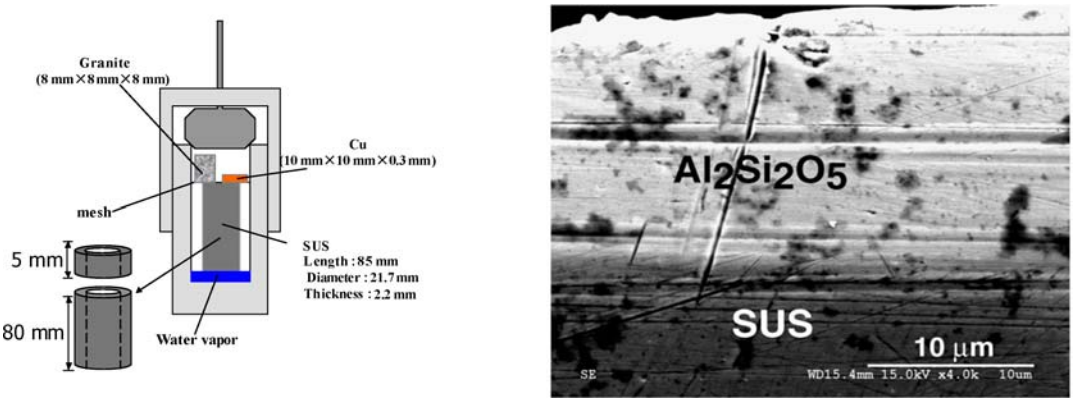

Figure 7 Left figure: Cu, Granite are set on Ni-alloy (SUS-304) mesh on Ni-alloy Pipe in autoclave, Right figure: SEM image of sectional view of SUS plate.

results show the ease migration of these materials not only with hydrothermal solution but also with dry steam. These aspects will be exciting subjects and application can be considered for extraction of noble metal from waste using non-equilibrium and flow system autoclave.

6. To design an underground boiler in hot dry rock, non-equilibrium dissolution and deposition hydrothermal processes may be studied using a tube reactor, which simulates fluid flow and temperature gradients in fractured hot rock [17–18]

Fig. 8 shows a general aspect of power plant using Hot-Dry Rock. If using temperature is around at 300°C, the temperature is most vigorous condition, so the life time of boiler using fracture become short by dissolution-deposition process. However, Fig. 9 shows a suitable area for low pressure and above 400°C area and under 20 MPa. These results show the suitable position in natural field is a volcanic area by the cost considering. The reason of the low pressure and high temperature fracture zone is not understand yet. This phenomenon may base on the basic character of water molecule. The OH polarity is a maximum value in one molecule however the polarity decreases with increase in hydrogen bond. The water molecule may be easily attack on granite surface when low pressure and high temperature for high polarity of water molecule.

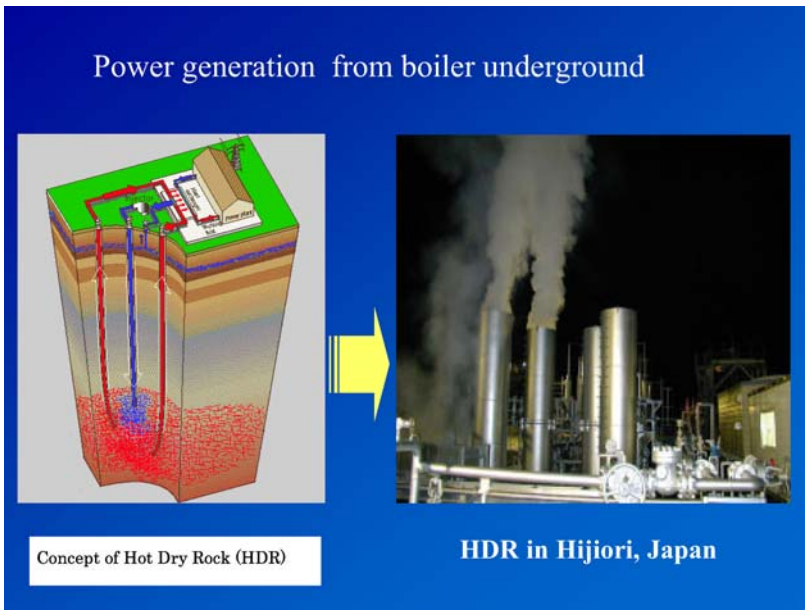

Figure 8 The concept of boiler using hot dry rock (HDR).

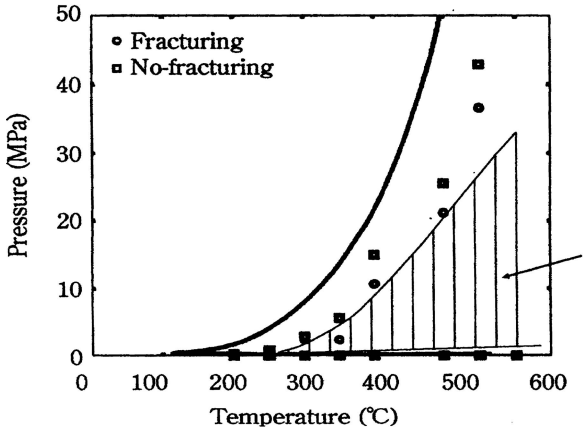

Figure 9 The fracturing area in P-T relation.

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