"Abiotic core" of Kakkonda geothermal system revealed by down-hole fluid sampling – depth limit of biosphere of a magmatic-hydrothermal system

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The depth limit of "deep biosphere" is defined by various physical, chemical and geological parameters (Pedersen, 1993), but the most crucial one could be the temperature. It is widely known that extremophiles are found even in 300 °C black smoker fluid and cells may remain viable at significantly higher than the known maximum temperature of growth of prokaryote under laboratory condition; that is, 113°C by Bloechl et al., (1997) or 121°C by Kashefi and Lovley (2003).

To test the hypothesis, we conducted in-situ aseptic water sampling from producing geothermal wells at Kakkonda geothermal field, northeast Honshu, Japan. Newly developed high-temperature fluid sampler (Sato et al., 2002) is used for sampling. The downhole tool enables us to collect in-situ wellbore fluid at temperatures up to 300°C without loosing gaseous components (gas-tight) upon recovery. We autoclaved all the parts of the sample chamber except inlet tubing that was heat-sterilized at 250 °C for 3 hours before sampling.

The liquid-dominated geothermal system in Kakkonda is "fueled" by a Quaternary granitic pluton that lies at depth between 1,950m and 2,770m. The K-Ar age of the constituent minerals is as young as 0.34 - 0.07 Ma (Kanisawa et al., 1994). Lines of evidence indicate that the pluton is still discharging magmatic fluid; that is, Na-K-Fe-Cl brine (7.1 mol/l Cl) was recovered at depth of 3.7 km of WD-1a well where down-hole temperature exceeded 500 °C (Saito et al., 1998, Muraoka et al., 1998).

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Two production wells which are drilled on a peripheral zone of the geothermal field were used for sampling: KB-5 well (hole depth=1,360m, casing depth=905m, sampling depth=900m and 1100m, fluid temperature=181.5°C, and fluid pressure=78.1kg/cm^2) and K2-7 well (hole depth=2,110m, casing depth=1,305m, sampling depth=1,305m, fluid temperature=191.1°C, and fluid pressure=79.3 kg/cm^2). Both wells have been flushed freely for several days before sampling and the possibility of contamination from the shallower portion is negligible. Sampled fluids are single phase because phase-separation is known at depth between 280m (KB-5) and 380m (K2-7).

The chemical composition of the fluids are (in mmol/l): Na=23.9-26.6, K=1.32-1.86, Ca=0.513-0.665, Mg=9.83E-07 - 2.40E-06, Cl=22.2-27.9, SO_4^{2-}=0.769-0.930, HCO_3^-=0.550-1.20, NH_3=0.061-0.079, and H_2S=0.0014-0.017. Silica geothermometer gives temperature between 213 °C and 227 °C. Methane content is 8,512-12,140 ppmv. The DOC is 8.907±0.274mg/L in KB-5 and 11.56 ± 0.456mg/L in K2-7. The organic carbon might be derived from shale and dacitic pyroclastic rocks which overlie the pluton.

The PCR and FISH analyses show no sign of archaeal or bacterial cells in the deep fluids. Besides, several attempts to culture microbes from the fluid have failed to get any signs of growth. This shows clear contrast to the rich microbial community found at a solfatara (max. temp=70°C) by a creek about 50 meters away from the K2-7 well. It contains abundant sulfate-reducing bacteria *(Ammonifex)* and sulfur-oxidizing thermophile *(Aquificales)*,

It is suggested that the reservoir temperature (181.5°C and 191.1°C) are too high for any form of life, in spite of the fact that the system has space and nutrients to support the life of chemolithoautotrophic prokaryotes. Besides, the geothermal system has abiotic core that is free from incorporation of cells from wall-rocks and down-circulating surface water. This negative experiment also indicates that the down-hole sampler worked perfectly to collect well-bore fluid before phase-separation and avoided surface contamination during sampling.

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