Geoscience for a sustainable Earth

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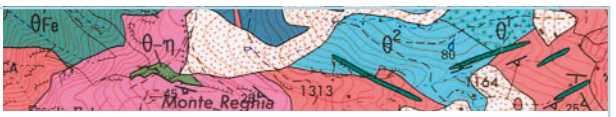

Could sequestration of CO_2 be combined with the development of Enhanced Geothermal Systems?

CO_2 injection in geothermal reservoirs may present some advantages compared injection in sedimentary reservoirs where the temperature usually lie in the range 30˚C to 120˚C . In hotter environments, typically from 160˚C to 270˚C, water-rock-CO_2 interactions proceed faster, and a higher part of the injected CO_2 can be permanently trapped through carbonate formation. However geothermal reservoir are not widely distributed throughout the crust. It could then be advantageous to study the feasibility of CO_2 injection in hot fissured fractured rock of medium permeability which can be found at moderate depth in very large portion of the earth crust.

Water-Rock interactions in geothermal reservoirs

> High temperature geothermal reservoirs have been exploited for electricity production since almost fifty years.
Drilling operations along with fluid and rock sampling, have provided a very large data base which could help to identify the most favourable properties of the different geological environments in terms of water rock interactions.

Example of fluid chemistry in geothermal fields

Geothermal Field	Geological settings	Temperature Ranges °C	pH	Na	K	Ca	Mg	Cl	SO_4	HCO_3	SiO_2
ASAL Djibouti	Basalt	260 - 350	4	37400	7273	23928	37	106000	32	66	520
Bouillante Guadeloupe West Indies	Andesitic	240 - 270	5,3	5100	770	1750	9	11600	25	50	550
Soultz sous forêt Rhine Graben	Granite	200	5,0	27400	2860	6500	98	5900	170	400	400
Nessavellir Well 18 (Iceland)	Basalt	203	9,67	164	18,4	0.9	0,001	61.5	35.9	122 (1)	407

(1) : Sum of HCO_3, CO_3

Concentrations are expressed in mg/Kg of geothermal fluids. This selection made over several hundreds of chemical analysis illustrates the very high variation of dissolved species. Magnesium content is always extremely low but calcium can reach very high values.

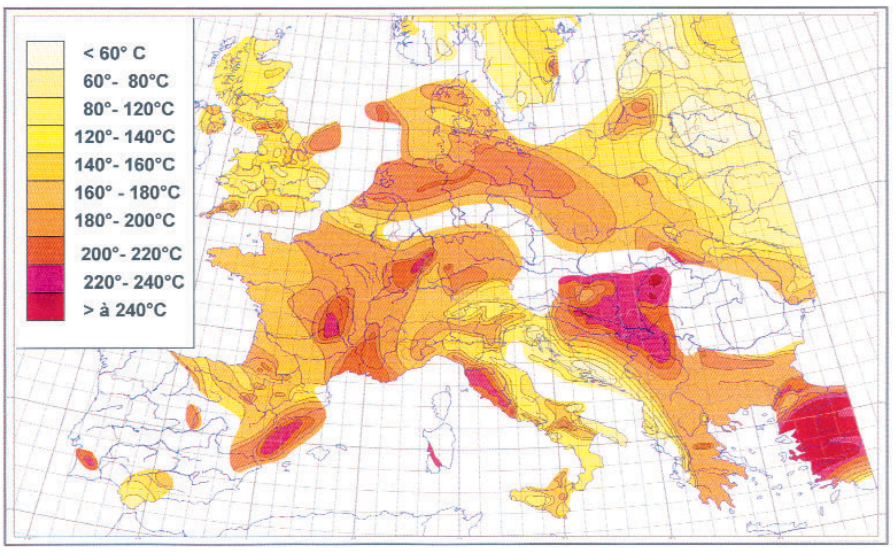

Fig. 1 - Extrapolated temperatures at 5 km depth in Europe

Potential for combined heat extraction and CO_2 storage

> Computer modelling of Water- rock- CO_2 interactions, combined with geochemical and mineralogical studies of geothermal reservoir, show that calcite formation could occur rapidly in granite reservoirs in the 160˚C - 200˚C temperature interval. At higher temperature, the increase of reaction rate is negatively balanced by the decrease of CO_2 solubility which will slow the overall reaction rate.

> The map of Fig. 1 shows that this temperature interval covers an appreciable percentage of continental Europe.

> Provided that a feasible exploitation scheme for recovering the heat stored in the fractured reservoir could be engineered, the cost of drilling deep wells for CO_2 storage could be partially offset.

Two different heat exploitation schemes can be envisaged

> According to the concept of D. Brown (2000),Fig. 2 the hydraulic fracturation and the heat extraction is achieved in a semi- closed loop which utilises super-critical CO_2 instead of water. The energy efficiency looks very promising, but the storage capacity of CO_2 is limited to the quantity which is lost during each cycle via CO_2 dissolution in water followed by subsequent calcite precipitation.

> after the experimental study of A. Ueda et al (2003), Fig. 3 we can think to a concept in which a period of CO_2 injection of several years is used to develop the permeability in some parts of the reservoirs, whilst trapping the CO_2 in other zones of the reservoir. Then, a delayed period of energy extraction could partially offset the cost of CO_2 storage.

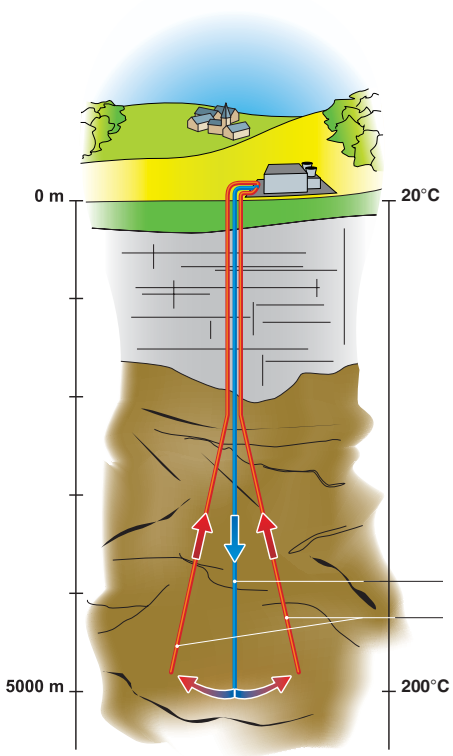

Fig. 2 - Enhanced geothermal system with supercritical CO_2 as working fluid

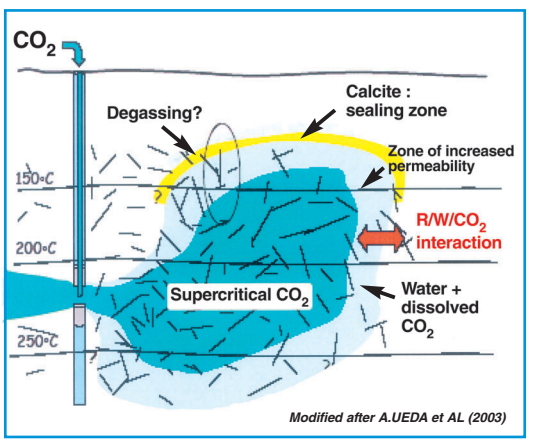

Fig. 3 - Permeability enhancement of a fractured geothermal reservoir by supercritical CO_2 injection.

Authors

**Fouillac Christian, Sanjuan Bernard
Gentier Sylvie, Czernichoski-Lauriol Isabelle**

**BRGM - Research division
c.fouillac@brgm.fr**

www.brgm.fr

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