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## Mining water from gypsum

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**Abstract:** Water resources in the world are scarce and unevenly distributed. In deserts, the only source of drinking water is groundwater, often saline and of poor quality. In many places, the groundwater levels have dropped dangerously due to overexploitation. Gypsum deposits, that are very common in deserts, are a potential source of drinking water, a fact that is realised by very few people. Gypsum contains 20% of water by weight, and in many arid and desert countries, there are billions of cubic meters of gypsum, representing trillions of litres of clean drinking water. It takes only moderate heating, to temperature around 100 °C, to liberate this water and convert the gypsum into bassanite or anhydrite. Such temperatures can be reached by solar power, or alternatively, the heat from flaring oil wells can be used. Anhydrite has a considerably smaller volume than gypsum, so the conversion of shallow underground layers of gypsum into anhydrite creates a subsidence, which can serve as a reservoir for the liberated water. Holland Innovation Team (HIT) is working on this project since 1987, and we have indicated that the macro-engineering concept of dewatering gypsum deposits can solve the water problem in many dry areas in future, for drinking purpose as well as for drip irrigation. We would like to thank Saint-Gobain Gypsum (Corneilles gypsum mine in Paris) and the SAMIA mine (Nouakchott, Mauritania) for the donation of pure gypsum blocks for testing purposes. We aim for a pilot test at a suitable desert location, in which several modes of heat supply and water capture will be tested. Several possible drilling and capture configurations are described in this paper.

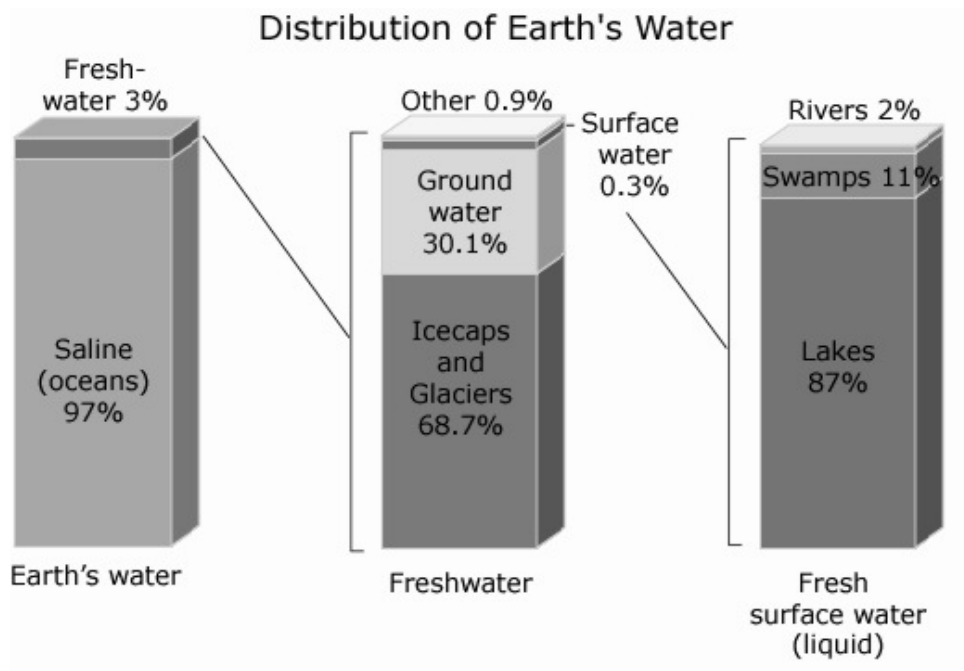
**Keywords:** anhydrite; dehydration; deserts; drinking water; gypsum.

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**Biographical note:** Peter van der Gaag graduated in Structural Geology in 1981. He founded Groundcontrol in 1984 ([www.ground-control.nl](http://www.ground-control.nl)), who worked on gypsum deposits in the OPLA underground waste disposal project (1987–1994). In 1987, the idea of mining water from gypsum deposits was born. In 1998, HIT was founded ([www.hollandinnovationteam.nl](http://www.hollandinnovationteam.nl)), which continued investigating of large scale water mining from gypsum deposits, for which a patent has been granted. A small-scale variant was also patented. He first described the occurrence of swelling clays in the Netherlands in 2004. Houses built on swelling clays suffer a larger damage from the frequent earthquakes triggered by the extraction of natural gas.

## 1 Introduction

Fresh water on Earth represents 3% of the total water present. It can be divided into lakes, ice, groundwater and several other minor occurrences.



**Table 1** Estimate of available water sources

One estimate of global water distribution:

Water source	Water volume, in cubic miles	Water volume, in cubic kilometers	Percent of fresh water	Percent of total water
Oceans, Seas, & Bays	321,000,000	1,338,000,000	--	96.5
Ice caps, Glaciers, & Permanent Snow	5,773,000	24,064,000	68.7	1.74
Groundwater	5,614,000	23,400,000	--	1.7
Fresh	2,526,000	10,530,000	30.1	0.76
Saline	3,088,000	12,870,000	--	0.94
Soil Moisture	3,959	16,500	0.05	0.001
Ground Ice & Permafrost	71,970	300,000	0.86	0.022
Lakes	42,320	176,400	--	0.013
Fresh	21,830	91,000	0.26	0.007
Saline	20,490	85,400	--	0.006
Atmosphere	3,095	12,900	0.04	0.001
Swamp Water	2,752	11,470	0.03	0.0008
Rivers	509	2,120	0.006	0.0002
Biological Water	269	1,120	0.003	0.0001
Total	332,500,000	1,386,000,000	-	100

Source: Gleick (1996).

In addition to these well-known sources, there is one potential water source that is overlooked so far, namely, the water that is locked up in gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ). In this paper, we will discuss possibilities for making this water available.

Before doing so, first a matter of terminology, we will distinguish between (de)hydration and (de-)hydratation. Hydration and dehydration refer to moisture, whereas hydratation refers to constitutional water of minerals and dehydration to the removal of such water from the crystal lattice.

Gypsum contains about 20% by weight of water. This means that one cubic meter of gypsum contains 426 L of water. If we realise that in many arid regions of the world vast gypsum deposits occur, covering many thousands of  $\text{km}^2$  and with the thicknesses of often several tens of metres, like in the Ogaden desert in Ethiopia, it is evident that these gypsum deposits represent enormous potential sources of drinking and irrigation water. Countries where such deposits can be found are among others Mauretania, Mali, Somalia, Ethiopia and Libya in Africa, and Oman, Iran, Jordan, Israel, Saudi Arabia, Pakistan and India in Asia. It is our opinion that in desert areas, often with poor and rare groundwater, such gypsum formations are by far the largest possible source of drinking water. The dehydration of a 30 m thick gypsum deposits will produce a lake of over 10 m deep!

## 2 Calcium sulphates and their behaviour

Calcium sulphates (gypsum:  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) and anhydrite:  $\text{CaSO}_4$  are evaporates and are widely described from all over the world. Although the stability fields of these calcium sulphates have been studied extensively, the results are not always consistent (McDonald, 1953; Hardie, 1967). Salinity, temperature and pressure are parameters which influence the stability field. There is plenty of geological evidence that with increasing temperature gypsum gradually turns into anhydrite. This is reported from all sedimentary basins in the world, and the thermal decomposition of gypsum is an important process in the early diagenesis. Currently, it may happen in the Danakil area (Ethiopia), one of the hottest deserts in the world, where wells below an overburden of many hundred metres of pure rock salts produce fresh water (Holwerda and Hutchinson, 1967), most likely derived from dehydrating gypsum layers at depth.

There are large differences between open and closed systems. Since the volume of anhydrite and water in a closed system is larger than that of gypsum alone, the decomposition of gypsum in closed systems can generate overpressures (Heard and Rubey, 1963). We will later describe how these properties can be used when gypsum deposits are mined to obtain fresh water.

## 3 The conversion process

By heating, gypsum is converted into bassanite and subsequently into anhydrite. This dehydration process is widely applied in the plaster board industry.



At high temperatures, directly it converts to  $\text{CaSO}_4$  plus water.

When we would succeed in applying this process in arid countries, it would create an enormous new source of drinking water. One could stop the process at the hemihydrate

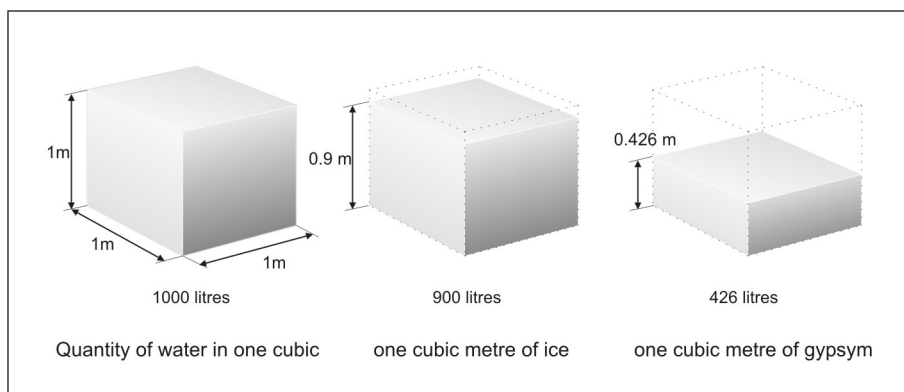
stage, since  $\frac{3}{4}$ th of the bound water is already liberated during this conversion. It is less energy-intensive, and it is easier to reconvert the hemihydrate into gypsum by exposing it to cooler and more humid night air. The produced water, in the form of steam or water vapour is very clean, and can be used for drinking water as well as for agricultural purposes.

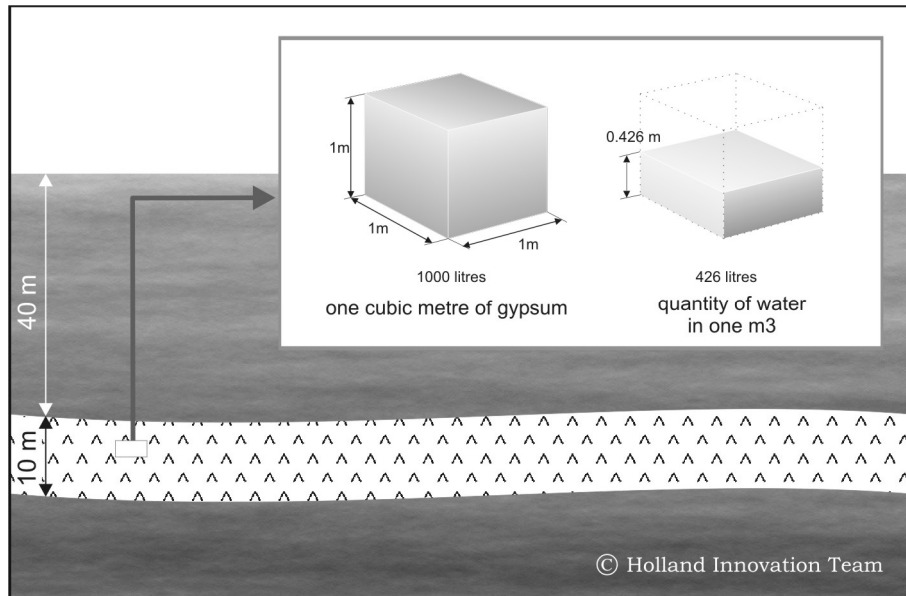
#### 4 The dehydration temperature

Temperature is by far the most important parameter, if we want to produce water from gypsum. Theoretically, the reaction should take place at 58 °C, but effectively the transformation becomes perceptible at temperatures of 80 ° or higher. Rapid heating, where high temperatures are generated almost instantaneously, gives a conversion of gypsum into anhydrite directly, whereas slow heating seems to give only hemihydrates. By changing the heating regime, one can optimise the quantity of liberated water as a function of the thermal energy added. Further, parameters are grain size and size distribution of the gypsum.

Further, our experiments show that for a solid rock, porosity and permeability are very important in the process of dehydration. We found out that the process under normal room conditions starts at temperatures of approximately 85 °C, and accelerates at temperatures above 100 °C. Then, the water liberates in the form of steam, which after condensation gives distilled water of high purity.

The best results of dehydration at low temperatures have been reached by dehydration of dune sands from Mauretania and Tunisia, composed of gypsum of fine grain size and high purity. Their dehydration starts rapidly with temperatures well under 100 °C.





Our conclusion is that above 130 °C, all gypsum formations will undergo dehydration and then are able to supply water.

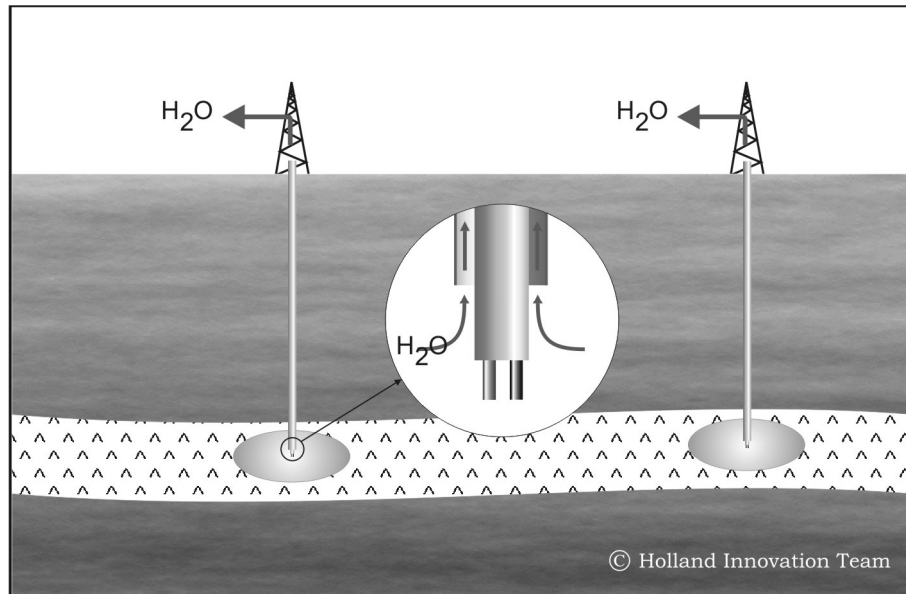
Since 1987, HIT is testing the conversion process. Tests show that the conversion of gypsum into hemihydrate is already possible at temperatures between 70 and 95 °C under certain conditions. This will be reported in a technical paper which also will deal with our patent:

“Extraction of water from underground gypsum formations”. (Van der Gaag, 2007)

Our experiments give remarkable results and feed the hope that dewatering underground gypsum deposits by macro-engineering will be a solution for large water problems in dry areas in the near future.

## 5 Heat sources and drilling examples

To generate thermal energy up to 130 °C in the desert is not a serious problem, because there is plenty of sun available. It is possible to dehydrate gypsum with solar power above ground surface (Mauretania, 1987). Especially, when we see that there are plans to make huge solar power plants in the desert, which can generate temperatures over 300 °C (du Marchie van Voorthuysen, this volume), it should be easy to combine things and mine water from gypsum layers.



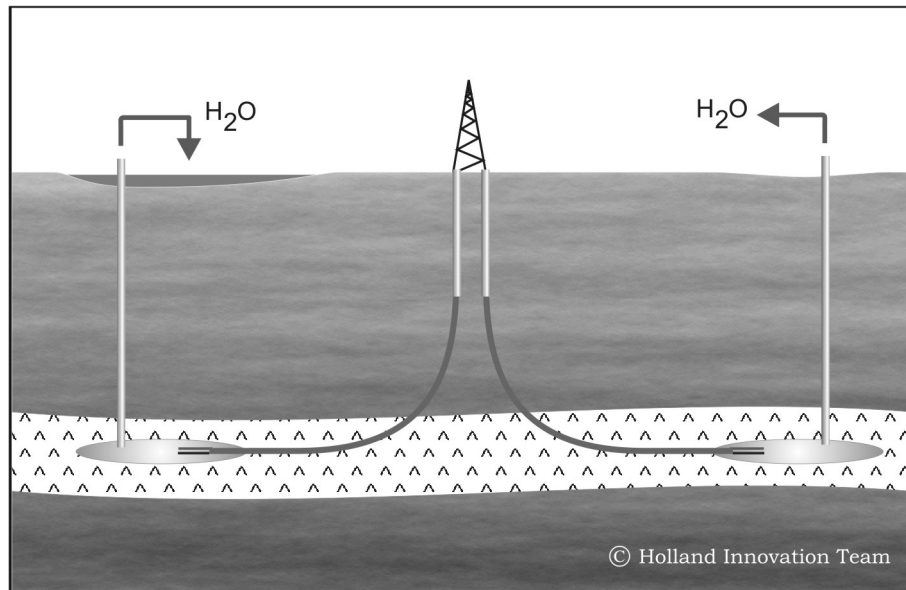
At other places, the thermal energy of flare gases can be used to generate heat for this purpose instead of polluting the air without any application. Small-scales tests show that all kinds of heat whether it is electrical, solar or hot pressurised air, should be able to dewater the gypsum present in geological formations.

We propose several configurations of drilling wells into underground gypsum formations. Some examples are pictured in the figures. We can use double tubing in which thermal energy is transported in an inner tube whereas the water will be pumped to the surface via the outer tube. It is also possible to drill at two locations. At well 1, heat is introduced into the gypsum formation. At a certain distance, a second well is drilled from which the (over pressurised) water can escape.

Small-scale tests with a soldering device to simulate a drilling operation in the underground show that water in the form of steam or vapour is coming out of the gypsum formations in both cases.

## 6 Creating water reservoirs and filling them with water

It is known that dewatering gypsum formations in an open system leads to a decrease of the volume of the formation. If the water can escape freely, this would permit to monitor and even to control subsidence (Dronkert, 1985). In the presence of an impermeable caprock, it might be possible to install wells to subtract water in a way that the water outlet could be controlled. Theoretically, this should work as follows: if there is an impervious caprock, enormous overpressures would be generated if the gypsum present turns into anhydrite and water and the water cannot escape (Heard and Rubey, 1963). In our experiments with closed drilling systems, we saw fracturing from the first to the second well, probably due to this overpressure (of water).



Anyway in a large-scale macro-engineering operation, the capture of water will generate a subsidence at the surface, thus creating a reservoir above the altered gypsum formation. This means that a smart engineering process of conversion of gypsum into anhydrite will create its own reservoirs. Since the gypsum–anhydrite transformation, geologically speaking, is a reversible process, the artificially created reservoirs with their natural anhydrite foundations below, could be filled with water in times when occasionally flooding occurs in the desert. Even if it might take years, it is worthwhile to consider the option of a reversible hydration–dehydration process, which will make the dewatering process reversible on a geological time-scale and thereby renewable. In case that the conversion has stopped at the hemihydrate stage, the rehydration proceeds even faster.

## 7 Conclusions and recommendations

It has been proven that water can be liberated from gypsum. It is also proven that liberating the water costs little thermal energy. In deserts, thermal energy of 100–130° is easily obtainable. Experiments of HIT show that dehydration under certain conditions (see technical paper) might be possible already at temperatures of 70–100 °C.

With this process, it would be possible to generate trillions of litres of drinking water from underground gypsum layers in arid regions. Many arid countries have an enormous potential of fresh water, since they have extensive and thick gypsum formations.

We continue to test the principle in the laboratory and on a small-scale in the field as well. A large-scale test at a proper location is recommended to gain knowledge before a large-scale macro-engineering operation could start.

## Acknowledgement

We would like to thank Saint-Gobain Gypsum (Cormeilles gypsum mine in Paris) and the SAMIA mine (Nouakchott, Mauritania) for the donation of pure gypsum blocks for testing purposes.

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