Energy
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Project

Deep underground heat reservoirs

Use hot water, store CO₂ – the potential deep beneath our feet

Use hot water, store CO_2 – the potential deep beneath our feet

To achieve the objectives of Energy Strategy 2050, attention is not only being turned to above-ground energy sources such as solar and wind power, but also to the potential available deep beneath our feet. This is because the warmth from the upper kilometres of the Earth's crust can also be used in Switzerland to generate energy. Furthermore, climate-damaging CO_2 that has been removed from the atmosphere can be stored on a sustainable basis in liquid form in suitable rock layers. This research project assessed the suitability of various regions of Switzerland for the application of these approaches. Different methods for investigating underground zones were also examined and improved.

Where boreholes hit hot water deep underground, power plants can use this to generate electricity. *Source:* Shutterstock

At a glance

- In this project, the potential for energy generation and gas storage offered by the Upper Muschelkalk, a rock layer situated deep beneath Switzerland’s Mittelland region, was investigated. Areas in the eastern Mittelland could be suitable for the storage of liquefied CO_2. However, the potential offered for electricity generation using geothermal energy is low.
- The investigation of hot springs in the area surrounding the Grimsel Pass shows that such Alpine regions have greater geothermal potential than was previously known.
- Several geothermal projects in Switzerland have failed in recent years as the underground conditions actually encountered were different to those that had been expected. The results of these research projects make it easier to predict the properties of the plutonic rock. This will make it possible to maximise the chances of success of future geothermal projects.

Contribution to Energy Strategy 2050

Alongside hydropower, solar energy and wind energy, deep geothermal energy is a further renewable energy source: electricity and heat are produced in a power plant using hot water from underground. The federal government believes that deep geothermal energy offers significant potential in Switzerland. Up to 2050, 4.4 terawatt hours of electricity is to be generated in this way – this equates to around 7 % of Switzerland’s current electricity consumption. However, several attempts at exploiting this potential have failed in recent years. In each case, the reason has been that the conditions encountered beneath the surface were less favourable than had been expected. To improve our understanding of deep underground areas, the properties of potentially suitable rock layers and their structure need to be investigated in detail. The interpretation of the geophysical measurement results must also be improved further. Both aspects were investigated as part of a joint research project of the Universities of Bern and Lausanne and ETH Zurich.

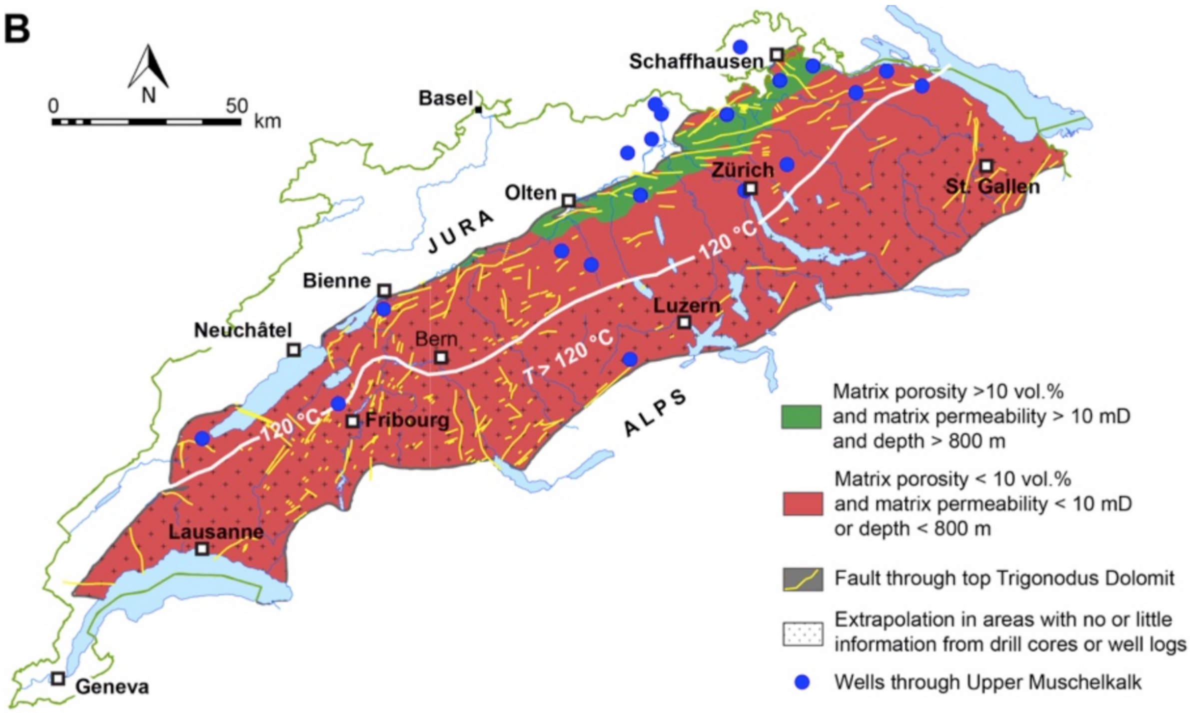
A beacon of hope: the rocks of the Upper Muschelkalk

Not all rock is suitable for obtaining warm water or storing gas. The porosity of the rock must be more than ten volume percent. And the permeability for water must be greater than 10 millidarcy.

One rock layer that promises these desired properties is the so-called Upper Muschelkalk, which is found at depths of 60 to 6,0000 metres beneath all of Switzerland's Mittelland region. This layer was deposited around 240 million years ago in a tropical, shallow primordial sea. In order to determine the properties of this rock, the researchers collected and investigated data and rock samples from existing boreholes of the National Cooperative for the Disposal of Radioactive Waste (Nagra) and the Swiss oil industry.

In order to generate geothermal electricity, the water encountered in the rock must have a temperature of at least 120 degrees Celsius. The water in the Upper Muschelkalk only reaches such high temperatures in the southern part of the Mittelland region, where the rock layer is situated at a depth of below 3,400 metres (marked on the map with a white line). The results of the study show, however, that these areas are unsuitable for geothermal electricity generation on an industrial scale. Due to the high load exerted by the overlying rock layers, the pores of the Upper Muschelkalk have been reduced in size over millions of years. The level of permeability is thus too small for the operation of a geothermal plant.

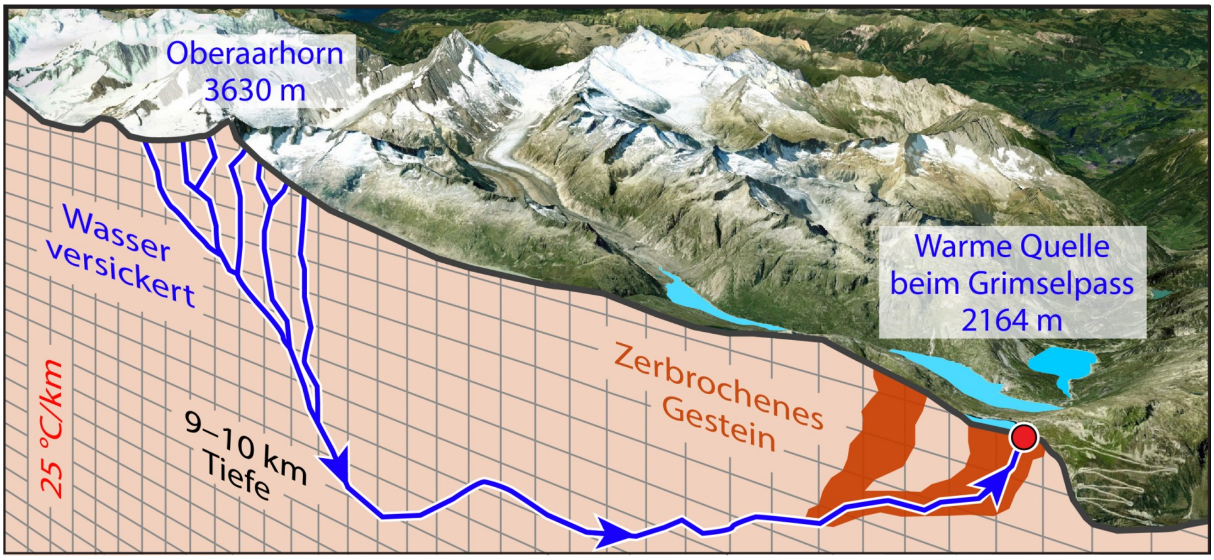
There is a better outlook with respect to the storing of CO_2 in the Upper Muschelkalk. As high temperatures are not required here, the Upper Muschelkalk is of interest at shallower depths of up to 1,130 metres. The levels of porosity and permeability measured here are considerably higher. In order to store CO_2 as a dense liquid under high pressure, however, the layer must be situated at a depth of at least 800 metres. At shallower depths, the CO_2 is gaseous, making the storage of large volumes impossible. This leaves a depth range of between 800 and 1,130 metres that would be suitable for CO_2 storage. These conditions are met by the Upper Muschelkalk in an area that stretches from Olten to Schaffhausen (marked in green on the map). In some places, however, this area exhibits large fractures which could make long-term storage more difficult. Nevertheless, almost half of the area is intact and thus offers potential as a storage site. Around 52 million tonnes of CO_2 could be stored in this region – a figure which equates to the emissions of a gas-fired power plant with a capacity of 400 megawatts over 75 years.



Suitability of the rocks of the Upper Muschelkalk for the storing of CO_2. Only in the area coloured in green does the rock have the required properties. Universität Bern

Geothermal energy in the Rhone Valley

It is not true everywhere that hot water can only be found at depths of 3,000 metres and below. For example, in the Rhone Valley in the canton of Valais, warm water penetrates right up to the surface in several places – for example at the Brigerbad and Lavey-les-Bains thermal baths. Warm water from fractures also reaches the surface on the Grimsel Pass. The upper part of this network has now been explored by geologists with a 125-metre-deep borehole. They investigated the drill cores and the chemical composition of the water and used these findings to take a look at even greater depths by means of computer simulations. This enabled them to determine that water infiltrates down to depth of between nine and ten kilometres where it is heated to 230 to 250 degrees Celsius before rising again along fractures. A single drop of water needs more than 30,000 years to complete this journey. However, the water does not reach the surface along the entire fracture zone, but rather only at two sites where the rock exhibits a particularly large number of fractures. This is a key finding for the commercial development of geothermal energy. This is because it means that such narrow zones will need to be sought on a targeted basis for future geothermal projects. The two aforementioned thermal baths are likely such outlet zones for hot water, meaning that Brigerbad and Lavey-les-Bains could possibly be suitable for the geothermal generation of electricity at an industrial scale.



Schematic diagram of the underground flow paths of thermal water at the Grimsel Pass.
Universität Bern

Avoidance of earthquakes during geothermal projects

In order to operate a geothermal power plant, the porosity and permeability of the underground zone need to be sufficiently high. Should this not be the case, the underground area can be stimulated, for example by pressing water into it at high pressure in order to enlarge existing natural cracks and join them together. In past projects, however, this process has led to palpable earthquakes and ultimately also to the discontinuation of these projects. The geologists from ETH Zurich therefore researched how the geophysical properties of the rock change under pressure. They exposed fractured rock samples to high shear stresses in a laboratory setting and at the same time screened them with X-rays in order to observe the changes in the fracture properties during the movement. Such experiments expand our understanding of how the geophysical properties of the rock change under pressure and help to ensure the better planning and implementation of future stimulation measures.

As part of this project, geophysicists from the University of Lausanne also investigated which indirect measurement methods can map the distribution of fractures in the rock around a borehole. To this end, they incorporated so-called geophones in the 125-metre-deep borehole on the Grimsel Pass. The borehole was then caused to vibrate by powerful hammer blows at the Earth's surface and the seismic noises were recorded via the geophones. The computer analysis of this data generated a three-dimensional image of the fractured rock around the borehole. Using this technique, it will in future also be possible to better localise fractures in the rock around a deep borehole. This method allows for the more targeted stimulation of underground areas through the introduction of water into certain zones of a borehole. It is hoped that this will make it possible to in future minimise palpable earthquakes such as those observed during the geothermal projects in St. Gallen (2012) and Basel (2006) which were jointly responsible for the discontinuation of both projects. The prevention of such earthquakes will be decisive for the success of geothermal energy going forward.

Produkte aus diesem Projekt

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