Earthquake Risks Resulting from Geothermal Power Plants- Reasons for the Earthquake Series in Basel in 2007

Dirk Ostermann

Offenbach, Germany, email: ostermann.dirk@vdi.de

ABSTRACT: *Due to global warming large efforts have to be taken in order to find a CO2-free energy supply for private consumers as well as for industry. One of the so-called renewable energies is geothermal energy. A new geothermal power plant was built in Basel, Switzerland, in 2006. A few weeks after the first water injections a series of earthquakes occurred in the region, which seems to be connected with the pressing of water into the ground.*

Keywords: Geothermal power plants; Earthquake risks; Basel; Energy supply

1. Introduction

The energy supply of most countries is covered by coal, oil, gas and nuclear power. In order to reduce the environmental carbon dioxide burden, the importance of the so-called renewable energy sources is increasing. Wind and solar energy are highly dependent on weather conditions. In contrast, geothermal energy is available 24 hours per day, 365 days per year at almost every place. It has to be distinguished between small geothermal projects near the earth-surface with depths of not more than 100m, which are already used for more than 15 years, and projects with injections deep into the ground, which are discussed in this article.

2. The Deep Heat Mining Project

In a first step the rock in a depth of about 5000m is fractured by water injections at a pressure of about 300 bar, see Figure (1). The aim is to create a geothermal reservoir consisting of many small cracks in the ground, through which water can be pumped. These subterrean crevaties remain permanently water permeable (1). The cleanout and stimulation program can be found in [4].

Later (at operation of the geothermal power plant) cold water is injected into the ground at a much lower pressure through a bore hole (2) and is heated in the subterranean crevices (3). Through additional depth drillings (4), the heated water can be recirculated to the surface, where it is routed through a heat exchanger (5). The heat exchanger is coupled with a secondary circuit that drives a turbine with a generator for power production (6). Another circuit feeds the heat into the district heat grid. A cooling unit (7) is inserted downstream of the power generator circuit. The cooled water is then again pressed into the deep bore hole (8). Closed circuits ensure that no byproducts can escape at the surface. More details concerning the functionality of the geothermal power plant can be found in [1].

3. Geological Conditions

For the success of the project it is favorable to find a location where the temperature in the ground increases very fast with the depth. This is the case in the Basel region, which is near to the Rheingraben, a border of tectonic plates. In a depth of 5,000 meter below the surface the temperature rises to more than 200°C. The geothermal heat from these hot rock formations shall be extracted by means of the "Hot Fractured Rock" process.

As mentioned above, the Rheingraben is a border of tectonic plates [7-8]. This has not only the advantage of high temperatures near the surface, it also has a big disadvantage: The increased earthquake risk in this region. Figure (2) shows the seismic map of Germany, which is taken from the

German building code *DIN* 4149 [7]. It can be seen that the highest earthquake risks exist along the Rheingraben and the Basel region (in the lower left corner of the map) belongs to earthquake zone 3 which is the highest earthquake zone in the map.

4. Series of Earthquakes

Table (1) gives an overview over the earthquakes, which occurred in the Basel region since the beginning of the Deep Heat Mining project. The

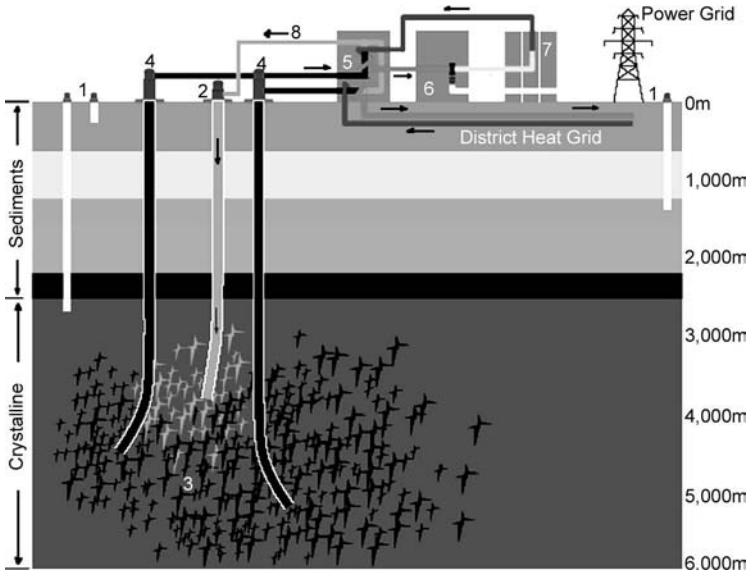

Figure 1. Geothermal Power Plant, taken from [1].

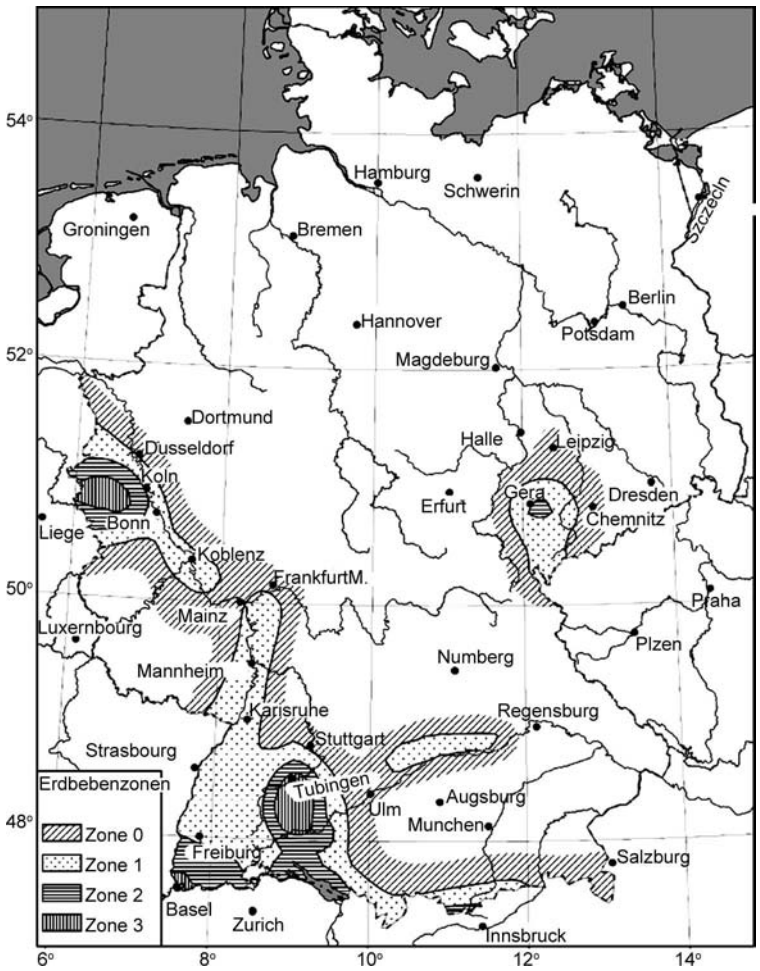

Figure 2. Seismic map of Germany, taken from DIN 4149.

Table 1. Earthquakes in Basel in 2006 and 2007.

Date	Time	Magnitude
December 8th, 2006	16:48	3.4
January 6th, 2007	07:19	3.1
January 16th, 2007	01:09	3.2
February 2nd, 2007	04:54	3.3
March 21st, 2007	17:45	2.8

average magnitude of all earthquakes was around 3.0. People in the densely populated Basel region were frightened, see article in [6], but fortunately no larger damages were found and nobody was injured.

5. Consequences for the Project

As a consequence of the earthquake series, injections into the ground were stopped. However, the series of earthquakes did not stop immediately and it is still possible, that some more (but smaller) earthquakes might occur. The seismic events lead to a broad discussion in the public. A group of experts and scientists were asked to investigate the reasons of the earthquakes and to find possibilities for further procedure [2]. After detailed scientific investigations and discussions with local authorities, the operation is permitted, if the conditions shown in Figure (3) are met. However, the works are still stopped and it is unsure, if the project will be continued.

It should be noted, that the thresholds given in Figure (3) are very conservative as damages to buildings are expected at peak ground velocities (PGV) larger than $20cm/s = 200mm/s$ and local magnitudes above $M_L = 4.5$.

6. Results of Expert Discussions

It has to be distinguished between natural seismic events, induced seismic events and triggered seismic events:

- Natural seismic events are earthquakes which would have taken place in any case, even if the geothermic power plant would not have been built. The Basel region is a very active tectonic zone. But since so many earthquakes occurred in such a short period of time after the first water injections, the possibility of a series of natural seismic events seems to be very unlikely.
- Induced seismic events are man-made earthquakes which would not have occurred if no power plant had been built. The relatively small amount of water, which was injected into the ground and the fact that the activities were only a local effect make the hypothesis of an induced seismic event very unlikely.
- The third possibility is a so-called triggered seismic event. This means that the injections and subsequent activities triggered natural seismicity. Natural tectonic displacements would have happened anyway, but due to man-made activities these seismic events only took place earlier.

In this case, most experts and scientists assume that we have to deal with the phenomenon of triggered earthquakes. Some experts even stated, that this might have a positive effect because the tectonic stresses in the ground could be reduced by many small earthquakes without any damages to public infrastructure instead of one big earthquake with large destructions of houses and even victims in the

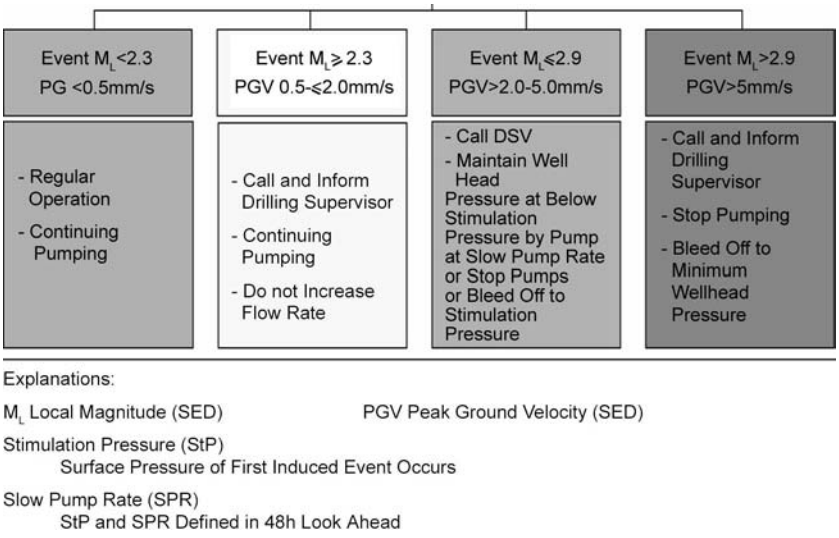

Figure 3. Consequences taken from [1].

public. Details on the scientific investigations can be found in [3, 5].

7. Summary

Geothermal energy is very ecological as no CO2 is emitted to the atmosphere. It is independent from imports of raw materials like coal or oil and it is nearly available everywhere, but with big power plants and high water pressures in the ground, the risk of inducing or triggering earthquakes increases as the cases in Basel reveal.

References

1. Website www.geopowerbasel.ch, Geopower Basel AG, Margarethenstraße 40, 4002 Basel/ Switzerland.

2. Geothermal Explorers Ltd.: Report Geopower, 04.01.2007.

3. Geopower Basel: Project Deep Heat Mining, Answers to Questions of the Local Authority of the Basel Region from December 15th, 2006, Concerning the Induced Earthquake from December 8th, 2006 in Basel.

4. Geopower Basel: Cleanout and Stimulation Programme (2006).

5. Geopower Basel: Responses to Questions Regarding the 8th December 2006 Seismic Events Related to the Basel Deep Heat Mining Project.

6. Swissinfo: Geothermie-Erdbeben der Stärke 3.1 in Basel, 06.01.2007.

7. DIN 4149, Bauten in Deutschen Erdbeben-gebieten, German Building Code.

8. Eurocode 8: Auslegung von Bauwerken Gegen Erdbeben, European Building Code.