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CO_2 blowouts in the German history of salt mining

Internal Report IR/04/124

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/124

CO_2 blowouts in the German history of salt mining

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Key words

CO_2 emissions, potash mine

Bibliographical reference

Wagner, D 2004. CO_2 blowouts in the German history of salt mining. *British Geological Survey Internal Report,* IR/04/124. 12pp.

Keyworth, Nottingham British Geological Survey 2004

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) and part of the NASCENT project working on the storage of industrial quantities of CO_2 in the underground. In order to address the global warning threat posed by anthropogenic greenhouse gases, the European member states have committed themselves, through the Kyoto protocol, to an 8 % reduction in their greenhouse gas emission. In the medium to long term, reductions of up to 60 % may be needed, requiring several approaches, including the storage of CO_2. Before large-scale underground CO_2 storage can take place, however, it will be necessary to demonstrate that the processes are well understood, risks to the environment and human populations are low, and environmental disturbances can be minimised. The study of natural analogues is crucial to understanding the long-term impact of CO_2.

Acknowledgements

I want to thank J. Pearce for giving me an overview about the CO_2 store project and its aims and also for reviewing draft chapters of this report. Also thanks to C. Rochelle for the German info material about the potash mines in Thuringia and Hesse.

Contents

Summary

The NASCENT project was a three-year research project (2001 to 2004) studying natural accumulations of CO_2 as analogues for geological storage of anthropogenic CO_2 emissions. These accumulations occur in a variety of geological environments and many can be demonstrated to have stored CO_2 for periods longer than those being considered for CO_2 storage. The study of natural analogues is crucial to understanding the long-term impact of CO_2 storage. Such long-term effects cannot be addressed by laboratory experiments. These include the long-term safety and stability of storage underground and the potential effects of leakage from an underground storage reservoir. Natural CO_2 fields, and places where CO_2 is actively migrating from underground to the Earth's surfaces, are widespread in Europe and one of them is the potash field of Thuringia and Hesse in Germany.

1 Introduction

During the centenarian history of German potash mining there have been several thousand salt-gas-blowouts. Whilst in the northern pits rare and very moderate emission of CO_2 has been registered, in the southerly-located Thuringian pits the most frequent and biggest blowouts of rock and gas in World mining of all industries occurred. Causes were both geological and historic progression: On the one hand the influx of CO_2 took part especially in the area of the "Vorderrhoen", and on the other hand the main mining was based in the Thuringian. This "command for Rhoenmarch" meant an everlasting undercutting of the area of the "Vorderrhoen", where CO_2 accompanied most part of the potash.

2 Natural, legal and economic conditions

2.1 THE DEPOSIT OF BOTH POTASH AND CO2

Sedimentation of potashes within the Werra-Fulda potash-mining district took place about 250 mill years ago in the Zechstein period, the infiltration of CO_2 into the saline maximum 25 mill years ago. So far the potash mining amount to circa 1,3 million t^3 cumulative over 300 km^2. Zechstein beds, almost 400m thick, are deposited under Buntsandstein (red sanstone). Within these Zechstein beds the salt stone beds of Werra are average 270m thick, based between limestone and anhydrite deposits underneath and clayish roof sediments. Two potash resources – the lower Kalifloez (potash bed) Thueringia and the upper potash bed Hesse – divide the sandstone beds of Werra into three parts. These beds are located from circa 300 to more than 1000 m depth, dipping 2-3° SW.

The main potash salts are hartsalz ($NaCl+KCl+MgSO_4+H_2O$), carnallite and sylvite. hartsalz dominates in the upper layers, in the lower layers carnallite is dominant. K_2O contents of hartsalz are typically between 8 and 10 %, those of carnallite 12-14 % and sylvite 20 to 40 %. $MgSO_4$ contents of Hartsalz range from15 to 25 % in upper levels and 8-12 % in lower levels, and of carnallite 2-4 %. Sylvite is often strongly CO_2 impregnated, as a result of hydro metamorphosis of carnallite to sylvite involving ascending waters.

Post-Permian tectonic events were relevant for the evolution of the potash mine, resulting in faulted structures. Along joints both descending waters and ascending waters, eruptive gases and basaltic magmas infiltrated, forming the geological basis of the CO_2 based danger for future mining.

2.2 MAIN FOCUS OF MINING IN THUERINGIA

The Werra-Fulda potash area spans 100km^2, whereas one third is part of Thueringia and two third are situated in Hesse. About one third of deposits are already exhausted, whereby until now wastage of deposits in Thueringia are twice as large as those in Hesse, hence the so called “Rhoenmarch” started playing an important role very early.

Mining in Thueringia was forced towards the southern parts into the dangerous “carbon acid fields” (traditional term for CO_2 by the miners) without knowledge of the dimension of the hazards. Different legal structures in both counties made the grant of mining areas in Thueringia much less time consuming than in Hesse, which lead to a greater exposure in Thueringia compared to Hesse. This absolute exploitation was not stopped until 1907 where in the Prussia Kingdom the so-called “Mutungssperre” was legislated, what meant that henceforth just the State could carry out or transfer mining to firms. During the 1st World War the German Empire legislated in 1916 potash mining prohibition that finally cemented the unbalanced distribution of the pits of Thueringia and Hesse.

After the 1st World War the mining of the Werra-Fulda area rose again as a result of economical changes. Germany lost its important potash mines in Alsace to France that lead to a general rationalisation and establishment of concerns within the potash industry. The top company was Wintershall-concern, owner of about 40% of all potash pits. Its president Mr. August Rosterg recognized that the Werra-Fulda area had the lowest prime costs, despite low K_2O contents and minor thickness of the two beds, in comparison to other potash mines. The reasons were: 1.potash beds were uncomplicated flat deposited within thick salt layers; 2.Hartsalz deposits contained high amounts of hardly soluble Kieserite; 3.Plattendolomite in the roof of Zechstein had a large joint and pore volume (allowing disposal of kieserite washing waters and $MgCl_2$-solutions from the sulphate production).

3 The matter of CO_2 and resulting considerations

3.1 FIRST EMISSIONS OF CARBON DIOXIDE AT “BERNHARDSHALL”

In 1895 first contacts with CO_2 gas were made during drilling to 347m depth in the Bernhardshall pit and were seen as the last exhalation of the volcanic basalt source. The general idea that the appearance of CO_2 was always related to basalt proximity was based on CO_2 exhalations that could be observed on the earth surface in relation to basalts (“Hundskoepfe”).

Between 1903 and 1908 about 20 salt-gas exhalations occurred in the Mine Bernhardshall, but the main blowouts were in 1925 with 720t salt emission. The main reason for not closing this dangerous mine before these accidents was the general belief in the so-called “Magma-Gas-Theory”. It was based on thoughts that carbon acid diffuses from the magma into the adjacent salt on the one hand and then also diffuses coming from the salt into the pits, if it has enough time to do so (no explosions). It turned out to be wrong, because the CO_2 didn’t degas from the salt.

3.2 INITIAL HYPOTHESIS OF CO_2 PHENOMENA BY EXPERTS

It was now understood that Rhoen volcanisms led to CO_2 infiltration and raised awareness of the possibility of a fresh increase of carbon acid. But the concepts of Tertiary rising fluids and CO_2 reservoirs were in these early times of potash mining very speculative and colourful.

It was accepted fact that CO_2 arriving from depths have diffused into suitable porous salts, such as sylvite (Dr. Beck, Leipzig 1911). But lots of questions remained unanswered, such as the origin of the porous salts or if the CO_2 came from primary depths or diffused during limestone thermal metamorphism involving basalts.

The idea that water has an important part of these processes grew slowly. People considered that **little** hydrothermal water ascended in the cleavages during Tertiary periods, allowing easy soluble potashes to dissolve the chloromagnesium content in carnallite that prepared the way for CO_2 infiltration. By keeping the water amounts low thinking the salt-gas blowouts must be in controllable limits.

4 First defensive and then offensive steps against CO_2

4.1 THE "SUPER BLOW-OUT" AT MENZENGRABEN

Over the years, the potash mining in the Menzengrabener pit was concentrated in huge knoll like accumulations of especially MgCl-rich carnallite (for aircraft construction), situated close to the mineshaft. Fortunately, being aware of possible salt-gas eruptions, detonation cables were chosen that were long enough for safety of the miners. Two massive eruptions were caused in 1942 and 1943 by expanding into altered sylvite, in which CO_2 content is much higher than normal.

After the Second World War there was a temporary reduction of potash mining caused by economic turbulences. In Menzengraben production was now focused on sylvinite instead of carnallite. To be prepared for possible gas exhalations there were CO_2 barriers built made of sheet steel and a weather-detour was brought off. But these protection efforts turned out to be useless after an accident and it was decided to close the pit. Probably economic reasons (high K_2O content) lead to a reopening of this pit two years later, whereby electric remote ignition was introduced. Production increased during the following years and so the danger of CO_2 increased. Several blowouts are recorded and made the pit Menzengraben the focal point of CO_2 events.

On the 7^{th} of July 1953 in pit Menzengraben the biggest salt-gas blowouts occurred in the world history of potash mining with about 100.000t salt blowouts and estimated 1 mill m^3 of gas exhalation. Activated by explosions massive clouds of CO_2 found their way through the two 520m deep mine shafts resulting in extensive damage. A lull in wind outside of the pit covered the valley along 5 km in a strongly carbon acid containing mixture of gases and put the inhabitants of the village Menzengraben at risk. In general 3 people were killed, rapid security procedures avoided the worst. The pit wasn't refurbished until October so that production could go on.

After the huge eruption in 1953 extensive security procedures followed. Gas barriers were built in the form of retractable doors, which shut automatically by gas pressure. A modern main fan was installed, the rescue place was modernised and the equipment protection was improved.

Based on these improvements a new phase of "Rhoenmarch" seemed likely, until another catastrophe in April 1985 caused a loss in confidence. But this time the cause of the disaster was not as usual salt bounded CO_2 but cavern, named as "gas-blower". After a massive gas blower two miners ran away in panic not activating the installed closing devices, which were installed to avoid gas exhalations. Gas spread out, whereby five people were killed. First after this accident danger of gas blowers was realised and additional CO_2-precautions were added. These were personal oxygen containers, setup of escape chambers with isolated air supply and installation of alarm equipment for carbon acid.

4.2 OFFENSIVE WAY TO THE SO-CALLED "CO_2-WEITUNGSBAU"

At the end of the 1950 extensive investigations, carried out by the leadership of the potash combination "Werra" and universities under the general leadership of Prof. Dr. Werner Grimm, started for an offensive combat of Rhoenmarch. Application of sonar in the 1930 and dielectricity probe in the 1950 obtained the first geological information. During the 1960's further methods evolved, like the so-called "Sondershaeuser Knisterprognose" (crackle prognosis) involving a calibrated voltmeter measuring CO_2 contents dependent of decrepitating noises during solution in bore hole samples under water as well as the "Freiberger Kernprognose" (core prognosis) based on analysis of bore hole schistosity affected by CO_2-impregnation. Later a third method, the so-called "Freiberger Gasdruckprognose" (gas pressure prognoses) was evolved measuring the increase of gas pressure shortly after setup of boreholes. This method was the most economic and has been the most common one since. At the beginning of the 1960's a project for a guard system was created based on preparing the environment for potential CO_2 exhalations in time, so accidents can be avoided. Thereby acquired 18 guard solutions included combinations of 31 technical-organisational tasks: for example, net linked remote ignition, fitting of gas barriers and self-saver equipment for workers. During the 1960's empirical investigations showed a link between special eruption intensity and geometric parameters, for example salt emission quantity – size of blow-out cavern. Proof that during chain reactions secondary inactive exhalation zones in front of active zones are formed causing sealing was an important step to controlling gas exhalations through explosion.

On the 14th Jan 1962 the first methodical pro-active salt-gas exhalation within the pit Menzengraben was put into action. Nearby traffic was blocked, pit fans were tuned to maximum and the whole action was published publicly as plan example. As these were proved successful further activated exhalations followed. Another realisation was that construction of exhalation port leads to less strong eruptions. So from 1965 onwards miners changed to a modern mobile mining including blast hole drill carts, deep digging carts, armature drill carts etc.
The resulting change in mining methods (system room and pillar) led to sedimentation of the erupted salt in the closed-by areas. So the guard of the pit kit was more competitive and less complex. This new technique also led to evolution of a new mining method for CO_2 impregnated sylvitic stones, the so-called "CO_2-Weitungsbau", introduced in 1984 using CO_2 as blasting agent.

5 Conclusion

During the "Rhoenmarch" two changes can be seen: On the one hand dimensions and frequency of CO_2 exhalations rose enormously, for example there have been about 1200 salt-gas blowouts between 1980 and 1987 in the Thuringian south pits.
On the other hand progressing investigations helped to get a grip on CO_2 exhalations with increasing success. There was progress in the explanation of the genesis and nature of CO_2 appearances, as well as mechanism and first signs of salt-gas blowouts leading to an improvement of mining kit, protecting equipment and the whole mining area.

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