SAFETY OF UGS OPERATION IN TERMS OF THE IMPORTANCE OF PRIMARY FACTORS OF TIGHTNESS OF STRUCTURES

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ABSTRACT

Underground gas storage (UGS) has become an essential part of gas transmission systems in all developed industrial countries. This is because transit pipelines transporting natural gas to consumers are limited by the maximum flow capacity and are not able to cover the increased seasonal or peak demand. UGS facilities then guarantee the security and reliability of gas supplies, especially in the event of a transit transmission failure. The actual safety of UGS operation is then given by the reliability of storage structures, technical and technological equipment, i.e. the so-called primary and secondary tightness. The article evaluates the primary conditions of tightness on selected UGS operated by MND Gas Storage a. s. Hodonín and MND Gas Storage Germany GmbH, Germany. These are the Uhřice, Uhřice-South (Czech Republic) and Hähnlein and Stockstadt (Germany) reservoirs.

Keywords: Geology; Tectonics; Tightness; Underground gas storage.

1   INTRODUCTION

Since 2016 we have been doing laboratory work in petrophysical assessment of rock samples and investigating the possibilities of increasing the total storage capacity of natural gas in underground gas storage facilities. For several years the situation in underground gas storage was rather stable, but in the last 2 years there have been significant changes in the underground gas storage conditions. Thus, today we are in a completely different world as the current fall in oil prices immediately caused a wave of panic in the financial markets.

This price shock in the oil market, together with the chaos that has arisen during the "coronavirus" slowdown in the world economy, may have tangible consequences for energy transformation. "It will definitely significantly reduce efforts to switch to cleaner energy," said Fatih Birol, the head of the International Energy Agency, about the historical drop in prices. He adds that "cheaper energy always leads to its use in a less cost-effective way" [1]. However, even before this shock, on Wednesday 4 March 2020, the European Commission presented a draft of European climate law, the so-called Green Deal, through which they want to achieve zero greenhouse gas emissions by 2050, which will require huge changes in the way energy is used [2]. The zero emission targets will be legally binding.

The attitude of Czech Members of Parliament and the Senate to the current set of rules for combating the climate change, as the EU is trying to enforce them, is significantly critical. Thus, various ways regarding the expected development are being prepared. Can a "short-term" fossil comeback occur, or will low oil prices speed up the

structural shift in production from fossil fuels due to the lower attractiveness of energy companies in the eyes of investors? How will these events affect the gas industry?

The current situation is (for the near future) a presage of low gas prices. The European natural gas storage facilities were at record levels at the end of winter 2019. At the end of March 2020, their capacity was filled by more than 50 %. The main reasons were the relatively warm winter, which reduced gas consumption, especially in the heating industry, and further increased imports of liquefied natural gas to European markets [3]. In view of the above-mentioned decline in industrial activity, the outlook for growth in demand for natural gas in Europe has been adjusted from 6 billion m^3 to just 2 billion m^3. Gas consumption in Europe should reach 556 billion m^3 in 2020 [4]. It should be noted here that Russia's share of total gas imports into the EU is around 40 %. How is the situation in the Czech Republic going to develop? For the time being, the prepared predictions have always stated an increase in natural gas consumption of at least tens of percent. This increase should occur mainly due to the transition of heating plants to more environmentally friendly operation. The extent of central heating, to which approximately 3.5 million inhabitants are connected today, is a typical Czech energy phenomenon. The biggest current problem for heating plants is the price of emission allowances for CO_2 emissions. In the last three years, their price has risen up to fivefold [5].

Switching from coal to gas would halve emissions. It should be noted here that almost half of all district heating is still produced from coal in the Czech Republic. The possibilities of transition are being discussed with distribution system operators, an essential part of which in all developed industrial countries are underground gas storage facilities (UGS).

In the Czech Republic, the current storage capacity of storage facilities is about 35 % of annual natural gas consumption [6]. In today's turbulent times, UGS must emphasize in particular their strategic importance in the event of possible outages of transit gas transport systems; see the crisis situation that occurred during the interruption of natural gas supplies from Russia through Ukraine in 2014.

2   FORMULATION OF PROBLEM

UGS serve mainly to cover increased seasonal consumption and also have a continuous positive effect on the smooth operation of gas distribution systems. The basic precondition for the fulfilment of these functions is the safety of their operation, especially from the point of view of their tightness. Underground gas storage facilities were built in their initial stage of development mainly in exploited hydrocarbon deposits [7]. However, the depleted deposit was not always available at a suitable distance from the place where the gas consumption was concentrated. In these cases, underground gas reservoirs, mostly of the aquifer or cavern type, began to be formed [8–10].

Due to the nature of gas storage activities, it is the logical interest of owners to operate UGS at the most efficient level, i.e. at maximum operating parameters with reasonable investment and operating costs. The explanation is mainly based on the fact that the original use of storage facilities was motivated by the need to keep the balance in the distribution network, while current and especially future use is mainly focused on performance, flexibility, and variability of storage volumes and significantly higher dynamics of all related processes. It therefore follows from the characteristics of UGS operation that storage capacities should be as high as possible. However, the safety of the operation of UGS can be realized only while maintaining the tightness of storage structures. In general, the tightness of the underground part of the UGS is divided into primary (original) and secondary one, caused by technical operations (i.e. anthropogenic human activity) [11, 12].

The primary tightness is related to the deposit object itself, which is proven by the existence of a primary deposit trap originally saturated with hydrocarbons (tightness in the dimensions of geological time). To predict the process of UGS development, it is necessary to know the structural closure and the extent of gas accumulation after UGS pressurization. When assessing the secondary tightness, we observe a disruption of the primary tightness by anthropogenic activity, either directly – by drilling and subsequent insufficient completion of gas wells (during their operation and after their disposal), or indirectly – by excessive increase in deposit pressures (associated with increase in the total volume of stored gas), which causes destruction of the original geological closures. The ways of forming the boundary of the reservoir rock are divided into: demarcation by fracture, water flood, facial change, and "cap layer" of a different rock massif [13]. Collectively, they can be referred to as limit factors of primary tightness.

3   METHODOLOGY

The above-mentioned limit factors are determined and controlled by special reservoir-engineering procedures – especially by monitoring the so-called p/z loop (deposit pressure reduced by the compressibility factor) and by modelling. These p/z curves represent the functional relationship between the reduced deposit pressure (ratio of gas deposit pressure and compressibility factor p/z) and the change of gas volume during gas injection and production [7].

The material balance equation (MBE) method is commonly used to estimate the initial hydrocarbon reserves in a deposit. The general material balance equation for gas deposits is expressed by the following equation:

$$\frac{p_{sc}G_p}{RT_{sc}} = \frac{p_iV}{z_iRT} - \frac{p[V-(W_e-W_p)]}{zRT}$$

(1)

where p_i = initial deposit pressure (MPa), G_p = cumulative gas production (m³), p = actual deposit pressure (MPa), V = original gas volume (m³), z_i = compressibility factor at p_i (dimensionless), z = compressibility factor at p (dimensionless), T = temperature (K), W_e = cumulative water inflow (m³), W_p = cumulative water production (m³), T_{sc} = standard temperature (K), p_{sc} = standard pressure (MPa), R = universal gas constant (8.31 J · K^{-1} · mol^{-1}). [5]

The material balance equation (hereinafter "MBE") can be expressed in different forms depending on the type of use and the deposit regime. In general, a gas deposit can be classified as follows:

- expansion type of deposit,
- deposit with active influence of water flood.

A graphical representation of the modified Equation 1 can be used to determine the existence of water inflow from water bodies. Depending on how the slope of the curve deviates from the linear slope of the curve (relationship of gas volume change vs. reduced deposit pressure in the reservoir), the level of water flood can be identified [7].

Based on the above, in order to monitor the primary tightness, the UGS is compared with the pressure and volume history of the deposit using p/z curves (relationship between reduced deposit pressure and change of the stored gas volume during UGS injection-production seasons) to determine whether or not the gas leaks from the storage structure.

Injecting into and producing gas from the deposit cause pressure changes in the reservoir. In case of completed start-up period of the UGS we can define the operational mode of the reservoir and the cyclical regime of storage in the UGS during the injection and production period. If the mutual comparison of the slope of the curve of individual injection-production seasons, which follow one another during the cycle, shows that the injection and extraction lines are identical from year to year, it will mean that the gas does not escape from the deposit. If gas is lost, the curves shift towards a larger volume of gas (at given p/z).

Gas loss from UGS can also be monitored by calculating the specific storage capacity from the relationship:

$$m = \frac{\Delta G}{\Delta p/z}$$

(2)

where m = slope of the curve, G = total gas reserves (10⁶ m³), p/z = deposit pressure reduced by compressibility factor (MPa).

If the resulting value is more or less constant, there is no loss of gas from the UGS. In the case of aquifers and reservoir with a significant water flood, the specific storage capacity is calculated only after the gas is injected into the reservoir to the level of 100% of the active charge [13].

In the operation of UGS, we distinguish three basic modes (expansion mode, water mode and mixed of both). The expansion mode is typical for UGS, which occupy the entire volume of a reservoir with a limited inflow of deposit water. These deposits represent a bounded trap in which the original deposit water has been substantially expelled by the gas of the primary deposit. The pressure effect of water is limited only to its compressibility in a pore environment. The functional dependence between the reduced pressure value p/z and the volume of gas reserves G_p is linear.

The water mode is rather a theoretical possibility of the UGS work regime, where the loss of energy in the deposit is fully compensated by the inflow of peripheral or "littering" water into the deposit. In the mixed mode, the energy of the deposit is formed by the action of both phases located in the UGS deposit space, namely by the pressure manifestation of a moving water flood and gas stored in the pore environment. Each decrease or increase in pressure during the operation of the reservoir is accompanied by the movement of the water flood, which is reflected in the different values of pressures during extraction and injection compared to the classical expansion mode. The movement of the water flood causes the functional dependence of the reduced value of the pressure p/z and the volume of the stored gas G_p, the graph of this dependence has a shape of hysteresis curve. [13] The more the curve (p/z) versus G_p deviates from the linear dependence, the greater is the effect of water flood [14].

The cyclical mode of operation of UGS is characterized by frequent and rapid changes in the volume of stored gas. These changes affect the intensity of the water component of the mixed work regime of UGS. This phenomenon is caused by differences in the phase permeability of reservoir fluids (water and gas). Movements in the water flood can only be observed in the long term. They reflect the correct choice of operating pressure range. The imbalance of cyclical work of UGS can be manifested either by reducing the volume of free pore space for gas, by its flooding, or by the opposite effect of the retreat of water flood and thus by increasing the free pore space of UGS. Shifts in the boundaries of water flood occur when the pressures in the free pore environment and the pressure in the water flood differ. In the case of a reduction in the pore space (Figure 1), the mean weighted pressure of gas is lower than the pressure in the water flood, so that the water-gas boundary shifts towards the "centre" of reservoir (to p/z towards the maximum gas pressure). [13]
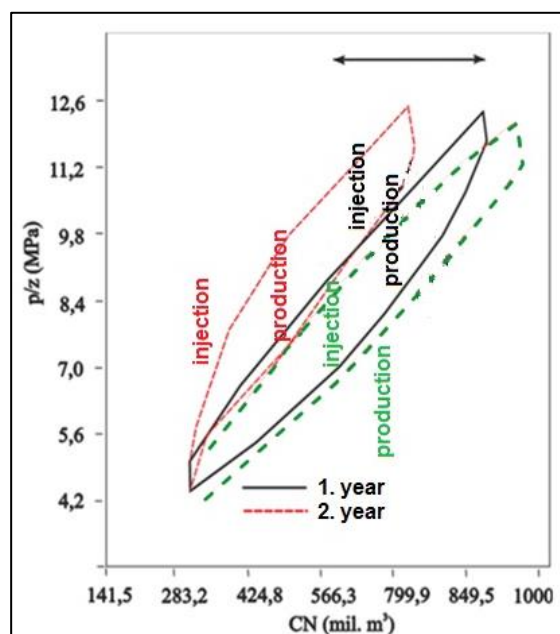

Figure 1. *Example of an injection-production cycle in the case of reduction (marked in red) and expansion (marked in green) pore space [adapted according to 13]*

In the case of increasing the free pore space (Figure 1), the mean weighted pressure of gas in the reservoir is higher compared to the pressure in the water flood, so the water-gas interface moves towards the water "periphery" of UGS (at p/z towards a larger gas volume).

The process of changing the position of the water flood boundary is an undesirable phenomenon during normal UGS operation. This change is acceptable only in the stage of commissioning of UGS (UGS conversion), when the storage space is increased by expanding gas to the required volume, or by a controlled increase of storage capacities. However, the expansion of the storage space is only possible until the water-gas contact is forced out of the reservoir structure and the stored gas escapes behind the structural closure [13].

4   MATHEMATICAL MODELING

The aim of modelling is to create a 3D static (geological) and dynamic (mathematical) model. After compiling the geological model and tuning the dynamic model, the model can be used to make predictions of the dynamic behaviour of the deposit during the injection and production of gas from the UGS during the time. As a rule, the finished model is updated once a year with data from the past injection-production season. Pressure data (well collar or deposit), data on the daily amount of gas injected or produced and daily liquid yields during the consumption season are entered, all by individual gas wells. After completing the data, the deposit behaviour is predicted for the next injection-production season.

The final geological model is implemented using Petrel software from Schlumberger. Tuning of the dynamic model and simulation (prediction) of mathematical modelling is performed in the Eclipse software from Schlumberger.

5   RESULTS

At present, the following UGS are operated on the territory of the Czech Republic: UGS Třanovice, UGS Štramberk, UGS Lobodice, UGS Tvrdonice, UGS Dolní Dunajovice and UGS Háje (Innogy s.r.o.), then UGS Uhřice and Uhřice-South (by MND Gas Storage a.s.), then UGS Dolní Bojanovice (by SPP Bohemia a.s.) and UGS Dambořice (by Moravia Gas Storage as) [15, 16].

These UGS facilities currently have an active storage capacity of approximately 3.4 billion m^3. Furthermore, the company MND Gas Storage Germany GmbH has two UGS in Germany - Hähnlein and Stockstadt storage facility. Due to the fact that the main co-author works in the mentioned company and has access to the operational documentation, the Uhřice, Uhřice-South, Hähnlein and Stockstadt reservoirs were selected for analysis, see Figure 2.

Figure 2. UGS Uhřice, Uhřice-South, Hähnlein and Stockstadt positions [adapted according to 16]

5.1. UGS Uhřice

UGS Uhřice is located in the land register of the village Uhřice, district Hodonín, South Moravian Region, on the north-eastern slope of the Nesvačil ditch, on a hanging wall of a significant fault in the NW-SE direction, separating the elevation area of the Ždánický Forest from the ditch itself, modelled in the Cretaceous to Paleocene period [17].

The deposit has the shape of a semi-dome elongated in the direction of west-northwest-east-southeast with a decline to the southwest. From the north it is limited tectonically; in the eastern part the existence of an erosion edge is assumed. In the lower structural position of the deposit there is an extensive water flood. It is a structural-tectonic type of deposit trap in the arenite layers of the Gresten Formation (Figure 3). The surface structure of the whole area is built by sediments of the Ždánice-Hustopeče Formation of the Ždánice unit, mainly in their claystone development.

The gas deposit is bound to a body of beach-type sandstones in the arenite layers of the Gresten Formation (Figure 4). The deposit rock is represented by medium to coarse-grained quartz sandstones, positionally by conglomerates. In places, these sandstones turn into arkose sandstones. The lime content of sandstones is variable, but mostly has low values (around 3 %).

The thickness of the reservoir rock is in the range of 100–135 m. The overlying sealing layer is formed by dark clays. The effective porosity of the collector is in the range of 10–25 %, the permeability reaches values of 10–500 mD (0.010 x 10^{-12} - 0.494 x 10^{-12} m^2). Positions alternate in the horizon with increased, resp. reduced, porosity and permeability. Collector rock parameters are improving along with increasing depth. [17]

The original gas-water contact was determined to a structural level of –1509 m. The initial reservoir pressure related to mentioned gas-water contact was determined to be 17.022 MPa. The reservoir temperature at this depth was measured to be 53 °C [17, 18].

The conversion of the building into an underground natural gas storage took place in 2001.
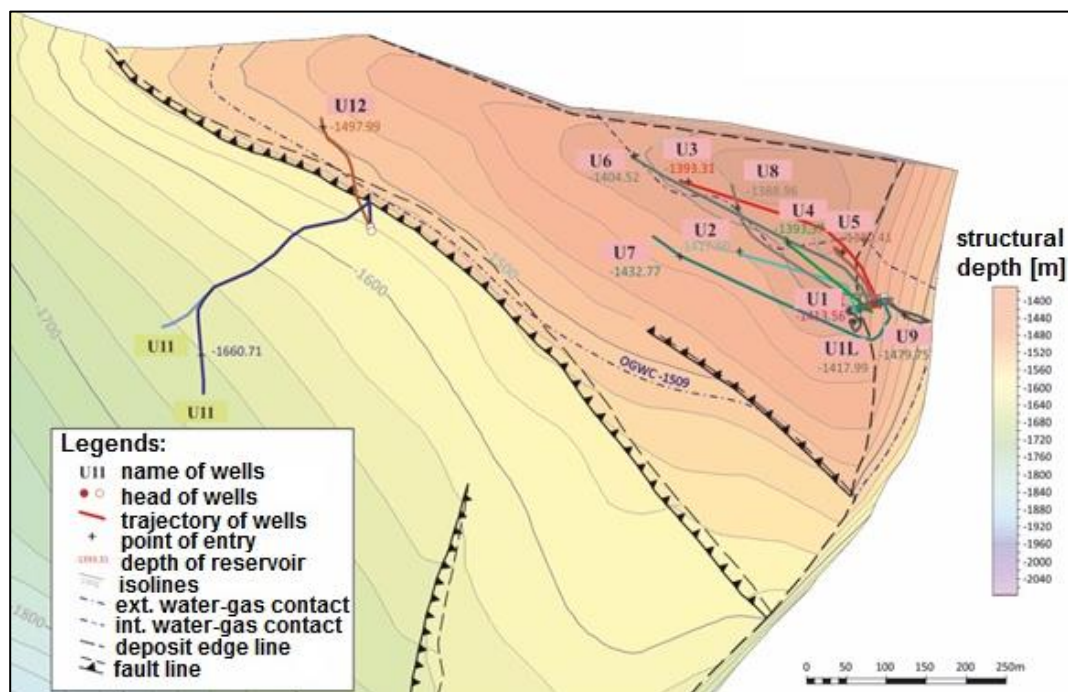

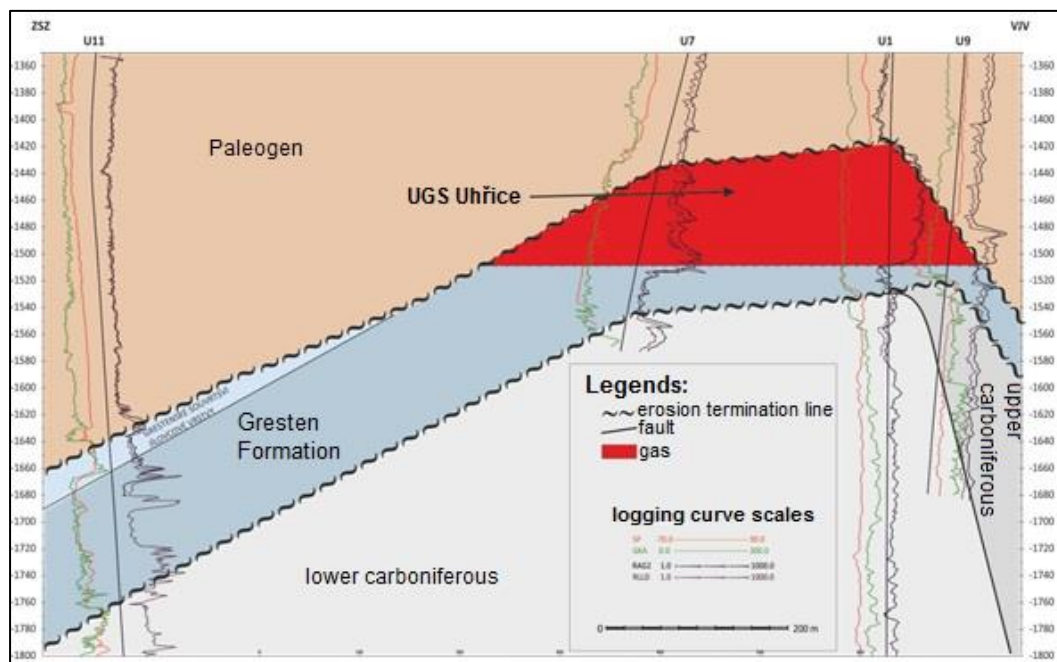*Figure 3. Structural map on the surface of Gresten sandstones UGS Uhřice [adapted according to 18]*

Figure 4. Longitudinal geological section of UGS Uhřice [adapted according to 17]

5.2. UGS Uhřice-South

The Uhřice-South deposit is located in the land register of the village of Uhřice, district Hodonín, South Moravian Region, on the north-eastern slope of the Nesvačil ditch, southeast of the Dambořice and Uhřice deposits, where the relief of crystalline rocks and Paleozoic sediments falls gradually into the central part of the ditch.

The reservoir is roughly elliptical in shape, with the axes of the ellipse reaching lengths of 400 and 650 meters. In the south-western direction, the deposit is lined with sandy sediments of erosion, which form part of the water flood of the deposit and are lithologically delimited [18] – see Figure 5.

The entire wider surroundings of the Uhřice-South deposit are built in the surface structure by sediments of the Ždánice-Hustopeče Formation of the Ždánice unit, mainly in their claystone development.

The Uhřice-South deposit is located in the depth interval of 1800–1900 m. It is an oil deposit with a gas cap, with dissolved gas and littered water flood (Figure 6). Oil and natural gas are accumulated in the sandstones and conglomerates of the basal part of the jury (Gresten Formation – arenite layers). The reservoir rock of the deposit is weakly calcareous to non-calcareous, medium to coarse-grained quartz sandstones, positionally to conglomerates. In places, these sandstones turn into arkose sandstones. The lime content of sandstones is variable, but mostly has low values (around 3 %). They are also characterized by a locally lower degree of consolidation, these parts contain only a small proportion of matrix and are easily disintegrating. These sandstones form one hydrodynamic unit with demonstrable sandstones of the Gresten Formation, they set directly on them [19].

The effective porosity of the reservoir rock ranges from 5 to 19 % in the upper part of the deposit, the permeability reaches 20 mD (0.020×10^{-12} m^2), some positions (according to core samples from wells U15 and U16) have very low porosity (below 5 %) and they are almost impermeable. Collector rock has significantly better properties in the majority of the horizon, effective porosity reaches values of 12–25 %, permeability reaches values of 1,500–4,000 mD ($1.48 - 3.95 \times 10^{-12}$ m^2).
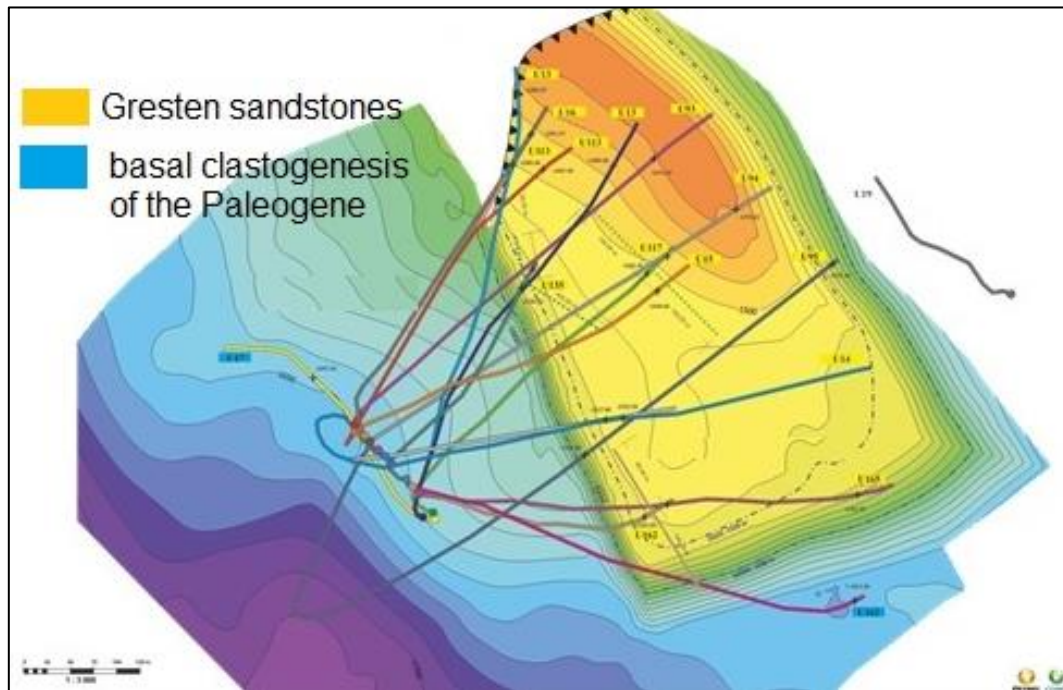
Figure 5. Structural map on the surface of Gresten sandstones UGS Uhřice-South [adapted according to 18]
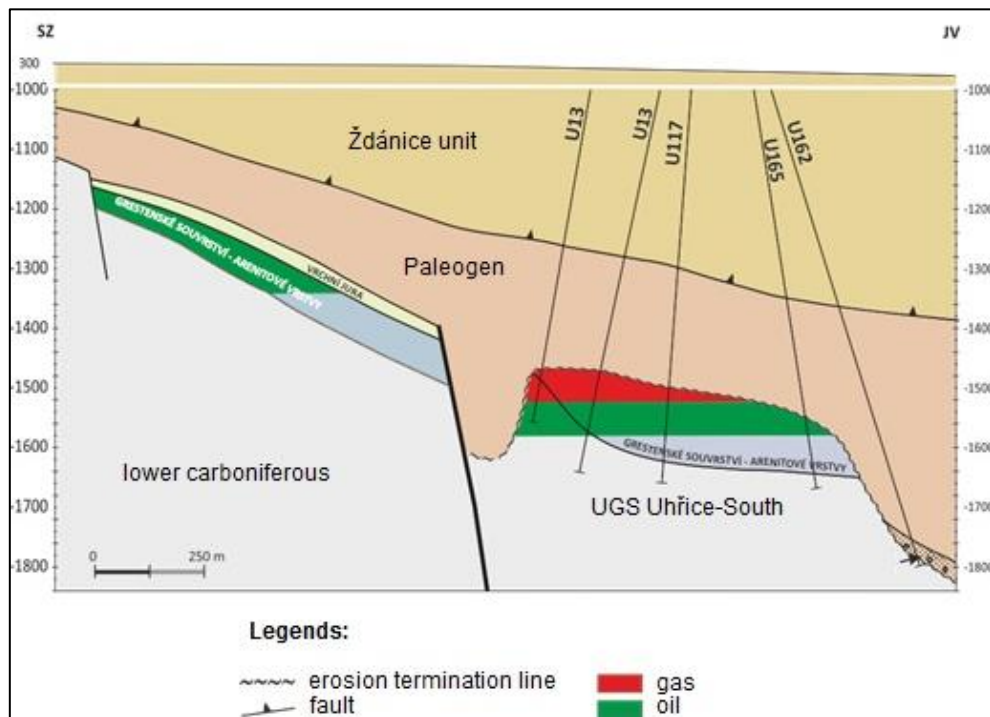

Figure 6. Longitudinal geological section of the UGS Uhřice-South deposit [adapted according to 18]

5.3. UGS Hähnlein

The Hähnlein underground storage area is located in Germany in the southern part of Federal State of Hesse, in the western part of the village of Alsbach [20]. Geologically, it falls into the northern part of the Upper Rhine fault (Oberrheingraben), which stretches from Basel in the south, towards the north to Frankfurt. The reservoir structures lie approximately midway among the edge faults extending approximately in the NNE-SSW direction, typically delimiting in one direction an elongated graben-type rift basin structure which is approximately 300 km long, 30–40 km wide and has a depth of up to 3.5 km in places.

The reservoir structure is a flat, slightly arched anticline extending approximately in the N–S direction, bounded on the east by one of the main faults, which falls to the west. On the west side, the structure is bounded by another fault, on which the largest jump is about 70 m, and which disappears in the north and south. Further in the west (behind the above-mentioned fault) there is a narrow, elongated and rising elevation to the south, which most likely serves as a migration path to a flat elevation lying in the west of the main reservoir structure (Figure 7). The depth of the horizon is between 498–523 m [21].

Lithologically, the collector is described as very poorly consolidated, fine-grained sandstone with claystone interspaces. The total thickness is between 10 and 19 m, but the horizon is formed by several layers of sandstone and claystone and the thickness of individual horizons ranges from several cm to several meters (Figure 8). The effective thickness is around 55 % of the total number. Therefore, it can be expected that each of the positions has its own range and it can also have its own hydrodynamic regime. The porosity of the collectors ranges from 20 to 30 % with a median of 25 % and the permeability on the cores was measured to be less than 0.9869×10^{-12} m^2 (1000 mD) [20].

The reservoir seal forms a 50–55 m thick complex of shales and calcareous claystone, and the first sandy horizon in their overburden is used as a control horizon for their tightness.

In the Hähnlein structure, the so-called 8.1 sand (Figure 8), which was originally an aquifer, is used for natural gas storage purposes. Its use as a storage facility began in 1960, when coal gas was injected into the structure for the first time. In 1973, the reservoir was rebuilt to store natural gas.
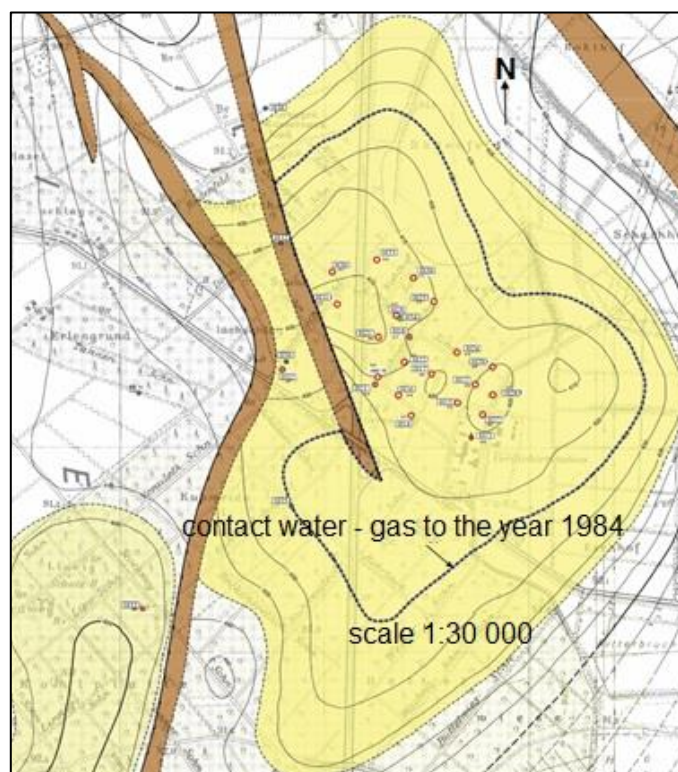

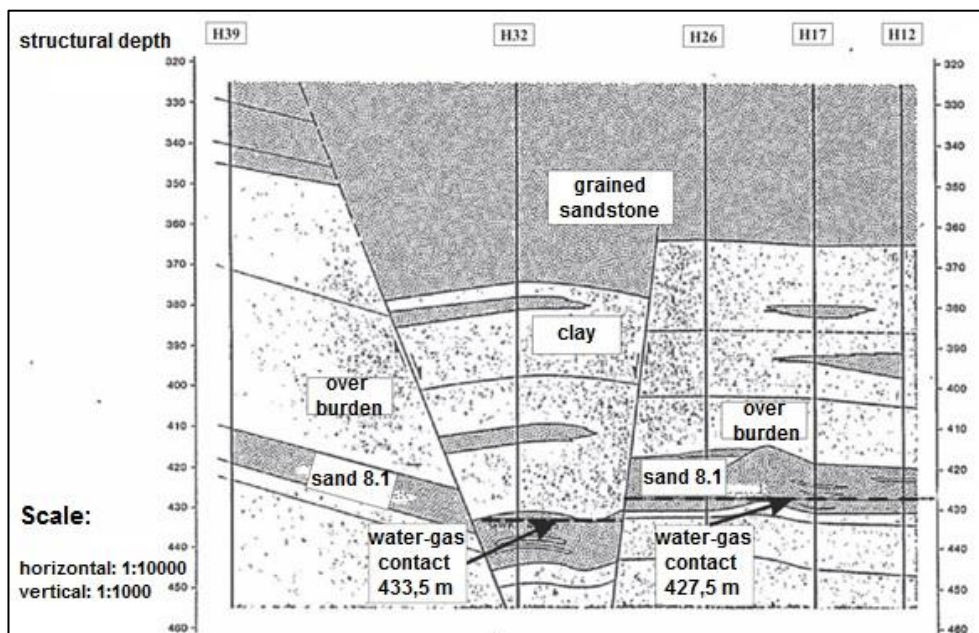***Figure 7.*** *Structural map of surface 8.1 sand [adapted according to 22]*

Figure 8. *Geological section of the UGS Hähnlein deposit [adapted according to 22]*

5.4. UGS Stockstad

The Stockstadt underground reservoir is also located in Germany in the southern part of the Federal State of Hesse, in the district of Gross-Gerau under Darmstadt.

On the Stockstadt structure, three horizons are used for the needs of the reservoir: the so-called sand 8.1, 8.2 and 7.2. Sands 8.1 and 8.2 were aquifers, while sand 7 was originally a hydrocarbon deposit. Before it was converted into a gas storage facility, 57 million m³ of natural gas were extracted from it. The original gas-water contact was located at a structural depth of 438 m. The main part of the structure (Figure 9) is located on the hanging wall of one of the main fault, where there is an elevation with an elevation difference of more than 30 m. Reservoir sands are in contact with the clays of the younger tertiary II. On the footwall, the layers are inclined towards the west. The complex of sands 8.1 and 8.2 lies 30–35 m above the sand 7.2. [23]

Lithologically, sands are described as very poorly consolidated fine-grained to coarse-grained sandstone with claystone interspaces. The total thickness of the objects is between 4–14 m (sand 7.2 approximately 4 m, sands 8.1 and 8.2 approximately 4-8 m). Each of the horizons consists of several sandstone bodies, alternating with the positions of calcareous clays. The thickness of individual bodies ranges from several cm to several meters. As in the case of the Hähnlein structure, it is assumed that the individual sands have their own extent and can also have their own hydrodynamic regime. The porosity of reservoir objects is between 28–20 %. Permeability was measured around 0.49×10^{-12} m² (500 mD) for sand 7.2 and about 1.48×10^{-12} m² (1500 mD) for sands 8.1 and 8.2. The reservoir isolator consists of an approximately 40 m thick layer of calcareous clays and shales.

Injecting gas into the sand 8.1 on the Stockstadt structure began in 1970, shortly afterwards pumping into the sand 8.2 started. Sand 7.2 was converted to a reservoir horizon in 1963. [24]
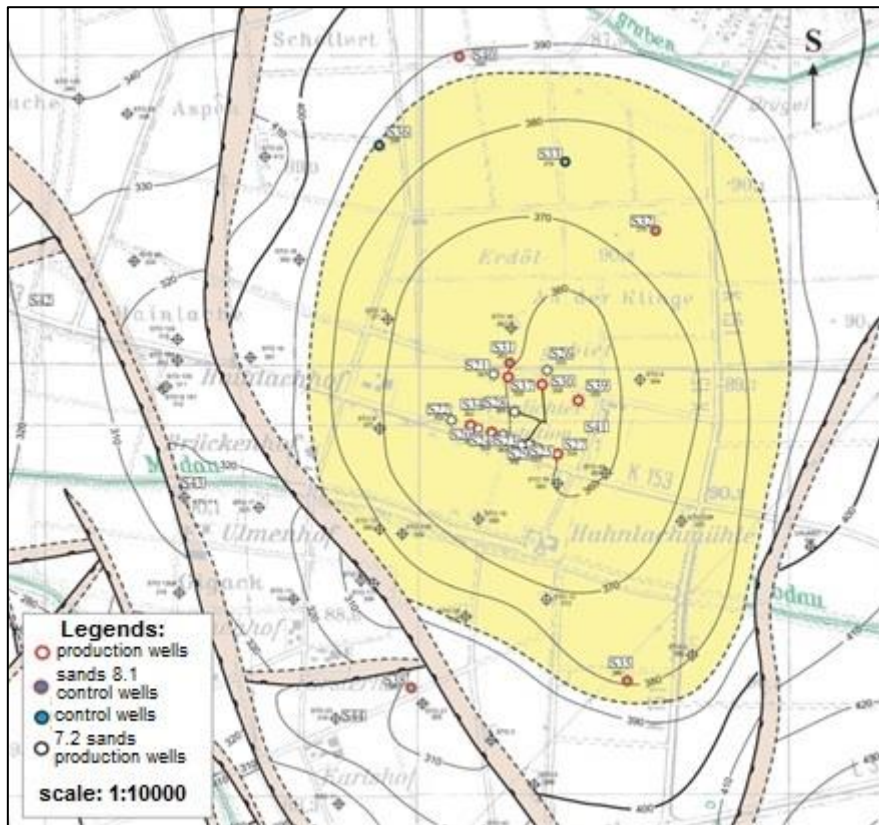
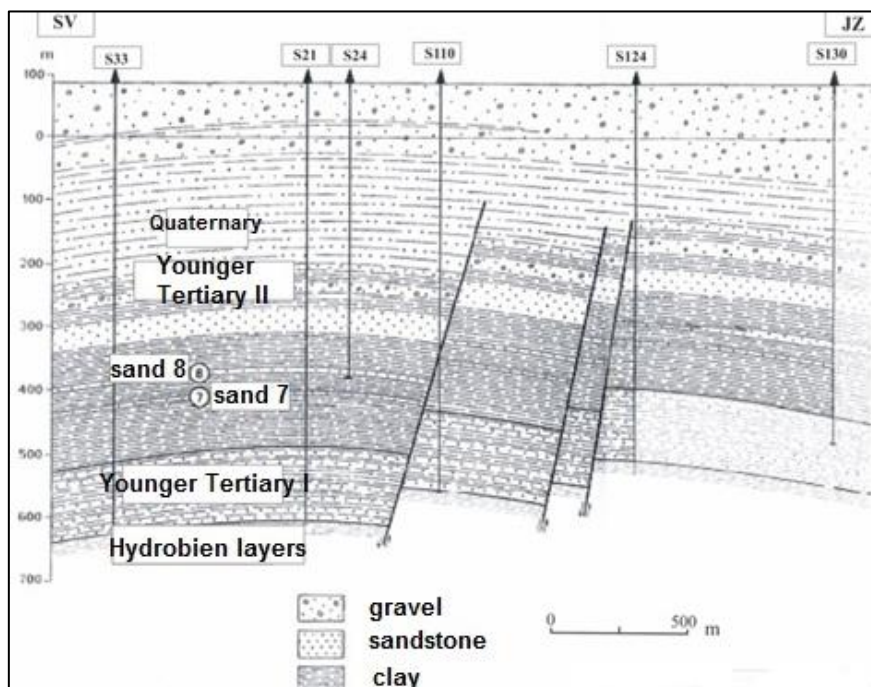**Figure 9.** *Structural map of surface 8.1 sand [adapted according to 22]*

Figure 10. *Geological section of the Stockstadt UGS [adapted according to 22]*

6   RESULTS – ANALYSIS OF PRIMARY TIGHTNESS OF UGS CONDITIONS

6.1. UGS Uhřice

The data given in Section 5.1 show that the storage structure (the original gas deposit situated in the arenite layers of the Gresten Formation) is erosively terminated in the overburden by the settling of pelitic Paleogene sediments and in the northern part by a fault. It is then bordered by a large water flood in the underlying strata.

Operating limit factors is a potential breach of the sealing function of the fault when the specified maximum operating pressures are exceeded. Gas-water contact shift during the expansion of gas accumulation, during which an unpredictable structural closure (spill point) is achieved. Due to the geological structure and the original level of contact, this risk of lateral overflows is not expected.

6.2. UGS Uhřice-South

It is originally an oil-gas deposit in the arenite layers of the Gresten Formation, delimited in the subsoil by a water flood and in the overburden by pelitic Paleogene sediments. In the north-eastern part it is bounded by a tectonic, impermeable fault.

Limiting factors of operation is the same as for UGS Uhřice, i.e. breach of the sealing function of the fault when the specified maximum operating pressures are exceeded. Gas-water contact shift during the expansion of gas accumulation, during which an unpredictable structural closure (spill point) is achieved. Due to the geological structure and the original level of contact, this risk of lateral overflows is not expected.

6.3. UGS Hähnlein

From the materials listed in Section 5.3 it is clear that the storage horizon, i.e. sand 8.1 is a complicated store structure that was originally an aquifer. It is laterally separated by faults and gas-water contact boundaries.

Limiting factors of operation is a shift of the gas-water contact when the specified maximum pressures are exceeded to the level of the assumed structural closures (SP) and overflow of gas into another permeable layer. In this way, gas leaks probably occurred until 1987, in a total volume of approximately 35.4 million m^3. Destruction of tightness of faults and tightness of overburden (slate and calcareous claystone) is not expected.

6.4. UGS Stockstadt

The storage facility consists of three horizons, namely: sand marked 7.2, which was originally a gas deposit with two originally aquifers called sand 8.1 and sand 8.2. Underlying strata are laterally bounded by a water-gas contact and a sealing fault in the west. Limiting factors of operation – the main thing is again the possibility of gas overflow into the adjacent permeable layers when shifting the gas-water contact or activating the permeability of fault structures.

At UGS Uhřice and Uhřice-South, the achievement of structural closures (by shifting the gas-water contacts) is not expected. However, it would be wise to be focused on the analysis on the possible "pseudo" activation of fault permeability. In the case of UGS Hähnlein and Stockstadt, it is necessary to analyze especially the conditions in which the gas-water contact shifted to the level of the so-called spill point when the critical operating pressures were exceeded.

7   CONCLUSIONS

Research and monitoring of the tightness of storage structures is one of the most important and integral parts of the UGS operation. Thus, further verification activities will focus on the detailed implementation of the so-called history matching (analysis of the development of p/z curves) for "crisis" phase of injection periods when the specified critical operating pressures are exceeded. The results will be compared with data obtained from measurements of layer pressures in the indication horizons in the overburden and behind the structural tectonic closures. Furthermore, data obtained from the analysis of stratified water chemistry and from the measurement of fluid pressures of monitoring wells, checks of the level of "first pressure barrier" liquid /packer fluid in the annulus, logging measurements in boreholes, performance tests of gas wells and surface methane screening will be analyzed. So, it will not be only an assessment of the primary, but also of the so-called secondary tightness arising from human activity. The obtained results will be used by MND Gas Storage a.s. Hodonín and MND Gas Storage Germany GmbH to optimize the subsequent operation of UGS Uhřice, Uhřice-South, Hähnlein and Stockstadt.

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