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Injection Triggered Occlusion of Flow Pathways in a Sedimentary Aquifer in Hungary

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ABSTRACT

Reasons for injectivity decline were investigated at a geothermal site located in Mezőberény, SE Hungary. Due to low injectivities, production rates must be reduced, and the site faces negative commercial implications. In addition to historical operation data, fluid and rock samples were investigated in the laboratory. Analysis and experiments focus on physical, chemical and biological processes and their interaction.

Results show different processes being responsible for injection-triggered occlusion of flow pathways. Fines migration is caused by washouts in loosely cemented rocks, from where fine sand or clay particles are transported and injected into lower aquifer layers. Precipitation of minerals is caused by cooling or oxygen exposure. Biological activity is seen at production and injection site.

In order to fully understand the processes taking place in the injection well, borehole measurements will be run in summer 2019. After evaluating the results, a specially tailored stimulation concept will be applied in the injection well. A combined chemical-mechanical treatment takes place at different depth. Borehole measurements and hydraulic tests will be done again after the stimulation to show the effect of the stimulation. A multiple monitoring and sampling program came along with activities onsite.

Activities are taking place in the frame of the DESTRESS project. The DESTRESS project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 691728.

1. INTRODUCTION

Injection into geothermal aquifers can lead to clogging of highly permeable flow-paths by small particles. We study clogging processes in a low-enthalpy geothermal aquifer in Hungary using fluid and solid analysis as well as operational data. Clogging processes in geological media are often related to field operations and artificially intruded materials. However, which processes are triggered by field operations, how the different processes interact and the subsequent implications for flow-paths are not yet fully understood. Injectivity decline and reinjection issues are a common challenge in Hungarian geothermal exploitation. Over 600 geothermal wells have been drilled in Hungary, but less than 10% of these are actually reinjection wells. Much of the produced water has been discharged at the surface in the past decades resulting is steady decline of the reservoir pressure at many sites (Szanyi and Kovács, 2010; Toth, 2015). With changing environmental concerns and an increasing need for more sustainable and long-term exploitation, addressing the reinjection issues becomes increasingly important. (Nador et al., 2016b; Szanyi and Kovács, 2010; Toth, 2015). This study is carried out in the framework of the EU-funded project DESTRESS (Demonstration of soft stimulation techniques of geothermal reservoirs). In this project, sites in different geological settings are studied in order to afterwards demonstrate the best stimulation technique. The key goal of DESTRESS is to demonstrate the success of stimulation treatments in long-term enhanced productivities and injectivities.

2. STUDY AREA AND GEOLOGICAL SETTING

Geothermal potential of the Pannonian Basin and its utilization has a long tradition in Hungary. The main aquifers in the country are karstified Mesozoic rocks and Cenozoic sandstones of the Neogene Pannonian Basin. This basin became isolated from the rest of the Paratethys in latest Serravallian to earliest Tortonian time changing the Pannonian sea into a lake (e.g. Csato et al., 2015). As a result, sediment infill changed from distal marine mudstones to increasingly lacustrine and ultimately alluvial (e.g. Phillips et al., 1994). The Békés Basin, where the Mezőberény geothermal site is located, is a sub-basin of the Pannonian Basin (Figure 1-A). Over 6000 m of Neogene and younger sediments accumulated in this sub-basin (e.g. Molenaar et al., 1994). Deltaic and turbidite sandstones within this succession form targets for both geothermal and hydrocarbon exploitation (Csato et al., 2015, 2007; Kováč et al., 2011; Phillips et al., 1994). The geothermal aquifer that is targeted by the Mezőberény doublet is part of the Újfalui Formation and consists of alternating sandy silty and marl deposits formed in a delta front to delta plain depositional environment (Csato et al., 2015; Kováč et al., 2011; Willems et al., 2019). Several 2-D seismic lines as well as Gamma-Ray logs and core fragments from nearby petroleum wells were available for our study (Figure 1-B). Examples of core fragments are presented in Figure 2, showing fine laminated sandstones with rootlets suggesting subaerial exposure but also marly deposits suggesting more a distal origin of other intervals. The variation reflects the heterogeneity of the sediments in the aquifer, ranging from terrestrial fluvial sandstone bodies and deltaic mouthbar lobes to more distal lacustrine deposits.

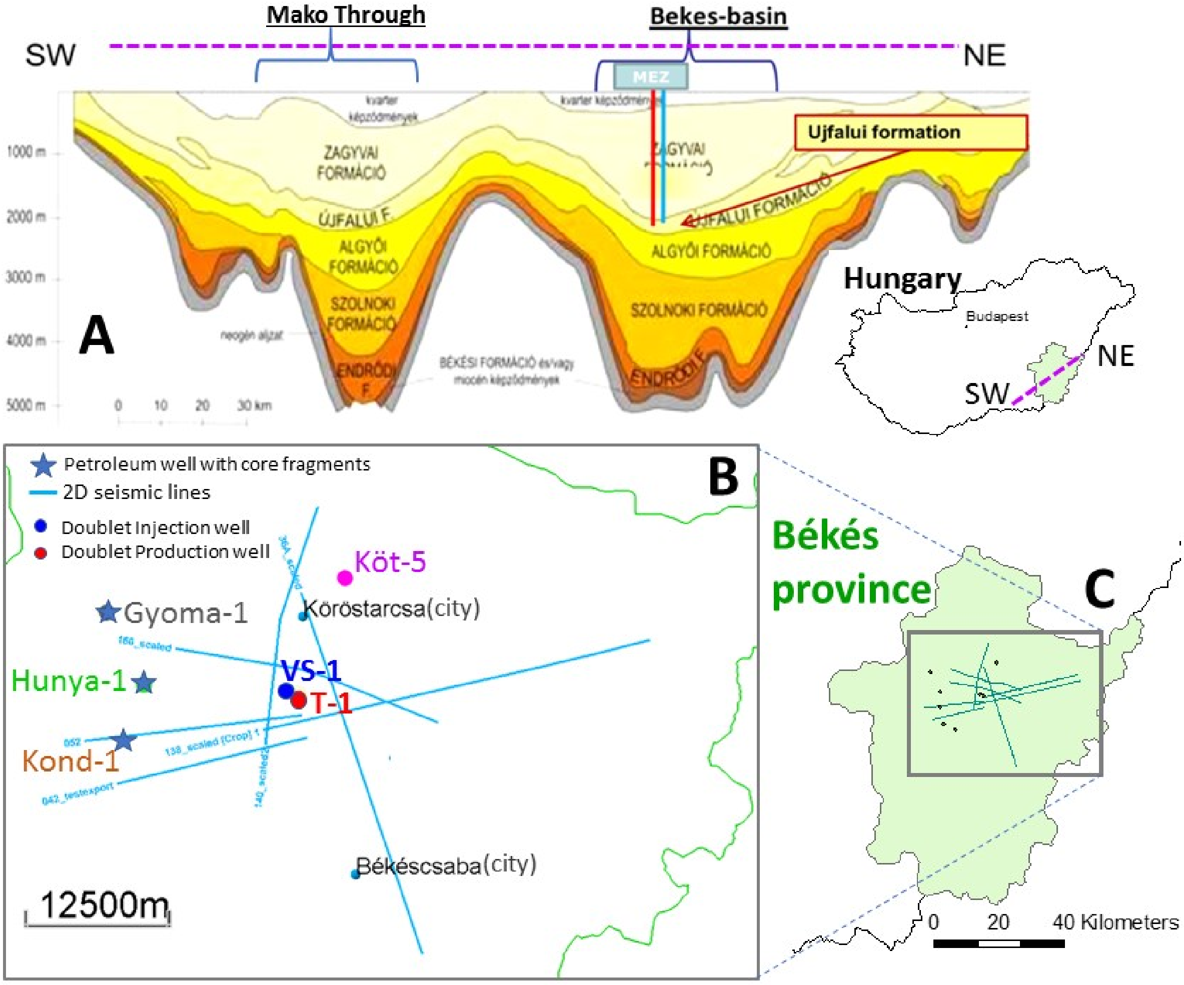

Figure 1: (A) Geological profile (modified from Junasz, 1994) across the Mako Through and the Békés basin with a sketch of the location of the Mezőberény doublet wells. (B) Overview of our study area, with the locations of the doublet wells, seismic lines and nearby petroleum wells. Stars indicate from which wells core fragments were available for our study, from other wells Gamma-Ray logs were used.

3. MEZOBERENY GEOTHERMAL SITE

The Mezőberény geothermal site was constructed in 2011-2012, with the aim to utilize the geothermal potential in the Békés Basin for district heating. The system consists of one production well (B-115) with a depth of 2003 m, and one reinjection well (K-116) with a depth of 2001 m. The injector producer spacing is approximately 1000 m. Inflow must have occurred from different depth intervals because the production temperature was 76.9°C, while Spencer et al. (1994) reported subsurface temperatures of 100 to 150°C at 2 km depth in different parts of the Békés Basin. After a three-week operation, injectivity radically dropped, which lead to a stop of operation. In 2017 a mechanical and chemical cleaning campaign was carried out to remove clogging material, but a long-term solution for injectivity increase has not been found yet (Siklósi, 2017).

4. APPROACH

The database compiled during this study consists of water and gas samples from different points in the thermal loop, drill cores, filter residual and historical operational data. Samples have been analyzed using various methods in order to understand physical, chemical and biological processes in the reservoir. Based on sample and data analysis, a stimulation program was designed. The stimulation aims at a long-term injection enhancement at the site. The program consists of pre-stimulation borehole measurements, a chemical soft-stimulation and post-stimulation borehole measurements.

5. POSSIBLE INJECTION PROBLEMS

Six different injection problems have been identified at the Mezőberény site: Reservoir thickness, low permeability in the reservoir, precipitation of minerals, microbiological activity, fines migration and poor hydraulic connectivity between the injector and producer.

The reservoir thickness, sedimentary architecture and associated risk of poor hydraulic connectivity were analyzed utilizing well logs and cores from deep wells in the Békés county. A regional Gamma-Ray log correlation in combination with sedimentological analysis of core samples suggests that the Mezőberény aquifer is formed by delta-plain to delta-front sediments. Gamma-Ray logs of the doublet show a relatively low net-sandstone content of the aquifer interval of some 10 to 20%. The net-aquifer thickness of the

Mezőberény doublet is only several tens of meters, while the entire production interval is some 400 m predominantly consisting of mudstones and marls. The large preservation of these fine-grained sediments can be explained by high sedimentation rates and and/or large accommodation space during formation of the Mezőberény aquifer. Under these conditions, amalgamation of sandstone bodies is limited and impermeable, finer sediment layers form flow baffles or barriers reducing hydraulic connectivity. This has been recognized in numerous hydrocarbon reservoirs studies of deltaic reservoirs (e.g. Gani and Bhattacharya, 2005; Zhang et al., 2017), but also for fluvial reservoirs (Larue and Hovadik, 2006; van Toorenenburg et al., 2016). Limited sandstone body clustering and amalgamation of the Újfalui Formation in the Mako Through, which is a neighboring sub-basin of the Pannonian Basin (Figure 1), was already recognized by Sztanó et al. (2013) utilizing Amplitude versus offset seismic attribute interpretations. In contrast, they showed that sand accumulation and amalgamation occurred more extensively in the more distal turbidite deposits of the Algyo and Szolnok Formations. These previous studies and our analysis of the aquifer architecture of the Mezőberény aquifer both highlight that that detailed sedimentological modelling and seismic attributes are required for efficient doublet placement in the Pannonian basin. This could reduce the risks of poor hydraulic connectivity and associated injection issues. Hydraulic connectivity of the Mezőberény doublet was evaluated with pressure interference test at the site.

Permeability of the reservoir has been analyzed using production test data and well logs. The permeability of the sandstones ranges between 20 and 220 mD. The near wellbore permeability 1.8E-13 m^2 is according to flow tests and the effective reservoir permeability is 8.7E-14 m^2. Moreover, 70% of the injected water flows into three of 12 filter sections.

Figure 2: (A) Core samples from the nearby Kondoros-1 (Kond-1) well (Figure 1) from 1500-1900 m depth, prepared for XCT porosity scanning and flow through experiments. (B) Fine laminated sandstone core sample with rootlets interrupting ripple structures from Gyoma-1 well at 1990-1995 m depth. (C) Light grey to green Marl and grey silt laminations in a unconsolidated core fragment from Kond-1 well at some 1500 m depth. (D) Thin light grey laminated sandstone with small burrows intersecting dark grey lignite-rich laminations.

Possible mineral precipitation is analyzed using water composition, gas composition and rock composition combined in a hydrochemical model. The total salinity of the water is 1855 mg/l with Na and HCO_3 as major ions. The gas phase is mainly composed of CH_4, while rocks contain quartz, feldspars, carbonates and clay minerals. The hydrochemical model suggests mainly carbonate and iron rich minerals to precipitate. A contact with oxygen generally increases the saturation indices of supersaturated minerals.

The total organic content was measured to be 1360 mg/l while the phenol index is 5540 µg/l. Both provide good circumstances for bacteria population in the wells. Bacteria detected at the site are sulphate-reducing (Desulfotomaculum, Desulfobulbus) and methanogene (Methanosarcina, Methanospirillum) groups. These bacteria can form biofilm or cause corrosion on the well casing.

Fines migration could not be proven by data yet but is expected due to high clay content in some reservoir layers. Fines which are injected into the aquifer can clog free pore spaces near to the wellbore.

6. REMEDIATION STRATEGY

The reasons for the decline in injectivity of well VS-1 (K-116) has been analyzed based on available data. For a more detailed analysis, adequate measurements and investigations have to be performed. Only then, further information on the status of the well and the reservoir will be available. The results of the logging before treatments will show the condition of the well. Based on that, the stimulation plan might be adopted. In long term, the operator of the plant will take action to counteract the causes for injectivity decline.

The works will be performed in three steps, which are Pre-stimulation measurements, Stimulation and Post-stimulation measurements. The operation is divided into two separate groups. Group 1 includes hydraulic tests and stimulation. This also covers production and injection tests, stimulation of borehole, cleaning lifts and all needed preparational work at the site (e.g. wellhead, fencing, lighting, piping, tanks...) as well as recultivation. Additionally, group 1 should take and analyze fluid and solid samples, supervise activities onsite and coordinate works from group 1 and group 2. Group 2 includes borehole-logging and bailer sampling before and after wellbore-testing, flowmeter-measurements during production and injection tests, logging in production well during tests in injection well.

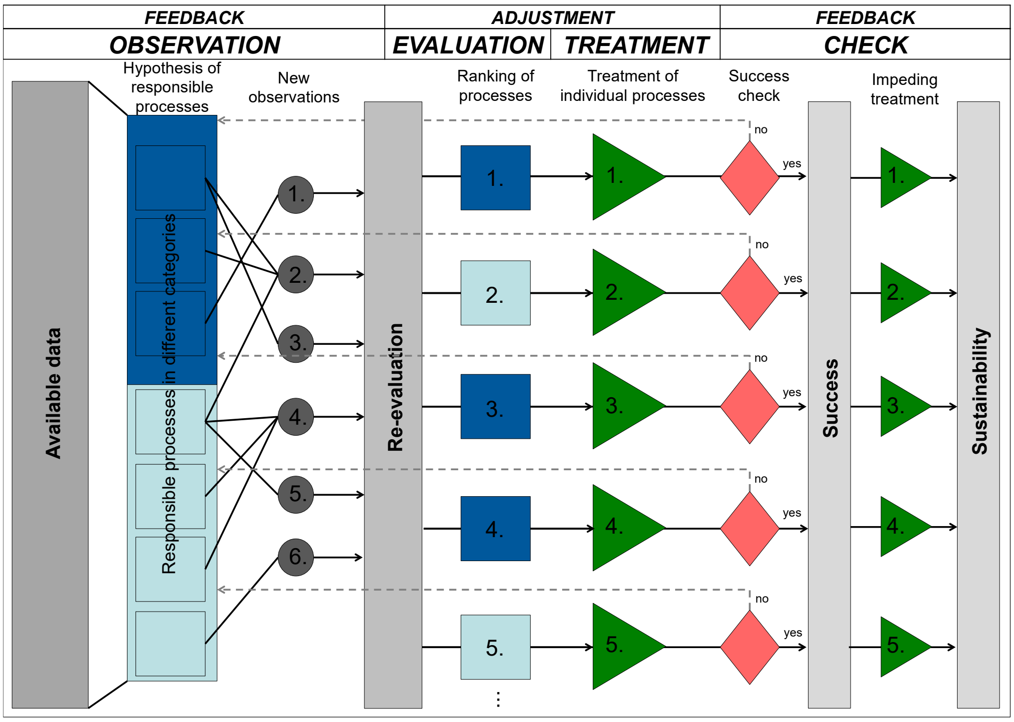

Figure 3: Schematic picture of the Feedback Adjustment Procedure according to Brehme et al. (2017).

The operations will for the first time apply the Feedback Adjustment Procedure, that ensures a sustainable soft stimulation (Brehme et al., 2017). The procedure started with analyzing all available data and evaluating and ordering potential injection problems. Any new observation during the observation requires a re-evaluation of processes based on an updated database. The stimulation treatment is tailored to wellbore conditions and aims for removing any injection hindering process. One important step in the procedure is a re-evaluation loop after each treatment that ensures regularly updated knowledge on site-specific processes. The loop ensures an adapted stimulation concept which considers interaction of different processes ending in sustainable reservoir enhancement. A final check of wellbore and reservoir conditions verifies that the treatments overcame formation damage.

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REFERENCES

Brehme, M., Blöcher, G., Regenspurg, S., Milsch, H., Petrauskas, S., Valickas, R., Wolfgramm, M., Huenges, E.: Approach to develop a soft stimulation concept to overcome formation damage – A case study at Klaipeda, Lithuania. 42nd Workshop on Geothermal Reservoir Engineering 1–5 (2017).

Csato, I., Tóth, S., Catuneanu, O., Granjeon, D., 2015. A sequence stratigraphic model for the Upper Miocene-Pliocene basin fill of the Pannonian Basin, eastern Hungary. Mar. Pet. Geol. 66, 117–134. https://doi.org/10.1016/j.marpetgeo.2015.02.010

Gani, M.R., Bhattacharya, J.P., 2005. Lithostratigraphy versus Chronostratigraphy in Facies Correlations of Quaternary Deltas: Application of Bedding Correlation, in: Giosan, L., Bhattacharya, J.P. (Eds.), River Deltas-Concepts, Models, and Examples. SEPM, pp. 31–48. https://doi.org/10.2110/pec.05.83.0031

Kováč, M., Synak, R., Fordinál, K., Joniak, P., Tóth, C., Vojtko, R., Nagy, A., Baráth, I., Maglay, J., Minár, J., 2011. Late Miocene and Pliocene history of the Danube Basin: Inferred from development of depositional systems and timing of sedimentary facies changes. Geol. Carpathica 62, 519–534. https://doi.org/10.2478/v10096-011-0037-4

Larue, D.K., Hovadik, J., 2006. Connectivity of channelized reservoirs: a modelling approach. Pet. Geosci. 12, 291–308. https://doi.org/10.1144/1354-079306-699

Molenaar, C.M., Révész, I., Bérczi, I., Kovács, A., Juhász, G., Gajdos, I., Szanyi, B., 1994. Stratigraphic Framework and sandstone facies Distribution of the Pannonian sequence in the Békés Basin, in: Teleki, P.G., Mattick, R.E., Kokai, J. (Eds.), Basin Analysis in Petroleum Exploration. A Case Study from the Békés Basin, Hungary. SPRINGER, Dordrecht, pp. 99–110.

Phillips, R.L., Révész, I., Bérczi, I., 1994. Lower Pannonian Deltaic-Lacustrine processes and sedimentation, Békés Basin, in: Teleki, P.G., Mattick, R.E., Kokai, J. (Eds.), Basin Analysis in Petroleum Exploration. A Case Study from the Békés Basin, Hungary. SPRINGER SCIENCE+BUSINESS MEDIA, Dordrecht, pp. 67–82.

Siklósi. I.: Internal Report on the Mezöbereny geothermal site, (2017).

Spencer, C.W., Szalay, Á., Tatár, É., 1994. Abnormal Pressure and Hydrocarbon Migration in the Békés Basin, in: Teleki, P.G., Mattick, R.E., Kokai, J. (Eds.), Basin Analysis in Petroleum Exploration. Dordrecht, pp. 201–219. https://doi.org/10.1007/978-94-011-0954-3_10

Sztanó, O., Szafián, P., Magyar, I., Horányi, A., Bada, G., Hughes, D.W., Hoyer, D.L., Wallis, R.J., 2013. Aggradation and progradation controlled clinothems and deep-water sand delivery model in the Neogene lake pannon, Makó Trough, Pannonian Basin, SE Hungary. Glob. Planet. Change 103, 149–167. https://doi.org/10.1016/j.gloplacha.2012.05.026

van Toorenenburg, K.A., Donselaar, M.E., Noordijk, N.A., Weltje, G.J., 2016. On the origin of crevasse-splay amalgamation in the Huesca fluvial fan (Ebro Basin, Spain): Implications for connectivity in low net-to-gross fluvial deposits. Sediment. Geol. 343, 156–164. https://doi.org/10.1016/j.sedgeo.2016.08.008

Willems, C.J.L., Westaway, R., Burnside, N.M., 2019. Hydraulic Connectivity in Pannonian Sandstones of the Mezőberény geothermal doublet, European Geothermal Congress 2019. Den Haag.

Zhang, L., Wang, H., Li, Y., Pan, M., 2017. Quantitative characterization of sandstone amalgamation and its impact on reservoir connectivity. Pet. Explor. Dev. 44, 226–233. https://doi.org/10.1016/S1876-3804(17)30025-3