Geochemical effects of CO2 flooding in natural and experimental rock-(pore)water systems and numerical models

Report

Researchers involved

CSERESZNYÉS Dóra: Involved in the project as BSc student. Her topic and role was the analysis and interpretation of stable isotopes form bulk rock and separated carbonates

KIRÁLY Csilla: Involved in the project as PhD student. Her topic was general description of reservoir and cap rock petrography, interpretation of mineral assemblages, with special emphasis on dawsonite formation

KÓNYA Péter: Involved as researcher. His main tasks were phase analytics and supporting reporting activities

KOVÁCS István János: Involved as senior researcher. His main role was the development of FTIR-ATR analytical protocol to detect low concentration dawsonite

KOVÁCS-KIS Viktória: Involved as senior researcher. Originally, her main task was TEM analysis of experimental clay samples. However this task shifted to the TEM analysis of carbonates

SZABÓ Csaba: Involved as senior researcher. His role was petrography analysis of reservoir and cap rock lithologies and FIB-SEM analysis of special samples

SZAMOSFALVI Ágnes: Involved as researcher. Her main task was reprocessing and reinterpreting geophysical well-log data as well as reprocessing archive documentation of boreholes and exploration reports.

SZÉKELY Edit: Involved as senior researcher. Her main role was to support batch experiments and interpret experiment results in supercritical CO2 environment

SZABÓ KRAUSZ Zsuzsanna: Joined the project on its go. Her main tasks were carrying out experimental research on clay minerals and the development of batch kinetic and 1D reactive transport models in various environments related to supercritical CO2-water-rock interaction

Czuppon György: Joine the project in its final year. His role was the support of measurements and experiments related to stable isotopes.

Abstract

Geochemical effects of CO_2 - pore water - rock interaction have been studied on natural CO_2 reservoirs and experimental mineral assemblages. Natural CO_2 reservoirs in the Mihályi-Répcelak area show evidence for remarkable changes in their mineralogy, texture and stable isotope geochemical signature as a result of intensive mineral dissolution and precipitation processes. One of the most spectacular feature among these mineral reactions is the occurrence of dawsonite both in the reservoir sandstones as well as the clayey caprocks.

Dawsonites have been described as primary indicators of CO_2 flooding worldwide, however, their occurrence in reservoir caprocks has been described first in the frame of the current research project. These observations imply that clayey caprocks could react with CO_2 which may compromise their capabilities to restrain CO_2 in the reservoirs. On the other hand cap rocks may actively take part in storing CO_2 in mineral form.

The studied natural reservoirs display a spectacular assemblage of 6-7 different carbonates representing detrital early stage and late stage (CO_2 flooding) diagenetic processes. Stable isotopes are excellent tools to distinguish between carbonates forming during the different stages of reservoir rock formation.

The current project provided several results that are not directly linked to natural CO_2 reservoirs. Comprehensive experiments have been run to analyse the behaviour of clay minerals in the presence of water and supercritical CO_2. A set of mineralogies as well as a wide pressure and temperature range have been analysed with respect to changes in mineralogy and water geochemistry to better understand physico-chemical processes taking place in the studied environments. These experiments were backed by batch kinetic models.

Geochemical modelling was also carried out for potential CO_2 storage sites in Hungary. The models aimed to predict geochemical processes that would take place during worse case CO_2 escape scenarios in these potential sites. The developed methodology in applied was adopted by the MBFSZ and is recently used in the risk assessment procedure of potential national storage sites.

Old wells are among the highest potential risk elements of a storage projects. Geochemical models including reactive transport modelling has been applied to understand and predict long term behaviour of old cement casings in future CO_2 storage projects.

Introduction

Storing carbon dioxide (CO_2) in the subsurface as mitigation tool to reduce the effects of climate change is not a new idea. It has been proposed already in the 1980s. Nevertheless, the first industrial scale CO_2 injection in relation with climate change mitigation only started in the mid 90s in Norway (*contemporaneously with CO_2 injection in Szank field, Hungary. This latter process was never recognized by the international scientific community as climate mitigation activity*). Following over a decade of negotiation and international activity (i.e., Kyoto Protocol, IPCC reports) the European Commission accepted a Directive related to CO_2 geological storage (2009/31/EC) as an important pillar of the Climate and Energy Package. This Directive obligates the Member States to assess their CO_2 geological storage potential and regularly report the results of assessment to the Commission. The Directive has been implemented to national legislation in May 2012.

The Directive prescribes Member states how to carry out regular assessment of potential storage structures. Among other activities, this includes the prediction of geochemical reactivity of potential structures as a result of CO_2 flooding. In order to be able to predict such phenomena a combination of activities, including lab experiments, mathematical models and the analysis of natural CO_2 reservoirs is required. These activities have been addressed for the first time in Hungary in the current project.

A set of scientific approaches was applied to better achieve the goals ultimately set by the Directive, concerning the prediction of geochemical reactivity of potential structures. Drill cores from natural CO_2 reservoirs and their cap rocks have been collected and studied in detail from the Mihályi Répcelak area, NW Hungary, using a broad collection of analytical instrumentation from petrography (optical microscope, SEM, TEM to phase analytics (i.e., SEM, FIB-SEM, XRD, FTIR ATR) as well as mass spectrometry and laser analysers for stable isotope compositions. Along with phase analytics and geochemical analysis, detailed reprocessing and reinterpretation of geophysical well-logs has been carried out in the study area in order to have a high-resolution stratigraphic and petrohysical control of the CO_2 reservoirs cap rocks and surrounding geological structures. Natural CO_2 reservoirs are widespread and have been studied in detail, among others, in China, Australia and the USA. Our results have been compared with these studies.

In addition to the detailed analysis of lithologies derived from natural CO_2 reservoirs lab experiments on clay minerals representative of reservoir cap rocks at elevated pressure and temperature ranges in supercritical CO_2 environment have been carried out to understand the behaviour of clay dominated low permeability seals in the presence of CO_2. Experimental products were analysed by XRD, FTIR ATR and ICP-OES for chemical analysis. The long term preservation of low permeability in cap rocks is key to restrain injected CO_2 in the reservoirs. The novelty of the experiments carried out in the frame of the current project is that instead of dry supercritical CO_2 we used a wet, water dominated high H_2O activity environment, analogous to that expected in the subsurface. Lab experiments were backed by sophisticated geochemical modelling mainly run in PHREEQC code. Dominantly batch kinetic models were run to reveal reactor processes and vice versa, results of lab experiments were used to verify model runs and refine modelling parameters.

Geochemical modelling was also used to understand long term geochemical reactions taking place in the natural environment. A new type of modelling approach, namely reactive transport models have been introduced for the first time in Hungary to predict worse case scenarios selected potential storage sites in Hungary. The methodology developed in the frame of the current research project is now applied in the reports by the MBFSZ to the European Commission. Furthermore, as part of risk assessment the performance of old concrete casings at potential storage sites has also been modelled using reactive transport models. Well casings represent the highest risk elements of CO_2 geological storage and their involvement in detailed risk assessment

Reservoir and cap rock

A natural CO_2 field with 26 known reservoirs was selected for detailed study. This area is known as the Mihályi-Répcelak natural CO_2 occurrence, where CO_2 production has been going on for over 80 years. Some 30 exploration wells transformed to production wells have been drilled in the area. Five of these wells with available drill cores were selected based on well-log data, and archive documentation. Out of these 5 boreholes 52 core samples were selected for detailed petrography using including optical microscopy and SEM and phase analytics, using XRD, FTIR-ATR and SEM. Detailed petrography of the sandstone samples is given by Király et al. (2016a) whereas clayey caprocks are described in detail by Király et al. (2016b). This general description of the reservoir and caprocks is supplemented by a detailed petrography of the spectacular carbonate assemblage occurring in the samples by Cseresznyés et al. (in prep.). The following section is an excerpt of Cseresznyés et al. (in prep.) petrography chapter and is focusing mostly on carbonates. According to this paper the sandstone samples are sublitharenites. Dolomite is the only from the carbonates which most likely represents original detrital grains. Pore filling material, cement, mineral replacement and overgrowth (the ankerite occurs as a rim around dolomite) were determined as diagenetic carbonates. The most common diagenetic mineral is ankerite in the studied samples. Ankerites are generally located around dolomite grains as rims. However, in some cases the ankerite rim is just rudimentary. In those samples where dawsonite is around 8-16 w/w%, the ankerite rim occurs in two generations. Late generation ankerite can be found along the cracks of the early ankerite and dolomite. Based on the petrographic observations, dawsonite and late generation of ankerite (the outer rim) are in close textural relationship.

Calcite is rare and occurs in the pores of the sandstones. The grains often show dissolution features. Siderite generally appears as a pore filling, fine grained carbonate, except for the one sample. In all samples, siderite mimics sheeted minerals. Siderite also appears in iron rich clayey clast, and it occurs as continuous thin layers in large (~200 µm) patches in the dawsonite-bearing sandstones Dawsonite occurs as a fibrous, pore filling mineral. Dawsonite is present in close textural relation with ankerite, kaolinite and the quartz overgrowths. It can be also observed that the dawsonite replaces the partially dissolved albite

According to Király et al (2016b) the cap rocks are grey and/or brown. Carbonate cement (calcite, ankerite and siderite) and organic material are found in all. The lamination of silts is variable and fractures were observed neither on macroscopic nor on microscopic scale. The results of SEM (secondary electron images and back-scattered electron images) analyses are used to discriminate detrital and diagenetic minerals. Detrital minerals in the samples are quartz, feldspar (plagioclase, K-feldspar), mica and dolomite. The micas are mainly oriented, parallel to the lamination, ankerite or siderite rim can be found around dolomite. Feldspars (plagioclase, K-feldspar) display dissolution features. The secondary electron images show that diagenetic minerals are carbonate minerals (calcite, ankerite, siderite) mostly in the cement, further diagenetic minerals are clay minerals (illite, kaolinite) and dawsonite. The diagenetic dawsonite crystals occur only in the close vicinity of partially or completely dissolved feldspars.

Rare conglomerates, representing the deepest sections crosscut by the exploration wells have also been studied. These reservoir rocks represent natural reservoirs in the Mihályi Répcelak area with high salinity pore water and display textural features and dissolution / crystallization that strongly differ from the more abundant sandstone reservoirs. Their detailed description is given by Forray et al. (submitted)

Dawsonite

The occurrence of dawsonite is among the most unique and spectacular features of the studied rocks from the Mihályi-Répcelak area. Dawsonite is generally accepted as an indicator for large CO_2 activity and thus it is believed to represent CO_2-flooded environment of the reservoirs.

Dawsonite $NaAlCO_3(OH)_2$ is a white fibrous mineral. In the sandstone reservoirs it is found as a late stage pore-filling phase. In the samples where the modal composition of dawsonite is greater than 3%, it occurs as late stage cement. In those samples with significantly lower modal dawsonite, the occurrence is dispersed and generally closely linked to feldspars.

Cap rock reactivity

The occurrence of dawsonite and hence the CO_2 flooding is not limited to the sandstone reservoirs. One of the main findings of this project was that CO2 invades the low permeability caprocks despite the observation and production experience that the clayey/silty layers provide hydrodynamic separation between the different reservoir structures. The invasion of CO2 in the studied structures is evidenced by the occurrence of dawsonite in the caprocks.

The occurrence of dawsonite in the cap rock implies that CO2 does infiltrate in the sealing lithologies, furthermore it clearly reacts with the cap rock mineralogy. These reactions are expected to change, among others, the petrophysical properties of caprocks, which could potentially compromise storage safety. However, on the other hand, mineralogical changes in the cap rock and the formation of new carbonates also indicate that cap rock may actively take part in the storage of CO2 in mineralized form. This means that storage potential estimation for geological structures should also include the storage capacity of caprocks when estimating long term containment in mineral form.

Stable isotopes

The application of stable isotope analysis to understand and distinguish carbonate mineralogy development as a result of CO2 flooding was one of the research activities that received a stronger focus than was originally planned in the project. This is because the different carbonates show a very complex petrography. During this project we physically separated the dawsonite and siderite from each other and from other carbonates to give an alternative methodology to general practice used in other natural reservoirs, which provides, to our understanding quite controversial data. Our method is described in detail by Cseresznyés et al. (in preparation). Stable isotopes of C, O and H from dawsonite were measured, this latter isotope system to our best knowledge first time ever.

The δ13C values of dawsonite vary between +1.5 ‰ and +1.3 ‰, while the δ18ODaw values range from +19.5 to +22.2 ‰. In contrast, the stable isotope compositions of siderite show much larger variation defining two groups. The δ13CSd and δ18OSd values of Group-1 range from +4.2 to +4.3‰ and from +24.8 to +25.1‰, respectively. Both the carbon and oxygen isotope compositions of Group-2 is characterized by more negative values (δ13CSd: from +1.3 to +2.1‰; δ18OSd: from +22.2 to +22.3‰ (Table 2). The determined δD values of dawsonite-bearing samples from the Mihályi field cover narrow range between –61 ‰ and –59 ‰, except one sample which shows a more negative value (–74 ‰). The hydrogen isotope composition of dawsonites from the Répcelak field ranges between –62 ‰ and –57 ‰.

Other results that are not directly linked to the Mihályi-Répcelak area

Besides the detailed petrographic and geochemical analysis of rocks from the Mihályi-Répcelak natural reservoir system, several other activities have been carried out to better understand reactions in the CO2-water-rock system.

Experimets

One of the major directions worldwide, which was also involved in the research project was the experimental approach of the problem. From the early stages of our research, we focused on cap rocks and cap rock mineral, mostly clays that are believed to be responsible for the low permeability and sealing capacity of these rocks. Therefore, the behaviour of clays in the presence of high CO2 concentrations is critical.

The first set of experiments was conducted on low permeability silts coming from the same facies as the caprocks of the Mihályi-Répecelak natural reservoirs, but from a CO2-free environment. These early experiments were described in detail in Szabó et al. (2016) paper. Their results show the development of smectite and boehmite in natural low permeability rocks (analogues for cap rocks). This paper also demonstrates the efficiency of experimental work supported by batch kinetic geochemical models.

The focus of our research shifted from natural cap rock "analogues" pure clay minerals, because, these represented a less complicated mineral system, where mineral reactions and fluid composition changes could be better understood. We used Na-montmorillonite standards in water-rich scCO2 environment at different pressure and temperature ranges, backed by PHREEQC-code based geochemical batch kinetic model., described in detail by Szabó et al. (2019). Their conclusion is that Na-montmorillonite (SWy-2 clay standard) starts to react quite fast already under atmospheric conditions but its reactivity highly increases when placed into higher pressure and temperature, which is relevant for a potential storage reservoir. It turns out that the measured solution compositions could only be modelled considering the clay cation exchange being active besides mineral dissolution and precipitation processes. With this combined approach, it was possible to simulate measured values on an order of magnitude level. The experimental data indicated that not only the main interlayer cations take part in cation exchange but a minor proportion of other ions as well.

Scenario modeling for escape

The most significant risk associated with the storage of industrial CO2 in geological structures is its escape to the surface or overlying aquifers used for other purposes. Injection of CO2 and the increase of pressure as a consequence of CO2 flooding may also result in the migration of saline porewater out of the storage structure contaminating surrounding aquifers.

During the research project we have developed a 1D reactive transport model using the PHREEQC code to predict what type of geochemical reactions are associated with the above scenarios. The models show how escaped CO2 or saline water influence the geochemical composition and mineral reactions in the overlying aquifers.

In the frame of the project we modelled these "worst-case" scenarios for a concrete potential storage structure and overlying aquifer used for drinking water purposes. The studies and results are described in detail by Szabó et al. (2017) and Szabó et al. (2018). In summary the all models suggest that certain ion-concentrations may exceed drinking water limit or indicator values in both of the studied worst-case leakage scenarios of CCS. Based on the present state of models, it is expected that reactivity between rock and fluid slows down the reaction front in the CO2 inflow case.

Cement – CO2 interaction

One of the most critical questions in CO2 geological storage is the behaviour of cements in the supercritical CO2 (scCO2) - water environment. Cements are widely used casing materials used in wells both for supporting steel casings and also to insulate layers and pore fluid therein cross cut by the borehole. Cements are generally ordinary Portland cements (OPC) that are reactive with scCO2. This reaction is expected to open rapid pathways for the CO2 to reach the surface or to contaminate permeable layers during its way to the surface.

The problem with well bore cements is that after their injection in the boreholes there is a mineralogical evolution of these materials which is strongly dependent on temperature and pore fluid compositions. Therefore, the current mineral composition of an old well is not known, and cement casing samples from old boreholes are practically unavailable.

In the research project the mineralogical composition of a 60 year old borehole was modelled for an existing well with known temperature distribution and pore water composition. This "aged" model was then reacted with scCO2 . The modelling methodology and results are given in Szabó-Krausz et al. (2020). Their major results can be concluded as follows: Regarding 60 years of cement hydration, the system reaches close to equilibrium conditions. However, excess water needs to be defined for allowing the hydration to complete. If there is enough water, the water to cement ratio has a moderate effect on the predicted composition.

Modeling results CO2 attack on 60 years old hydrated cements show that CO2 induces the decay breakdown of portlandite and C1.5SH, which process releases Ca, and Si. These cations are precipitating as calcite and amorphous silica in the outer layers of the cement. The reaction front continuously moves forward at all depths, which is significantly slower at the shallowest layer. The literature, however, raises the attention to potential pore clogging (carbonate fill of pores and fractures) which cannot be considered in present models. The mass transfer among minerals indicates 2-5% elevated average porosity left behind.

Topics under preparation

In the research project we applied a multi-disciplinary approach to better understand the CO2 -pore water - rock system. Certain areas of the research activity evolved slower or started too late to reach the maturity of publications. However, these topics are also quite important to have a more comprehensive picture about the studied system and are expected to be completed and published in the near future. Nevertheless, these topics have been shared with the wider public as presentations

Covasna

Covasna is a well-known zone of CO2 emanations to the surface. These surface emanations in some cases are associated with the formation of dawsonite at atmospheric pressure and surface temperature. Dawsonites, water and CO2 have been collected in several times. All phases have been analysed concerning their C, O and H stable isotopes. Data processing and interpretation of results is an ongoing activity. Publication of the results will acknowledge the support of the research grant.

Carbonate dissolution protocol for stable isotope analysis

During the attempt to analyse the complicated carbonate mineralogy of the Mihályi-Répcelak area we realized that bulk sequential dissolution of carbonates in the studied rocks results in erroneous stable isotope compositions. This dissolution method is widely used in the literature dealing with carbonates form natural CO2 reservoirs. We have compiled a set of carbonate standards with known stable isotope compositions and produced a variety of physical mixtures. We applied the sequential dissolution method used in the literature. Our results show that the applied method results in unrealistic stable isotope compositions. We aim to develop a dissolution procedure that would result in realistic values. Publication of the results will acknowledge the support of the research grant.

Synthetized dawsonite

One of the major problems with dawsonite stable isotope interpretation is that currently there is no existing fractionation factor for dawsonite-CO2 gas and dawsonite-water. Currently all papers in the literature use existing fractionation factors of calcite. However, dawsonite unit cell parameters strongly differ from that of calcite. Therefore all calculations concerning phases in equilibrium with dawsonite are expected to be biased by the lack of adequate data. We have cooperated with the Technical University of Graz to synthetize dawsonite where fluid compositions and temperature are controlled in order to derive a calibrated fractionation factor for dawsonite. Most of the experiments and the stable isotope composition measurements are ready. However, data interpretation has not yet been accomplished. Publication of the results will acknowledge the support of the research grant.

Noble gas isotopes of Mihályi-Répcelak area

Noble gas samples have been collected in two surveys in 2018 and 2019. He, Ne, Kr and Xe isotopes have been analysed in cooperation with the University of Glasgow. Data are currently processed and interpreted. Publication of the results will acknowledge the support of the research grant.

Ölbő rocks

Ölbő natural CO2 reservoir was discovered during the same exploration activity when the Mihályi-Répcelak field, in the 1960s. The production of CO2 started in the late 1980s and today it is producing comparable amounts to that produced in the Mihályi Répcelak field. The most interesting feature is that despite the very similar geological structure, Ölbő reservoirs are found in deeper stratigraphic units than those at the Mihályi-Récelak area, namely in Miocene carbonates. The detailed analysis of rocks from the area offers multiple scientific outcomes. So far only very few carbonate natural CO2 reservoirs have been studied, and our results could contribute to extend potential geological structures to carbonates. Furthermore, Ölbő offers an exceptional opportunity to study the lithologies serving as reservoirs in the Mihályi-Répcelak area but without experiencing influence by CO2. This enables the identification and separation of CO2-related reactions from diagenetic processes predating the CO2 flooding. The processing of lithologies is in progress. Publication of the results will acknowledge the support of the research grant.

Quantitative assessment of 'products'

During the active period of the project 01.11.2015 - 31.12.2020 the following manuscripts and publications have been published. Conference abstracts are not listed in detail, because in several cases, due to limitations and restrictions in abstract texts, the acknowledgements to the grant could not be displayed.

Scientific Conference of Students

2018 - Dóra CSERESZNYÉS

BSc theses

2016 - Dóra CSERESZNYÉS

2020 - Alexandra GACSAL

MSc theses

2018 - Viktória Forray

2018 - Dóra CSERESZNYÉS

PhD thesis (completed)

2014-2017 - Csilla KIRÁLY

PhD theses (running)

2018 - Dóra CSERESZNYÉS

2019 - Neda ARIDHI

Publications

Viktória Forray , Csilla Király, Attila Demény, Dóra Cseresznyés, Csaba Szabó, György Falus Mineralogical and geochemical changes in conglomerate reservoir rocks induced by CO2 influx at Mihályi- Répcelak natural analogue, NW-Hungary ENVIRONMENTAL EARTH SCIENCES submitted

Szabó-Krausz, Z; Gál, NE ; Gável, V ; Falus, G Wellbore cement alteration during decades of abandonment and following CO2 attack – A geochemical modelling study in the area of potential CO2 reservoirs in the Pannonian Basin APPLIED GEOCHEMISTRY 113 Paper: 104516 (2020)

Szabó, Zs ; Gál, N E ; Kun, É ; Szőcs, T ; Falus, Gy Accessing effects and signals of leakage from a CO2 reservoir to a shallow freshwater aquifer by reactive transport modelling. ENVIRONMENTAL EARTH SCIENCES 77 : 12 Paper: 460 (2018)

Szabó, Zs. ; Hegyfalvi, Cs. ; Freiler-Nagy, Á. ; Udvardi, B. ; Kónya, P. ; Király, Cs. ; Székely, E. ; Falus., Gy. Geochemical Reactions of Na-montmorillonite in Dissolved scCO2 in Relevance of Modeling Caprock Behavior in CO2 Geological Storage PERIODICA POLYTECHNICA-CHEMICAL ENGINEERING 63 : 2 pp. 318-327. , 10 p. (2019)

Szabó, Zs ; Gál, N E ; Kun, É ; Szőcs, T ; Falus, Gy Accessing effects and signals of leakage from a CO2 reservoir to a shallow freshwater aquifer by reactive transport modelling. ENVIRONMENTAL EARTH SCIENCES 77 : 12 Paper: 460 (2018)

KIRÁLY, CS ; ., SENDULA E. ; SZAMOSFALVI, Á. ; KÁLDOS, R. ; KÓNYA, P. ; KOVÁCS, I. J. ; FÜRI, J. ; BENDŐ, ZS. ; FALUS, GY. The relevance of dawsonite precipitation in CO2 sequestration in the Mihályi–Répcelak area, NW Hungary. In: Armitage, P J; Butcher, A R; Churchill, J M; Csoma, A E; Hollis, C; Lander, R H; Omma, J E; Worden, R H (Eds.) Reservoir quality of clastic and carbonate rocks: analysis, modelling and prediction London, United Kingdom / England : Geological Society of London (2018) 543 p. pp. 405-405. , 1 p.

CSERESZNYÉS, D. ; CZUPPON, GY. ; SZABÓ, ZS. ; KIRÁLY, CS. ; SZABÓ, CS. ; FALUS, GY. Stable isotope compositions of different mineral phases found in a natural CO2 -reservoir (NW Hungary): implication for their origin. ENERGY PROCEDIA 2017 : 114 pp. 2812-2818. , 7 p. (2017)

Sendula, E ; Páles, M ; Péter, Szabó B ; Udvardi, B ; Kovács, I ; Kónya, P ; Freiler, Á ; Besnyi, A ; Király, Cs ; Székely, E et al. Experimental study of CO2-saturated water – illite/kaolinite/montmorillonite system at 70-80°C, 100-105 bar ENERGY PROCEDIA 114 pp. 4934-4947. , 14 p. (2017)

Király, Cs ; Szabó, Zs ; Szamosfalvi, Á ; Kónya, P ; Szabó, Cs ; Falus, Gy How much CO2 is trapped in carbonate minerals of a natural CO2 occurrence? ENERGY PROCEDIA 125 pp. 527-534. , 8 p. (2017)

Szabó, Zs ; Gál, N E ; Kun, É ; Szőcs, T ; Falus, Gy Geochemical modeling possibilities of CO2 and brine inflow to freshwater aquifers. CENTRAL EUROPEAN GEOLOGY 60 : 3 pp. 289-298. , 10 p. (2017)

Szamosfalvi, Á ; Zilahi-Sebess, L ; Király, Cs ; Jobbik, A ; Szalai, Z ; Falus, Gy New investigation of old well-logs and core samples in a natural CO2 occurrence ENERGY PROCEDIA 114 pp. 4477-4485. , 9 p. (2017)

FALUS, GY. ; SZAMOSFALVI, Á. Szén-dioxid tárolással kapcsolatos „ásványvagyon" nyilvántartás nemzetközi rendszereinek áttekintése. FÖLDTANI KÖZLÖNY 146 : 2 pp. 163-167. , 5 p. (2016)

Király, C ; Szamosfalvi, Á ; Zilahi-Sebess, L ; Kónya, P ; Kovács, IJ ; Sendula, E ; Szabó, C ; Falus, G Caprock analysis from the Mihályi-Répcelak natural CO2 occurrence, Western Hungary ENVIRONMENTAL EARTH SCIENCES 75 : 8 Paper: 635 (2016b)

Szabó, Zs ; Hellevang, H ; Király, Cs ; Sendula, E ; Kónya, P ; Falus, Gy ; Török, Sz ; Szabó, Cs Experimental-modelling geochemical study of potential CCS caprocks in brine and CO2-saturated brine INTERNATIONAL JOURNAL OF GREENHOUSE GAS CONTROL 44 pp. 262-275. , 14 p. (2016)

Other important notes

The circumstances of the realization of the current research project was far from ideal. During the project there was a legal status change of the Principal Investigator's (PI) affiliation, which was followed by a the change of workplace by the PI. These multiple changes are evidenced by 3 different project codes in the 2015-2020. Period. During these changes the project financing was practically unavailable in the 2017-2019 period.

The final year of the project was deeply struck by the pandemy and planned grant spending had to be replanned.