GEOPHYSICAL STUDY OF A SALT BODY FOR ENERGY STORAGE

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Abstract. In the context of global and national efforts to mitigate climate change, renewable energies from intermittent sources are starting to have considerable shares in the global and national energy mix. In order to maintain security and stability of energy networks, there is an increasing need for energy storage. Geological (underground) energy storage could be a solution for storing large amounts of energy and, at present, there are several technologies, at different levels of maturity. We decided to start the evaluation of geological energy storage possibilities in Romania with the evaluation of salt caverns created through dissolution during salt exploitation through boreholes. After selection, several salt caverns were, geophysically, investigated in an area of salt exploitation from Romania. The results of the gravity and electric survey indicated that the investigated caverns have stability problems and that there is a channel through which the brine is circulating between caverns.

Key words: Gravity survey, rezistivity survey; modelling; salt cavern

INTRODUCTION

Global efforts are made to reduce greenhouse gas emissions as a mitigation measure for climate changes whose devastating effects started to show. These efforts are materializing through action plans, which include increasing the share of renewables in the production and consumption of energy, development of technologies for the production of renewable energy, energy storage (particularly for increasing energy security and to combat destabilization caused by intermittent energy production in some industries as wind and solar energy production), promoting energy efficiency and CO_2 capture and geological storage (as a bridge technology until renewables will be able to cover the entire global energy demand).

According to the energy scenarios presented in the EU Energy Roadmap for 2050 (European Commission, 2012), Europe could generate by 2030 more than 40% of its energy from renewable sources, using 38% less energy than in 2005 and emitting 50% fewer greenhouse gas emissions compared to 1990 and could finally provide a 0 emission energy system by 2050. The Roadmap also emphasizes the importance of sustainable and integrated use of the subsurface relative to exploitation of fossil fuels, geothermal energy, carbon capture and storage, waste disposal and geological energy storage, protecting the environment in the same time.

Concerning the geological energy storage, there are several technologies available at present, at different levels of maturity. These technologies are natural gas storage, underground pumped hydroelectric energy storage, compressed air energy storage, aquifer thermal energy storage, borehole thermal energy storage, cavern thermal energy storage and hydrogen storage (GENI, 2012; IEA, 2014). The geological solutions are mainly depleted hydrocarbon fields, salt caverns and aquifers.

Underground pumped-storage hydroelectricity refers to storing electricity in water in the form of potential energy (GENI, 2012). The technology consists in pumping water from a lower underground reservoir to a high-level reservoir (at surface or underground) in times of high energy production and low demand and releasing the water that flows through a turbine producing electricity in high demand or low production periods.

Compressed air energy storage technology involves storing energy in the form of compressed air and to power a turbine with the stored air and generate electricity in periods of high demand.

Aquifer, borehole and cavern thermal energy storage are technologies that use pumps to store heated or cooled water underground (in aquifers, man-made boreholes or caverns) for later use as heating or cooling agent (IEA, 2014).

Hydrogen storage technology involves using excess electricity to make hydrogen through electrolysis of water and, in further steps, methane (GENI, 2012), that can be introduced in natural gas grid.

On the national level, Romania is committed to decrease the greenhouse gas emissions and to increase the share of renewables in the energy mix while increasing energy security and stability. In the recent years, the share of renewables (wind, hydro, solar), in the energy mix continuously increased (Fig. 1), accounting in 2015 approximately 40% from the total energy mix (Ministry of Energy, 2016).

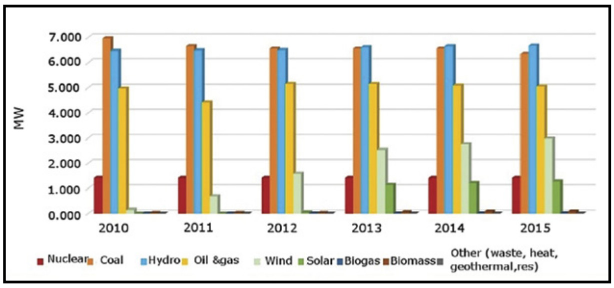


Fig. 1. The evolution of installed power capacity by type of energy for the period 2010-2015 (ANRE, 2016)

During the same year, as it is illustrated in Figure 2, the wind and solar energy reached the targets of 11.03 % and respectively, 2.43 % for solar energy (ANRE, 2016).

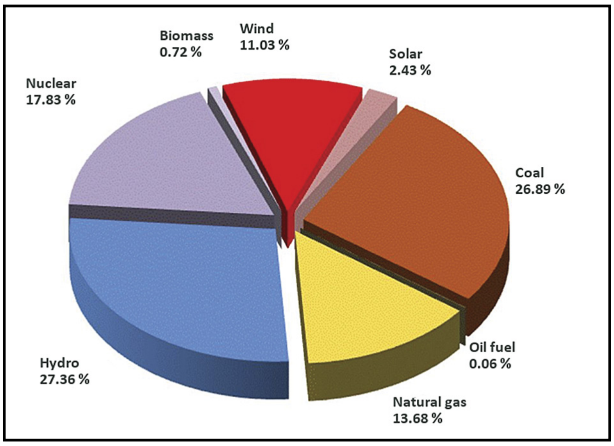


Fig. 2. Romania energy mix for 2015 (ANRE, 2016)

Taking into account this situation and the fact that Romania is currently exporting energy, the need of energy storage has become widely recognized. As for geological energy storage, Romania has the experience of storing natural gas, for decades.

Considering that Romania has potential and need for geological energy storage, we have analysed the geological solutions available and decided to start the evaluation of storage possibilities in the form of salt caverns, created as a result of exploitation of salt bodies through dissolution. These caverns, if stable and properly sealed, are suitable for compressed air energy storage and hydrogen storage (GENI, 2012; IEA, 2014). Taking into account the problems reported in the last two decades with ground subsidence and brine infiltration in the salt dissolution exploitation areas from Romania, we have set the objective to investigate the stability of selected salt caverns using geophysical methods (gravity and electric measurements).

GEOLOGICAL SETTING AND SURVEY LOCATION

The selected investigation zone is located within the area of Gura Slanic (Targu Ocna) salt deposit. From a geological and a structural point of view, this deposit represents a continuation to the South of Targu Ocna salt massif, located at the contact between the marginal flysch of Eastern Carpathians and the sub-Carpathian molasses deposits.

The morphology of the salt body from Gura Slanic sector is more complicated than the one from Targu Ocna due to the presence of a large impure salt blade which led to exploitation of salt in dissolution through wells.

The salt exploitation in dissolution at Targu Ocna (Gura Slanic) is made within two fields: the western field, comprising a total of 29 exploitation wells located on the western bank of Slanic river (except one well) and the eastern field currently under development.

We selected for geophysical survey a perimeter of 0.0738 km^2 within the western exploitation field, south west of Targu Ocna town (Fig. 3), on the left bank of Slanic river.

There are nine exploitation wells within the perimeter, but, after discussions with the field operator, we have decided to focus on the area of three wells named 259, 251 and 253, where there might be a near surface channel through which the brine is flowing towards the Northern area where a brine lake was formed.

GEOPHYSICAL SURVEY PLANNING AND DATA ACQUISITION

In order to be able to detect the supposed channel, a brief modelling of the gravity effects of the dissolution caverns was made and the results were used to design the gravity survey and the location of the electric measurements profiles (Vertical Electric Sounding – VES). The gravity stations were spaced at 25 m in order to cover homogeneously the investigated area. The electric measurements (VES) were made on a line transverse to the direction of the supposed channel.

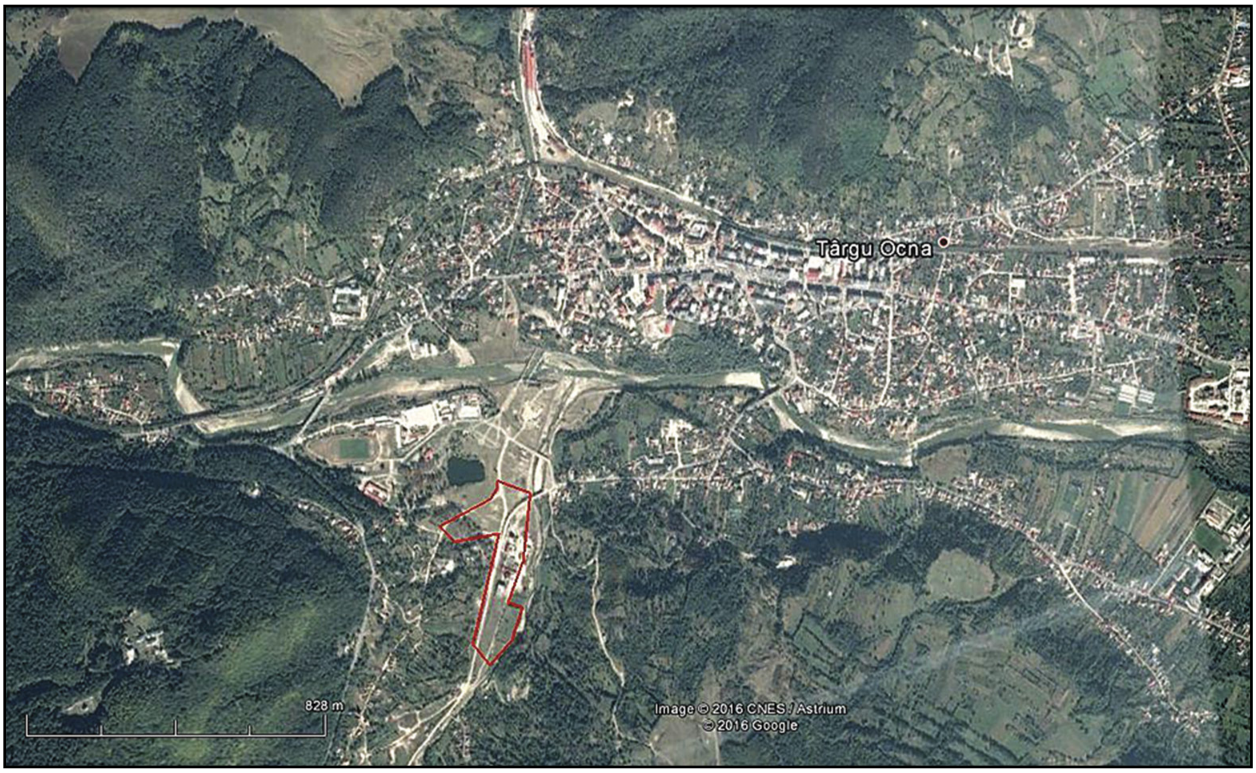


Fig. 3. Location of survey perimeter

Gravity was measured on 101 stations using CG5 Autograv relative gravimeter (Fig. 4) from Scintrex. The standard resolution is 1 μGal. The gravity values were transmitted from the closest station of the national gravity network to the work perimeter, where two gravity local bases were determined. From these local bases four measurement cycles were made.

Fig. 4. The equipment used for gravimetric measurements CG5 Autograv Scintrex

The electric measurements were conducted using a rezistivimeter and a Schlumberger array on four VES lines spaced at 10 m, with the measuring electrodes spaced at 2 m and the injection electrodes positioned at 4, 10, 30, 70, 91, 110 and 130 m.

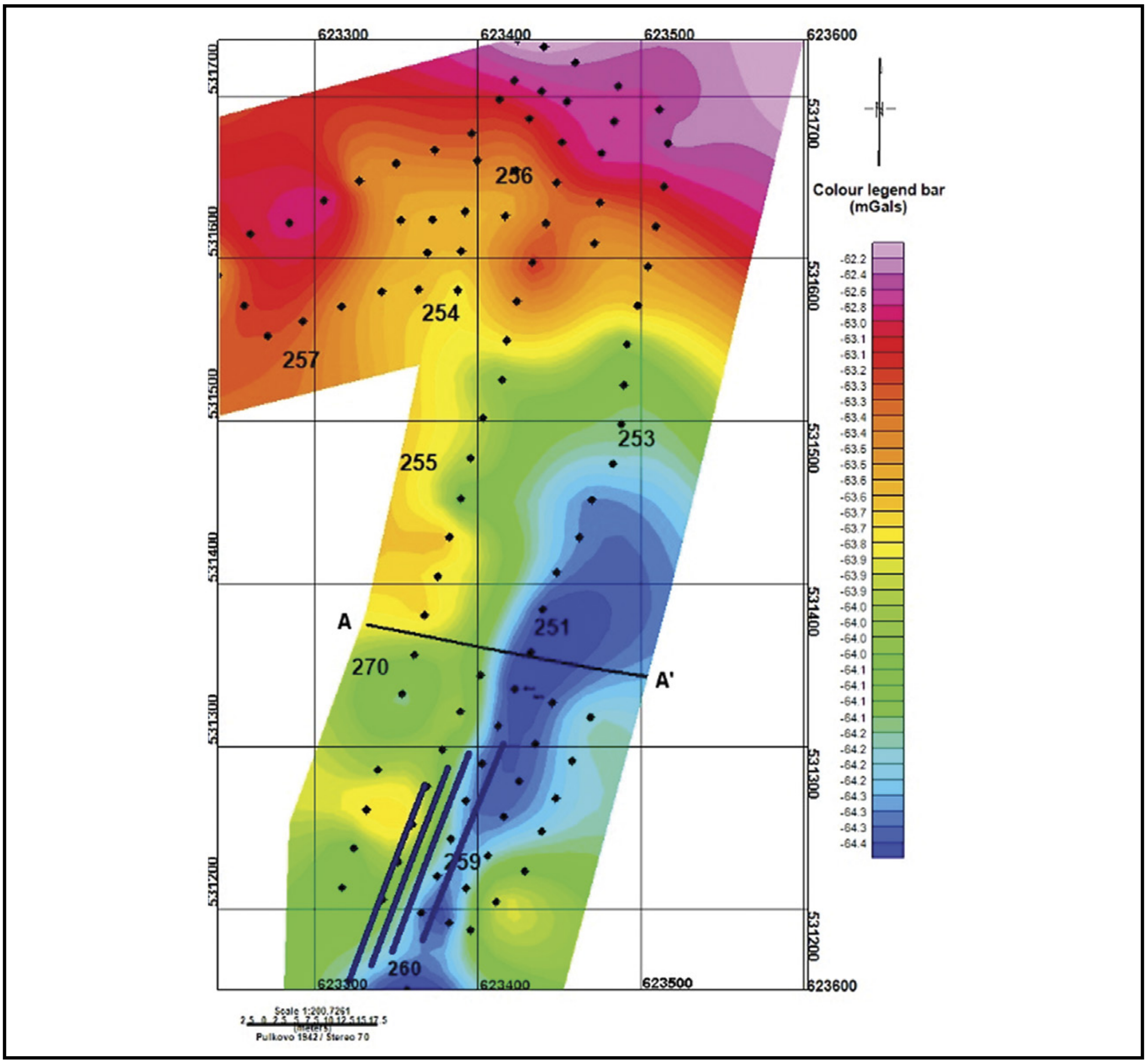
DATA PROCESSING AND RESULTS

Gravity anomaly was calculated for a density of the environment of 2.2 g/cm^3. The obtained values were interpolated at 0.01 mGals and the resulting map is presented in Figure 5. As it can be seen from Figure 5, within the perimeter of the wells 259, 251 and 253, there is a minimum gravity anomaly of 0.3 mGals, extending on a NE-SW direction that could be the effect of a channel of brine circulation between wells and dissolution caverns.

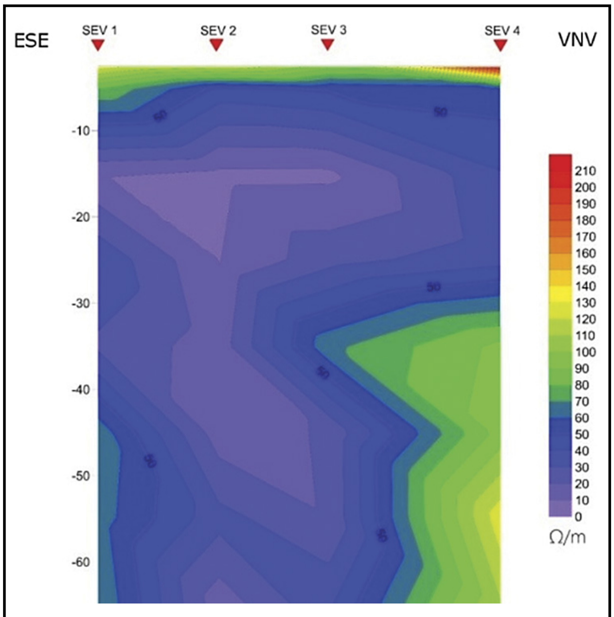
The apparent resistivity section is presented in Figure 6 and indicates a decrease of resistivity near ground surface that could also be an effect of brine accumulation.

2 D MODELLING

In order to analyse the minimum gravity anomaly obtained on the gravity anomaly map, we have made a 2D modelling, using Potent Q modelling extension of Oasis Montaj software on a profile with WE orientation. The result, illustrated in Figure 7, was that the minimum gravity effect could be due to the presence of an ellipsoidal body, with the centre at



▲ **Fig.** 5. Gravity anomaly map (blue lines - VES profiles, AA' - modelling profile, black points - gravity stations, exploitation numbers - wells)



◀ **Fig.** 6. Aparent rezistivity section

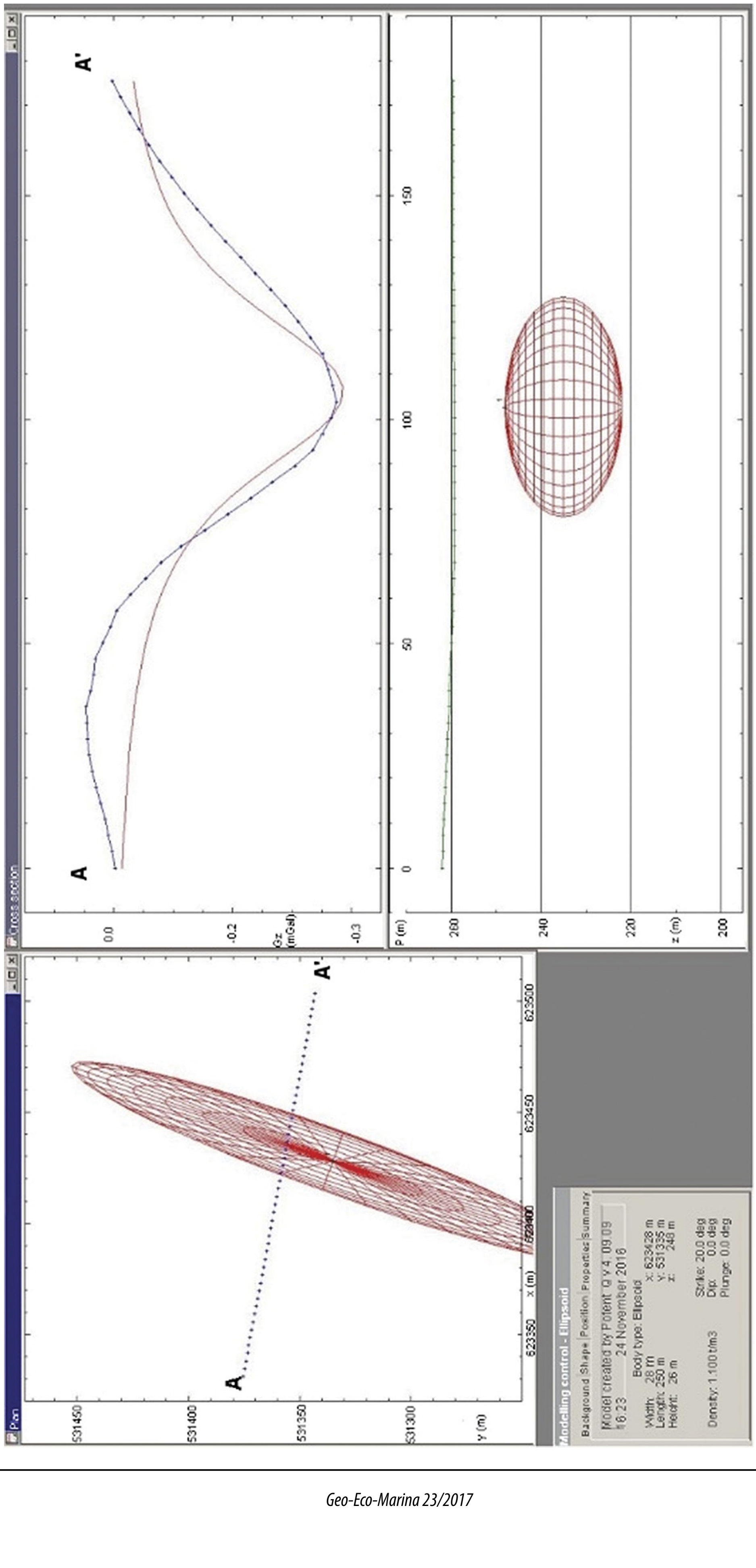


Fig. 7. Result of 2D modelling

approximately 30 m below ground surface, South from 251 exploitation well, 28 m width, 250 m length, 26 m height and with a density of 1.1 g/cm^3. The density used for modelling corresponds to a body filled with brine. The configuration of the modelled body seems to match the channel through which the brine is circulating.

CONCLUSIONS

Given the increase in the contribution of intermittent renewable energy sources (wind and solar) to the national energy mix, there is a need for energy storage to maintain the stability and security of Romanian energy networks. The geological energy storage technologies can be implemented in Romania to assure the storage of large amounts, given also the long experience in natural gas storage.

A solution of storing energy in Romania could be represented by the salt caverns created by salt exploitation through dissolution. Following a selection process, we decided to focus on an area with fewer historic stability problems, namely Targu Ocna.

In order to investigate the stability of the caverns in this area, we planned a geophysical survey using gravimetric and electric methods. The results of the gravity survey and modelling and the results of the electric survey indicate that it is very likely that in the investigated area a channel through which brine circulates was formed, most probably, as a result of the salt exploitation through wells.

The most probable implication is the area is not suited for geological energy storage due to instability issues. Nevertheless, our results should be further investigated in order to be able to design solutions for increasing stability of the caverns, establish dissolution control and prevent ground sinking and cavern collapsing.

ACKNOWLEDGEMENTS

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