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Integrated approach for hydrogen storage in a salt mine: the case of Realmonte, Sicily (Italy).

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The crucial role of hydrogen in future energy systems, particularly in balancing fluctuations in electricity generation, underscores the need for effective storage solutions. For the underground storage of chemical energy carriers such as hydrogen, the underground salt cavern is the sole underground space that has been successfully used as storage facilities. This study explores the potential of underground salt caverns for storing hydrogen. Salt caverns offer advantages such as low investment costs, high sealing potential, and minimal cushion gas requirements. Geological considerations, including a salt top depth of 400-600 m, >95% pure halite, a deposit thickness of 200-300 m, and a diapiric salt bank or internally homogeneous lenses, are necessary for successful cavern exploitation. From a microbial point of view, during the water evaporation process leading to the underground salt cavern formation, small parts of the in-situ brine become trapped in the salt and end up as fluid inclusions, potentially including halophilic microorganisms subsequently freed during the process of solution mining. Autotrophic microbial life is feasible under salt cavern circumstances, especially if a suitable electron donor like H_2 is introduced.

The study focuses on a salt mine in Realmonte, Sicily and explores the geology, geochemistry, geomechanics and microbiology properties of the halite section. The mine, extracting 97% pure rock salt, serves as a natural laboratory for geochemical and geo-mechanical studies. It is characterized by four depositional units. Unit A comprises laminated gray halite (50 m); Unit B (100 m) features massive gray halite with kainite laminae up to 18m thick; Unit C (70-80m), consists of white halite layers separated by dark mud laminae and Unit D (60m) which includes anhydritic mudstone transitioning to an anhydrite laminite sequence. Utilizing well log data and a 3D geological subsurface model, the study reveals a salt bank with an average thickness of 500 m (of

which only the upper 220 m b.s.l. is exploited) and defines the top and bottom of the halite subunits. Pore-perm analysis on 28 rock salt and kainite cores, including XRF analysis and Mercury Intrusion Porosity, provides insights into geochemical and porosity characteristics. Pore network model was obtained from the processing and interpretation of the micro-tomographic images collected on 10 rock salt and 1 kainite sample. A hydrogen injection test under varying conditions simulates cyclic storage under both static and dynamic conditions and a geochemical model of the internal conditions of a cavern has been produced using PHREEQC model.

Results indicate limited diffusion under relatively high pressure. Microbiology and the linked geochemistry of two salt cores, both from the Realmonte mine but of different composition, is being investigated. The integrated geochemical, geomechanical, microbiological and experimental data support the feasibility of storing hydrogen in a stratified salt geological context, particularly where pure rock salt and kainite interlayers are present. Finally, we explore the potential for a large-scale project, envisioning coexistence of traditional mining activities up to 200 m b.s.l. and hydrogen storage activities at greater depths (Units B and A) between 300 and 600 m.