Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.20789

# Sulfur oxidation states in underground salt caverns and sedimentary formations: Geochemical considerations for underground $H_2$ storage

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Vast quantities of $H_2$ gas will be produced, stored, and retrieved in the zero-carbon global energy future. Underground salt caverns and porous sedimentary formations are storage options for $H_2$. A major concern inhibiting advancement of underground $H_2$ storage is the possibility of bacterial sulfate reduction, utilizing $H_2$ as the electron donor and generating $H_2S$ gas, which is highly toxic and dangerous. In this work, the oxidation states of sulfur in salt dome samples and sedimentary formation samples were examined to increase understanding of the conditions for $H_2S$ gas generation. Predominantly, mineral sulfur occurs in the +VI oxidation state, such as in gypsum, or the -I reduced state, such as in pyrite. Only oxidized sulfur can be used as an electron acceptor. We hypothesize that the sulfur minerals in the two types of geological formations are very different in oxidation state and are categorically different in terms of $H_2S$ risk. We used the tender x-ray beamline (TES 8BM) at the NSLS-II synchrotron for x-ray absorption spectroscopy (XAS) and x-ray absorption near edge structure (XANES). This research is the first comparative analysis of sulfur oxidation in salt vs sedimentary rocks. We found that the salt formation rock samples uniformly contained sulfate minerals, and we conclude that safe and reliable storage of $H_2$ in salt caverns may be jeopardized if the risks are not thoroughly characterized. In contrast, we found that the sedimentary formation rock samples contained mostly disulfide minerals, and some evaporites and shales contained a mix of sulfur oxidation states. If $H_2$ is stored in these formations, the risk of $H_2S$ gas is likely to be lower.