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# Using ASTER Multispectral and EnMAP Hyperspectral Remote Sensing for Lithological Mapping of Salt Diapirs in the Zagros Mountains, Iran

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Over a hundred salt diapirs, which are fed by the Precambrian Hormuz Evaporites, extrude through anticlines of the fold and thrust belt of the Zagros Mountains in southern Iran. The sheer number of diapirs, the arid climate, and the mountainous landscape have presented a long-standing challenge for traditional geological field mapping to produce high-resolution lithological maps of prominent salt features. Such maps are crucial for comprehending the role of salt diapirism in the evolution of the landscape and exploring hydrocarbon and mineral resources within the region.

To overcome this challenge, we take advantage of the rapidly expanding satellite imagery database to explore the potential of employing satellite-based multispectral and hyperspectral remote sensing for producing lithological maps of salt diapirs in arid environments. Enhancing this analysis with mineral and rock spectroscopy, our goal is to map diverse lithologies characteristic of salt diapir cupolas and genetically associated salt glaciers at the resolution permitted by currently available satellite imagery.

To test the utility of satellite-based remote sensing to lithological mapping of salt diapir features, our study focuses on three salt diapirs — Karmostaj, Siah Taq, and Champeh — in the Zagros Mountains. We used previously established ASTER-based NIR and SWIR mineral indices (Cudahy et al., 2020; Hewson et al., 2005; Rowan & Mars, 2003; Shuai et al., 2022) to delineate the distribution of $SO_4^{2-}$-, Al-OH-, Mg-OH-, and $CO_3^{2-}$-bearing minerals, and of ferric and clay minerals. We also investigated potential temporal and seasonal changes in the distribution of the target minerals and the strength of the spectral signals of the mineral groups. Furthermore, we calculated mineral indices from ASTER thermal imagery suggested in previous work (Guha & Vinod Kumar, 2016; Ninomiya et al., 2005; Rockwell & Hofstra, 2008) to map quartz-, sulfate-, and carbonate-bearing rocks. To validate the accuracy and precision of the ASTER-based mineral indices, we carried out Raman and FTIR spectroscopic analysis to spectrally characterize rock and mineral samples collected from cupolas, caprocks, and country rocks of various salt diapirs in the region. We

subsequently applied Spectral Information Divergence (SID) classification on multispectral ASTER and hyperspectral EnMAP optical imageries.

As we extend the mapping technique to other salt diapirs across the Zagros and Arabian Peninsula regions, our findings suggest that satellite-based remote sensing offers a cost-effective and labour-saving approach for generating high-resolution lithological maps. This method has the potential to advance our understanding of the halo-tectonic evolution of the Zagros landscape once a sufficient number of salt diapirs are mapped at the current resolution. However, we note that the accuracy of lithological mapping is influenced by the spectral and spatial resolution of the available satellite imagery. Furthermore, the strength of the spectral signal of gypsiferous outcrops exhibits distinct seasonality, weakening in warm periods and strengthening in cold seasons. In conclusion, our study demonstrates the efficiency as well as the limitations of satellite-based remote sensing in improving lithological maps of exposed salt diapirs in desert environments, providing valuable insights for geological research and resource exploration in the Zagros Mountains.