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Monitoring underground gas storage for seismic risk assessment

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Temporary gas storage facilities play a fundamental role in the design of energy supply. The evaluation and recognition of induced seismicity, geodetic displacements and wellbores damages are their main associated risks that should be minimized for a safe management of these facilities, especially in densely populated areas.

Injection and withdrawal of gas into/from a porous reservoir generally lead reservoir rocks to deform. Rock deformation is due to variations of the state of stress of rocks, both in the reservoir and the surrounding: subsidence, wellbore damages and induced or activated seismicity are primary consequences of these variations.

In this paper we present a case study on induced deformation by an exploited gas reservoir, converted to temporary natural gas storage since 1994, in North-Eastern Italy. The reservoir, composed by 2 independent carbonatic sandstone intervals, approximately 10 meters thick, and 1400 meters deep, has been exploited since 1983, recording a pressure drop of about 16 MPa.

The inversion of gas pressure and volume data, together with a 26 year ground displacement dataset monitoring, allow us to define reservoir deformations, modelled by a semi-analytical method based on an equivalent Eshelby's inclusion problem, able to account for mechanical differences between reservoir and surrounding rocks. Stress field changes, and displacement fields around the reservoir and on the ground mainly represent the results of this modelling.

A Coulomb Failure Stress analysis, performed by FEA, was applied to define and evaluate the influence of magnitude and shape of stress field changes on rock stability, highlighting rock volumes that mainly suffer stress changes eventually leading to induced/activated earthquakes. The microseismic monitoring provides then the control on failures and their location.

The methodology here used provide a solid base for induced or activated seismicity risk assessment: it provides an easy tool to quantify magnitude and shape of elastic fields variations induced by reservoir activities, which alter rock stress state and can generate earthquakes.