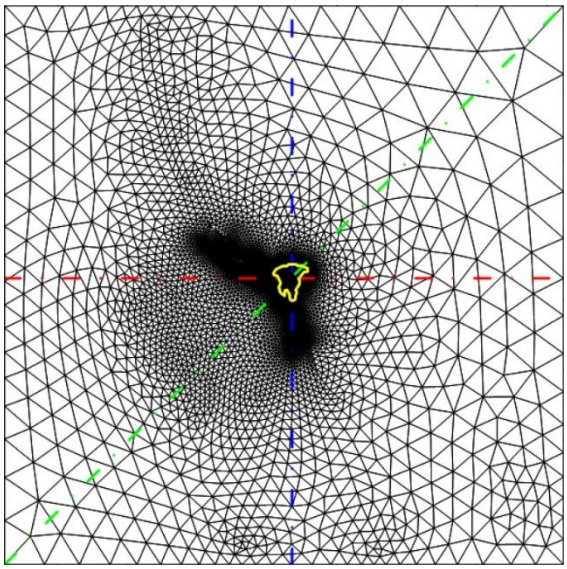
# Geomechanical modelling of underground gas storage (UGS) activities in an developed gas field

## Project summary



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| Client: | EDISON Spa |
| Year: | 2017 |
| Site: | On-shore |
| Service: | Computer Modelling |
| Sector: | Geomechanical Engineering |
| Geological setting: | Sedimentary basin |
| Constitutive law: | Anisotropic hypo-plasticity with mechanical hysteresis |
| Project in numbers: | 2,233,290 degrees of freedom |


## Abstract

This study, developed in cooperation with the University of Padova, is aimed at the numerical modelling of the geomechanical effects induced by the storage of natural gas in an underground exhausted field. The geomechanical analysis is performed with the aid of a state-of-the-art 3D finite-element numerical model, developed by the M3E team, with the following objectives: (1) predict the land surface displacements over the field, (2) analyze the variation of the natural stress field induced by the field activities, and (3) analyze the possible activation of faults and fractures located in the proximity of the reservoir.


## Project description

The gas field is located close to urban areas, at a depth of about 1200 m. Two layers are used for storage purposes and mainly consist of turbidites (middle and upper Pliocene). The reservoir caprock is a rigid clay formation with a variable thickness between 65 and 100 m.

The geomechanical model has an areal extent of 40 km × 40 km with the storage reservoir approximately located in a baricentric position.

The characteristic elemental size is approximately 50 m in the field zone, consistent with the discretization used in the dynamic reservoir model. The 3D computational grid was obtained using the automatic grid generator

specifically developed by the M3E team for geological applications. The domain is confined below by a rigid bedrock located at 5 km depth and above by the Digital Elevation Model of the ground surface. The discretization is made by unstructured tetrahedral elements so as to reproduce with accurately the pinch-out closure, the volumes of mineralized pools, Gas-Water-Contacts elevations, and aquifer geometries hydraulically connected to the field.

The geological analysis of the field provided evidence of the presence of some faults surrounding the aquifer connected to the storage layers. Two regional faults close to the field delimiting the zone where pressure variation takes place are introduced in the geomechanical model by doubling the nodes lying on the surface along which discontinuity develops and introducing in the grid special interface elements.

In particular, 25531 interface elements were used to simulate the mechanical behavior of the two faults, described by an elastic-plastic constitution law based on the Mohr-Coulomb breaking criterion. The grid thus generated consists of a complex of 744430 nodes and 4329363 elements. The local faults in the top of the field were not taken into account since, by not generating a break in the layer pressure distribution, they cannot be activated by UGS activities.

The 3D geomechanical model is used to simulate the storage activities within the gas field, with the aid of a state-of-the-art finite element code developed by the M3E team, taking in particular into account the non-linear mechanical behavior of the material and the discontinuity caused by the fault. The storage activity produces a variation of the effective stress which propagates also in the aquifers hydraulically connected with the gas layers. Such a variation is the forcing function causing a local deformation of the reservoir which can propagate up to the ground surface and possibly induce a re-activation of the nearby faults.

The development of an accurate geomechanical model allows for the reliable prediction of deformations at both a local and a regional scale, thus helping the oil company to manage the reservoir and the administration responsible of the authorization process to take the most appropriate decisions.

## Project outcome

The project gave the following outcomes:

- Development and calibration of a 3D geomechanical finite-element model.
- Forecast of the vertical and horizontal displacements induced by the gas storage activity.
- Analysis of the differential movements and their impact on buildings and infrastructures.
- Prediction of the stress field variation induced by the gas storage.
- Analysis of the stress field propagation on the caprock and underburden.
- Analysis of the potential fault reactivation caused by the operational activities.