Monitoring and modelling 3-D ground movements induced by seasonal gas storage in deep reservoirs

P. TEATINI1, G. GAMBOLATI1, N. CASTELLETTO1, M. FERRONATO1, C. JANNA1, E. CAIRO2, D. MARZORATI2, D. COLOMBO3, A. FERRETTI3, A. BAGLIANI4, F. BOTTAZZI4 & F. ROCCA5

1 Department of Mathematical Methods and Models for Scientific Applications (DMMMSA), University of Padova, via Trieste 63, I-35121 Padova, Italy
teatini@dmsa.unipd.it
2 Stogit S.p.A., Via dell’Unione Europea 3, San Donato Milanese (MI), Italy
3 Tele-Rilevamento Europa S.r.l. (TRE), Via V. Colonna 7, I-20149 Milano, Italy
4 Eni S.p.A. – Divisione E&P, Via Emilia 1, I-20097 San Donato Milanese, Italy
5 Dip. di Elettronica ed Informazione, Politecnico di Milano, piazza Leonardo da Vinci 32, I-20133 Milano, Italy

Abstract Underground gas storage (UGS) in depleted hydrocarbon fields is a strategic practice to cope with the growing energy demand, and occurs in many places in Europe and North America. In response to summer gas injection and winter gas withdrawal the reservoir expands and contracts almost elastically, namely it “breathes”, as a major consequence of the fluid pore pressure fluctuations. Depending on a number of factors, including the field burial depth, the difference between the largest and the smallest gas pore pressure, and the geomechanical properties of the injected formation and the overburden, the porous medium overlying the reservoir is subject to a three-dimensional deformation related to the cyclic motion of the land surface in both vertical and horizontal directions. We present a multidisciplinary methodology to evaluate the environmental impact of UGS from a geomechanical point of view in connection with the ground surface displacement that may cause some concern for the integrity of the existing engineered structures and infra-structures. Long-time records of injected/removed gas volume and fluid pore pressure, together with multi-year detection of vertical and horizontal west–east displacement of the land surface above the field by an advanced PSInSARTM analysis have allowed calibration of a 3-D fluid-dynamic model and development of a 3-D transversally isotropic geomechanical model. The latter has been successfully implemented and used to reproduce the vertical and horizontal cyclical displacements, in the range 8–10 mm and 6–8 mm, respectively, measured between 2003 and 2007 above the “Lombardia” gas reservoir, northern Italy, where since 1986 a UGS program has been under way by Stogit S.p.A. (Eni), following an initial 5-year field production life.

Key words underground gas storage; 3-D geomechanical model; PSInSAR