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TI: Anisotropic mechanical behaviour of sedimentary basins inferred by advanced radar interferometry above gas storage fields

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AB: Natural gas is commonly stored underground in depleted oil and gas fields to provide safe storage capacity and deliverability to market areas where production is limited, or to take advantage of seasonal price swings. In response to summer gas injection and winter gas withdrawal the reservoir expands and contracts with the overlying land that moves accordingly. Depending on the field burial depth, a few kilometres of the upper lithosphere are subject to local three-dimensional deformations with the related cyclic motion of the ground surface being both vertical and horizontal. Advanced Persistent Scatterer Interferometry (PSI) data, obtained by combining ascending and descending RADARSAT-1 images acquired from 2003 to 2008 above gas storage fields located in the sedimentary basin of the Po river plain, Italy, provide reliable measurement of these seasonal vertical ups and downs as well as horizontal displacements to and from the injection/withdrawal wells. Combination of the land surface movements together with an accurate reconstruction of the subsurface geology made available by three-dimensional seismic surveys and long-time records of fluid pore pressure within the 1000-1500 m deep reservoirs has allowed for the development of an accurate 3D poro-mechanical finite-element model of the gas injection/removal occurrence. Model calibration based on the observed cyclic motions, which are on the range of 10-15 mm and 5-10 mm in the vertical and horizontal west-east directions, respectively, helps characterize the nonlinear hysteretic geomechanical properties of the basin. First, using a basin-scale relationship between the oedometric rock compressibility *cM* in virgin loading conditions versus the effective intergranular stress derived from previous experimental studies, the modeling results show that the ratio *s* between loading and unloading-reloading *cM* is about 4, consistent with in-situ expansions measured by the radioactive marker technique in similar reservoirs of the same basin. Even more interestingly, a traditional isotropic stress-strain model does not prove suitable for simultaneously matching both the vertical and the horizontal displacements. The basin overall 3D deformation is indeed well captured by a transversally isotropic model where the medium elastic properties in a horizontal plane differ from those in a vertical plane. In particular, the satellite observations are successfully predicted by setting *s*=4 and with a horizontal/vertical Young modulus ratio of 3, a Poisson ratio equal to 0.15 and 0.25 in the horizontal and vertical plane, respectively, and the same shear modulus in the two directions.

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