In-Situ Stress and Fault Reactivation Associate with LNG Injection in the Tienchanshan Gas Field, Fold-Thrust Belt of Western Taiwan

Jih-hao Hung (1) and Jong-chang Wu (2)

(1) National Central University, Taiwan, Geophysics, Jhongli, Taiwan (jhhung@ncu.edu.tw), (2) Exploration and Production Research Institute, Chinese Petroleum Corporation, Taiwan

The Tiechanshan gas field located in the fold-thrust belt of western Taiwan was depleted and converted into underground storage of Liquid Natural Gas (LNG) decades ago. Recently, CO$_2$ sequestration has been planned at shallower depths of the structure. In this study we intend to characterize the in-situ stresses from over 40 wells and assess the leakage potential through fault reactivation in response to pore-pressure increase as a result of LNG injection. Formation pore pressures ($P_f$), vertical stress ($S_v$), and minimum horizontal stress ($S_{hmin}$) were measured from repeated formation tests, density logs, and hydrofrac including leak-off tests and fluid injection, respectively. Formation pore pressures are hydrostatic above depths of 2 km, and increase with local gradients of 0.62 and 0.94 psi/ft above and below 3.2 km. Extremely high pore pressures ($\lambda_p=0.8$) are observed at depth below 3.8 km. Lower than normal pressures (average 0.42 psi/ft) are observed in the gas-bearing reservoir of Talu A-sand. The gradient of $S_{hmin}$ is $\sim 0.77$ psi/ft or equivalent to 0.74 of $S_v$ ($\sim 1.04$ psi/ft). Combined the structure contour map of A-sand top with measured $S_{hmin}$ and $S_v$, stress state in the Tiechanshan field is a predominantly strike-slip stress regime ($S_{Hmax} > S_v > S_{hmin}$). Without extended leak-off tests and images of borehole wall, the upper-bound values of maximum horizontal stress ($S_{Hmax}$) constrained by frictional limits and coefficient of friction ($\mu=0.6$) is about 1.21 psi/ft. Caliper logs from two wells show that borehole breakouts is oriented $\sim 28^\circ$N, or maximum horizontal stress being $\sim 118^\circ$N, which is sub-parallel to far-filed plate-convergence direction. Geomechanical analyses on the reactivation of pre-existing faults at the depths of LNG reservoir sand indicate that all faults are relatively stable. Sensitivity analyses of affecting parameters indicate even the pessimistic risk scenario would require $\sim 5.9$ Mpa excess pore pressure to cause the optimal oriented F1 fault to reactivate. This corresponds to LNG column height of $\sim 760$ m (density $\sim 790$ kg/m$^3$), whereas the structure closure of the A-sand does not exceed 400 m. Therefore, LNG injection will unlikely to compromise the F1 fault stability.