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Integration of subsurface dynamic coupled modelling and monitoring technologies for CCS: examples from existing projects

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Introduction

Host rock injectivity and storage complex integrity (containment) for CO_2 sequestration are critical factors to ensure that capacity targets are met while preventing CO_2 leakage over time and confirm permanent storage.

Figure 1 sketches the typical CO_2 injectivity problem. Evaluating injectivity, capacity and containment requires assessing key phenomena such as: seal and faults capillary controls, non-isothermal reactive flow, geomechanical failure induced in the seal, along faults and/or fractures and in the vicinity of the wells. Additional analyses will also be needed to evaluate the completion integrity of the wells (injectors, monitoring and existing wells) under variable load conditions in terms of pressure, temperature and chemistry. The listed phenomena, and their likely effects, are analysed by means of dynamic coupled modelling, considering co-existing (geo)mechanical and dynamic flow simulations. Therefore, coupled modelling improves the risk analysis allowing to evaluate the Thermo-Hydro-Mechanical-Chemical (THMC) processes associated to CO_2 injection.

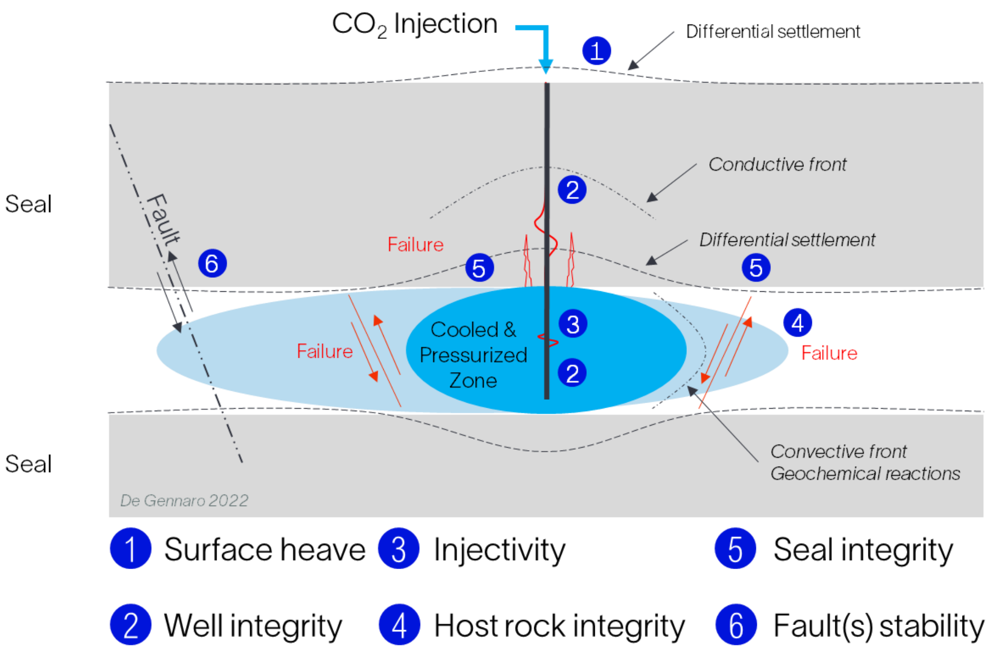

Figure 1: Coupled processes associated to CO_2 injection and their possible consequences.

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Analyses

In this presentation we will provide some examples of integration of subsurface dynamic coupled modelling and monitoring technologies for CCS. Some of these examples are derived from existing projects.

Injectivity impairment during CO_2 injection is a well-known issue often observed at well and field scale (e.g. Snøhvit, Ketzin, Decatur projects [1], [2]). Loss of injectivity is governed by the interactions between CO_2-brine phase behavior, CO_2-solid phase (rock) behavior, salt precipitation, multi-phase flow. Characterizing zonal injectivity and developing mitigation strategies will be therefore important for project success. Figure 2 (left and center) shows an example of time-lapse CO_2 saturation evolution during injection and consecutive non-isothermal processes associated to Joule-Thompson effect (H_2O vaporization, cooling and induced salt precipitation due to dry-out). Temperature and pressure changes can lead to near wellbore failure (thermal and pressure induced fracturing) impacting injection performance due to near wellbore fracturing and consecutive permeability changes (Figure 2 right).

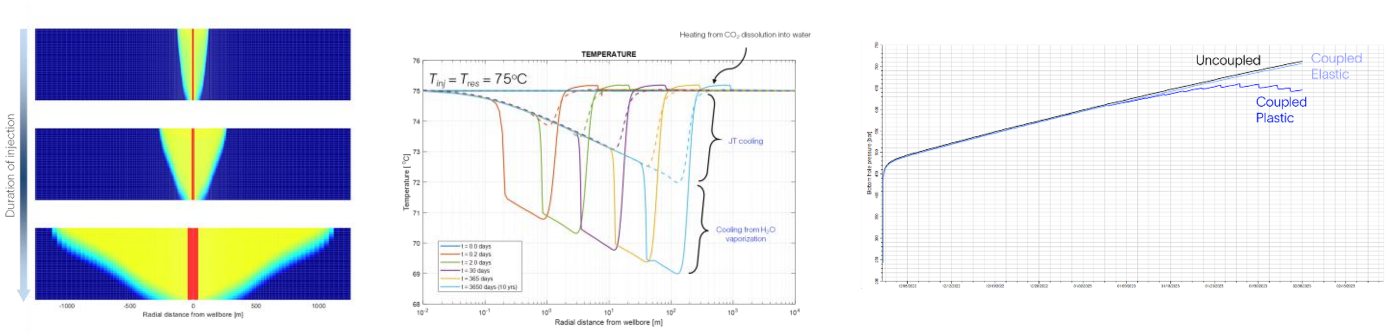

Figure 2: Time-lapse CO_2 saturation during injection (left), non-isothermal induced processes (center), bottom hole pressure decrease during injection due to near wellbore fracturing (right).

To close the evaluation loop, the integrated subsurface characterization workflow is completed by measurements to image the subsurface before and after CO_2 injection. This provides essential insights into the storage complex quality before injection and effective monitoring during injection and permanent storage, tracking the position of the CO_2 pressure and concentration plumes, assessing surface heave, and detecting any risks or potential leakage paths. There is a tight link between subsurface dynamic coupled modelling and existing monitoring technologies. This link expands the well-known MMV (Measurement, Monitoring and Verification) process into a more integrated 3MV process (Modelling, Measurement, Monitoring and Verification), opening to the definition of a subsurface digital twin supporting successful CCS operations. We will briefly introduce methods and technologies enabling the subsurface dynamic modelling and monitoring of CO_2 injection and storage. Seismic and borehole petrophysical and geophysical measurements for initial subsurface characterization and consecutive monitoring will be described.

Contributor statement

Writing, conceptualization, visualization: all authors.

References

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