Baseline characterization and modeling of a fractured reservoir for potential CO_2 storage: the Longyearbyen CO_2 Lab case study

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The aim of the Longyearbyen CO_2 Lab project is to develop an onshore, pilot-scale (ca. 60.000 of CO_2 tons/year) site for geologic sequestration of CO_2 in a tight, siliciclastic aquifer belonging to the upper Triassic-middle Jurassic De Geerdalen and Knorringfjellet Formations, located at 700-1000 m depth in Central Spitsbergen, Svalbard. We here present the baseline study of the target Mesozoic sedimentary succession, which integrates high-resolution structural and stratigraphic analyses of outcrop and borehole data. Through this integrated approach, we identified recurrent litho-structural and structural units (LSUs and SUs, respectively) on the basis of their fracture associations, lithologies and dominant sedimentary facies. A principal fracture set trending approximately E-W (J1) and a subordinate fracture set trending approximately N-S (J2) have been recognized. Subordinate systems of shear fractures (S1) trending roughly NE-SW and NW-SE, and a secondary low-angle, fracture set (S2) striking E-W to NW-SE have been observed. Their origin is interpreted as related to the far-field stress of the Paleogene West Spitsbergen fold-and-thrust belt. The identified units are thought to influence the local hydrogeologic regime due to the intrinsic variations in the matrix and fracture network properties. The architecture of the reservoir-caprock succession is thus segmented, with the vertical alternation of intervals characterized by varying 1) fracture porosity and permeability, 2) microfracturing-related matrix porosity, and 3) preferential subsurface fluid flow pathways. The moderate injectivity (ca. 45 mD/m) recorded during water injection tests suggests that CO_2 may potentially be injected and stored in the tight, naturally fractured reservoir of the Longyearbyen CO_2 Lab project, with a major contribution from the regional network of meso-scale fracture sets mapped and analyzed in both drill cores and outcrops. Due to the present day stress regime and the orientation of the most promising fracture systems (i.e. J1) in terms of possible fluid conductivity, we propose a NNW-SSE oriented horizontal drilling of the injector well at the reservoir level to optimize the fracture permeability and to maximize the related fluid flow. In the proposed framework we expect an E-W spreading of the injected buoyant plume with a focussed drift toward the E-NE, through horizontal and vertical diffusion within the finer- and coarser-grained intervals, respectively. The derived semi-quantitative results are recommended for the reservoir modeling efforts. Accordingly, the processed data were directly used as input parameters in the development of a static geological model of the unconventional target aquifer.