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Seismic Methodology for Characterization of Deep Saline Aquifers for CO2 Storage

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The MUSTANG Project attempts to develop and disseminate tools and methodologies for the identification, assessment, characterization and evaluation of deep saline aquifers for CO2 storage. The Heletz area is located in Israel, in the southern part of the Mediterranean Coastal Plain, about 7 km from the sea shore. The target CO2 storage layer is heterogeneous and consists of sandstone, low-permeability sandstone and shale. Approximately 1400 tons of CO2 are planned to be injected at a depth of approximately 1600 m. The diameter of the plume is expected to be of the order of 100m. It is not expected that conventional seismic reflection surveys produce an image of a plume of this size. Diffractions and a non-coherent backscattering may however appear as local changes of amplitude and phase. The approach discussed is to detect, as opposed to delineate, a small CO2 plume, by means of limited and/or sparse seismic arrays. Such arrays could reasonably be installed permanently or semi-permanently, to allow cost-effective active and passive measurements from surface and boreholes. Small amounts of CO2 can be mapped by borehole seismic methods.

Seismic modelling studies were carried out in support of determining suitable source and receiver geometries and most appropriate seismic source frequencies. The main reason for carrying out these studies is that 3D surface seismic surveys are expensive and time consuming to perform and borehole methods only provide data in the vicinity of the boreholes. Migrated images of surface lines and VSP profiles were modelled. The CO2 plume intersected at the correct depth and displayed the correct lateral extent. The surface source and receiver spacing was 12 m. Borehole receivers were 80, placed at 5 m intervals. Modelling results showed that a reduced number of active sources and receivers can be used to detect subsurface changes that may be induced by injection of a relatively small amount of CO2. Pseudo 3D coverage could be obtained with relatively sparse coverage from surface & borehole.

Pairs of profiles were modelled without and with the CO2 plume, as generated by sources with centre signal frequencies from 10 Hz to 100 Hz. Above 50 Hz the caprock layer and the CO2 plume become clearly distinct. However, frequencies above 80-90 Hz were required to detect non-ambiguously the plume. At Heletz, such frequencies can be difficult to obtain using surface sources and receivers. Therefore, it is recommended that borehole seismics should be used.

At the cost of reduced resolution, low frequencies allow larger volumes to be probed. The capability of producing and recording high frequencies should also be conserved for detailed monitoring whenever possible. Various ideas and designs are being considered, in order to extend the bandwidth.

Further models must be built having in mind the possibility of validating them by a real life experiment. After all the practical details are clarified, the planned experiments should be modelled with the highest accuracy possible with respect to the layout and with a maximum of available data regarding the geology, hydrogeoplogy, structure and physical properties at the experimental site.

The most challenging issue will be to demonstrate that containment will be effective in the short and long term. This involves firstly determining the spatial extent and geometry of the seal and predicting (and subsequently monitoring) the size of the injected plume of CO2. It must also be demonstrated that the seal is not compromised by faults, fractures or thinning over the entire potential footprint of the CO2 plume. The detection of steep structures before injection can be difficult solely by surface methods but the VSP layout, with a receiver array extended vertically in a borehole, can accomplish this task.