Monitoring of a CO_2 injection by time domain SIP

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Contamination of potable groundwater by leaking CO_2 is a potential risk of carbon sequestration. With the help of a field experiment, we investigate if surface monitoring of electrical resistivity and induced polarization can detect geochemical changes induced by CO_2 in a shallow aquifer. For this purpose, we injected CO_2 at a depth of 5 and 10 m and monitored its migration using 320 electrodes on a 126 m × 25 m surface grid. A fully automated acquisition system continuously collected direct current (DC) resistivity and time domain full-decay induced polarization (IP) data using a Syscal Pro resistivity meter. CO_2 was injected for a period of 72 days and DC/IP monitoring started 20 days before and continued until 120 days after the beginning of the injection. The DC/IP data were supplemented by chemical analysis of water samples collected in 29 wells at time intervals of approximately 10 days (Cahill et al. subm.).

The high temporal sampling of the DC/IP data allowed detailed analysis of the resistance time-series for each measurement configuration (quadrupole) for outlier detection and error estimation (for details, see Auken et al. 2014). The time domain IP decays were also estimated for each quadrupole and each of the 20 time gates, using data variation within 2-5 day time windows. Baseline and time-lapse DC data were inverted in 3-D using the finite-element program BERT (Günther et al. 2006). The time-lapse inversion used differences in measured resistances to invert for changes in resistivity. Figure 1 shows the DC inversion results as resistivity ratio between the time-lapse results and their pre-injection values and compares them to the water sampling resistivity results. Both methods independently show a consistent decrease in resistivity that is moving advectively with the groundwater. The decrease in bulk resistivity is therefore attributed to a decrease in water resistivity, caused by the dissolved CO_2.

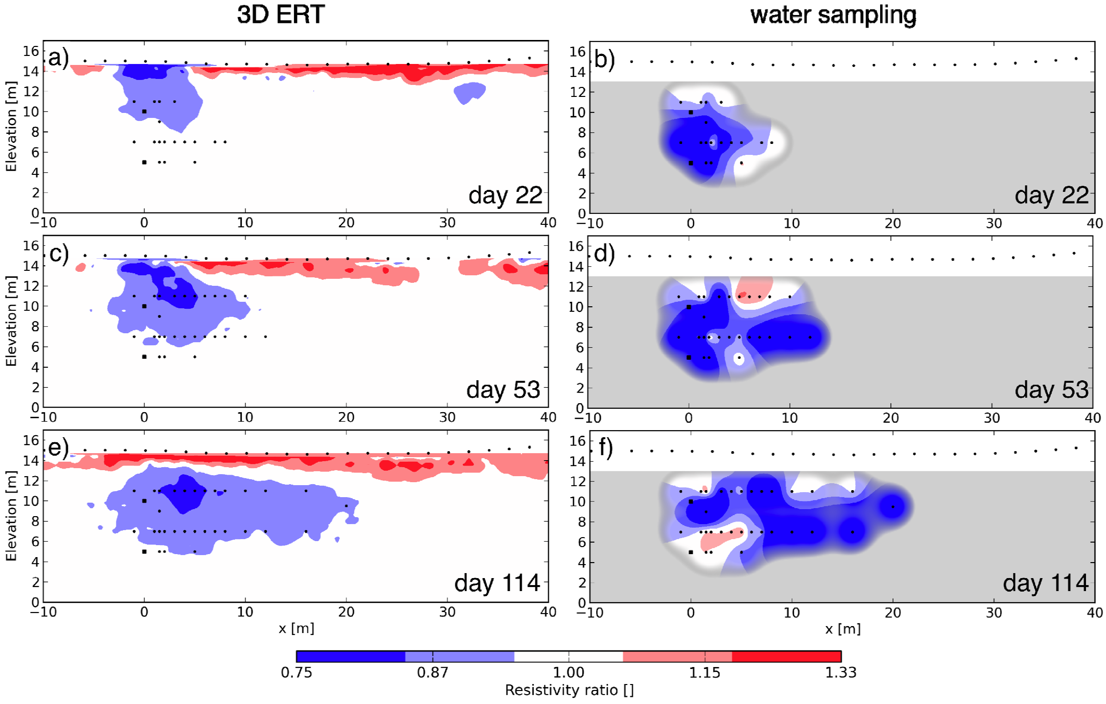

Fig. 1: Comparison of resistivity variation from 3D ERT inversion results (left panels) and groundwater samples (right panels) at 22, 53 and 114 days after the beginning of CO_2 injection. Shown resistivities are normalized by their pre-injection (baseline) values. Black dots at the surface indicate electrodes; black dots below the surface indicate water sampling locations. From Auken et al. (2014).

DC and IP data are inverted jointly using the 2-D algorithm AarhusInv (Fiandaca et al. 2013) that incorporates the full voltage decay of the IP response to resolve DC resistivity, intrinsic chargeability and spectral IP content parameterized using the Cole-Cole model. Following the injection, we use a time-lapse inversion where differences in the DC/IP data are inverted for changes to the Cole-Cole parameters. Data differencing is here used both for the DC-resistances and each time domain IP gate. The resistivity sections of the DC/IP inversion results are consistent with the 3-D DC-only results discussed above. Additionally, a chargeability (m_0) decrease has been observed after the injection, but in contrast to the decrease in DC resistivity, the chargeability anomaly remains localized around and slightly downstream of the injection wells throughout the experiment (Fig. 2). This chargeability decrease correlates in space and time with an increase in Al^{3+}, which is observed in the water samples and is caused by a decrease in pH. Consequently, we attribute this change in chargeability to pH-induced changes to the grains surfaces.

These results highlight the potential for monitoring of field scale geochemical changes by means of surface DC/IP measurements. Especially the different development of the DC resistivity and chargeability anomalies and the different associated geochemical processes, highlight the added value of induced polarization to resistivity monitoring.

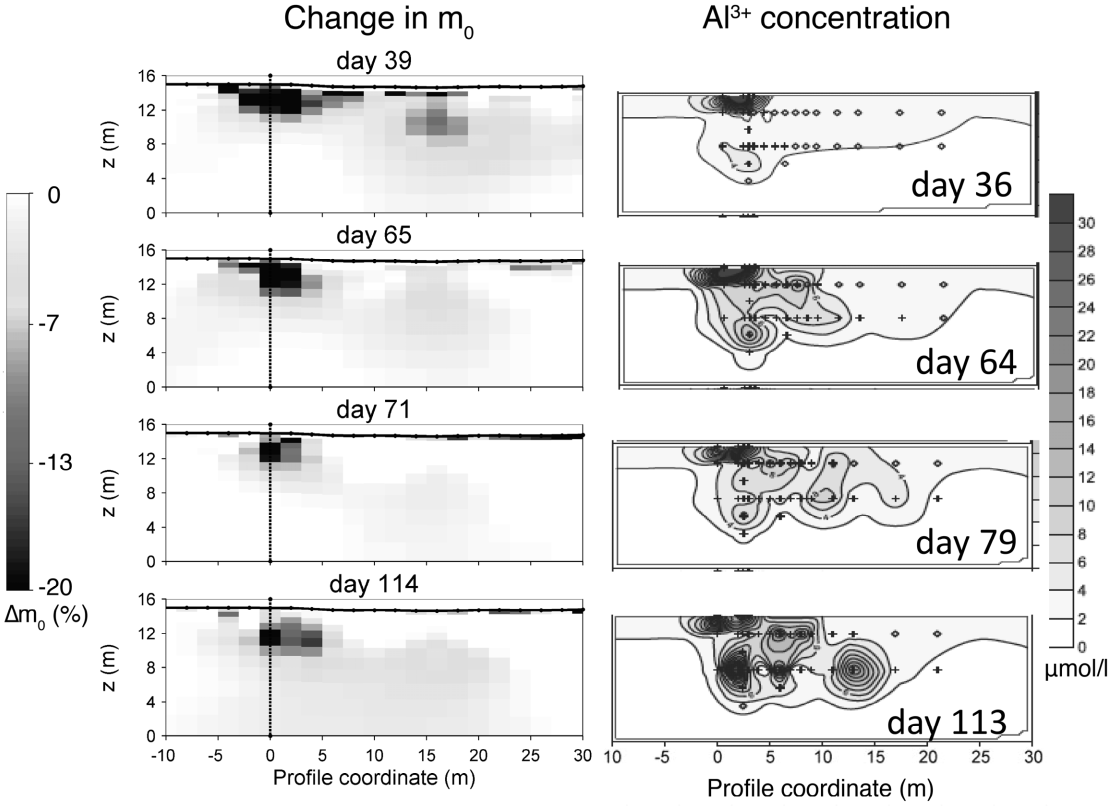

Fig. 2: Comparison of relative change in chargeability m_0 (left panels) and water-sample aluminium concentrations (right panels) for four times.

References

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