Evaluation of ERT data acquisition geometries for robust monitoring and time-lapse studies

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Summary

This paper focuses on the use of surface and borehole DC/IP electrical methods for monitoring of near surface hydrogeophysical and petrophysical parameters. Integrated surface, borehole and borehole-to-borehole DC/IP test surveys have been conducted to evaluate acquisition strategies for monitoring of temporal and spatial variations in conductivity and chargeability. We have established that borehole-to-borehole acquisition geometries are best suited for fully repeatable DC/IP measurements. The use of surface electrodes may introduce severe challenges for the processing and interpretation of time-lapse surveys.

Introduction

DC/IP electrical resistivity surveying along the earth's surface is a well established hydrogeophysical exploration technique. Due to its conceptual simplicity, low equipment costs and ease of use the method is routinely applied in near surface groundwater exploration and aquifer monitoring. Borehole resistivity tomography, in which both current electrodes and borehole electrodes are place in two (or more) boreholes, can provide detailed information about subsurface resistivity distribution between the boreholes (Daniels & Dyck, 1984; Shima 1992) and can be used for time lapse tracer monitoring studies (Mueller et al, 2010). During the summer of 2011, we have collected several surface, borehole-to-borehole and borehole-to-surface ERT (electrical resistivity tomography) studies. Various 1D, 2D and 3D acquisition geometries are shown in Figure 1a. What is unique about the DC/IP data acquisition system is its electrode and borehole design, which allows seamless integration of borehole and surface measurements (Qian et al., 2007). We use this configuration for resistivity tomography proposed by Zhou and Greenhalgh (2000). In this configuration, geometrical factors accounting for near the air-earth surface effects must be applied (Qian et al., 2007). The use of multi-electrode borehole cables (with up to 24 electrodes each) allows the system to acquire more than one thousand DC and IP readings of full waveform data.

Repeatability

A castle waveform of current was injected into the formation. A complete measurement cycle for combinations of borehole and surface electrodes (Fig. 1a) took approximately 25 minutes. Data were grouped into 3 categories: borehole-to-borehole, borehole-to-surface and surface-to-surface measurements. Figure 1b shows an example of source signal (left panel) and voltage measured (right panel) for a borehole-to-surface acquisition geometry. While the injection current remains constant (Fig. 1b, left panel), the voltage measurements with electrodes at the earth's surface exhibit high temporal variability (Fig. 1b, right panel). In contrast, the borehole-to-borehole surveys were highly repeatable.

References

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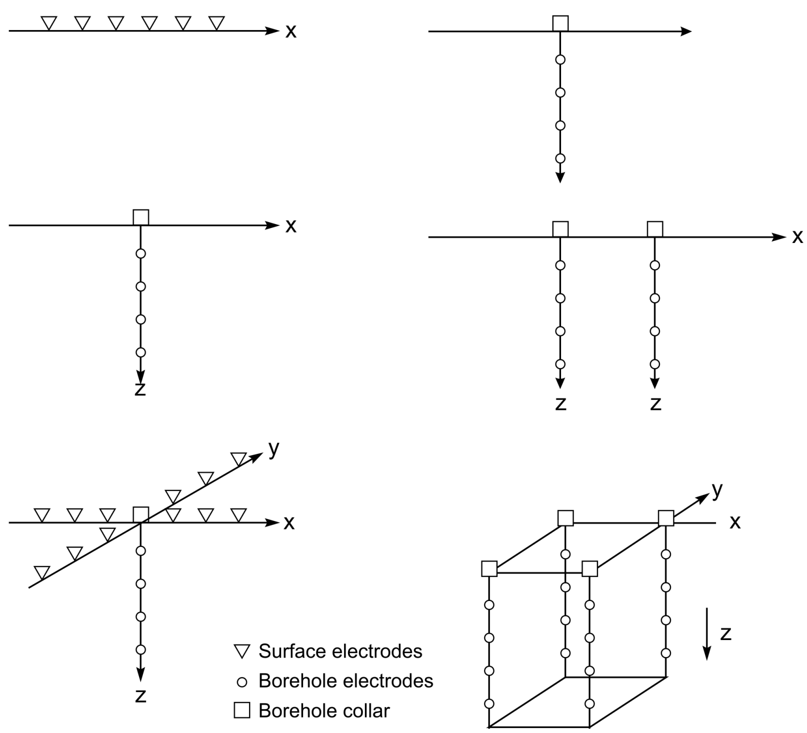

Figure.1a Surface and borehole DC/IP acquisition geometries evaluated for time-lapse and monitoring studies. Multi-electrode borehole cables were deployed in water-filled boreholes.

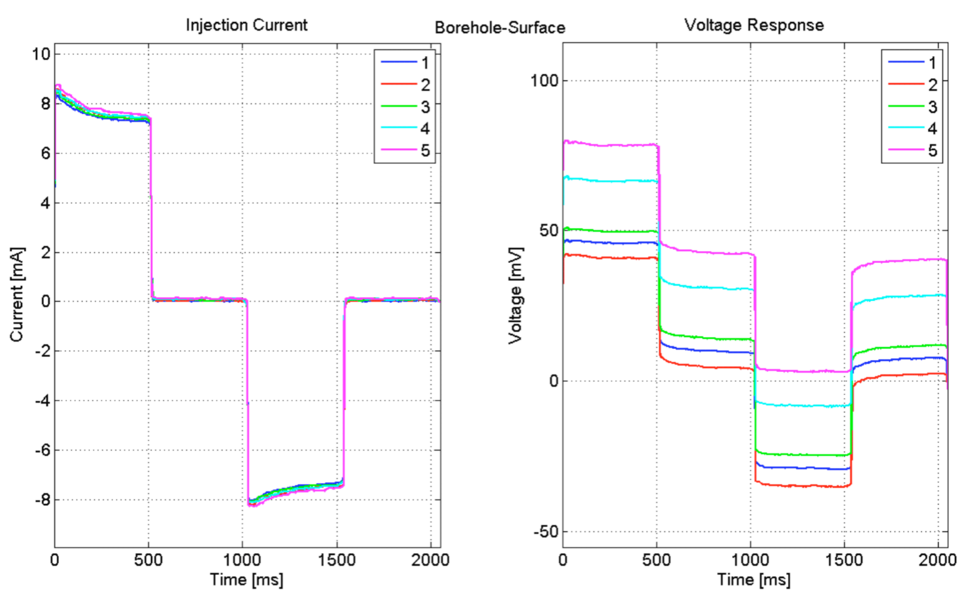

Figure. 1b Example of repeat measurements of injection current, I(t), and potential, V(t), for a fixed borehole-to-surface acquisition geometry. Note the stable injection current and temporal variation in V(t) (observation times marked 1 to 5).