Borehole Resistivity Logging and Tomography for Mineral Exploration

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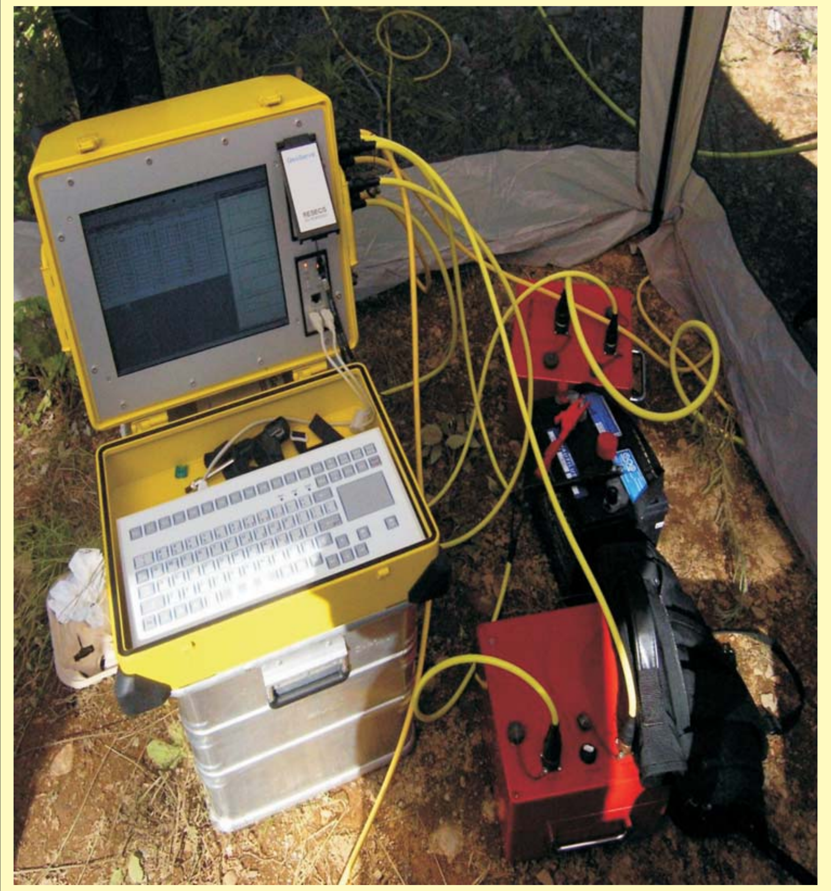
Abstract

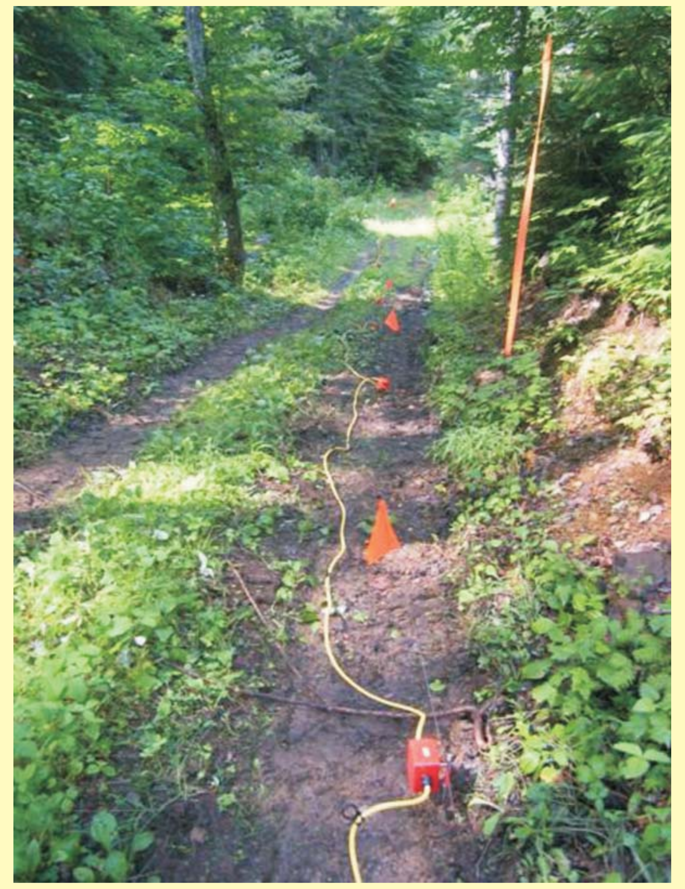
This paper focuses on the use of cross-borehole electric methods in ore body delineation. A BRT (Borehole Resistivity Tomography) test survey has been conducted to map massive sulfide zones between boreholes up to 130 m apart. The boreholes need to be water filled, so as the electrode array couples to the rock formation. We have established a multi-step procedure for data acquisition, processing and interpretation. Between boreholes, we have successfully imaged the massive sulfide mineralization in a very resistive host. We have demonstrated that the equipment is easy to deploy in water filled boreholes and we conclude that single borehole Vertical Resistivity Profiling (VRP) data can detect conductive zones within a 30 m range around the borehole and it also provides an independent estimate of bulk (4 - 100 m) resistivity for calibration / interpretation of other EM datasets. The cross-borehole tomography data can map conductive zones between boreholes up to 130 m apart. We did not test the larger offset during the present experiments.

Instrumentation and Data Acquisition

Data Acquisition System



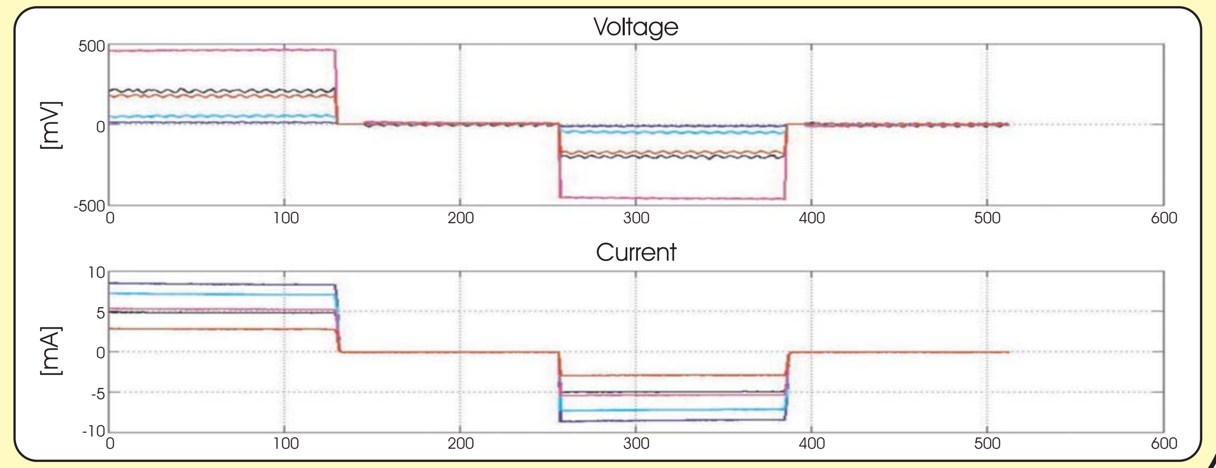
Surface Line Layout



Borehole Cable

- Very easy to deploy in open, water-filled boreholes
- Can acquire vast amount of data rapidly
- Only battery power required
- Instant QC during data aquisition
- Rugged design
- Near real time data inversion

Typical Waveform Data Acquired

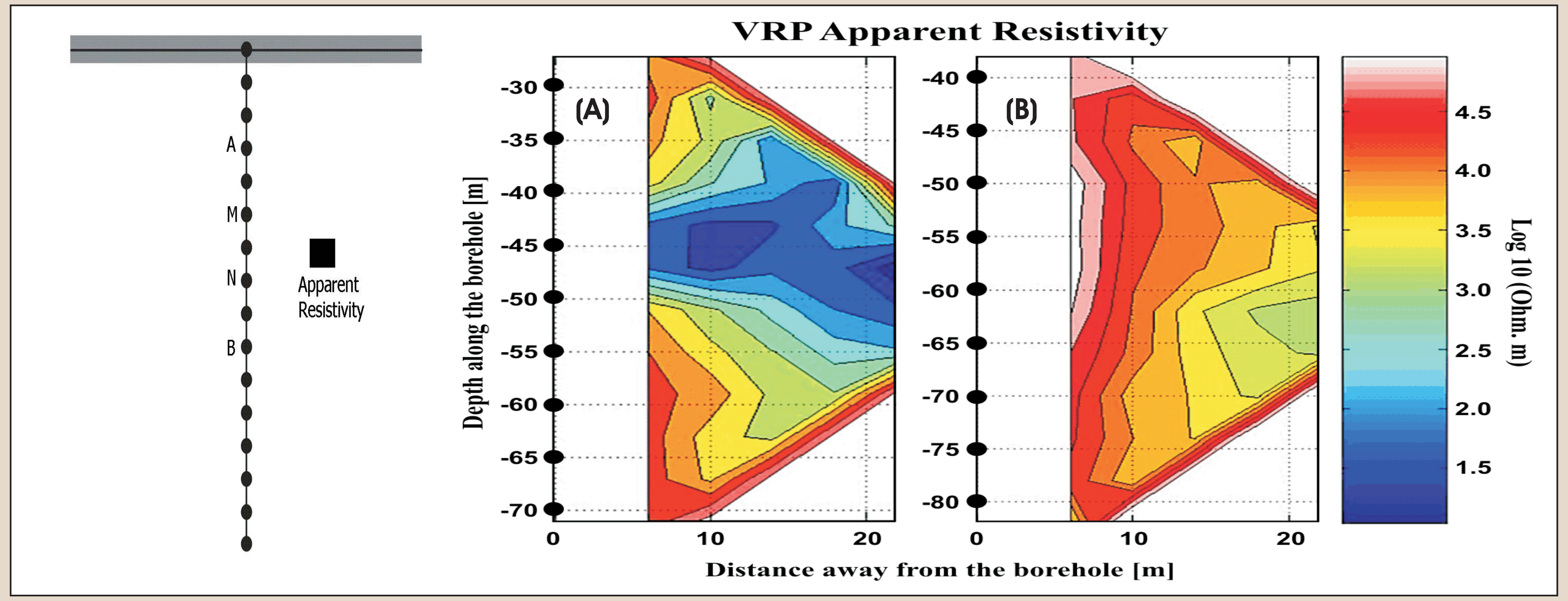


Vertical Resistivity Profiling (VRP)

From the electrode array in a single borehole, we perform Vertical Resistivity Profiling (VRP), in which the current and potential electrode setup is the same as surface Schlumberger survey. The measured voltages are converted into apparent resistivity through a geometry factor, which takes into account the earth-air surface. The apparent resistivity pseudo-section is created by assigning the apparent resistivity at AB/2 away from the borehole. The VRP data can usually be collected within half an hour. This data provides bulk (~ 4 m) and in-situ resistivity measurements for the calibration / interpretation of other EM data sets. Furthermore, the VRP data gives information about the resistivity structures in the vicinity of the borehole. In the following figure, we show VRP data characteristics for two different situations:

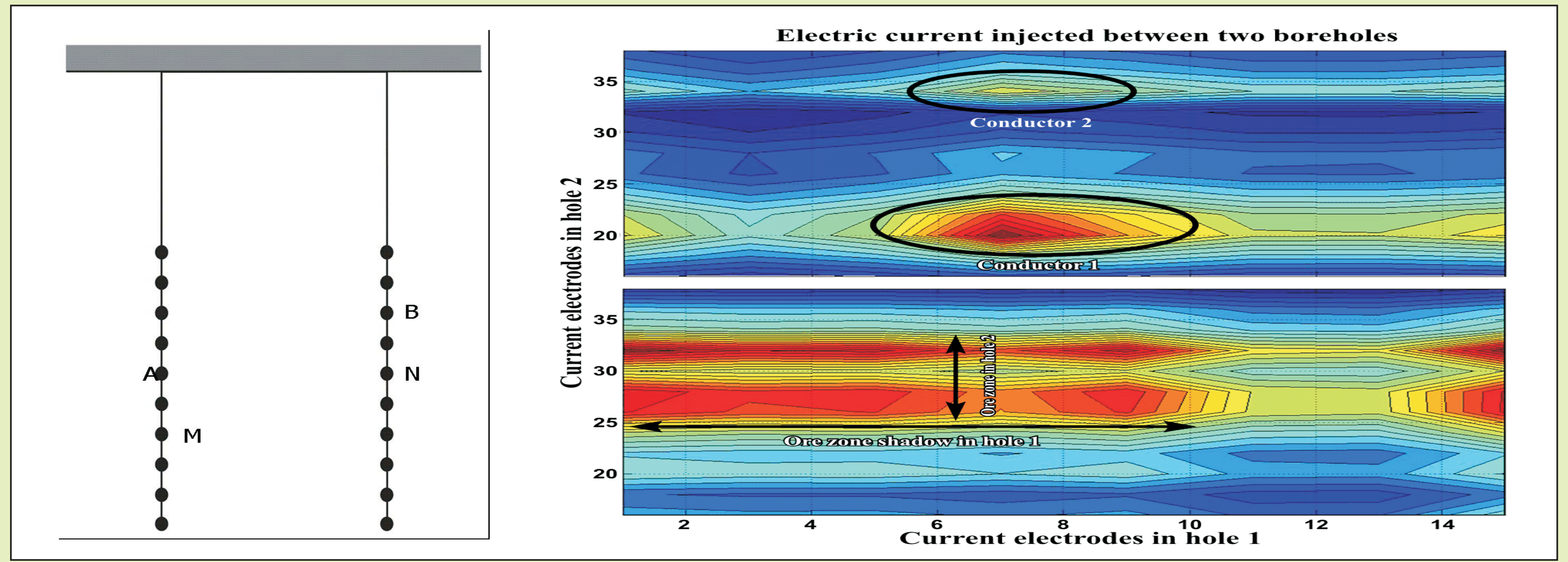
(A) Borehole intersects sulfide zone; From the apparent resistivity pseudo-section, we can clearly identify that the sulfide zone has an apparent resistivity of less than 50 ohm.m. This zone is located between the depths of 40 and 50 m and its lateral extension is more than 30 m. There is a tinge of a weak conductor at the depth of 25 m. This thin zone is not in contact with the borehole.

(B) Borehole pass by a sulfide zone at a distance; The VRP apparent resistivity pseudo-section shows that there is a conductive zone at the depth of 60-70 m. This zone is about 10 m away from the borehole.



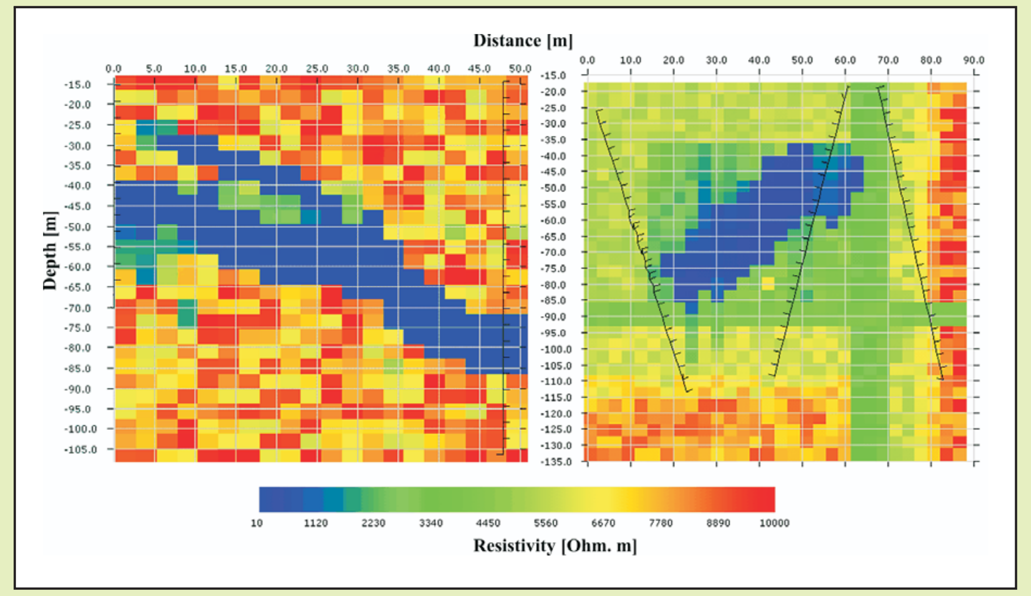
Cross Borehole Electric Current Mapping: A Quality Control Tool

When a constant injection voltage is applied between electrodes A and B across the two boreholes, the electric current flowing between A and B depends on the contact resistances of electrodes A and B, and the rock formation resistance from A to B. If the borehole is water filled, we can assume the contact resistance is uniform. Thus the electric current from A to B maps the rock formation resistance between points A and B. Two examples of the electric current between A and B is shown in the figure below. Note the data shows characteristics of two conductive zones between the two boreholes. The borehole separation is 48 m. The second example shows a case where one borehole intersects an ore zone, while the other borehole passing this zone at a distance. We can see that for the borehole intersects the ore zone, large electric current is observed for electrodes within certain depth range. For the borehole passing the ore at a distance, the ore zone shadow is visible from the injected electric current.



Cross Borehole Resistivity Tomography (BRT)

We construct the BRT model by applying the following steps: (1) use VRP pseudo section to build a starting model at the two borehole locations; (2) perform inversion on VRP data only (use the starting model to constrain the inversion, no smoothness stabilizations applied); (3) build a starting model between two boreholes using the two resistivity inversion models derived from VRP data; (4) constrain the near borehole resistivities and let the tomography inversion adjust the resistivities in the central region; and finally (5) fine tune the tomography inversion model with geological / petrophysical constraints (where available). Two BRT models from two survey locations are shown below with borehole traces.



Conclusions about the Geoserve Survey

- Detect conductive zones in the vicinity of a borehole
- Provide independent estimate of bulk (4 - 100 m) resistivity data for calibration / interpretation of other EM datasets
- Map conductive zones between boreholes (tested up to 180 m apart)
- Works for weak and strong conductivity contrasts
- Very easy field operation procedures

Acknowledgements

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