Z-99 In-mine electrical resistance tomography for imaging the continuity of tabular orebodies

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Abstract

One of the strengths of the electrical resistance tomography (ERT) technique is its flexibility in terms of survey geometries. In this paper an unconventional and novel ERT application that is geometrically analogous to in-seam seismic tomography is introduced. The novelty of the application is its in-mine tunnel-to-tunnel use to target a thin, near-horizontal, tabular orebody. The objective of this ERT application is to delineate geological features that disrupt the lateral continuity of the economic horizon. Results from in-mine trial surveys are presented to support the concept.

Introduction

The majority of documented ERT applications in earth sciences relate to either cross-borehole or 2D surface profiling surveys. In these cases the output is a vertical cross-section of subsurface resistivity variations, and the purpose of the surveys is to correlate this output with geological or environmental anomalies in the otherwise undisturbed background. The ERT application introduced in this paper differs from the above in that it does not exploit boreholes or the earth's surface, and in that it produces near-horizontal cross-sections rather than vertical sections through the subsurface. In other words, the image plane does not cut across the normal stratification, but is oriented parallel to it and is effectively the tomographic footprint of a single thin geoelectrical layer. The application in question is that of in-mine tunnel-to-tunnel ERT in platinum mines of the Bushveld Complex of South Africa. This igneous complex is the world's primary source of platinum, with approximately 75% of the world's production and reserves being attributed to it (Cawthorn, 1999). The mineralisation occurs in thin, near-horizontal tabular orebodies, locally referred to as reefs. These reefs exhibit remarkable lateral continuity over vast distances and are, from a regional perspective, relatively straightforward to mine. On a mine scale, however, the continuity of the reefs is often disrupted slump structures, locally referred to as 'potholes', and iron-rich ultramafic pegmatite bodies (IRUPs). Mine-scale potholes and IRUPs may vary in size from only a few metres to several tens of metres and can result in local distortions or discontinuities in the reef horizon, with inevitable adverse economic implications. The detailed extent and geometry of potholes and IRUPs are unpredictable and quantitative advance knowledge of these disruptive features is highly desirable in terms of mine planning. In the last three years the concept of using ERT to solve the problem of delineating these disruptive features ahead of mining was investigated as part of an ongoing collaborative research programme, known as PlatMine. PlatMine is co-sponsored by CSIR, Division of Mining Technology (Miningtek) and four major platinum mining houses. In this paper the concept of tunnel-to-tunnel ERT is described and is illustrated with results from a couple of promising trial survey case studies.

Description of typical mining layout and ERT survey parameters

In recent years ERT has evolved into a mature geophysical imaging method and the underlying principles and theory are well documented (Beasley and Tripp, 1991; Daily and Owen, 1991; Griffiths and Barker, 1993) and will not be repeated here. The focus of this paper is on the unique geometrical and logistical challenges of in-mine, tunnel-to-tunnel ERT in a hard rock geological setting. The typical depth of underground platinum workings in the Bushveld Complex is a few hundred metres below surface. To access the orebody, vertical mine shafts are developed from surface and through the tabular orebody (Figure 1). Strike-parallel haulage tunnels are developed from the shaft along the orebody, at different levels above and below the orebody. A series of parallel cross-cut tunnels branch out perpendicularly from these haulages and intersect the plane of the orebody. From these intersection points, raises are developed in the plane of the orebody, in directions perpendicular to the strike (up-dip and down-dip). Mining activities (drilling and blasting) are started from within these raises, and the virgin block between two adjacent raises is gradually mined out in segments called panels. A natural support pillar is typically left behind. Depending on factors such as the mining method and the dip of the orebody, the typical raise spacing may vary from 35 m to 200 m.

In-mine ERT data is acquired in a manner similar to that of conventional surface dipole-dipole resistivity imaging. A fixed source and receiver dipole length is used and the ideal is to acquire measurements for all possible combinations of source and receiver electrode pairs. A typical survey thus comprises a combination of in-line dipole-dipole measurements along the respective tunnels, and tunnel-to-tunnel measurements in which the source and receiver dipoles are located in opposite tunnels.

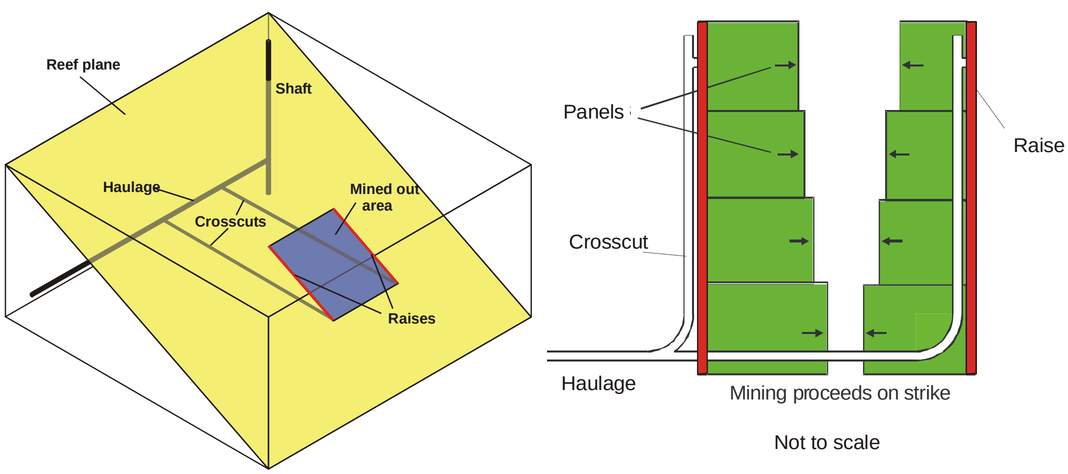

Figure 1: 3D and 2D schematics of the typical platinum mining layout and method

Trial survey 1 – Western Platinum Mine (WPM)

The WPM site has been developed on the Merensky Reef and is framed by two raises spaced 35 m apart (Figure 2). The primary targets were known pothole and IRUP occurrences observed in the tunnels and the mined out area surrounding the survey area. A mine plan shows the inferred targets based on available geological information (Figure 2). A standard dipole-dipole survey that involved 24 electrodes was conducted. Galvanic coupling with the sidewalls was established by using anchored bolts. The ERT output image is also shown in Figure 2. The resistive anomaly (A) located in the centre of the image correlates well with the observed signs of potholing in the raise tunnels and appears to be associated with the pothole occurrence in the mined out area in the northeastern corner of the survey area. The extremely resistive anomaly (B) is interpreted as the combined effect of the inferred smaller pothole in the vicinity of electrodes 16 and 17, the known IRUP occurrence in the southwest corner of the survey area and the large pothole located southeast of the survey area. The fact that the IRUP extends further north than inferred on the mine plan was confirmed by a post-survey underground visit.

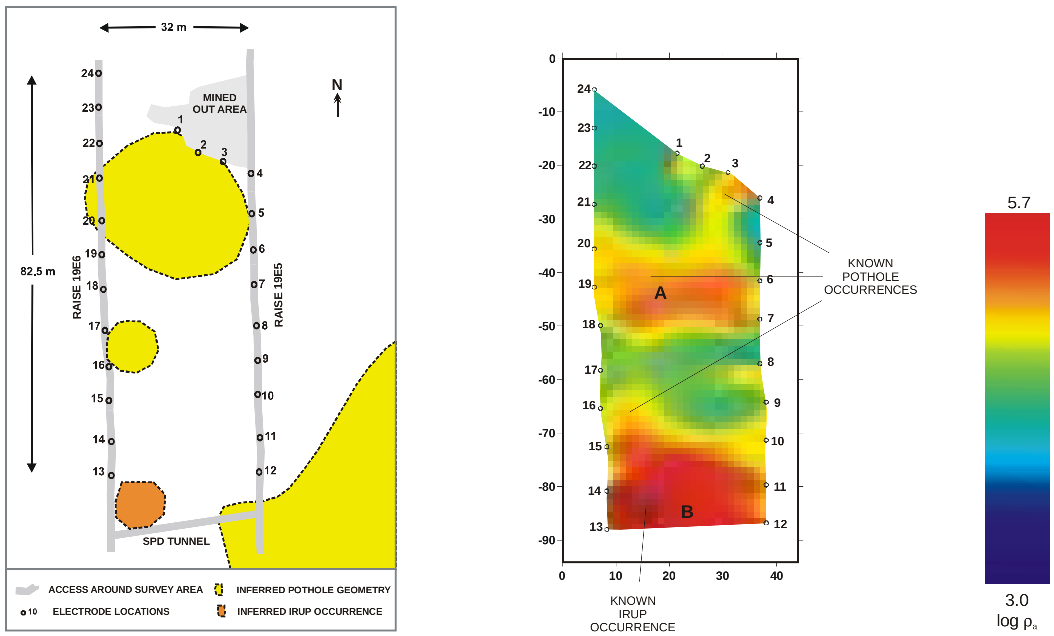

Figure 2: *ERT trial survey result from Western Platinum Mine*

Trial survey 2 – Eastern Platinum Mine (EPM)

The EPM survey area had a similar geometry to that of the WPM site except that the site is developed on the UG2 Reef and that an additional strike parallel development or SPD was exploited (Figure 3). A total of 34 electrodes were employed around the survey block and a standard dipole-dipole configuration was used. Galvanic coupling with the sidewalls was established with the use of conductive paint. The ERT result is shown in Figure 3. The position of a geologically inferred circular pothole near electrode 13, which is the intended target, is indicated. At first glance the output image appears to be somewhat disappointing in that the target is not detected. Instead, two other prominent resistive anomalies are evident, one around electrode position 30 and one between the raises near the northern side of the survey area. There is also a further isolated weakly resistive anomaly in the vicinity of electrode 9. A thorough analysis of the detailed geological information that was obtained after the ERT survey revealed that the inferred pothole does not affect the UG2 reef horizon itself, but only the immediate footwall layers. The absence of slumping on the reef explains the non-detection of the inferred pothole. A gentle roll in the UG2 topography is present in the vicinity of electrode 9. Along this 12-15 m stretch, the UG2 top contact slumps approximately 2-3 m, explaining the weakly resistive anomaly observed in the image. A localised zone where the UG2 splits up and almost ‘disintegrates’ into minor chromitite stringers is present in the vicinity of electrode 30. The disruption to the lateral continuity of the reef and hence to the electrical continuity accounts for the prominent resistive anomaly observed in the output image. The prominent resistive anomaly near the northern end of the survey area is possibly another disruptive feature. It must, however, be pointed out that image resolution is expected to be very low where this anomaly occurs and it should therefore be interpreted with caution.

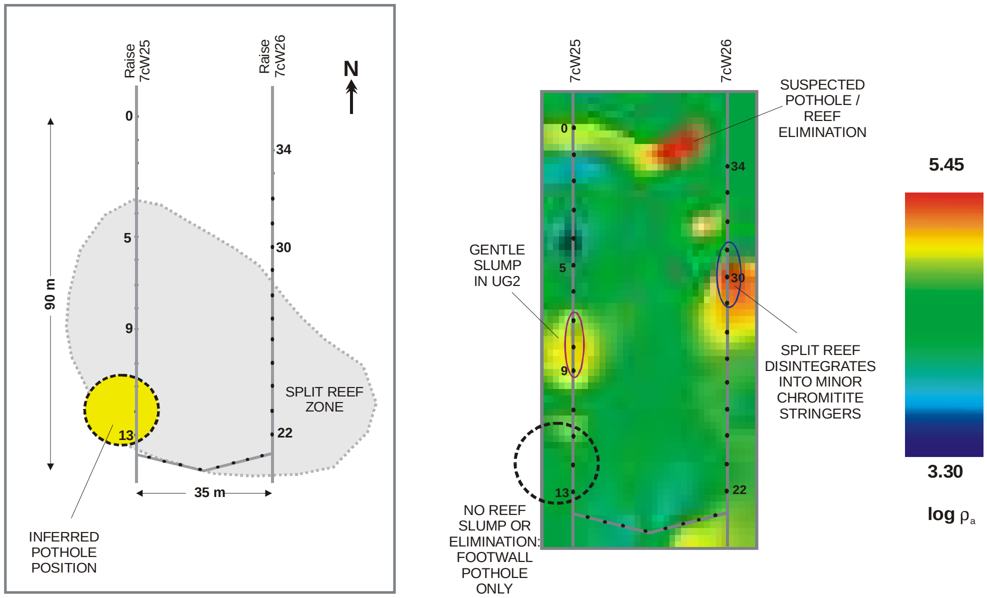

Figure 3: ERT trial survey result from Eastern Platinum Mine

Conclusions

ERT is capable of detecting local topographic and grade variations that affect thin tabular orebodies ahead of mining. Disruptive features manifest as resistive anomalies on ERT images because of the distortion of, or discontinuity in, an otherwise continuous conductive plane associated with the mineralised zone. Information obtained through routine in-mine ERT surveys can be used to predict reef elevation changes and low grade areas, and mine planning can be adjusted accordingly. Mineral extraction can be optimised by locating natural support pillars in affected areas and by avoiding unnecessary delays in production. The unconventional ERT application described here may also prove useful to geometrically similar near-surface problems. For example, in civil engineering ERT could be used to image the integrity of concrete slabs in cases where access for geophysical monitoring is only available around the sides of the slab. The imaging of anomalous features within earth layers immediately below infrastructure such as buildings or dams is another possible ERT application.

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References

Beasley, C.W. and Tripp, A.C., 1991. Application of the cross-borehole direct-current resistivity technique for EOR process monitoring - a feasibility study. *Geoexploration*, **28**, 313-328.

Cawthorn, R.G., 1999. Platinum in South Africa. *South African Journal of Science*, **95**, 481-489.

Daily, W. and Owen, E., 1991. Crosshole resistivity tomography. *Geophysics*, **56**, 1228-1235.

Griffiths, D.H. and Barker, R.D., 1993. Two-dimensional resistivity imaging and modelling in areas of complex geology. *Journal of Applied Geophysics*, **29**, 211-226.