3D FAULT INTERPRETATION FROM BOREHOLE RADAR IMAGING IN AN UNDERGROUND THREE-HOLE DRILL FAN

SUMMARY

Increased certainty in a previously modelled fault location is required prior to the advance of underground mining operations.

Joint, 3D interpretation of borehole radar data acquired in an underground three-hole drill fan yields a high certainty interpretation for geological and structural features which were not intersected by the drill holes.

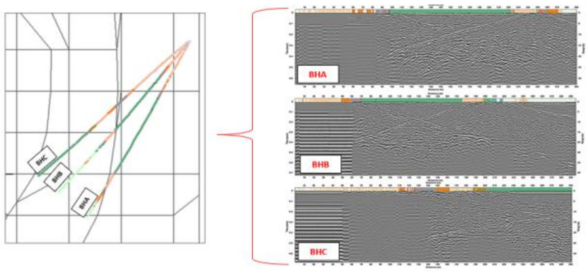
PROBLEM

Underground mining operations extracting mineralised chromitite layers (reefs) within the Bushveld Igneous Complex often face geomorphological complexity associated with syngenetic slumping and subsequent brittle deformation (faulting). Three sub-horizontal boreholes of ~300m in length were drilled ahead of underground development to map the location of the UG2 reef and locate a previously modelled fault. The holes were drilled from the same collar in the UG2 hanging wall, intersecting the UG2 some distance along the borehole and terminating in the footwall.

After the completion of the three holes, core logging captured the UG2 intersection in each borehole but failed to locate the modelled fault. Uncertainty in the location, orientation and throw of the fault remained.

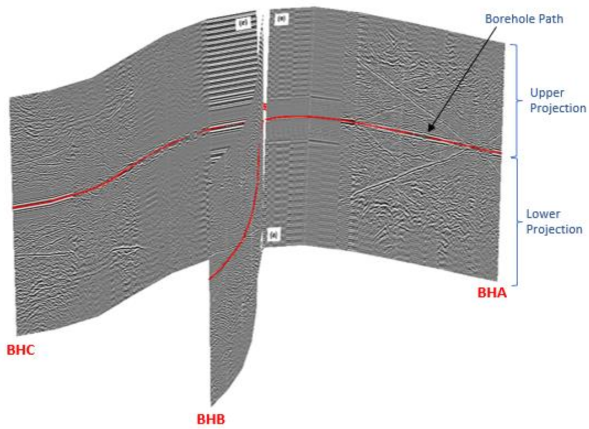
SOLUTION

A suite of downhole tools, which included borehole radar (BHR), was deployed in each hole. Of the tools deployed only the BHR has the capacity to image reflectors away from the borehole. In this case the BHR imaged reflectors some 35 to 40m into the formation.



Orientation of the three boreholes in the drill fan with captured 2D radargrams for each borehole.

Knowing the regional dip for the UG2 reef, the 2D radargrams can be orientated in 3D space and attached along the borehole path. A second set of radargrams projected at 180 degrees to the first facilitate the continuous interpretation of any radar reflector along its entire length.



2D radargrams projected above and below the borehole path (red line) in 3D space.

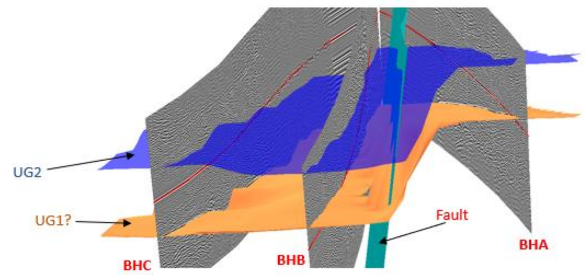
In all three boreholes the radar reflectors could be attributed to the UG2 (upper reflector) and a lower reflector parallel to the UG2 (possibly the UG1).

With the radargrams orientated in 3D space, creation of triangulated surfaces for the UG2 and the lower sub-parallel reflector make it possible to infer the location and throw on the fault between BHB and BHA.

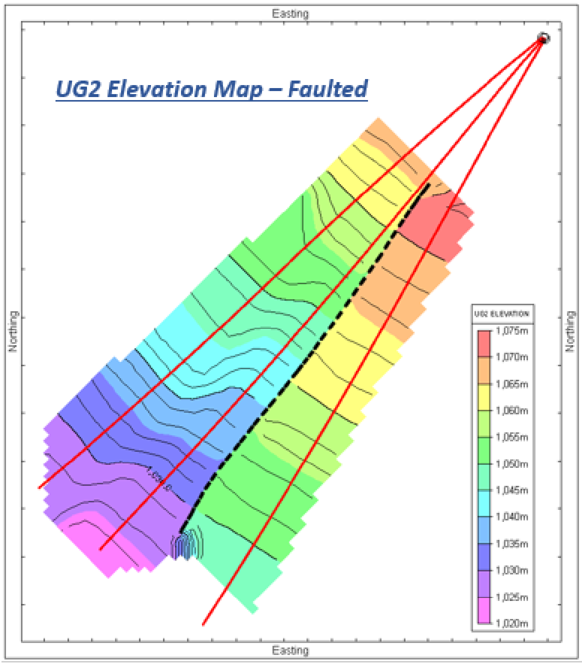
IMPACT

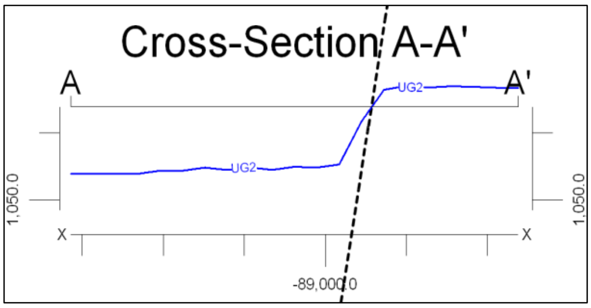
Conventional core drilling often under-samples the near-mine volume, resulting in elevated technical risk associated with advancing underground excavations. The ability of BHR to map reflectors away from the borehole de-risks advances by locating geological and structural features in the off-hole rock mass. BHR maximises the value of boreholes with comparatively low additional cost and time investment.

Jointly interpreting multiple, closely-spaced radargrams in 3D, enhances the possibility of interpreting off-hole features not directly apparent as reflections within the individual radargrams.



Digitized triangulated surfaces for the UG2 (blue) and sub-parallel reflector (orange) with interpreted fault (cyan).





UG2 elevation map (top) with interpreted fault indicated and fault throw cross-section (bottom).

BOREHOLE RADAR TECHNOLOGY

Evolved from ground penetrating radar systems, borehole radar technologies operate within the radio frequency (250MHz) electromagnetic spectrum. Signals radiate outward from the tool within a borehole into the surrounding formation. Radar reflections occur at contrasts in dielectric permittivity, usually occurring at changes in lithology and brittle fault structures. Tools can be deployed into holes of ~34mm in diameter either by hand (push in) or deployed by anchored winch or on the end of drill rods for further conveyance.