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3D Seismic Imaging of the Ghost-Carbon Leader Reef of the World's Deepest Gold Mine - Mponeng Gold Mine, South Africa

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SUMMARY

The re-interpretation of the old 3D seismic data from the world's deepest gold mine of the Witwatersrand basin, have proven to be effective in enhancing the detection of fault zones and unstable lithologies that are potential mining hazards. Most of the structures identified seem to offset the gold-bearing horizons such as the Ventersdorp Contact Reef (VCR) and Carbon Leader Reef (CLR) with throws below seismic resolution limit (equivalent to one-quarter dominant seismic wavelength ($\lambda/4$)). To derive or ghost the seismically transparent Carbon Leader Reef model, we used more than 2000 drillholes that intersect the CLR (within the Central Group), VCR (top of the Central Rand Group) and Crown lava (top of the West Rand Group). The final ghosted CLR shows a very consistent dip with the VCR and Crown lava. The model also shows that 60% of the structures imaged at the VCR level at 2-3 km depth continue and displace the ghosted-CLR at 3.5-4.5 km depth in a similar manner. This model represents the gross-structural architecture that was formed following the massive Platberg age extension on the first-order scale structures.

Introduction

The Witwatersrand basin (South Africa) holds some of the world's largest gold reserves, having produced over 1.5 billion ounces. In 1992, AngloGold used 3D seismic reflection method as a great exploration tool for their mine planning at several deep gold mines in the Witwatersrand Basin. This 3D seismic survey was aimed at imaging the key economic gold-bearing reefs or conglomerate units such as the Ventersdorp Contact Reef (VCR ~ 1.5 m thick) and Carbon Leader Reef (CLR ~ 1 m thick). The 3D seismic design, acquisition and re-processing are summarized by Manzi et al. (2012).

The AngloGold Ashanti currently aims at using their historical 3D seismic data to assess the feasibility of their deepening world's deepest gold mine (Mponeng Gold Mine) in order to give access to additional reserves below 4 km in depth. To achieve this goal, the VCR and CLR reflectors were re-interpreted in detail to provide a depth 3D ore body model that could be used in conjunction with the existing orebody geological models. The Mponeng Mine exploits the VCR at depths between 2400 and 3900 m below the surface, whereas the CLR is exploited at depths up to 4 km below the surface (Figure 1).

Figure 1 Left: The location map of the Mponeng Gold Mine. Right: West-to-east seismic section illustrating the seismic imaging of the VCR and a good correlation between the ghost-CLR and an underground borehole (courtesy of AngloGold Ashanti).

Seismic interpretation

The horizons and faults were manually picked on every seismic line of the depth-converted PSTM data. More than 2000 underground and surface boreholes as well as synthetic seismograms (calculated from surface holes) were used to constrain the seismic interpretation. The smallest fault that could be manually picked on a migrated section had a throw of about one-quarter of the dominant wavelength, or about 25 m for this data set.

The seismic section reveals a very strong quality of the VCR reflector amplitude because it occurs at the reflective interface between basic to ultrabasic Klipriviersberg lavas of the Ventersdorp Supergroup and quartzites to conglomerate of the Central Rand Group. However the CLR, the world class gold orebody, which is inter-bedded within sonically uniform quartzitic units, could not be imaged seismically because it occurs at the interface where the reflection coefficient is approximately zero. Seismic attributes were also used to enhance the structural and horizon resolution further (Rijks and Jauffred, 1991). Even so, the CLR could not be seen and picked in the seismic section. Borehole data, the reflectors above and below the CLR were used to determine the depth position of CLR, which is here termed the 'ghost reflector'. The final ghosted CLR shows a very consistent dip with the VCR and Crown lava. The model also shows that 60% of the structures imaged at the VCR level at 2-3 km depth continue and displace the ghosted-CLR at 3.5-4.5 km depth in a similar manner. This model represents the gross-structural architecture that was formed following the massive Platberg age extension on the first-order scale structures.

Fault-horizon projection

Horizons and faults were compared with regional control to quantify possible depth discrepancies. Consequently, the seismically-defined VCR, ghosted-CLR and intersecting faults were modelled to create a robust geologically constrained structural framework, which was then imported into mine and exploration plans (Figure 2).

Figure 1 Detailed horizons-faults projection model incorporating the CLR and VCR gold ore bodies. The insert image shows the VCR ore body integrated with drillholes that intersect the both the CLR and VCR (courtesy of AngloGold Ashanti).

Conclusions

Re-interpretation of the of the historical 3D seismic data integrated with synthetic seismograms and currently drilled surface and underground boreholes have provided the detailed seismically defined model of the VCR and ghost-CLR gold orebodies. The ghost-CLR model, in particular, may reduce risks associated with deep mining in Mponeng Gold Mine and increase efficiency and safety

References

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