 SUMMARY

This paper demonstrates the impact of a high-resolution 3D seismic survey on the development program of a platinum mine, and shows that reflection seismology can play an important role in positioning the structural position of thin, layered ore bodies.

A case history shows that seismic methods are capable not only of directly detecting sub-metric layered platinum ore bodies at depths of 800 m, but they can also help the mining industry to optimize mine-planning in a cost effective manner. For such shallow targets, compared to the more traditional oilfields, the acquisition parameters were tuned to meet the survey’s objectives, including a bin size of 7.5 * 7.5 m² and a fold of 30. This led to a very high density of shots per km² of over 900. The vibroseis source was well adapted to the surface conditions of the area.

After full 3D processing, the seismic data provided a clear image of the structures of Merensky and UG2 reef horizons and led to a significant increase in the level of confidence. In addition, effective application of new advanced processing seismic and visualization software used in the oil industry also permitted accurate highlighting of some geological features which disrupt the platinum reef horizons, such as slump structures (known as potholes), faults, pegmatoid bodies and dykes. These disturbances are of prime importance for implementing galleries, optimizing reef extraction, mining engineering and positioning the shafts. Their interpretation helped optimize mining in a significant, cost-effective way.

INTRODUCTION

The first 3D survey was recorded over a deep gold mine in South Africa in 1993. Since this time, acquisition techniques and processing have evolved to improve resolution of shallower targets, particularly for platinum mines.

In this paper, we describe the 3D seismic data acquisition with vibrators, the data processing and the 3D interpretation of the Karee Mine structure. Special attention was paid to identifying the slump structures (known as potholes) and the faulting, which disrupts the ore body using new visualization software normally dedicated to geologic interpretation of sedimentology basins.

The geographical and geological setting can be described as follows: the area is a plateau of low relief, lying between the Magaliesberg range to the South and West, the Pilanesberg massif to the North-West and the hills of the Bushveld Main Zone Gabbro to the North and East. Isolated conical-shaped hills of hortonolite dunite and ultramafic pegmatoid are present...
SEISMIC DATA ACQUISITION

The 3D survey was designed to focus on maximizing the structural resolution on Merensky and UG2. The main 3D parameters were:

- Group interval: 15 m
- Shot interval: 15 m
- Receiver line interval: 120 m
- Shot line interval: 150 m
- Number of receiver lines: 7
- Number of channels: 680
- Fold: 30

It is interesting to note the specificity of certain important aspects of this design:

- The bin size 7.5 * 7.5 m² was chosen to be compatible with the aliasing for high frequencies and the stratigraphic dip.
- The offsets ranging between 182 m and 1332 m are well adapted to the main target, which is situated at depths between 500 m and 1200 m.
- Due to the small bin size and the medium coverage fold, the density of shot points per km² attained 900 VP/km² using the cross-line acquisition mode.

The equipment also had some special characteristics to meet the resolution constraints of such a prospect:

- The recorder was a Sercel SN 388 24-bit system, and the record sampling rate was set at 1 millisecond
- The 40 000 Pound peak force of the vibrators ensured good signal strength with only two vibrators, and reduced the size of the emission source array.
- Sweep frequency: The first sweep considered as low frequency is used to compute refraction arrivals, and to compact the ground to eliminate the presence of creeks which are considerable during the dry season. This sweep is recorded alone. The three others sweeps, used for reflection, pushed the M18 vibrators to the limits of their capabilities. These very high-frequency emissions increased resolution to detect the very thin ore body layers.
- The sensors are SM 4LD, with a spurious frequency over 250 Hz.

SEISMIC DATA PROCESSING

Two phases of data processing were carried out: in the field during data acquisition and in the main processing center in for Final 3D processing.

- Phase 1: Field processing
  At the beginning of the survey, the field management system software was used to create a theoretical prospect, which included all survey parameters. It contained all the information about the theoretical spread, the source and receiver patterns and coordinates. Then, on a daily basis, adjustments were made according to field constraints and actual coverage maps were computed to meet the survey’s objectives, by staying as close as possible to the survey’s theoretical plans. Field processing software was used to control the quality of the recorded
data with in line and cross line brute stacks but also for frequency analysis, vibrator similarities and recording instrument tests.

- Phase 2: Final 3D processing
  In these types of projects, the most fundamental problems we have to face are static corrections and conservation of high frequency content.

  - Statics
    A detailed up-hole survey and a modelling of the weathering zone by using first break picking computed with a generalized linear approach achieved good primary static control in the near surface. The basic first model was updated by means of the inversion method. Nineteen out of twenty-three up-holes were used to calibrate the static correction solutions.

  - Frequencies
    A noise reduction using a 3D-F-Kx-Ky filter applied before stack rejected coherent noise with velocities ranging between 100 and 4500 m/s and a low cut at 55 Hz was retained. A spectral flattening of 30-200 Hz allowed the high frequency content of the seismic signal to be retained.

**ADDITIONAL PROCESSING AND INTERPRETATION**

- Attribute Classification
  For the first time, software commonly used by oil companies to interpret complex hydrocarbon reservoir systems, was applied in a mining context. The first phase consisted in defining horizons, which were picked automatically. Then different maps were derived, such as dip, azimuth, curvature (first derivative of dip), and roughness (first derivative of azimuth). These attribute maps were used to detect major and minor discontinuities (faults, for example).

  The second phase used a Neural Network Technology to classify seismic trace shapes into seismic facies based on the numerical value of each trace. The interval must be a constant thickness interval. An example for UG2 is given in the figure below:
This example clearly shows three different domains of classification, which can correspond to a variation in UG2 thickness. Some pot-holes are evident in the southern part of the survey.

- **Semblance processing**
  The program produces a volume of « semblance » coefficients for each sample of the 3D block and this information can be loaded onto a workstation and visualized in the same way as the seismic amplitude. An example is shown in the figure below:

![Semblance coefficients](image)

**CONCLUSION**

The high-resolution 3D seismic over Karee Mine demonstrates that reflection seismology can play an important role in positioning the structural location of thin, layered platinum ore bodies.

The effective application of new seismic software used in the oil industry can also accurately highlight some geological features and mine-planning problems. Interpretation will then help to optimize the mining in a cost-effective way.