MODIKWA – a successful example of a shallow ore-body imaging by surface 3D seismic

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ABSTRACT

Surface 3D is now a widely imaging tool used in the Western Bushveld to derive continuous **structural image** for ore bodies with a depth ranging from 600m to 1700m below surface. The cost of such surveys is directly linked to the source and receiver **surface sampling**.

Such structural model was requested for the Modikwa Platinum mine, in the Eastern Bushveld, with an ore body whose depth is ranging from 200m till 450m. In order to balance the costs versus the expectations, a trial was conducted in 2004 whose main focus was to determine the most **optimum surface sampling scenario** and also benchmark the results of surface seismic versus initial model derived from boreholes. This test has delivered as expected an acquisition model for shallow UG2 surveys in Eastern Bushveld and also a structural model with reliable small features such as fault throws down to 12m due to the achieved **vertical resolution**.

In 2006 the main survey took place and the expected structural image was achieved after processing. The fault network when compared to the initial model had its accuracy and reliability push down till **fault throws** around 12m for a cost balancing current density of boreholes.

INTRODUCTION

Boreholes were considered for a long time to be the main tool to derive a 3D structural image of an ore body in South Africa. Boreholes will always be required to directly sample the grade of the target ore-body, but have two significant drawbacks:

1- The time taken to drill with respect to the size of the target and
2- The density of boreholes required for adequate structural sampling is often many times that required for facies & grade sampling

Surface 3D seismic was introduced for the deep gold reefs imaging in the early 1990's and in early 2000 only for the platinum reefs in Western bushveld (MR & UG2). The depths investigated were shallower than oil exploration by an order 2 to 3. The shallowest platinum reef imaged were around 800m to 1000m deep.

The need to image shallower ore bodies arose in 2003 from the Modikwa platinum mine. The structural model from boreholes was inadequate as far as small faults were concerned and small faults were known to exist but were not imaged so far. Overall the depth range to investigate was the interval 200m to 450m.

The validity of surface seismic as a cost effective and reliable shallow ore-body imaging tool needed to be demonstrated on a feasibility test prior a full scale survey. The key element to investigate was the density of source and receiver surface sampling.

FEASABILITY STUDY

A dense surface patch was designed in 2004. The goals were to study the surface sampling density and also as a by-study the size of the sampling cell (subsurface bin).

The main surface patch parameters were:

Receiver sampling: 5m
Source sampling: 10m
Receiver lines interval: 20m
Source line interval: 20m
Number of receiver lines: 16 lines of 140 receiver points
Number of source lines: 48 lines of 64 source points

With this set-up the minimum bin size is 2.5m by 5m and by decimation 5m by 5m bins or even larger sampling can be tested. Same philosophy can be applied for the receiver and source line interval, one every two can be discarded leading to a 40m by 40m elementary pattern size and the process can be repeated.

Another important issue is the vertical resolution achieved, which is a function of the dominant wavelength.

The more high frequencies passed in the ground the smallest vertical resolution will be achieved.
After intensive testing a 30Hz to 250Hz signal was sent in the ground with an emphasis around 150Hz.
The expected vertical resolution could resolve fault throws down to 10m. Data has been processed using the standard "Bushveld platinum imaging sequence" applied in all previous Western Bushveld 3D for deeper targets.
Then the data was decimated in order to compare the following combinations:

Bin 2.5m x 5m versus bin 5m x 5m

The 5m square bin was delivering nearly the same structural accuracy than the smaller bin. All subsequent combinations were done with 5m bin sizes. The main Middle fault was known but not included in the mine initial planning and the other faults were only detected by this survey (Fig 1).

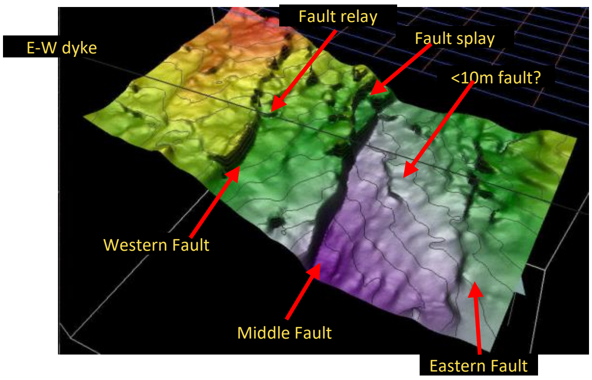

Figure 1: structural image achieved by 5m bins and Decimation 1

These combinations were:
Elementary pattern 20m by 20m: Decimation 1
Elementary pattern 40m by 40m: Decimation 2
Elementary pattern 40m by 80m: Decimation 3

The interpretation of the results over the varying depths of the UG2 leads to the following surface sampling rules:

Depth UG2	Decimation
100m to 230m	1
230m to 350m	2
350m to 450m	3

The acquisition sampling rate was tested for its potential effect on the model resolution. The data set was recorded with 0.5ms sampling against the usual 1ms sampling rate of all previous surveys. Except an extra CPU effort for processing the smaller sampling rate has not brought any additional information.

MAIN SURVEY

Using the conclusions of the pilot survey, a wider area was surveyed in 2006 on the same mine. The full fold area was 1.43km^2 and the UG2 depths were in the 200m to 450m range. The decimation rules were applied in order to optimize the density of surface points and consequently meet the mine budget, giving this project an economical viability. Furthermore, as the portion theoretically requiring decimation 1 was quite small, it was decided to use only decimation 2 for the shallowest part of the survey.
With this optimum surface sampling the cost of imaging 1.4km^2 was quite balanced when compared to a continuous borehole imaging over the same area.
The data was processed on site leading to a fast track interpretation and then further process abroad leading to a later final interpretation.
The data was migrated twice, on PSTM Kirchkoff migration in order to output the most reliable structural image and also a Post stack migration to preserve the highest frequencies above 130Hz required to resolve vertical features around 10m.

The fast track structural image confirmed the features already highlighted by the pilot survey, namely the Middle fault and Western fault. The vertical resolution helped to resolve fault throws of 10m, small pothole on the East of the survey and a series of small fault mainly North South but one East West on the West of the Middle fault.

The main Middle fault generated a small antithetic fault on the Northern half of the survey, and this fault also was never previously integrated in any model
Figure 2 display the final structural depth map of UG2 related to MSL, with all the small faults detected by the seismic.

CONCLUSIONS

By a careful planning through a feasibility study it was possible to derive a cost effective surface sampling required for the shallow target depth (200m-450m). The application of this sampling delivered an accurate and high frequency structural image with a resolution of 10m for fault throws and other seismic objects. Variations in dip and strike of the target UG2, are also imaged. These facilitate accurate mine planning and allow future exploration to be accurately targeted. Current technology enables the imaging of any ore body as shallow as 100m deep for costs balancing the same image through boreholes. The only requirement is a good acoustic impedance contrast at the ore body level.

ACKNOWLEDGMENTS

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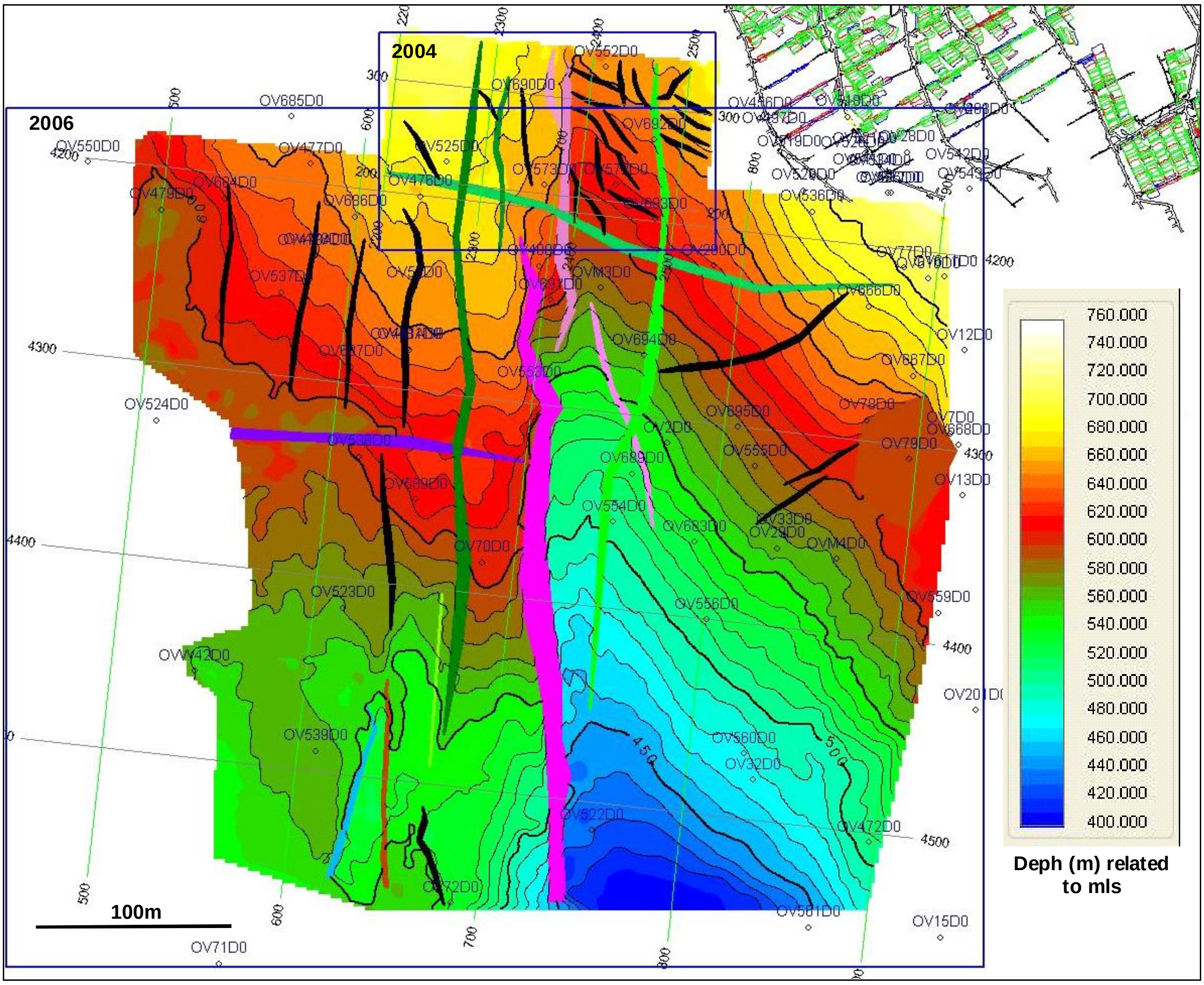

Figure 2: Final structural image of UG2 with depths related to MSL