Seismic Data Integrity and its Effect on Analysis

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ABSTRACT
In South African deep level gold mining operations, the high level of hazard and risks posed by large seismic events ($M_L \geq 1.5$) is well known both in terms of safety and profitability. An accurate level of assessment of this hazard is therefore essential. The accuracy of the interpretation of data as obtained from seismic monitoring, like with any other geophysical method is dependent on the quality of the data acquisition and processing.

Network layout, technical maintenance and software algorithms are some of the major aspects affecting data quality. In addition, the location of large geological structures, bad ground conditions and the quality of processing has almost as much of an effect on the confidence of interpretations.

A number of case studies highlighting the effects of substandard instrumentation, networks and data will be presented together with the effects these have on both temporal and statistical analysis. The myth of seismic instruments being black boxes and the over glorification of computers needs to be realistically evaluated.

1. Introduction

Seismicity in deep gold mining environments is an unavoidable phenomenon. The gold fields of the Witwatersrand basin are well known for generating a high level of seismicity that has sometimes resulted in fatal consequences.

Seismicity induced by mining is usually defined as the occurrence of seismic events caused by rock failures as a result of changes in the stress field in the rock mass around and near mining excavations (Cook, 1976) or those induced by the movement of major geological discontinuities (Parysiewicz, 1966; Hurtig *et al*., 1979; Joughin and Jager, 1983; Kijko *et al.,* 1987; Stankeiwicz, 1966; Johnston and Einstein, 1990). Generally a close spatial relationship of seismicity to that of mining is observed.

Quantifying the potential hazard posed by these induced seismic events is paramount to the safety efforts on all of the seismically active Harmony mines. Numerous methods including statistical, spatial and temporal variations of a number of parameters are routinely used in this effort. Obviously all of these methods are influenced by the quality of the monitored data. This quality is influenced by a number of factors namely:

- Network design and instrumentation
- Location algorithms and velocity models
- Source parameters calculations and their models

All of the above has been researched with significant developments over many decades. However, this paper focuses on routine problems encountered in the mines and the effects these have on analysis. Some of the aspects assessed are:

1) Deteriorated waveform, due to failing components
2) High level of noise
3) Different versions of software
4) Quality of processing

A number of digital networks were installed during the early 1990's and over time the quality of data sometimes deteriorates. This is due to either deteriorated ground condition, instrumentation or external electrical noise. However, these bad quality waveforms are often included in the calculation of the source parameters. Some of the effects of this on the quantification of the source parameters are as follows:

2) Deterioration of wave forms.

Figure 1 shows the seismograms from a $M_L = 0.5$ event clearly showing three "bad" waveforms (with failed components), one intermediate waveform and two "good" waveform. **Figure 2** depicts the spectra of the event recorded by the seismograms shown in **Figure 1**. From this it is clear that the spectra are influenced by the sites that encounter problems with components.

Table 1 depicts the values of the source parameters of the seismograms shown in **Figure 1.** There are up to 2 orders of magnitude (20 times) differences in the calculated source parameters from the P-wave and 0.2 – 0.4 order (2 to 4 times) difference from the S-wave.

Table 1:		P-waves	S-waves
"Good " sites	Corner frequency	24	33

	Moment (Nm)	2.1E+11	2.6E+10
	Energy (Joules)	3.3E+04	2.0E+04
"Bad" sites	Corner frequency	36	36
	Moment (Nm)	6.9E+09	1.1E+10
	Energy (Joules)	1.1E+02	4.7E+03

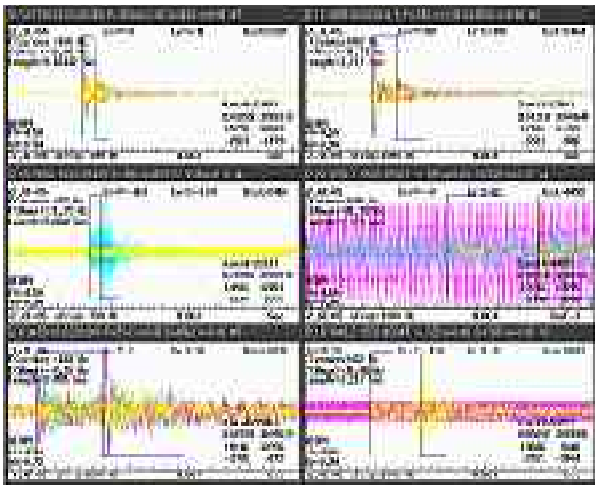

Figure 1: Seismograms of events with $M_L \geq 0.5$.

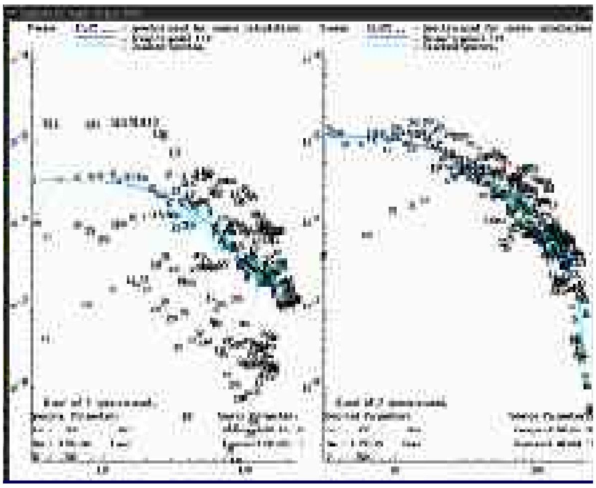

Figure 2: Spectra of seismograms shown in **Figure 1**.

3) High level of noise

From **Figure 3** it is clear that this specific station suffers from 50 Hz noise interference. As **Table 2** depicts, there is a difference in the source parameters, thus the final interpretation of the event recorded by the network including these sites that suffer from high noise interference will have some degree of error. The quality of the processing is also being complicated by the presence of high noise levels on the seismograms.

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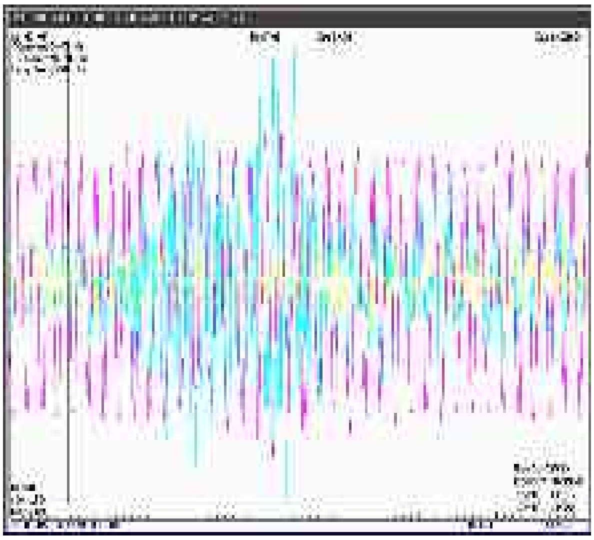

Figure 3: Waveform with 50 Hz noise present.

Table 2		P-waves	S-waves
Good*	Corner frequency (Hz)	36	17
	Moment (Nm)	4.7E+10	4.8E+10
	Energy (Joules)	5.2E+03	1.1E+04
Bad**	Corner frequency (Hz)	103	55
	Moment (Nm)	8.2E+09	2.6E+09
	Energy (Joules)	4.2E+03	9.9E+02

* Seismic parameters when waveforms from this site were good.

** Seismic parameters from site when waveforms had deteriorated to the level shown on **Figure 3**.

4) Different versions of software, different algorithms

As any back analysis or hazard assessment requires a consistent database, the data from previous versions should be recalculated which is again time consuming. The following figures (**Figure 4** and **Figure 5**) depict the change in parameters with different software versions using different methods of calculating source parameters.

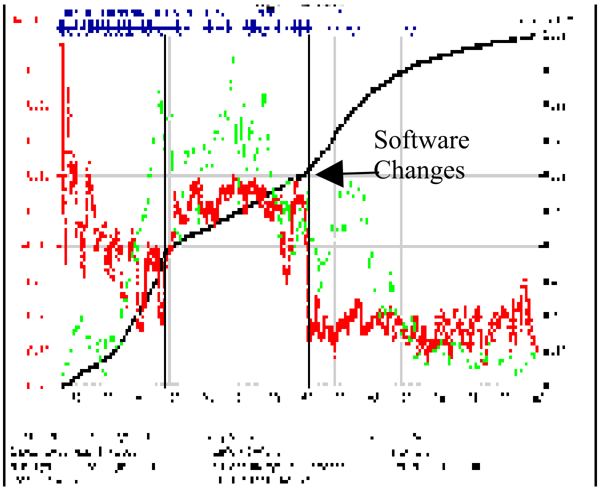

Figure 4: Database with different software versions.

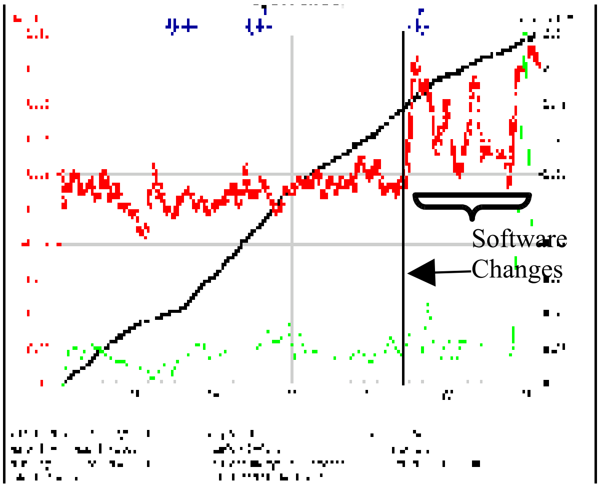

Figure 5: Database with different software versions.

5) Quality of the processing

Figure 7 shows the effect of poor quality processing of data. From the figures it is clear that the quality control of processing was not of an acceptable standard, as a number of events were located very deep (up to 8000m) or very shallow (up to 4500m above surface).

Conclusion:

- The quality of data is paramount to any interpretation and is very vulnerable to garbage in garbage out.
- A lot of care is given to ensuring that all stations are on line but the quality of waveforms is often ignored particularly when recording large quantities of data.

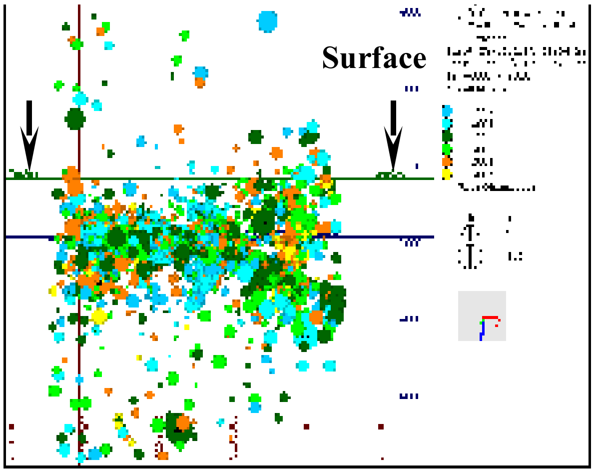

Figure 6: Location of seismic events with M_L>0.0 – cross-section

- Seismic processors are often taught quick computer generated arithmetical short cuts to minimize errors rather than the correct seismological reasons.
- The tedious nature of processing results in mass deletion intermittently of small and difficult to process events seriously affecting any method incorporating activity rate.
- Very large quantities of data often results in automatically processed data, with a higher level of poor quality picks, being used for analysis

Reference:

Gibowicz, S.J., Kijko, A. (1993) "An Introduction to mining seismology". Academic press, California