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Joint interpretation of high-precision tilt data and mining induced seismic events recorded underground in deep level gold mine in South Africa

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Seismicity associated with deep-level mining has for long been a problem, leading to rockburst and other similar hazards. Several studies have been completed in an attempt to minimize the total amount of seismicity.

In this study high resolution measurements of ground tilting in combination with seismic monitoring is used to observe how the rock mass responds to mining.

A good correspondence between the coseismic and the aseismic tilt was found. The rate of coseismic and aseismic tilt, as well as seismicity recorded by the mine seismic network, are approximately constant until the daily blasting time, which takes place from about 19:30 until shortly before 21:00. During the blasting time and the subsequent seismic events, the coseismic and aseismic tilt shows a rapid increase.

In an attempt to distinguish between the different mechanisms of tilting two types of events were recognized. The “fast” seismic events characterized with sharp increase of the tilt during the seismic rupture and “slow” seismic events characterized by creep type post seismic deformations.

Tilt behaviour before and after a seismic event was also analysed. The fact that no recognizable aftertilt was observed for more of the “fast” seismic events means that there is no gradual release of stress and an associated continuous strain rate change afterwards. It can therefore be concluded that a large seismic event causes a rapid change in the state of stress rather than a gradual change in the strain rate.

The mechanism of the observed “slow” seismic events is more complicated. Although several explanations have been proposed, a suggestion for further work could be to investigate the presence of “slow” events in or after blasting time more closely.
During the monitoring period a seismic event with MW 2.2 occurred in the vicinity of the instrumented site. This event was recorded by both the CSIR integrated monitoring system and JAGUARS acoustic emission network.

More than 21,000 AE aftershocks were located in the first 150 hours after the main event. Using the distribution of the AE events the position of the fault in the source area was successfully delineated.

The rupture area, elastic properties of the rock, the state of stress before the event occurred and frictional parameters of the rupture were used as input parameters to both numerical and analytical tools to reproduce the expected tilt. The calculated values were compared with the real values as recorded by the installed tiltmeters. A good correlation between the calculated and monitored amount of tilt was found.

The tilt changes associated with this event showed a well pronounced after-tilt. The distribution of the AE events following the main shock was related to after tilt in order to quantify post slip behavior of the source. There was no evidence found for coseismic expansion of the source after the main slip. Therefore the hypothesis of the post-seismic creep behaviour of the source was proposed to explain the large amount of tilt following the main shock.