Quasi-static and dynamic deformations of the rocks associated with mining induced seismic events around deep level mining in South Africa

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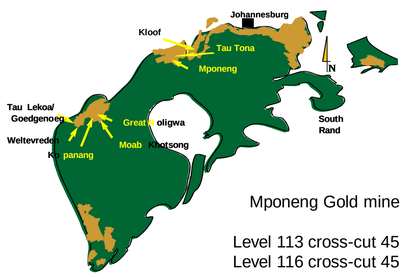
Underground monitoring

Two underground sites in a deep level gold mine in South Africa were instrumented by the Council for Scientific and Industrial Research (CSIR) with tilt meters and seismic monitors. One of the sites was also instrumented by JApanese-German Underground Acoustic emission Research in South Africa (JAGUARS) with a small network, approx. 40 m span, of eight Acoustic Emission (AE) sensors.

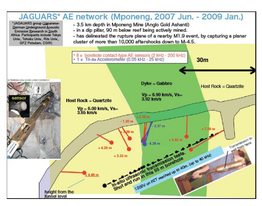
The rate of tilt, defined as quasi-static deformations, and the seismic ground motion, defined as dynamic deformations, were analysed in order to understand the rock mass behavior around deep level mining. In addition the high frequency AE events recorded at hypocentral distances of about 50m were analysed. This was the first implementation of high frequency AE events at such a great depth (3300m below the surface).



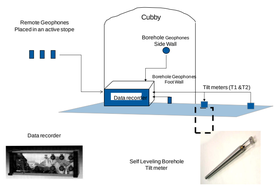
Mponeng Gold mine

Level 113 cross-cut 45
Level 116 cross-cut 45

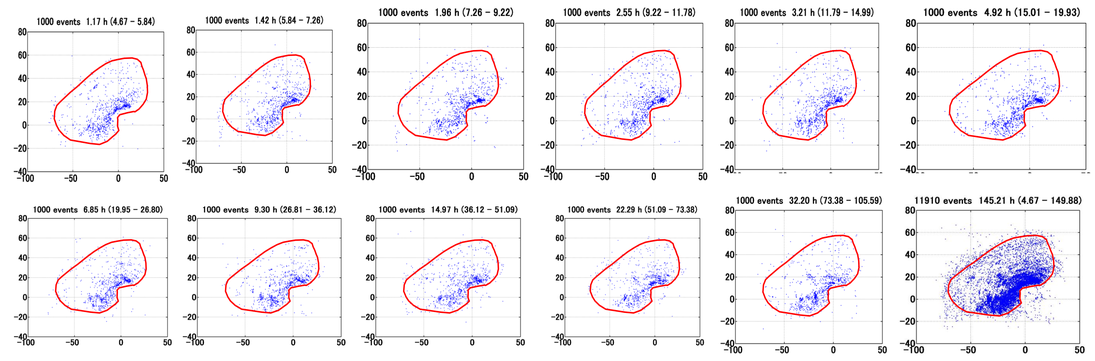
Geographical Location of the Mine



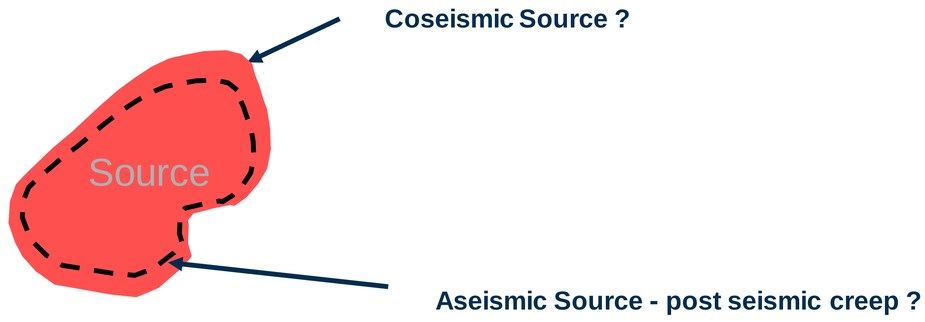
AE Monitoring Configuration



Integrated Monitoring System

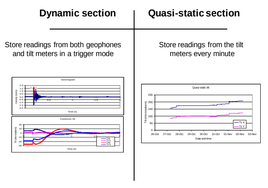


Incremental snapshots 1000 aftershocks in time

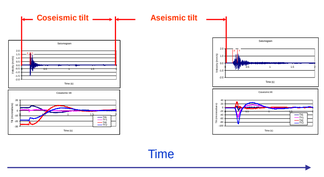


Hypothetical model of the post seismic creep

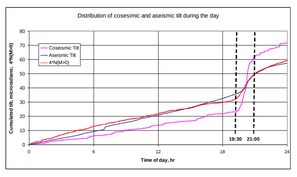
A good correspondence between the dynamic and quasi-static deformations was found. The rate of coseismic and aseismic tilt, as well as seismicity recorded by the mine seismic network, are approximately constant until the daily blasting time, which takes place from about 19:30 until shortly before 21:00.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



Acquisition system

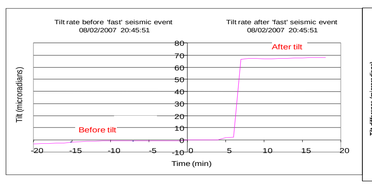


Coseismic and aseismic tilt

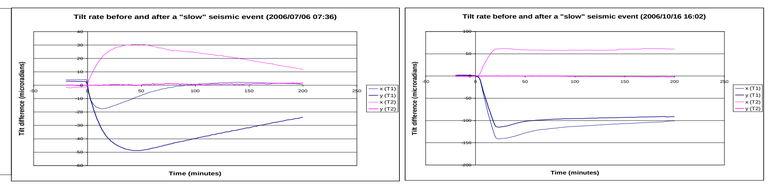


Coseismic and aseismic tilt during the hours of the day

Much of the quasi-static deformation, however, occurs independently of the seismic events and was described as ‘slow’ or aseismic events.



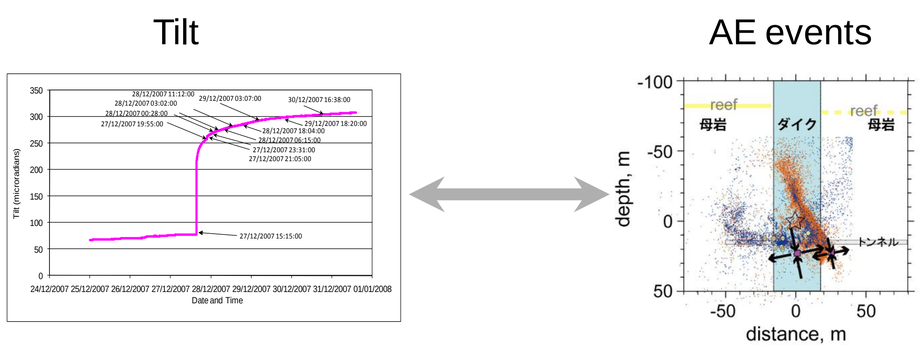
Example of ‘fast’ event



Examples of ‘slow’ event

Seismic event M=2.1 on 12/27/2007 located close to the Site 116 Mponeng mine

During the monitoring period a seismic event with M_W 2.1 occurred in the vicinity of the instrumented site. This event was recorded by both the CSIR integrated monitoring system and JAGUARS acoustic emotion network. The tilt changes associated with this event showed a well pronounced after-tilt. The aftershock activities were well recorded by the 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 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.



Correlation of the tilt and distribution of the seismic events in time

Coseismic and aseismic deformations relative to mining

An attempt to associate the different type of deformations with the various fracture regions and geological structures around the stopes was carried out. A model, was introduced in which the coseismic deformations are associated with the stress regime outside the stope fracture envelope and very often located on existing geological structures, while the aseismic deformations are associated with mobilization of fractures and stress relaxation within the fracture envelope.

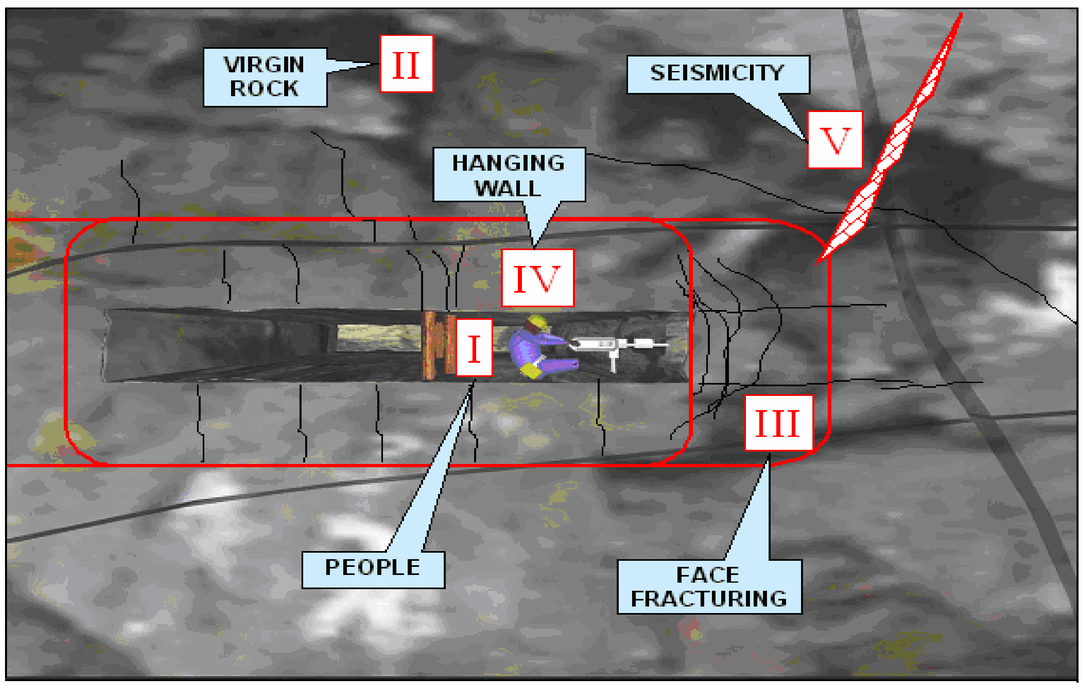


Illustration of underground opening and with the various fracture regions and geological structures

Conclusions

- The seismic tilt increases rapidly during the seismic event and blasting
- Much of quasi-static deformations were found to occur independently of seismic events and were described as ‘slow’ or aseismic events
- The rate of tilt before and after a seismic event shows luck of after-tilt in most of the cases studded
- The tilt direction associated with the M_w = 2.1 seismic event is consistent with the fault plane position delineated by AE events
- The distribution of the AE events following the main shock showed no evidence of coseismic expansion of the source after the main slip