Multidisciplinary Monitoring of the Entire Life Span of an Earthquake in South African Gold Mines

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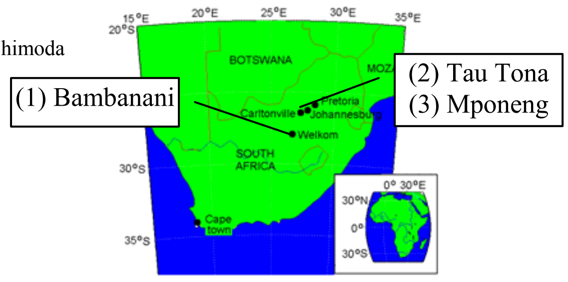


ABSTRACT

*Hundreds or thousands of years are the typical life spans of huge natural earthquakes, not allowing us to have enough number of lessons. Hypocentres are too distant to close-up the source process. So, since 1992, we have attempted to monitor stress, its build-up and strength at the closest proximity of M>~2 in South African deep gold mines. In our second field experiment, we have successfully monitored the entire strain history within a hundred metres from the hypocentres, associated with a few seismic events with M>2 (See **(1)**). However, there were no close strong-motion meters available to locate asperities; only a single strainmeter was available, so we were not able to locate the strain-change source; no in-situ stress measurements were carried out at the site, and no information was available to constrain strength. In order to address these deficiencies, from 2003 to 2004 we deployed new experimental instrument arrays at fault bracket/stabilizing pillars. We installed strainmeters (Sa: 13m, Sb: 23m deep), arrays of strong ground-motion meters, sensitive thermometers to monitor seismic heat generation, and fault displacement meters, as introduced in **(3)** in this poster. We successfully began monitoring, but learnt that we have to develop instruments for much quicker drilling and installation, especially at highly stressed pillars adjacent to mining operations (See **(2)** in this poster). The collaboration with ICDP started in 2004 at Tau Tona.*

(3) Successful upgrade of the experiment at a planned pillar

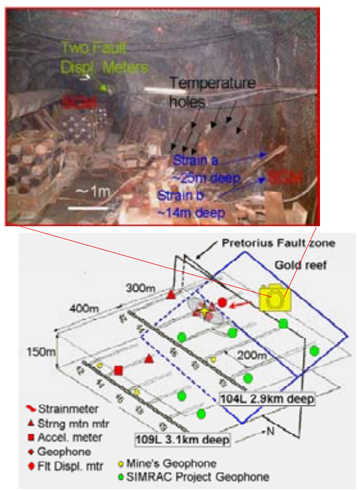


Fig.1

Mponeng project: Strainmeters (Sa: 13m, Sb: 23m deep), temperature meters to measure fault frictional heating, fault displacement meters, and strong ground motion meters around a distinct weak plane located with a 10-cm accuracy

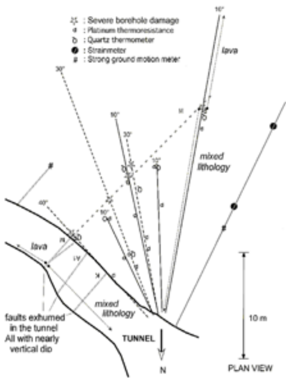


Fig. 2 Configuration of sensors. Displ. meter at M & K

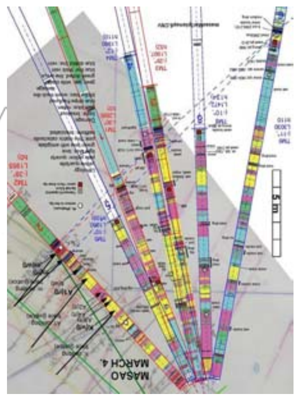


Fig. 3 Simplified lithology (yellow: quartzite, green/blue: basaltic lava, pink cataclasite)

Fig.4 A typical example of the complicated lithology in the fault zone, with fragmented patches in every size, consisting of country rock (light green: hangingwall basaltic lava; light grey: footwall quartzite), filled up with cataclasite (dark grey).

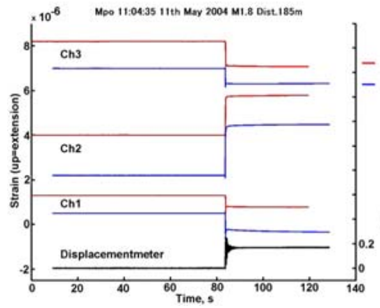


Fig.5 An example of the largest seismic steps event (Morishita et al. 2005).

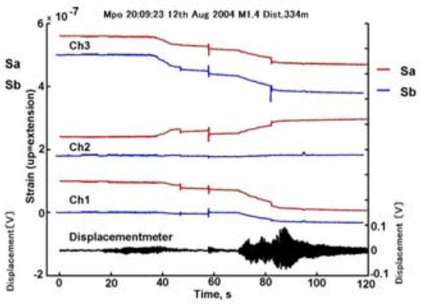


Fig.6 An example of significant blasting strain change with seismic events (Morishita et al. 2005).

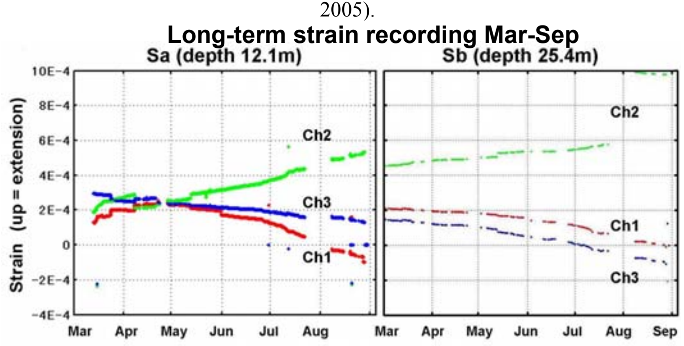
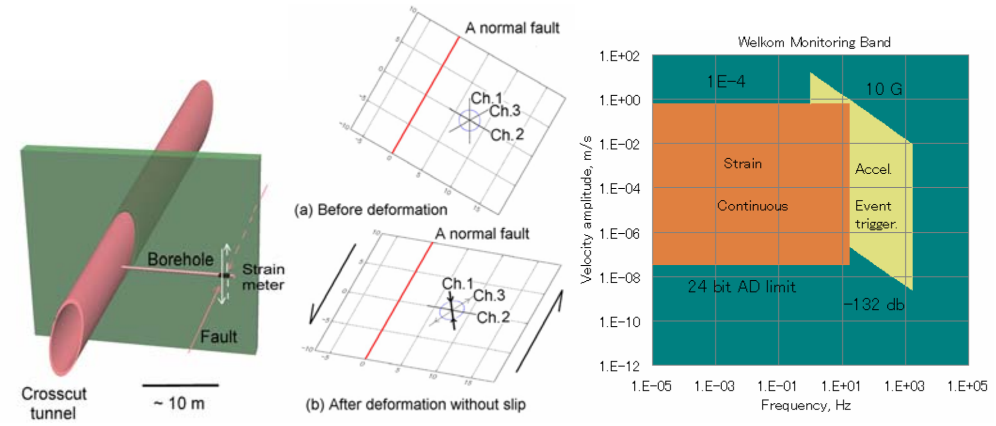
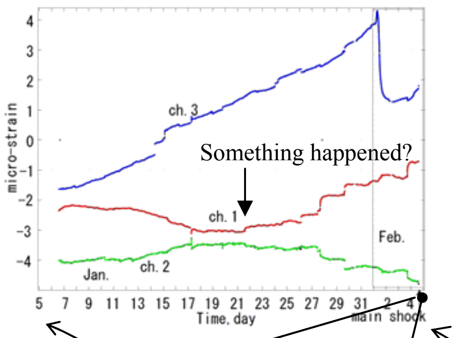


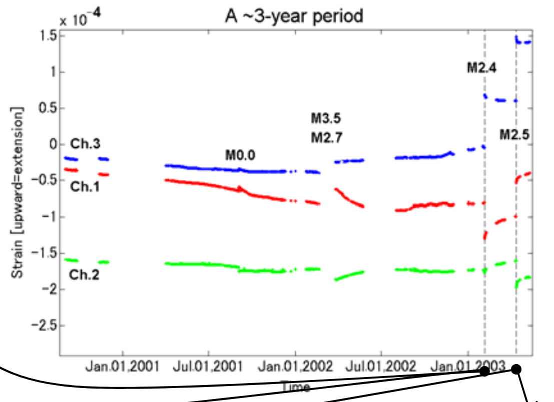
Fig.7 Secular strain build-up. Larger strain accumulation is seen at smaller depth. Channel 1 contracts (vertical//σ1) with channel 2 extending. This corresponds to an increase in shear strain. 10-4 strain change corresponds to the several MPa change (Morishita et al. 2005).

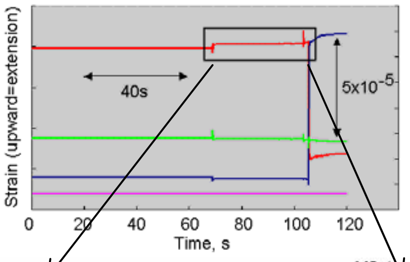
(1) The world first complete 25Hz 24bit recordings of strain build-up and release within seismic source areas (Talked at 17:00 on 10 Mar)



A 3-yr period continuous monitoring of slip-driving shear & normal strains on a 100-m fault with a 4-component borehole Ishii strainmeter, installed at a 15-m depth in a 92-mm diameter hole in quartzite (Vp=5.5km/s).. The meter accommodates strain larger than 10^{-4}, and sensitive enough to detect Earth tide. With a combination of accelerometer, the entire life span of an earthquake

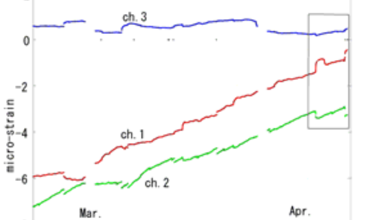


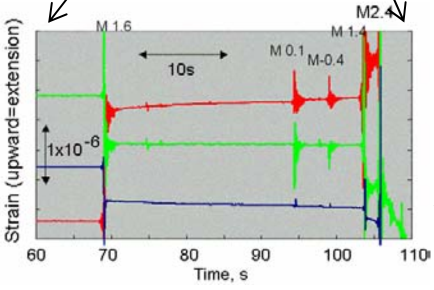


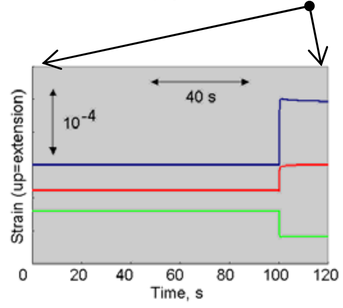


Until Jul. 2002,
Ch 1 (//σ_1) contracted
=>σ_1 increased
by several MPa
After which Ch 3 extended
with Ch 1 ~constant
=> Shear increased
Meanwhile Ch 2
(fault-normal) ~constant

M0.0 in 2001 (< 20 m);
M3.5 & 2.7 in 2002
were relatively far;
M2.4 & M2.5 in 2003
< 100 m
Coseismic steps > 10^{-4}
(~7MPa ~ a stress drop)
11 foreshocks preceded M2.4,
while no foreshocks M2.5
No accelerating aseismic
strain recorded.







(2) Unsuccessful upgrade of the experiment because of high stress

Tau Tona project

A site at a fault-bracket pillar 2.9 km deep (Figs.1&2)

Two faults (light grey) intersect gold reef (mottling brown; dark grey: already mined; dipping 20 degree to SE)

Two cubbies A & B along a so-called T-shape slot (a tunnel (yellow) covered with a thin waste-slot (red))

Target = Ken's fault. An M2.5 took place before our experiment, being well exposed in the eastern stope (Photo 1) or newly excavated tunnel (Photo 2)

Drilling into the pillar to install instruments was difficult because of severe borehole breakout at a depth of several meters (photos 3 & 4).

In June 2003, the borehole breakout was not so severe. So, we grouted the strain cell for overcoring (Fig.3).

However, a considerable increase in stress and deformation associated with quick mining advance, followed by an M2. The cell couldn't be recovered.

One continuous-monitoring Ishii strainmeter, two strong motion meters were finally installed.

Lessons at the highly-stressed pillar:
*Mining was faster than drilling.
*Instruments and procedures must be specially designed for an adverse condition.

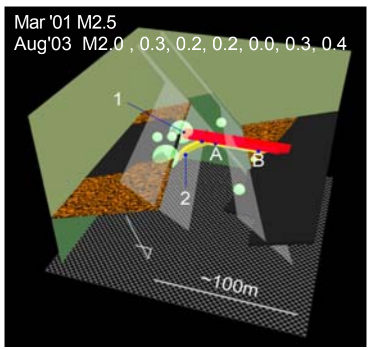


Fig. 1 Perspective schematics illustrating geology, tunnels and our site.

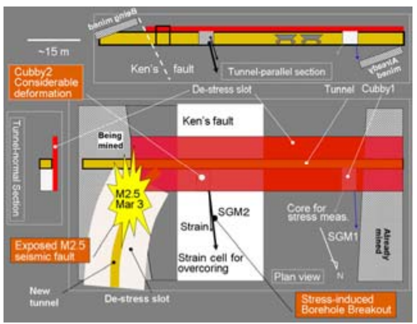


Fig.2 A plan schematics illustrating drill-holes tunnels and geology,

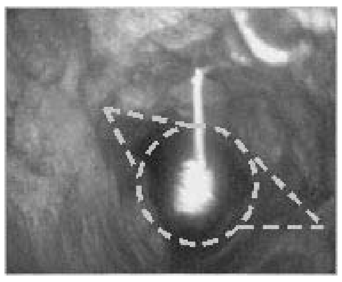


Photo 3. borehole breakout in a 114 mm diameter hole

Photo 4. An example of drill core with disking and borehole breakout

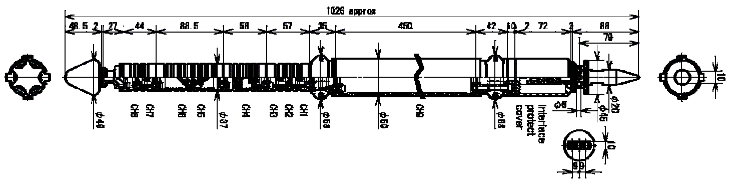


Fig. 3. Recoverable, intelligent Ishii strainmeter for overcoring with a diameter of 38 mm. Except grouting and overcoring underground, all are done on the surface

Acknowledgments

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