A 24-bit 25-bit continuous monitoring of strain on a fault where an $M > 3$ is expected. (1): Bambanani mine, Welkom, South Africa

*Ogasawara, H
ogasawar@se.ritsumei.ac.jp, Faculty of Science and Engineering, Ritsumeikan University, 1-1-1 Noji Higashi, Kusatsu 525-8577 Japan


The Research Group for Semi-controlled experiments in South African Deep Gold Mines**

In this poster, we documents our attempt to monitor strain build-up and transients on a fault at the Bambanani mine, Welkom, South Africa where an $M > 3$ event is expected.

We use Ishii strainmeter that can be installed in a several-cm diameter hole and detect diameter changes in three directions as well as a strain change along borehole axis as an option. It accommodates as large strain as $10^{-4}$ and detect as subtle change as the earth tide. If we install it in a borehole in sub-parallel to the strike of a normal fault, we can monitor shear and normal strain on the fault. Utilizing a 24-bit 25-Hz sampling data recording system (specially designed MS by ISS International Ltd.), we purpose to monitor on the fault (1) strain buildup associated with mining, (2) strain transients like a nucleation phase forerunning a major event or (3) following remote triggering by a large event. (4) Also, we can indirectly infer stress change by comparing the observed earth-tide with theoretical tide because stress change in South African mine is controlled by the location of cavities excavated with mining. In addition, unclipped 120-dB seismic data of these mines are available to discuss stress change.

To date, we have had four experimental fields in three deep gold mines in South Africa (e.g. Ogasawara et al. 2001 (RaSim5), 2002 (Seismogenic Process Monitoring, Balkema)). In the third field at Bambanani mine, Welkom, South Africa, from a crosscut tunnel ~2400 m deep we drill a NXC hole in sub-parallel to the strike of a fault with a throw of several tens of meters (Ishii et al. 2000 JSS Fall meeting). There are also some minor weak planes like dyke contact surface or smaller faults within several tens of meters from the strainmeter.

After long intermissions by underground fire and problems in cables and electric power shortage, strain and seismic data recording started from September 2001. So far, several tens of CD-ROMs were sent to us, in which more than 27,000 seismic events were recorded within an area of 400 m x 400 m centered on the strain meter. Strain data are chopped into 2-minutes files, being sent to the surface central workstation. Data traffic jams during blasting hours, increasing missing rate of strain data. Most period from March to September 2001, the missing rate of strain data was less than several %. Before and after Anglo Gold Ltd. sold Bambanani mine to Harmony mine, the missing rate increased because of problems in cables and power shortage. After January 2002, however, it is getting better.

While no significant mining didn’t undergo near the strainmeter, the secular strain build-up exceeded $3 \times 10^{-5}$ during a 7-month period from March 2001 in the largest component. It first changed linearly with time and was apart from a linear change from ~3 months before an $M =$

** Members on South African side of our research group: personnel of ISS International Ltd. contributes greatly for software development, installation and logistics. On Japanese side, the group consists of national universities (Tokyo, Kyoto, Nagoya and Tohoku), national institutes (AIST / Geological Survey) and Ritsumeikan University.
If we take typical Young’s modulus of about 70 GPa into account, the corresponding stress change is about 2 MPa. Associated with the $M = 0$ event, logarithmic post-seismic relaxation as large as strain build-up were observed, lasting for a few months. Associated with some other farther events ($-0.1 < M < 2.5$) within 300 m from the strain meter, clear co-seismic strain steps and the following post-seismic change were also observed although not so large as those for the $M0.0$ event.

Mining within several tens of meters from the strain meter goes on during 2003. Prominent seismicity closest to the strain meter started to occur: in February 2003 an $M 2.7$ event took place on the fault adjacent to which the strainmeter is installed, followed by two $M \sim 3$ events on the fault several tens of meters beneath the strainmeter. It was found that a minor fault intersecting the grids of box exhibit aseismic shear deformation that could not be accounted by the co-seismic deformation by recent $M 2\sim3$ events. We will compare the strain recordings with the aseismic deformation.

Although already found by McGarr et al. (1982), post-seismic relaxation is as significant as co-seismic change, resulting in much more relaxation in source area and causing much more stress increase in adjacent area than those expected only from seismic change. So, continuous strain monitoring is very important to learn the real stress state.

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