Some of the slow strain steps and infrequent forerunner observed during an M2 class earthquake sequence induced by mining

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The Research Group for the Semi-controlled Earthquake-generation Experiments in South African deep gold mines (SeeSA) had attempted to continuously monitor strain changes with a resolution of 24bit25Hz at the Bambanani mine, Welkom. At the mine, the Ishii borehole strainmeter (Ishii et al.[2000a]) is installed around the potential source area of earthquakes (M3 class) at a depth of 2.4km (Ishii et al.[2000b]).More than 1000 earthquakes (M:-1 to 2.6) took place within 100m of the strainmeter over a 3-year period. Some of the associated, interesting strain changes have been reported, including the instantaneous strain step of 1E-4 strain (corresponding stress drop 7MPa; Takeuchi et al.[2004]), which is recorded only within a seismic-fault length; the step was followed by a significant post-seismic creep-like drift, but not preceded by a forerunner. This time, we thoroughly went through the 25Hz continuous data, finding many steps with significantly longer durations than those of normal earthquakes. Some of especially slow steps were preceded by significant accelerations in strain, the maximum being as large as 1/3 of the step (Figure (c)). In this presentation, we detail about these data.

In this study, we plotted the 25Hz continuous strain data for every 1 hour, and checked each over a 2-year period from June 2001 to June 2003. Consequently, we found 2030 examples of strain changes with absolute amplitudes of 1E-9 to 1E-4 and durations from 10ms to 1000s (hereinafter referred to as strain event). We excluded the changes that are associated with blasting, recorded in only a component, or smaller than 1E-8. Then we had 911 strain events to analyze. When an earthquake occurs, the impulse response (IR) of the strainmeter and acquisition system is recorded (e.g. Figure (a)), which looks like a poorly-dumped oscillation lasting for about a second. However, about 30% of the 911 events didn t have a significant record of IR (hereinafter referred to as non-IR strain event; e.g. Figure (b)). In the non-IR strain events, there were 19 events with much longer duration by an order of 4 than those for typical earthquakes (hereinafter referred to as slow step; e.g. Figure (c,g)).

Convoluting IR, we theoretically synthesized strain steps for assumed variable rise times. Consequently, it came out that the rise time of non-IR events is longer than about 0.5 second. The duration is much longer than the earthquakes (M:-1 to 2) having source durations of 1ms to 50ms.

Significant strain accelerations preceded some of the slow step (e.g. Figure (c)), while no forerunners did other 892 non-IR events with shorter duration time.

With the seismic array with an average station spacing of about 500m, all over M-1 earthquakes can be detected and catalogued at the Bambanani mine. So, we checked whether 64 strain events (47 IR and 17 non-IR events) with strain steps over 1E-7 had corresponding earthquakes in the catalogue. In result, 38 out of 47 IR events had the corresponding catalogued earthquakes, while non-IR events (including slow steps) didn't at all. For the smaller slow steps with absolute steps less 1E-7, we again confirmed that they didn t have a corresponding catalogued earthquake.

The magnitude-frequency relationship of non-IR and IR strain events are both characterized with the fractal distribution with similar slopes to each other. For comparison, we simulated spatially random seismicity with a b-value of 1 in the Gutenberg-Richter's law. Then, the simulated slopes (the fractal dimension) were significantly smaller than those for the IR and non-IR events. This suggests that the IR and non-IR events occur in a different manner than spatially random seismicity with b=1.

We also report on other characteristics of the strain event in the presentation.

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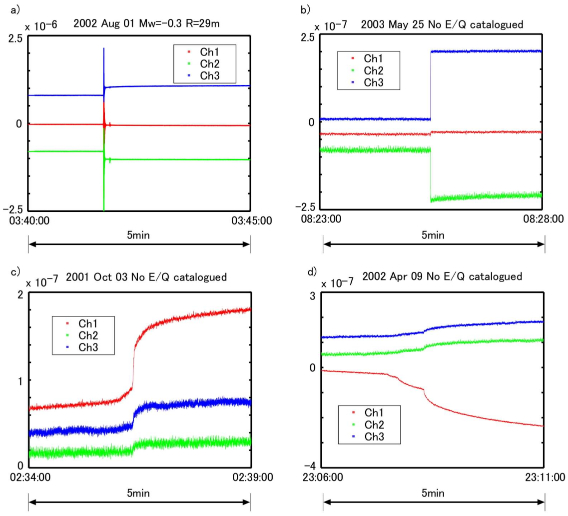
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x 10−6
2002 Aug 01 Mw=−0.3 R=29m
2.5
0
−2.5
Ch1
Ch2
Ch3
03:40:00
03:45:00
5min
b)
x 10−7
2003 May 25 No E/Q catalogued
2.5
0
−2.5
Ch1
Ch2
Ch3
08:23:00
08:28:00
5min
c)
x 10−7
2001 Oct 03 No E/Q catalogued
2
1
0
Ch1
Ch2
Ch3
02:34:00
02:39:00
5min
d)
x 10−7
2002 Apr 09 No E/Q catalogued
3
0
−4
Ch1
Ch2
Ch3
23:06:00
23:11:00
5min