Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS28-P20 会場:コンベンションホール 時間:5 月 23 日 18:15-19:30

南アフリカ金鉱山 M1.5 地震極近傍の応力測定
In-situ stress measurement at the closest proximity of an M1.5 earthquake at Tau Tona gold mine in South Africa

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In-situ stress measurements were successfully carried out in close proximity to a M1.5 damaging seismic event at 104 level (about 2950 m depth) at Tau Tona gold mine in South Africa. This event occurred on 3 December 2012, and on the 6th and 7th of February 2013, three overcoring stress measurements were done. The seismic event took place almost at the end of a pilot tunnel (see a photo attached), and significant dynamic rock mass ejection from the sidewall of the tunnel occurred. Elastic numerical modelling did not indicate any anomalous stress levels, but due to the severity of the damage it was important to better understand prevailing stress conditions. Stress measurement methods commonly used in South Africa (e.g. CSIR triaxial cell method or CSIRO HI method) was not suitable for such high stress conditions or adverse drilling conditions.

We used the BX CCBO technique (60mm diameter CCBO overcoring), a downsized version of the Compact Conic Borehole-end Overcoring technique (76mm diameter overcoring; Sakaguchi et al. 1992; Sugawara and Obara 1999; ISRM suggested). For overcoring, 6-15m BX pilot holes are drilled from tunnels at depths. Tools are used allowing implementation of the technique for typical South African geological drilling setups with small pneumatic machines. The procedure was first proven effective in South African gold mine conditions in 2011, on 98 L at Moab Khotsong Mine (about 3.0km depth) at an area with supposed minimal mining perturbation (Ogasawara et al. J. SAIMM 2012) . The technique was also implemented on 28 and 29th of January 2013 at Mponeng Gold Mine, 120L (an about 3350 m depth) also at an area with least mining stress perturbation.

At both the 3.0km-deep site at Moab Khotsong mine and the 3.4km-deep site at Mponeng mine, the measured maximum principal stress was consistent with overburden pressure. The determined orientations of intermediate principal stress (the horizontal maximum principal stress) and its ratio to the maximum principal stress was also consistent with the stress fields that well accounted for the fault slip mechanisms of nearby M2-4 earthquakes in the mines (e.g. Hofmann and Murphy 2007; Hofmann and Scheepers 2010).

At the moment, we have to wait for lab test for elastic modulus of the cores recovered from the measurement hole. However, if we used a typical elastic modulus for the lithology of the site, the measured stress at 104L (about 3.0km depth with least mining) at Tau Tona was much larger than the measured stress at 120L (a 3.4km depth with least mining) at Mponeng mine.

No in-situ stress measurements have been carried out close to the area of the damaging seismic event before, and hence no stress information was available towards mitigating seismic risk. It was proven that the BX CCBO technique can be implemented in adverse underground conditions - high stress and limited shift working hours in the South African gold mines. We hope that stress measurement can be done regularly together with a pilot geological drilling program, prior to advancing the pilot tunnel, which will fundamentally contribute to mitigate seismic risk in South African gold mines.

We were very much encouraged to make additional plans to see more detailed of stress distribution of seismic sources in South African gold mines.

These measurements were funded by JST-JICA SATREPS and Anglogold Ashanti Ltd.

Photo. The M1.5 seismic damage at a pilot tunnel at 104L at Tau Tona, at the closest proximity of which the BX CCBO in-situ stress measurement was carried out. Harumi Kato and Gerhard Hofmann look at a potential rupture plane on the side wall. Photo by Hiroshi Ogasawara.

キーワード: 現場応力測定, 震源極近傍, 南アフリカ金鉱山, BX 円錐ひずみ法
Keywords: In-situ stress measurement, Closest proximity of a hypocenter, South African gold mine, BX CCBO technique

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