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Seismicity Induced by Mine Flooding

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In November 2008, the closure of the East Rand Proprietary Mines resulted in the closure of the last pumping station in the Central Rand Basin, South Africa, which previously maintained the underground water level. The consequent large scale rise in the water level was and still is responsible for increased levels of seismicity in the area. Monitoring of seismicity in the Central Rand Basin has been an on-going process for over five years.

A fundamental question is: how does fluid-induced seismicity in the Central Rand Basin change over time? The level of seismicity in the Central Rand Basin is not showing signs of decreasing with time since the number of strong events with moment (M_w) magnitudes above 2 is still as high as it was when monitoring began over five years ago.

The spatial and time variation of seismicity in the Central Rand Basin area was analyzed. Special attention was given to seismic source parameters such as magnitude, scalar seismic moment, radiated seismic energy and static stress drop. Static stress drop heavily influences ground motion characteristics, which, in urban areas, affects the risk assessment. The observed static stress drop varied from 0.05MPa to 10MPa. The static stress drop increases with an increase in the seismic moment for seismic moment values ranging from 10^{10} Nm to 10^{13} Nm. However, for a seismic moment larger than 10^{13} Nm, an upper limit for the static stress drop at 10MPa was found.

Most events are located within historical mine boundaries. The seismicity pattern shows a strong relationship between the presence of the mining void and high levels of seismicity. The seismicity did not, for the most part, appear to migrate to areas outside of the old mining boundaries.

The temporal evolution of the inter-event time confirms that the fluid-induced seismicity follows a clustering pattern and is not random. The temporal evolution of the inter-event time provides an understanding of the physical mechanisms of earthquake interaction. Changes in the characteristics of the inter-event time are produced when a stress change is applied to a group of faults in the region. Results from this study indicate that the fluid-induced source has a shorter inter-event time in comparison to a random distribution. This behaviour corresponds to a clustering of events, in which short recurrence times tend to be close to each other, forming clusters of events.

A detailed analysis of the cumulative seismic moment revealed that initially, the eastern part of the area was responsible for the largest portion of the total seismic deformation but on 18 November 2013 the biggest event appearing in the catalogue, occurred in the western part. This implies that the dynamic forces that control seismicity in the area are fluctuating. The evolution of the seismicity pattern over time indicates that the Central Rand Basin is still in a very unstable state. Over the last five years, the total cumulative seismic moment released in the Central Rand Basin was 9.0×10^{14} Nm. This is equivalent to a single earthquake of magnitude M_w 3.9, which is significantly less than the largest earthquake

experienced during mining times. In 1972 a magnitude M_w 4.8 earthquake was observed in the East Rand Proprietary Mines.