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Water Ingress into Underground Mine Voids in the Central Rand Goldfields Area, South Africa-Fluid Induced Seismicity

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Abstract : The last active mine in the Central Rand Goldfields area (50 km x 15 km) ceased operations in 2008. This resulted in the closure of the pumping stations, which previously maintained the underground water level in the mining voids. As a direct consequence of the water being allowed to flood the mine voids, seismic activity has increased directly beneath the populated area of Johannesburg. Monitoring of seismicity in the area has been on-going for over five years using the network of 17 strong ground motion sensors. The objective of the project is to improve strategies for mine closure. The evolution of the seismicity pattern was investigated in detail. Special attention was given to seismic source parameters such as magnitude, scalar seismic moment and static stress drop. 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; no seismicity migration patterns were observed outside the areas of old mining. Seven years after the pumping stopped, the evolution of the seismicity has indicated that the area is not yet in equilibrium. The level of seismicity in the area appears to not be decreasing over time since the number of strong events, with Mw magnitudes above 2, is still as high as it was when monitoring began over five years ago. The average rate of seismic deformation is 1.6x1013 Nm/year. Constant seismic deformation was not observed over the last 5 years. The deviation from the average is in the order of 6x10^13 Nm/year, which is a significant deviation. The variation of cumulative seismic moment indicates that a constant deformation rate model is not suitable. Over the most recent five year period, the total cumulative seismic moment released in the Central Rand Basin was 9.0x10^14 Nm. This is equivalent to one earthquake of magnitude 3.9. This is significantly less than what was experienced during the mining operation. Characterization of seismicity triggered by a rising water level in the area can be achieved through the estimation of source parameters. Static stress drop heavily influences ground motion amplitude, which plays an important role in risk assessments of potential seismic hazards in inhabited areas. The observed static stress drop in this study varied from 0.05 MPa to 10 MPa. It was found that large static stress drops could be associated with both small and large events. 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.

Keywords : inter-event time, fluid induced seismicity, mine closure, spectral parameters of seismic source
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