Safety in Mines Research Advisory Committee

Project Summary: SIM 11-02-01

Project Title:	*Fluid-Induced Seismicity in the Central Basin Area: Ground Motion Prediction and the Development of an Early Warning System for Risk Reduction*

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Report Date:	**August 2013**	**Related Projects:**	
Category:	**Mining**	**Applied Research**	

Summary:

Three and a half years after pumping out water in the ERPM mine was stopped, the evolution of seismicity has indicated that the Central Rand Basin area is not yet in equilibrium. Because the seismicity is located directly beneath the densely populated area of Johannesburg, a full understanding of its mechanism is required. Seismic data clearly shows that the level of seismicity in the rock mass influenced by water ingress tends to be much larger than in the surrounding rock mass.

3D modelling was used to identify areas of instability within the abandoned mines. This led to a description of the spatial distribution of seismic activity with a possible explanation and an estimation of maximum shear displacement along a geological feature. There was good agreement between the spatial distribution of seismicity and the positions of potentially unstable features, which suggests two possibilities: (1) Seismicity is being controlled by stresses induced by the shape and orientation of the mined-out reef on intersecting geology rather than tectonic stresses and (2) The shallow crust can be described by a homogenous material and uniform stress model.

Probabilistic seismic hazard analysis was conducted for the area. A hazard map was produced for spectral acceleration at T = 0.1s and T = 1.0s, both at return periods of 475 years and 979 years. Maximum expected peak ground acceleration values are 0.16 g and 0.2 g for the return periods of 475 years and 979 years respectively. The acceleration values are almost the same at OR Tambo and Johannesburg, whilst values at Soweto are much less. The expected damages for 12 of the most characteristic building classes found in the Johannesburg CBD are included. The assessment of the maximum regional seismic event magnitude is also provided.

One of the objectives was to determine the subsoil and groundwater conditions at the site in order to delineate the most favourable locality for a first level microzonation map in support of the strong ground motion amplification prediction and the development of an early warning system for risk reduction. The results have indicated that the most favourable topographic situation for thick soil deposits in the study area occupy the Johannesburg graben valley.

A catalogue of almost 1000 earthquakes was created and the spectral parameters of the events were estimated. A new relation between M_L and M_w was obtained. An increase in static stress drop with increasing seismic moment is observed. The attenuation of the P- and S-waves in the Central Rand Basin is estimated using the coda normalization method. The frequency dependence of parameters for the P- and S-waves is calculated for a set geometrical spreading constant. The dependence between seismic moment and radiated energy in different studies shows a similar pattern to the one observed here. However, there are some significant differences; static stress drop for the Central Rand Basin area is one order of magnitude larger than in the case of observed seismicity induced by a water reservoir in China. The amplitudes of ground motion are controlled by the amount of static stress drop during a seismic event; therefore, areas where large stress drop is observed are areas where strong ground motion is expected.

The spatial variation of seismicity in the area was analysed. The number of events increased significantly within the last year of monitoring. The distribution of seismicity shows a reduction in the level of seismicity in the western part of the Central Rand Basin during 2012. The strongest events in 2012 were concentrated in the eastern part the Central Rand Basin. However, the earthquakes with the largest stress drops are observed in the eastern and central parts of the Central Rand Basin.

The variation of cumulative seismic moment and radiated seismic energy as functions of time indicates that a constant deformation rate model is not suitable for the Central Rand Basin area. However, evolution with time of the cumulative parameters and estimated strain rate could be used as indicators of future seismic activity**.**