CHARACTERIZATION OF NATURAL AND HUMAN-RELATED SEISMICITY IN SOUTH AFRICA

Thomas H. Jordan, Eliza Richardson, Jeffrey J. McGuire
Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology
Cedric Wright, Sue Webb, Eldridge Kgaswane, Teresia Nguuri
Department of Geophysics, University of Witwatersrand, Johannesburg, South Africa

Sponsored by U.S. Department of Defense
Defense Threat Reduction Agency
Contract No. DSWA01-98-C-0158

ABSTRACT

We have begun a two-year collaborative project between the Massachusetts Institute of Technology (MIT) and the University of Witwatersrand to investigate the natural and human-related seismicity of southern Africa. The project is focused on the seismic activity of the Witwatersrand Basin during the two-year period from April 1997, through April 1999. The data for this project come from three principal sources: (a) permanent seismic observatories operated by the South Africa Council for Geosciences, (b) a broadband, 52-element temporary array operated by the Carnegie Institution of Washington and MIT as part of the Kaapvaal Project under the sponsorship of the National Science Foundation, and (c) a number of local arrays operated by companies engaged in deep gold mining.

The project has four principal objectives: (1) to catalog the seismicity of the Witwatersrand Basin and surrounding regions during this two-year period; (2) to calibrate locations in this region using events with hypocenters and origin times precisely determined by in-mine networks, and to use these calibrations to refine three-dimensional crustal and upper-mantle models for the region; (3) to determine moment-tensor solutions and spectral characteristics of a subset of events for the purpose of assessing such information as discriminants among tectonic earthquakes,[1] mine tremors, rockbursts, and chemical explosions; and (4) to employ three-component waveform data from the local events to assess anisotropic propagation effects and wavefield scattering by small-scale crustal heterogeneities.

Project personnel have worked directly with the Council of Geosciences to establish a preliminary catalog for the study period from phases reported by the permanent stations. The seismicity of the region is much higher than most stable cratons, owing to frequency of mining-induced events. In the 10-month period of April to December 1997, for example, there were 557 events locatable by the permanent observatories; 415 of these had local magnitudes of 2.5 or greater. The highest seismicity rates were observed in the Far West Rand and Klerksdorp mining districts, which accounted for 43% and 30% of the seismicity, respectively.

Detailed investigations of the seismicity of the Far West Rand district using in-mine arrays have revealed two populations of mining-induced events, designated as Type A and B, with distinct frequency-magnitude statistics and other characteristics. Type A events are small in magnitude ($M_L<1$) and highly clustered in time and space, usually within 100 m of active stope faces; their spectra are rich in high frequencies, and their mechanisms often involve significant tensional components. We associate these events with new fractures in competent rock induced by dynamic stresses during blasting and quasi-static stress perturbations from the excavation and closure of individual stopes. According to this model, the upper magnitude of these events is limited by the dimensions of the stress-perturbation aureoles around the stopes. Type B events, on the other hand, show distributed locations, spectra depleted in high frequencies, and double-couple mechanisms. In the Far West Rand regions, these events can have large magnitudes (> 4), but they show a distinct lower magnitude cut-off at $M_{min} \approx 0$. Type B events are caused by ruptures on preexisting faults and other weak geological structures, such as dyke faces and bedding planes, and they can be used to place significant constraints on the physics of the faulting process. In particular, their frequency-magnitude statistics and spectral properties are consistent with a rate-and-state friction model in which M_{min} is controlled by a critical slip distance D_c of approximately 10^{-4} meters.

Key Words: seismicity, South Africa, mining activities, earthquakes, discrimination, calibration

---

[1] The earthquake moment tensors will be used to study the tectonic stress field in the region and its relationship to geological structures.