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Technical Note

Mine-induced Seismicity at East Rand Proprietary Mines

A. M. MILEV†
S. M. SPOTTISWOODE†
K. R. NOBLE‡

INTRODUCTION

Mining results in seismic activity of varying intensity, from small microseismic events to larger seismic events, often associated with significant seismic induced damages. This work deals with the understanding of the present seismicity in the actively mined areas of East Rand Proprietary Mines (ERPM). It includes previous observations of the regional seismicity [1] as well as a more detailed data base.

For more detailed analyses, the active regions of the mine were divided into sub-regions around specified seismogenic volumes (Fig. 1). The sub-regions sizes were determined from the following considerations: (i) the seismicity associated with face advance; (ii) the stress activity on abutments and pillars; (iii) the local geological features.

A linear relation between seismicity and elastic closure has been reported by McGarr [2]. We simplify this relationship and consider ΔV_M as the total volume of mining. We write:

$$\Sigma M_0 = \gamma G \Delta V_M \qquad (1)$$

where ΣM_0 is cumulative seismic moment; ΔV_M was estimated from the volume of rock mined out assuming a stope width of 1.1 m; γ is a factor which can vary between 0 and 1; G is the modulus of rigidity, which is assumed from laboratory measurements to be 3.0×10^{10} N/m².

The right side of the equation (1) is a measure of seismic failure in response to shear stresses which are caused by the volume change. $G\Delta V_M$ represents the volumetric moment and γ is the ratio of cumulative seismic moment to volumetric moment. McGarr [3] interpreted γ as being dependent on the local geology.

The relation described by equation (1) was subsequently confirmed by McGarr and Wiebols [4] using data from the Hercules shaft area of ERPM and by Spottiswoode [5] using data from Blyvooruitzicht Gold Mine.

†Rock Engineering Programme, CSIR—Miningtek, P.O. Box. 91230, Auckland Park, 2006 South Africa.
‡Randgold & Exploration Company Limited, Randgold House, Ormonde 2091, P.O. Box 82291, Southdale, 2135 South Africa.

The seismic moment for each of the sub-divided areas has been calculated from automatic fits to the P and S spectra for each individual event.

The b-value was calculated according to the Gutenberg–Richter relation:

$$\log N = a - bM \qquad (2)$$

where N is the number of events with magnitude greater than or equal to M; M is the local Richter magnitude; a is a constant related to the seismicity; b is related to the ratio of the number of smaller events to the number of larger events for given area and given time period.

Another point of interest is the relation between the span of the mined out area and the level of seismicity. Theoretically there should be a linear relation between stope convergence and span of the mining area. Two measures of span are used in this work: SPAN (1) is defined as the face length between two stabilizing pillars, SPAN (2) is defined as the average length of the adjacent stabilizing pillars. We have investigated the level of seismicity and maximum event magnitude which occurred in each sub-divided area as a function of SPAN (1) and SPAN (2).

DATA AND RESULTS

The data used here were collected during the two-year period (1992–1993). The events were recorded by a Portable Seismic System [6], which was underground installed and covered the "K1", "L", "O" and lower "F" shaft areas. The data set consists of 2017 seismic events with magnitudes in the range of $0.0 \leqslant M \leqslant 3.1$. The location of the larger events ($M \geqslant 2.5$) and the geophones are shown in Fig. 1. The mine has been divided into seismogenic regions, although there is not a perfect match between the seismogenic regions and the mining areas. This may lead to some complications in correlation.

Table 1 contains: the total number of events per area; number of events with magnitude above $M \geqslant 1.5$; the maximum magnitude occurring in a single area; the cumulative seismic moment; the cumulative production for about two-year period of time; the γ-factor; τ—the static stress drop and the b-value.
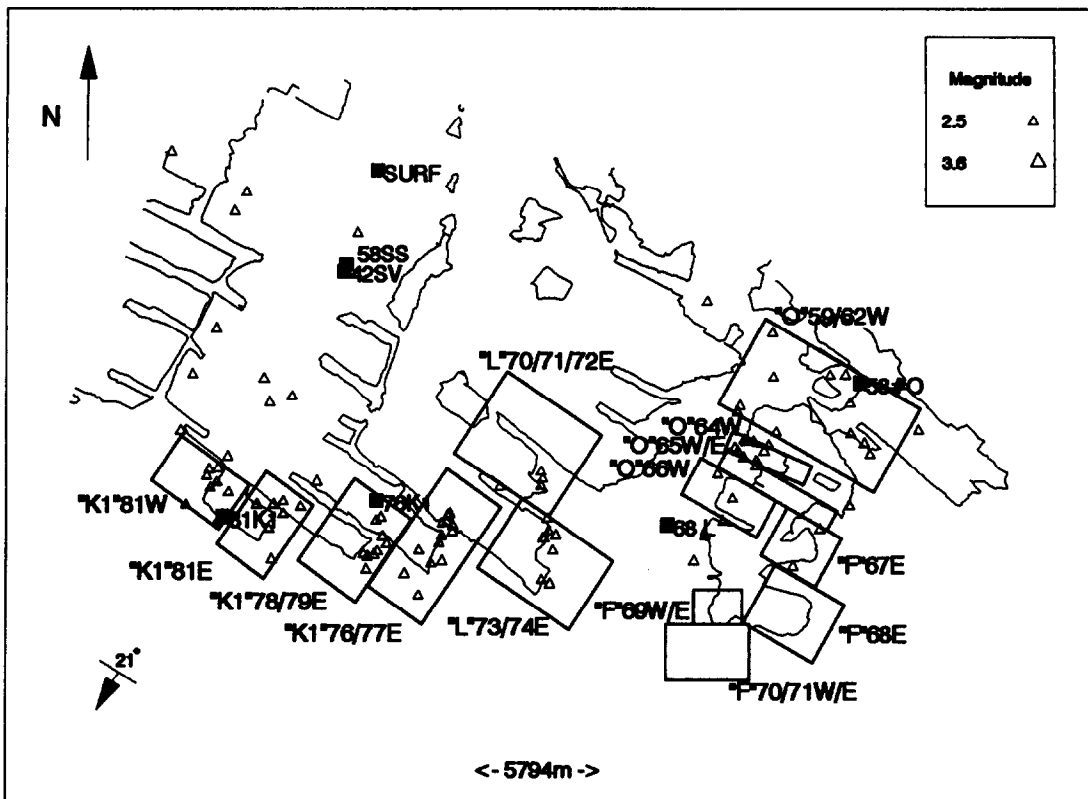
Fig. 1. A plan view of stabilizing pillar layout with the location of large seismic events for the East section of ERPM; ■—geophone positions; boxed areas show the sub-divided seismo-active regions.

The *b*-value, listed in Table 1 shows comparatively similar values throughout all the sub-regions of the mining area. It varies from 0.48 to 0.85 and seems to be not strongly influenced by changes in mine production.

The *γ* value represents a direct measure of the seismic deformation with respect to mining. It is seen from the Table 1 that *γ* varied between 0.006 and 0.55. The "K1" shaft shows higher activity compared to "L", "O" and "F" shafts. This fact can be explained by the presence of large mined-out area neighbouring the "K1" sub-regions. Thus, the "K1" areas have "inherent" seismicity from years of previous mining and extensive stope closure. The rate of seismicity in "L" shaft and more specially sub-regions "L" 73/74E and "L" 70/72E has been reduced by the establishment of stabilizing pillars. The low value of *γ* obtained for the lower part of

"F" shaft indicates that the shorter spain induces less seismicity.

Figure 2 shows the parameter *γ* as a function of span. The data indicate only small rates of change in *γ* with increased span of the mined area. However *γ* for the more active "K1" shaft are clearly separated. The areas "O" 59/62 West and "O" 64 West also show higher activity than the normal for that part of the mine.

Figure 3 is a plot of maximum event magnitudes which occurred in the area as a function of span. The scattering M_{MAX} is larger than for *γ* in Fig. 2, and it is difficult to define any trend with increase of span. It indicates that maximum event magnitude is probably not linearly controlled by face length.

The results obtained for SPAN (2) show similar patterns for these two parameters. We have therefore decided to limit our discussion to SPAN (1).

Table 1. Seismic parameters for the "K1", "L", "O" and "F" (lower FEV) shafts on ERPM

|	Area name	Number of events	Events $M \geqslant 1.5$	M_{MAX}	ΣM_0	ΔV_M (m^3)	*γ*	*τ*	*b*-value
1	K181W	98	17	2.17	2.0 E14	—	—	3.05	0.48
2	K181E	249	98	3.09	4.2 E14	29,040	0.48	2.50	0.73
3	K178E	300	128	2.81	3.0 E14	19,008	0.53	1.80	0.65
4	K176/77E	349	177	2.72	3.9 E14	23,760	0.55	2.90	0.65
5	L70/72E	150	80	2.71	1.6 E14	35,640	0.15	5.33	0.61
6	L73/74E	180	102	2.75	2.5 E14	52,800	0.16	3.81	0.58
7	O59/62W	278	125	2.58	2.9 E14	29,040	0.33	3.37	0.61
8	O64W	91	54	2.89	3.1 E14	36,960	0.28	6.62	0.51
9	O65W/E	83	26	2.51	4.8 E13	50,688	0.03	0.91	0.85
10	O66W	88	33	2.38	7.3 E13	22,440	0.11	1.88	0.68
11	F67E	72	22	2.70	8.8 E13	36,960	0.08	1.52	0.74
12	F68E	59	19	2.08	1.7 E13	31,680	0.02	1.67	0.84
13	F69W/E	10	—	2.10	3.2 E12	31,680	0.003	0.63	0.71
14	F70/71W/E	10	—	1.90	5.8 E12	33,000	0.006	1.73	0.63

GAMMA
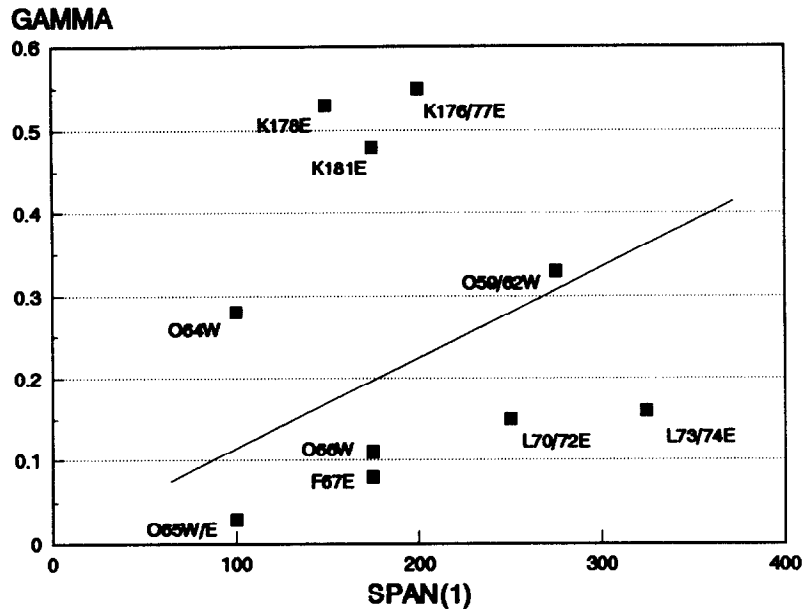
Fig. 2. Parameter *y* as a function of SPAN (1).

The average static stress drop τ was not found to be function of either SPAN or *y*.

CONCLUSIONS

The "K1" shaft shows higher seismic activity compared to the "L", "O" and "F" shafts. This can be explained in terms of the large mined-out areas around the "K1"81E, "K1"78E and "K1"76/77E sub-regions. Generally, "K1" areas have "inherent" seismicity from years of previous mining and extensive stope closure.

The rate of seismicity in "L" shaft and more specially in sub-regions "L" 73/74E and "L" 70/72E has been reduced by the presence of stabilizing pillars.

The areas "O" 59/62 West and "O" 64 West show higher activity than normal for this part of the mine.

The low value of *y* obtained for the lower part of "F" shaft indicates that shorter span induces less seismicity. When the spans at "F" shaft reach larger dimensions, we expect the seismicity to be controlled by the pillars, as in "L" shaft.

The *b*-value and τ show relatively similar values throughout all the mine sub-regions and indicates that changes in mine production does not have strong influence on it.
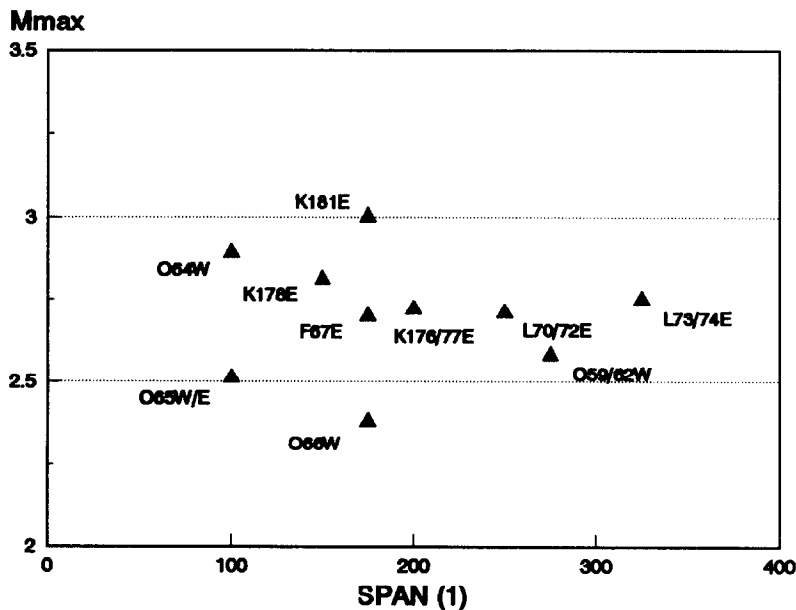
Mmax

Fig. 3. Parameter M_{MAX} as a function of SPAN (1).

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