Micro-seismic events: an aid in studies of deep-mine rock structures

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SYNOPSIS

A system for the monitoring cf micrc-seismic events, which is designed for use in feasibility studies of rock-burst prediction, has been operating at Western Deep Levels Limited since 1977. Analyses have revealed that the presence and orientation of geological discontinuities ahead of the mine face can be predicted from the data produced by this system.

SAMEVATTING

'n Stelsel vir die monitering van mikroseismiese gebeurtenisse wat ontwerp is vir gebruik in uitvoerbaarheidstudies van rotsbarstingsvoorspellings is reeds sedert 1977 by Western Deep Levels Limited in gebruik. Ontledings het getoon dat die aanwesigheid en oriëntasie van geologiese onderbrekings voor die mynfront voorspel kan word aan die hand van die gegewens wat deur hierdie stelsel ingewin is.

Purpose

The purpose of this paper is to draw the attention of rock-mechanics researchers to the use of micro-seismic monitoring in studies of deep-mine rock structures since there are indications that micro-seismic monitoring can provide a forewarning of the presence of unexposed geological discontinuities.

Location of Monitoring Station

The Carbon Leader Reef (CLR) is mined at Western Deep Levels (WDL) at an average depth of 3000 m below surface. It is a tabular orebody dipping at an angle of approximately 21° in a direction 62° south of east. The grade has allowed for total extraction by use of an overhanding longwall-mining method. The basic unit of production consists of 187 individual panels, which average 35 m in length on dip and are separated on strike by leads of varying length. The average stoping width is 0,96 m, and face advance on strike is about 8 m per month.

Fig. 1 shows ten panels on a portion of the CLR approximately 3100 m below surface in the vicinity of the micro-seismic monitoring station. The face positions shown are those as at 12th June, 1980.

The CLR is a band of pebble conglomerate that varies in thickness from a microscopically thin gold veneer contact to a conglomerate band 0,5 m thick with pebbles averaging 1 cm across. At the monitoring site, the footwall and hangingwall rocks are clean siliceous quartzites with a 2 m-thick chloritoid shale (the Green Bar) situated some 2 m above the CLR.

The only significant geological joint set in the area of the site consists of fairly regularly spaced (0,2 to 2 m) vein quartz and/or chlorite-filled joints dipping from 70° to almost vertical in a direction E15°S (Fig. 1).

The majority of dykes at WDL are of Ventersdorp age and have a diabasic composition. They strike approximately parallel to the dominant joint direction described above, and many have faulted contacts[1].

At least 700 (and often as many as 3000) micro-seismic events are recorded nightly in the vicinity of these stope faces by the use of a single three-dimensional accelerometer at the monitoring site depicted in Fig. 1. Events up to 50 m from the reef plane (hanging- and footwall) are recorded and, with the aid of a computer, the locations are projected onto a horizontal and vertical plane. The concentrations are contoured, and these are then plotted on plan and section as shown in Fig. 1.

Detection of Faults and Dykes

The effect of geological discontinuities on the distribution of micro-seismic events in the solid rock ahead of the mine face is considerable, and has been observed since the early stages of monitoring. Contour plots of micro-seismic events, especially for days on which no blasting was done at the nearby faces, showed concentrations of events about the major geological discontinuities. Dyke D1 was particularly active, and its presence and strike orientation were detectable approximately 30 m ahead of the mine face[2].

Mining standards require that all geological weaknesses should be adequately supported to prevent rock-fall accidents. In many instances, however, the personnel working in the area have difficulty in recognizing minor discontinuities, and continue working in potentially hazardous areas. It would be highly advantageous if one could in a position to forewarn personnel of the presence of such features ahead of the face. It was therefore decided that an attempt should be made to predict the presence of unexposed discontinuities.

As a result, particular note was taken of an anomalous concentration of micro-seismic events in the vicinity of panel 3, which is shown in Fig. 1. Fig. 1 gives a plan and section of a contoured plot of 2472 micro-seismic events that were located during one night —from 20h00 on 11th June, 1980, to 07h00 on the following morning. Panels 1 and 3 were blasted at approximately 16h00 on the afternoon of the 11th. Similar plots showing anomalous concentrations in the vicinity of panel 3 were observed some two weeks before that date. In the light of these observations, the presence of an active geological discontinuity was predicted.

During the ensuing two months, a small but troublesome reverse fault was exposed in this stope, confirming

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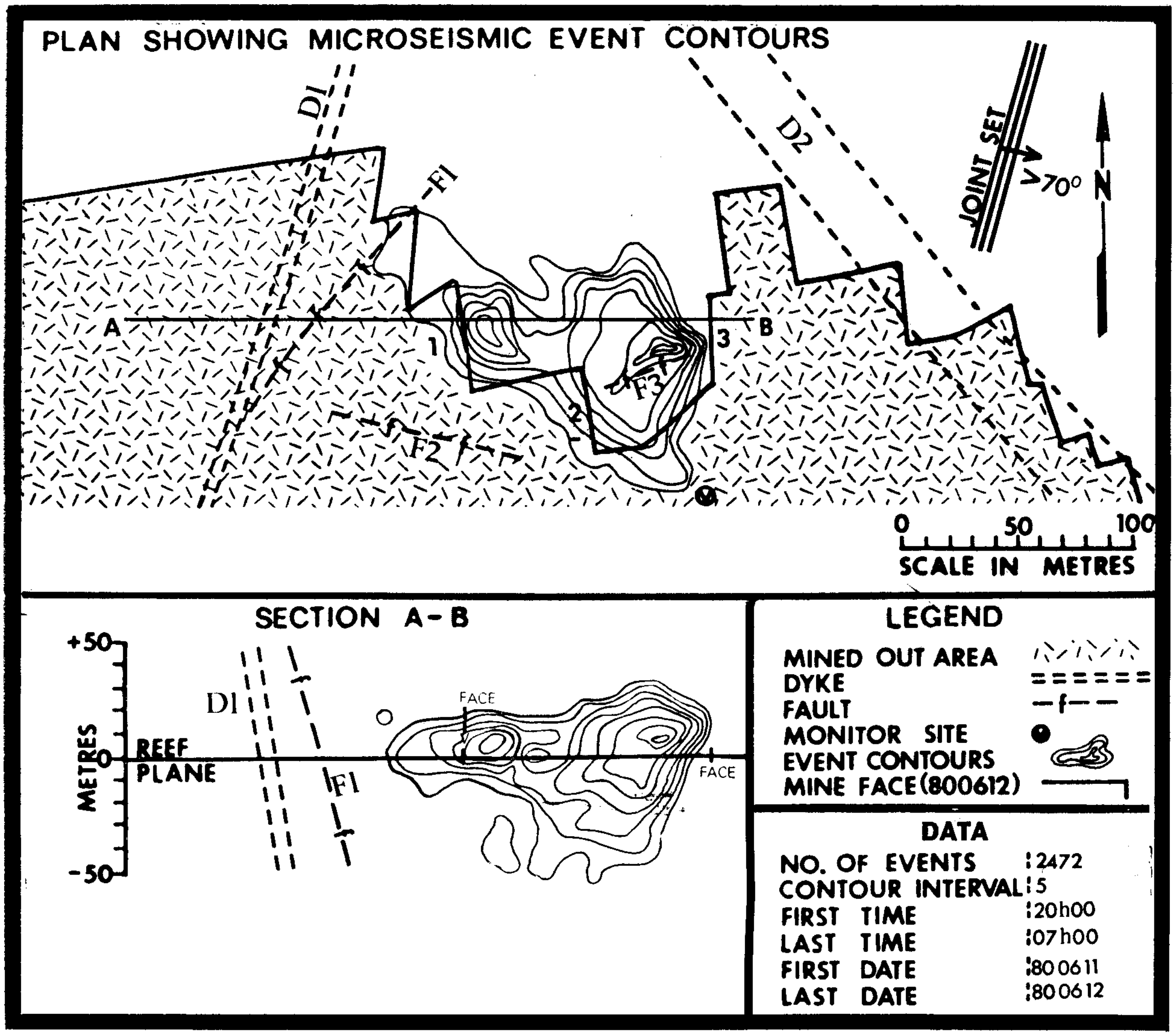

Fig. 1—A plan and section of a contoured plot of 2472 micro-seismic events

the prediction made on the basis of the micro-seismic concentrations. The strike orientation, based on the elongation of the micro-seismic event contours, was correctly predicted. However, there was a discrepancy of 10 m between the predicted position and the actual position of the fault. The fault zone consists of an 8 cm wide highly fractured chlorite-filled zone dipping steeply (85°) north (F3 on Fig. 1), with a down-throw of approximately 10 cm on the south side. As indicated by mining personnel, there were areas in the immediate vicinity of this fault where extensive rock falls had taken place, with consequent adverse effects on production and safety.

Conclusion

The presence and approximate orientation of a previously unexposed geological discontinuity was predicted by the use of micro-seismic event-location data, showing that these data can be used for the short-term delineation of unexposed geological discontinuities and as an additional tool for rock mechanics researchers.

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