# Discussion: Computer simulation of mining in faulted ground*

by S. L. CROUCH

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The procedure described by Professor Crouch for the modelling of mining in faulted ground allows the elastic and inelastic deformation to occur simultaneously, that is, fault slip occurs while an element is being mined. The energy release rates (ERR) shown in Crouch's Fig. 10 are apparently calculated from his equation 9 using the total deformation $\overset{i}{D}_n$ (see the upper load line of Fig. 1). However, the use of the equation is not justified if the deformation includes a large inelastic component.

An alternative approach is to separate the elastic and inelastic deformation on the fault. At each mining step, the fault is first allowed to deform elastically before the ERR is calculated according to equation 9 by use of $\overset{i*}{D}_n$ (see Fig. 1). The fault is then allowed to slip according to the Mohr–Coulomb slip condition. As a result of slip, closure at the mined element i changes from the intermediate value $\overset{i}{D}_n$* to its final value $\overset{i}{D}_n$, but this occurs while $(\overset{i}{\sigma}_n)_{total}$ is zero and therefore no work is done during the latter phase (see the lower load line of Fig. 1).

The energy dissipated on fault elements by inelastic deformation therefore does not contribute to the ERR.

Mining experience is that fault slip seldom occurs concurrently with mining, and the usual load line of an actual mining situation would therefore lie on the lower load line of Fig. 1.

The example dealt with by Crouch, namely mining at a depth of 2000 m through a fault dipping at 60° (case 1), was repeated with the above modification made to his computer program (case 2). The large increase in ERR as mining passes through the fault in case 1 no longer appears in case 2, and only the reduction in energy release rate following the fault intersection is still present (Fig. 2).

It therefore appears that energy dissipated on the fault through inelastic deformation results in a subsequent decrease in the average ERR.

## Author's Reply

The numerical procedure described in my paper assumes that fault slip can be modelled as a quasi-static time-independent phenomenon. My method of computing the energy release rate due to mining is consistent with this assumption.

The procedure suggested by Mr Diering assumes that inelastic deformation of the fault occurs at some unspeci-

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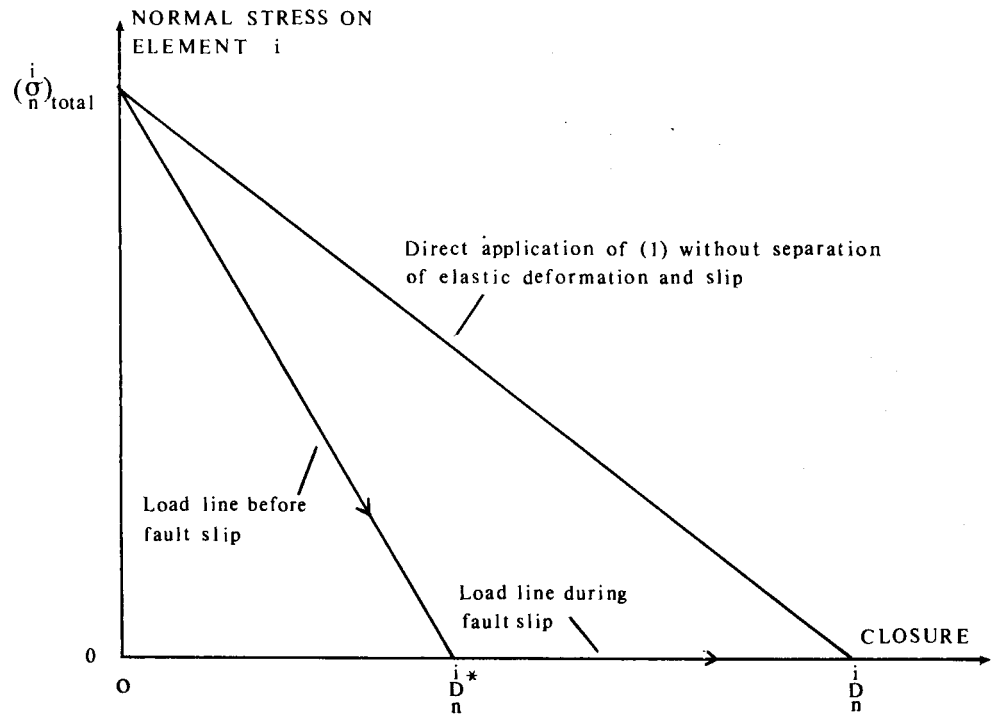


**Fig. 1—Load lines for the mining of element i**

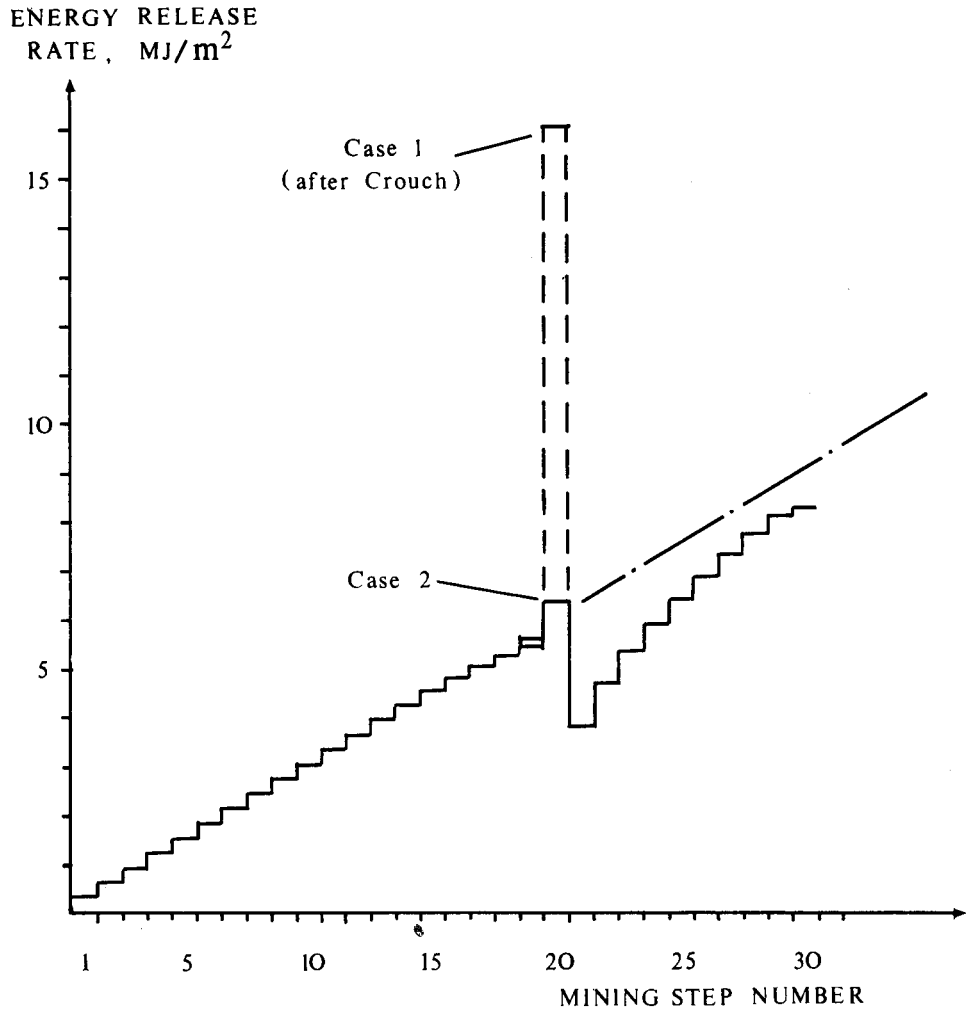


**Fig. 2—Comparison of energy release rates for case 1 versus case 2**

fied time after a mining step has been completed. Physically, this is equivalent to assuming that the Mohr–Coulomb elements exhibit a simple kind of 'time-dependent' behaviour, in which their cohesion and angle of friction increase just before a particular mining step and then decrease just afterwards. Apart from this distinction, Mr Diering's numerical procedure is the same as mine. In particular, his procedure also assumes that fault slip can be modelled as a quasi-static phenomenon.

Mr Diering's modification of my model is based on his observation that 'fault slip seldom occurs concurrently with mining.' If this observation is correct, then we must conclude that the energy release rate due to mining is not an appropriate indicator of the problems associated with mining in faulted ground. It is possible, however, that the energy dissipation due to slip along the fault may provide such an indicator. For quasi-static slip, the energy dissipation does not depend upon when the slip occurs in relation to the mining sequence.

We clearly have much to learn about the ways in which geological discontinuities can affect the displacements and stresses induced by mining. The work described in my paper represents a simple step in this direction.

# Refractories

The institute of 'Gesteinshüttenkunde' of the technical university at Aachen, the Refractories Research Institute at Bonn, and the Verein Deutscher Eisenshüttenleute (VDEh) at Düsseldorf are to hold the XXII International Refractory Colloquium on 27th and 28th September, 1979, at Aachen.

The main theme will be 'Refractories for reheating and heat-treating furnaces'. The presentations will be in German, English, or French, and simultaneous translation will be provided in the three languages.

Further information is obtainable from the Institut für Gesteinshüttenkunde, der RWTH Aachen, Mauerstrasse 5, D-5100 Aachen, West Germany.