The seismic profiling was successful in defining the deeper of the two target seams. The aim of the study was to detect faulted zones and, in particular, to define areas that were free from structural disruption. The seismic did this, but unfortunately for the prospects of the area, it has shown more structural complexity than was previously indicated.

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Faults and Absorption in Coal Seams

Dr Lawrence A. Drake

Centre for Geophysical Exploration Research
Macquarie University NSW 2109

Summary

At the Centre for Geophysical Exploration Research at Macquarie University, computer programs have been developed to model the propagation of SH and P–SV waves in coal seams. These computer programs are based on the finite element method and include allowance for irregularities in the coal seam and for absorption in the coal and rock. In the longwall mining method, it is of the greatest economic importance to be able to detect faulting and other serious interruptions of the coal seam well ahead of the mining face. Scientists of the Broken Hill Proprietary Co. Ltd have conducted surveys of the transmission of SH and P–SV coal seam waves both by borehole observations and underground roadway observations. At frequencies below 200 Hz, interruptions of the coal seam are not readily detectable by SH and P–SV seam waves. At frequencies above 200 Hz, it is not easy to distinguish the effects on the transmitted SH and P–SV seam waves of interruptions of the seam from the effect of more than usual absorption in the seam. Thus, at a frequency of 400 Hz, for a coal seam offset one seam width by a vertical fault, finite element modelling shows that the effect of the fault is to reduce the amplitude of the SH fundamental mode by 82 percent. Allowance for a Q value of 25 in the coal seam and of 50 in the rock above and below the seam indicates a further decrease of 11 percent in only 24 m. Similar results have been obtained for the P–SV $M_{2\,3}$ mode in the same finite element model and for SH and P–SV modes in a model of a coal seam intersected by a vertical hard dyke. Because interruptions of the seam scatter SH and P–SV energy back and above and below the seam, it is desirable to make both reflection measurements and transmission measurements near the central plane of the seam to distinguish more readily the effect of a seam interruption from that of high absorption.

Introduction

With the increasing use of longwall methods in coal mining, knowledge of the presence of interruptions in a coal seam ahead of the mining face or ahead of a roadway, is of the greatest economic importance in mine planning (Hatherly, 1987). To overcome the difficulties of interpretation of observed SH and P–SV waves (from small charges detonated in coal seams), analogue and computational modelling has been carried out. At Ruhr-Universität, at Bochum in West Germany, the propagation of SH waves has been studied by finite difference methods (Kerner and Dresen, 1985) and the propagation of P–SV waves has been studied by analogue modelling (Dresen *et al.*, 1985). Recent analyses have been made in Australia by finite difference, finite element and tomographic methods (Mason *et al.*, 1985; Scaife *et al.*, 1986). At the Centre for Geophysical Exploration Research at Macquarie University, computer programs, based on finite element methods, have recently been modified to allow for absorption of seismic waves in the coal seam and in the roof and floor rock above and below it. Finite element models of a coal seam offset one seam width by a vertical fault and of a coal seam intersected by a vertical hard dike have been analysed at a range of frequencies of from 50 to 400 Hz.

Finite element models and results

A finite element model of a coal seam of Q value 25 at a depth in the earth of 160 m in a layered sandstone-shale sequence of Q value 50 is shown in Fig. 1.

The model was analysed for incident SH fundamental mode motion from the left, first, without allowance for absorption;

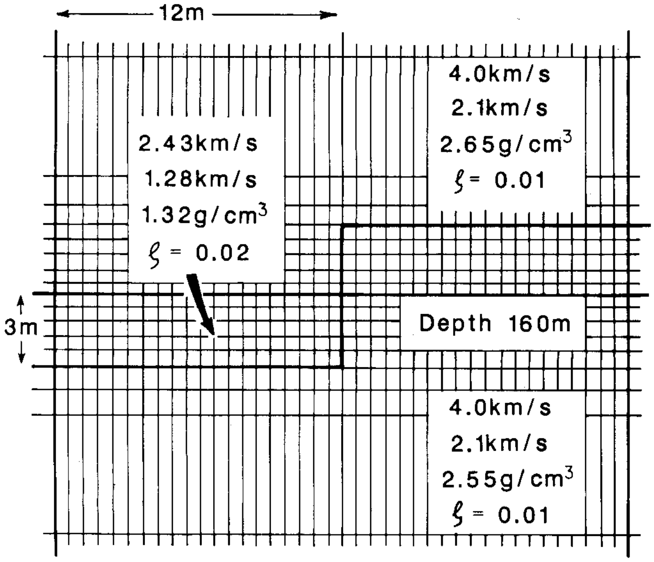

FIGURE 1
Central section of the finite element model of a faulted coal seam.

it was then analysed with allowance for absorption only in the coal and, finally, it was analysed with allowance for absorption in both the coal and the rock (cf. Asten *et al.*, 1984). At frequencies of approximately 100 Hz, the amplitude of the SH fundamental mode was reduced by 1 percent by the fault, by 5 percent in 24 m by the combined effect of the fault and the absorption in the coal, and by 8 percent in 24 m by the combined effect of the fault and the absorption in the coal and the rock. At frequencies of approximately 400 Hz, the amplitude of the SH fundamental mode was reduced by 82 percent by the fault, and by 93 percent in 24 m by the combined effect of the fault and the absorption in the coal (and also the absorption in the coal and the rock). The reason for these values is indicated in Fig. 2, which shows the variation of displacement with depth in the ground of the SH fundamental mode at the frequencies of 100 Hz and of 400 Hz; the modes are normalized so that the energy carried by them is proportional to the products of their frequencies and wavenumbers (Lysmer and Drake, 1972).

The model was similarly analysed for incident P-SV $M_{2\,3}$mode motion (cf. Edwards *et al.*, 1985). The P-SV fundamental mode is $M_{1\,1}$. The mode $M_{2\,1}$ has zero horizontal displacement in the central plane of a coal seam, so that the mode $M_{2\,3}$ is the mode of lowest velocity with a large displacement in the central plane of a coal seam. For finite element models of thickness equal to 320 m, the mode $M_{2\,3}$ has the third lowest velocity below a frequency of approximately 110 Hz, as shown in Fig. 3 (wavenumber × thickness = 107), and at frequencies above 110 Hz, it has the second lowest velocity. At frequencies of approximately 400 Hz, it has the second lowest velocity. At frequencies of approximately 100 Hz, the amplitude of the P-SV $M_{2\,3}$ mode was reduced by 3 percent by the fault, and also, in 24 m, by the combined effect of the fault and absorption in the coal; it was reduced by 10 percent in 24 m by the combined effect of the fault and absorption in the coal and the rock. At frequencies of approximately 400 Hz, the amplitude of the P-SV $M_{2\,3}$ mode was reduced by 72 percent by the fault, by 76 percent in 24 m by the combined effect of the fault and absorption in the coal, and by 80 percent in 24 m by the combined effect of the fault and the absorption in the coal and the rock. In Fig. 4 the variation of horizontal and vertical displacement with depth of the P-SV $M_{2\,3}$ mode at a frequency of 100 Hz is shown; again the mode is normalized so that the energy carried by it is proportional for the product of its frequency and wavenumber (Lysmer and Drake, 1972). At a frequency of 400 Hz the P-SV $M_{2\,3}$ mode is much more confined to the coal seam, but its vertical component still has significant displacement in the rock above and below the seam. At this frequency, waves of the SH fundamental mode are more affected by a seam interruption than waves of the P-SV $M_{2\,3}$ mode are.

A finite element model similar to that shown in Fig. 1, but with a vertical hard dyke of thickness 3 m (and Q = 50) replacing the vertical fault and offset shown in Fig. 1, was similarly analysed for SH and P-SV motion. At frequencies of approximately 100 Hz, the amplitude of the SH fundamental mode was reduced by 3 percent by the dyke, and by 5 percent in 24 m by the combined effect of the dyke and the absorption

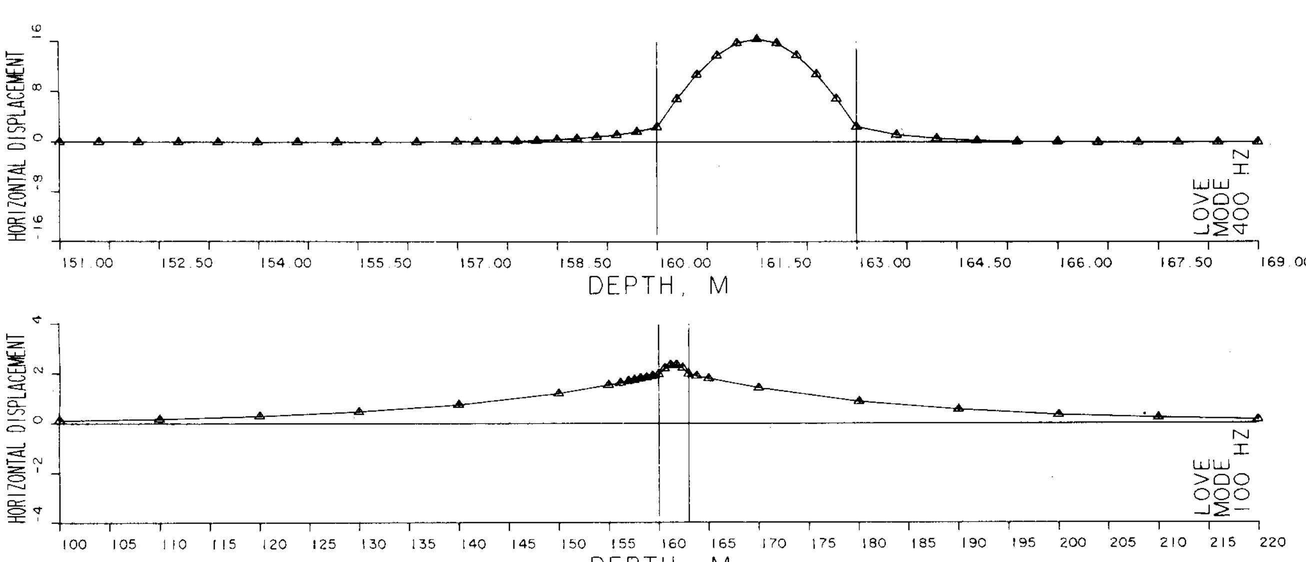

FIGURE 2
Variation of displacement with depth of the SH fundamental mode for a coal seam.

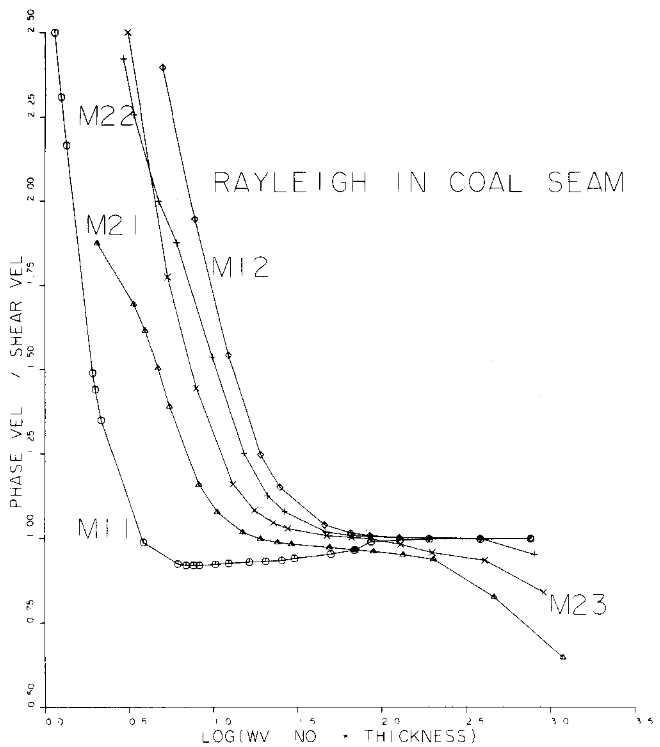

FIGURE 3
Phase velocity of P-SV modes in a coal seam.

in the coal, the dyke and the other rock. At frequencies of approximately 400 Hz, the amplitude of the SH fundamental mode was reduced by 62 percent by the dyke, and by 84 percent by the combined effect of the dyke and absorption in the coal, the dyke and the other rock. At frequencies of approximately 100 Hz, the amplitude of the P-SV $M_{2\,3}$ mode was reduced by 5 percent by the dyke, and by 11 percent in 24 m by the combined effect of the dyke and the absorption in the coal, the dyke and the other rock. At frequencies of approximately 400 Hz, the amplitude of the P-SV $M_{2\,3}$ mode was reduced by 37 percent by the dyke, and by 57 percent in 24 m by the combined effect of the dyke and the absorption in the coal, the dyke and the other rock.

Conclusions

Computer programs, based on the finite element method, and including allowance for absorption in the coal and rock, have been written to model the propagation of SH and P-SV waves in damaged or interrupted coal seams. Results obtained for models of a seam interrupted by a fault and of a seam interrupted by a hard dyke show that, at frequencies above 200 Hz, SH and P-SV seam waves are diagnostic of the interruption, but that, at these frequencies, the effect of an interruption of the seam on the waves is similar to that of more than usual absorption. Additional reflection measurements are desirable to distinguish these effects.

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This work has been suggested and supported from the Central Research Laboratories of the Broken Hill Proprietary Co. Ltd (BHP), Wallsend, N.S.W.

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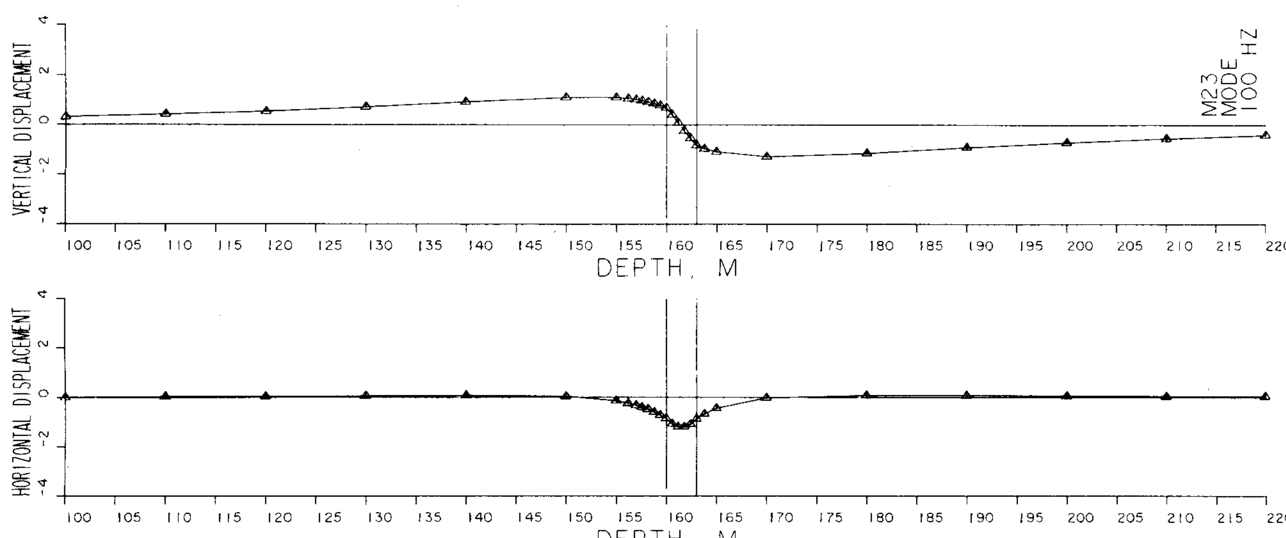

FIGURE 4
Variation of displacement with depth of the P-SV $M_{2\,3}$ coal seam mode.