514 m being particularly prominent. No control is available below 553 m, although the character of the basalt reflections is maintained to 750 – 800 m. A quieter zone beneath this is followed by a weak reflector at about 1 000 m, which is in the vicinity of depth to magnetic basement.

Further experiments are being undertaken in this and other areas on the Stuart Shelf. As more core becomes available for measurements, and with the purchase of new equipment to allow vertical seismic profiling and attenuation measurements to be performed, it is hoped that a viable technique for exploration in such environments can be produced.

References

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SEISMIC REFLECTION TECHNIQUES IN COAL EXPLORATION

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In recent years coal has regained its importance in the world as a major energy source. Much of Australia's coal lies at depths necessitating extraction by underground techniques which are extremely vulnerable to coal seam disruptions such as faults and washouts. In order to plan for the most economic and efficient mining of underground reserves, there is a need to know the exact location of these features long before they are encountered at the working face. Experience has shown that deep drilling is prohibitively expensive and lacks the ability to indicate even large structures between drill holes.

Geophysical methods are now being adapted to solve the "ahead of the face problem" and recently in Europe, seismic reflection methods have been successfully applied.

There is at least an order of magnitude difference in scale between the application of seismic for oil exploration and seismic for coal exploration. The oil geophysicist deals with structures tens of metres in size at depths of thousands of metres, whereas the coal geophysicist deals with structures often less than ten metres in size at depths less than 500m. Two factors have made the use of seismic methods possible in coal exploration; firstly, advanced data recording and processing; secondly, the increased value of coal.

The B.H.P. Co. Ltd. first used seismic reflection methods in coalfields during 1962 but the existing technology severely limited the usefulness of the data and the vertical resolution of structures was no better than 15 m. In 1978, the geological and structural complications encountered by the miners at two collieries in the Blackwater coalfield, Queensland, led B.H.P. to consider applying detailed seismic reflection surveys in the area.

The purpose of the survey was to locate small faults beyond the current zone of mining so that mine planning could be more effective. Experimental surveys were also carried out at Broke in N.S.W. where the coal seams are outcropping and dip at about 15°; and also at Capella in Queensland where the coal seams are covered by Tertiary basalts and soft Tertiary sediments.

Strata Resolution

The main concern in coal seismic work is not to define the thickness of a coal seam but to identify accurately the structures which disrupt the seam. Consequently the surveys at Blackwater were not designed for deep penetration and total resolution of a coal seam sequence, but were designed to give the maximum information concerning the upper seam being mined, so that faulting could be confidently identified. The ultimate structural resolution is the minimum sized structure that can be positively identified. It depends on the quality of the seismic record and the ability of the seismic interpreter. The seismic section can be improved by advanced technology and field techniques, being limited only by the earth itself; but the ability of the interpreter depends on a basic confidence in the data quality and a clear understanding of the geological environment.

The Field Approach to Higher Resolution

To improve resolution, more data is required both vertically and horizontally, or, in another sense, there is a need to sample a high frequency wave form at close spaced geophone positions.

The field parameters were based on those developed in the U.K. by the National Coal Board. Two ounce charges were placed below the weathering zone and shot into 50 Hz geophones. The geophones in marsh cases were buried 20 cm at intervals of either 5 or 10m. The recording instruments used a fully floating point digital system, sampling the wave form at 1 millisecond intervals. Hi-cut alias filters of 375 Hz, 72 dB/octave, and lo-cut filters of 80 Hz, 12 dB/octave were used. Single geophones were used throughout, because of the filtering effect of even short geophone groups, an effect which is exaggerated by the dip moveout. Six-fold redundancy was obtained for better subsurface coverage.

Residual static corrections between adjacent geophones were as high as 10 milliseconds which also supported the use of single geophones. Any static difference of four milliseconds between two geophones in a group would be sufficient to place two incoming signals of 130 Hz, about 180° out of phase.

A comparison of parameters used in the first seismic survey at Blackwater in 1967, and the 1978 survey are shown in Table 1.

Static Corrections

The static correction is a major problem with all seismic reflection surveys. The problem is increased in coalfields where, because of the shallow depth of investigation, a larger proportion of the wave travel-time is spent in the

Table 1

Comparison between 1967 and 1978 coal seismic survey parameters.

	1967	1978
Recording Instrument	Analogue 24 trace with fast A.G.C.	Floating point digital with 1 millisecond sample rate
Spread Dimensions	200 or 400 metre split spreads continuous single fold shooting with 15m or 30m between groups of geophones	5 or 10 metre station spacing. 6 fold shooting
Geophones	30 Hz geophones in groups of 8 spread along the line	Single 50 Hz geophones buried 20 cm
Recording Filters	10 – 500 Hz	80 Hz, 12 dB/octave lo-cut 375 Hz, 72 dB/octave hi-cut
Shot	0.5 – 1 Kg below weathering	0.06 Kg below weathering
Statics	First arrival analysis	First arrival analysis and residual correction
Processing	Analogue and some elementary digital	Full digital processing

weathered zone. In order to increase accuracy and approach as near as possible a unique solution, hand computed field statics were applied prior to the use of automatic residual statics programmes. Static corrections were computed using a detailed analysis of the first refractor arrivals; this was followed by an examination of the single-fold sections to remove serious static errors still remaining. An accuracy of two milliseconds in hand computed statics was considered satisfactory. The method used was very consistent in itself and led to good ties at line intersections, but for ultimate coherency automatic static programmes were necessary.

Processing

A very careful approach to processing was required because of the fine tolerances needed to retain the higher frequencies. Careful sorting and trace editing was necessary. A standard route was adopted consisting of pre-filter spike deconvolution before stack, NMO correction, CDP consistent automatic statics, deconvolution after stack, filter and coherency filter. Clearer resolution of many structures was obtained by wave equation migration which however had to be applied with care.

It is considered that in future more advanced processing techniques will play a greater role in analysing coal reflection seismic data.

Results and Interpretation

Results in the Blackwater coalfield were excellent with the dominant frequency on the main coal reflector varying between 120 and 150 Hz. Faults of throw as little as 4 metres were clearly detertable in areas of particularly good data. The interpretation however was not trivial and required a good knowledge of the geology, the type of structures known to occur and also of the processing which was applied to the data. Many features of the seismic sections are as yet uninterpretable but clearly they have some geological significance. An interpretation problem was that the character of faults changed between lines and structures on one line could not be recognised on adjacent lines.

A number of known structures were clearly located by the seismic surveys. The results of the Broke survey where numerous coal seams outcrop and dip at 15^{o} were surprisingly good; but data from the Capella area were poor, probably as a result of the difficult surface conditions. Clearly the method, like all geophysical techniques, is eminently suited to some areas and should not be applied without great care in others. This is determined generally by the near-surface geology and the type and depth of weathering. It is the job of the professional geophysicist to advise management accordingly.

Numerous possibilities exist for the improvement of the seismic reflection method in coalfields both in field technique and processing. The ultimate development will be limited only by the degree to which the technique can be taken before cost-effectiveness becomes too low in relation to other methods.