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In-seam seismic application for detecting inhomogeneties in coal seams - a review

Mechanized coal winning systems require thorough knowledge of seam structure for planning of layout as well as selection of machines. In-seam seismic method can be used to study seam structure, thereby existence of inhomogeneties such as faults, dykes, sills, thinning of seams, washouts, etc. The basic principle of in-seam seismic technique involved survey of reflected and refracted seismic waves to detect the inhomogeneties. Among the two types of seam waves that are Rayleigh-type and Love-type, the latter is of more practical interest in in-seam seismic method. The paper describes the principles by which the various inhomogeneties can be detected in the coal seams.

Introduction

Bulk production of coal from underground mines presupposes comprehensive knowledge of seam structure so as to make choice of mechanised coal mining systems. It is well known that mechanisation of underground coal mining involves mega investments and if the systems chosen do not match with seam conditions both efficiency and efficacy of the system are likely to suffer. The various structural inhomogeneties in coal seams which affect efficiency of mechanisation can be listed as

- Faults,
- Dykes,
- Sills,
- Thinning of seams,
- Washouts, and
- Abrupt changes in seam gradients,

which are diagrammetically illustrated in Figs.1 and 1a.

The presence of dykes, sills and faults not only affect the efficiency of coal mining machines but also can be expected to cause strata control problems. They may also act as reservoirs of methane gas.

Thinning of coal seams, washouts and abrupt changes in seam gradient directly affect the performance of mechanisation.

How the seam structures and thereby inhomogeneties can be detected and with what accuracy depends upon the method employed. The various methods which can be employed for detection of the inhomogeneties are

- advance drilling,
- proving drivages,
- resistivity, and
- seismic.

Among the above methods the most suitable and inexpensive method is seismic and the system used is termed as 'in-seam seismic'. The method has been successfully used in most of the developed countries and in some places in-seam seismic studies have become routine work because they help in mine planning by fully mechanised longwall system. Some trials of in-seam seismic studies have also been made in India with encouraging results.

In this paper the author intends to outline the principles of in- seam seismic studies, methodologies and their application in Indian context.

Development of in-seam sesmic system

The earliest evidence of in-seam seismic studies is from New Zealand where Evison (1955) recorded seismic waves in a coal seam and compared the results with theoretical dispersion of long waves. Krey (1963) opined that a coal seam should act as a wave-guide to seismic energy and the faults may be detected by seismic reflection techniques. The development of in-seam seismic method continued on a low key till the oil crisis in the beginning of the eighth decade when coal mining got a boost due to hike in petroleum prices. By the end of the eighth decade the method had been successfully demonstrated in a variety of condition followed by rapid application in the ninth decade. The first application of the method in India was in 1980 when a German firm attempted to determine the thickness of coal barrier against a water logged area at Patmohna Colliery in Ranigunj coalfield. The results were inconclusive.

In the present state in-seam seismic technique is probably the best tool to detect inhomogeneties in coal seams for suitably designing underground mining layouts.

Principle of in-seam seismic technique

The characteristics of coal seams towards transmission of

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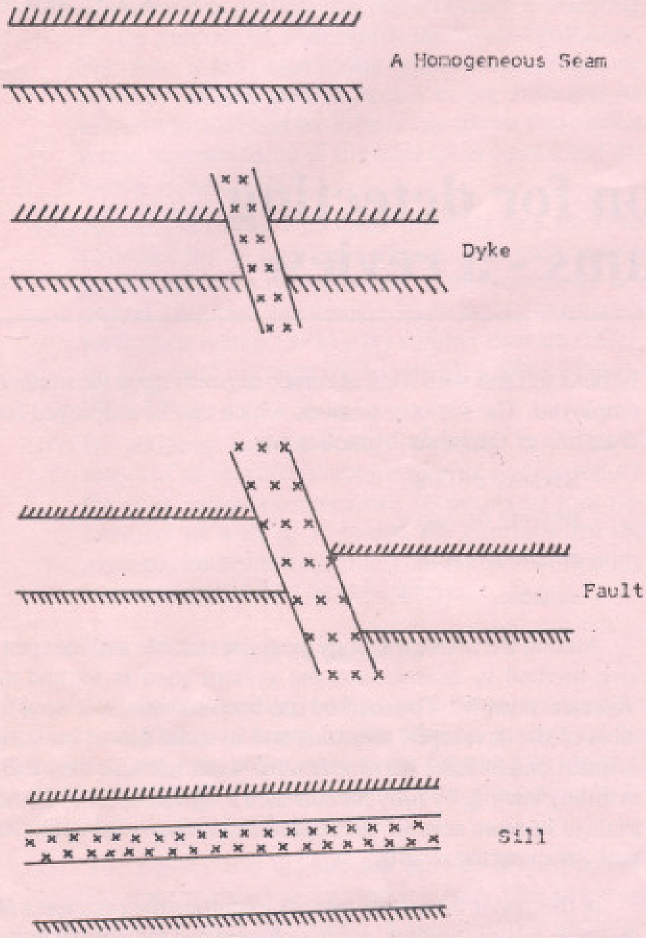

Fig. 1

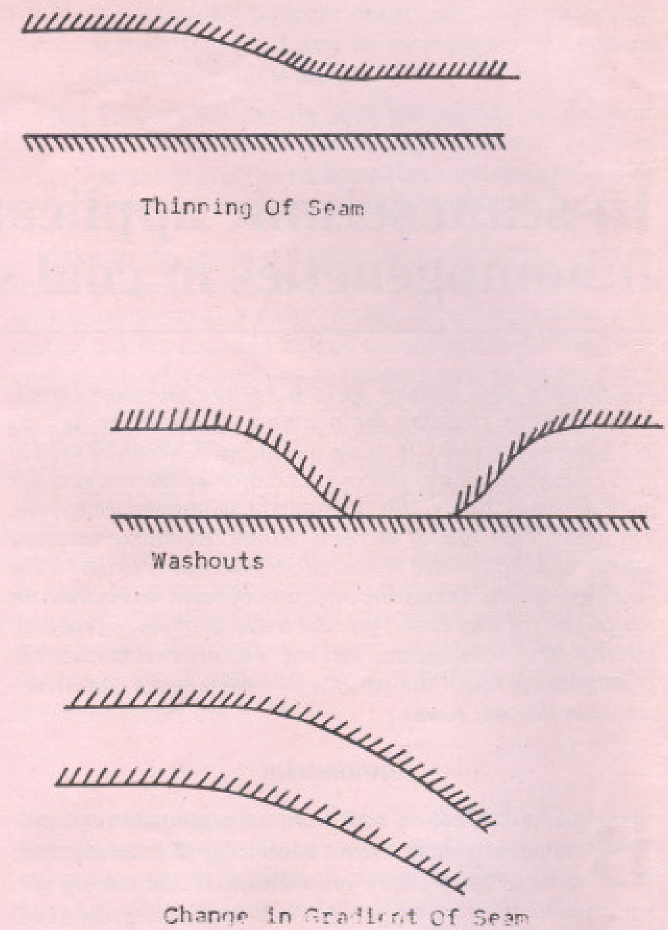

Fig. 1a

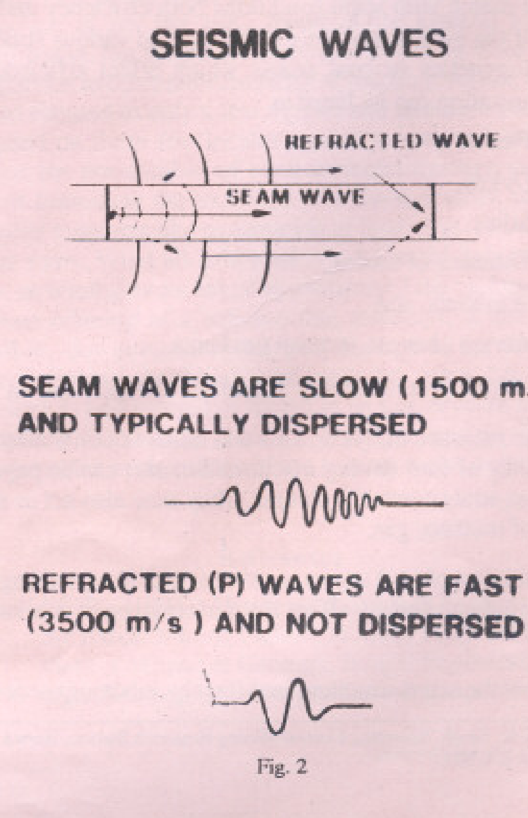

Fig. 2

seismic energy are utilised in the in-seam seismic technique for detection of inhomogeneties in the seams. Coal seams are considered as layers of solid having low density and low seismic velocity characteristics sandwiched between two layers (roof and floor strata) of sedimentary beds having comparatively higher densities and higher seismic velocities. The contact planes between the coal seams and roof floor strata act as interfaces and hence do not permit spread of seismic energy in all the three dimensions (Fig.2). This results in formation of a special wave called as seam wave/channel wave (Krey, 1963). Due to sandwich type of layering the seam wave is guided by the seam and can normally be received only inside the seam. The seam waves are of two types as given below :

- Rayleigh-type waves, which are defined as vertically polarised secondary waves having retrograde motion in character.
- Love-type waves, which are defined as horizontally polarized secondary waves.

The characteristics of these two waves are shown in Fig.3. Both these waves can be mathematically described by an infinite number of modes, among them only fundamental modes of Love-type waves are of practical interest.

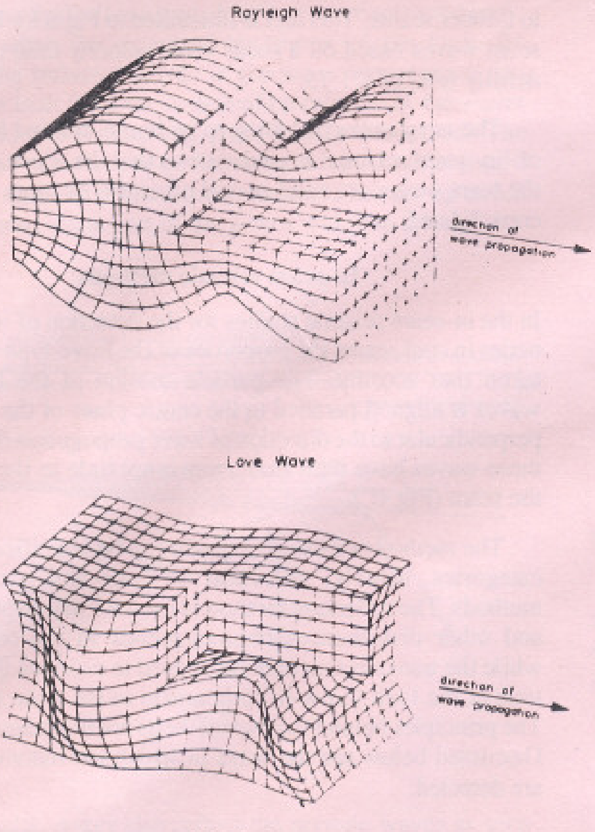

Fig. 3

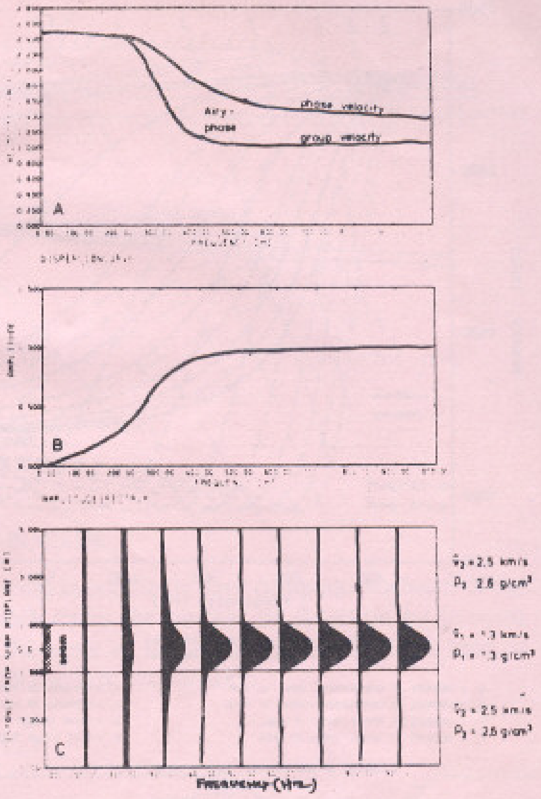

Fig. 4

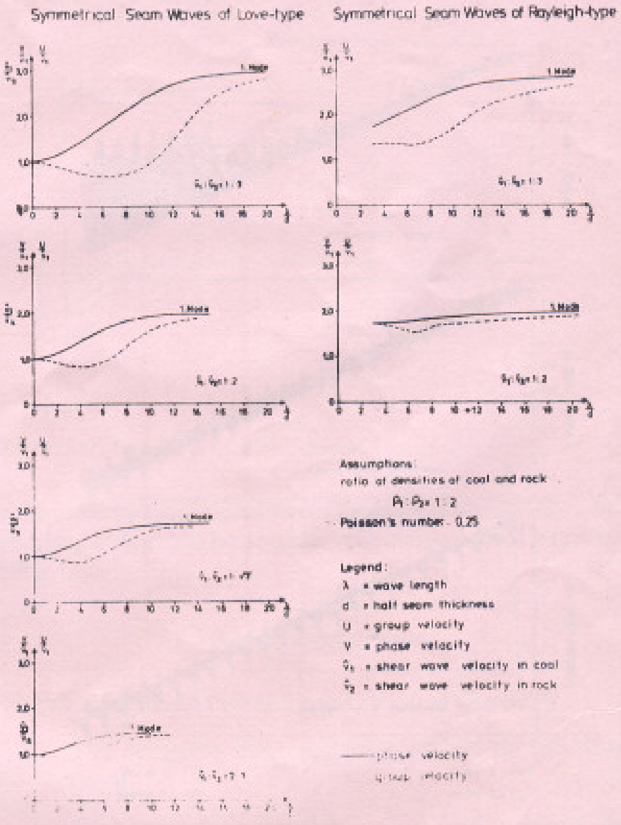

Fig. 5

The seam waves exhibit dispersion and their frequency depends on the propogation velocities. This dispersion results in a train of long waves in which phase velocities and group velocities are to be differentiated (Figs.4A, 5, 6 and 7A). The Most important parts of these waves are the ranges of minimum group velocities which yield special phase in the seam wave train. It is called the 'airy-phase' (Fig.7A) and it occurs at the end of the seam wave train with high amplitudes and high frequencies. This interpretation about the airy-phase is confirmed from the amplitude-frequency relationship shown in Fig. 4B. The seam waves have not only the greatest amplitude inside the seam, but are tied to seam itself as seen in the amplitude distribution inside and outside the seam (Fig.4C).

The degree to which the seam wave energy is tied to the seam depends on the ratio of seam wave velocities in coal and country rock. The difference between phase and group velocities decreases with decreasing shear wave velocity in rock in case of the Rayleigh type seam waves (Fig.5). The dispersion increases the degree of adherence of the wave energy to the seam, which is true in case of the Love-type seam waves (Fig.5). The wave energy of Love-type seam waves is more strongly tied to the seam than that of Rayleigh-type waves. Hence, Love-type seam waves are of greater importance from practical standpoint.

The frequencies of the seam waves depend on the seam thickness. Thicker seams have low frequencies, specially for the airy-phase range of minimum group velocities, compared

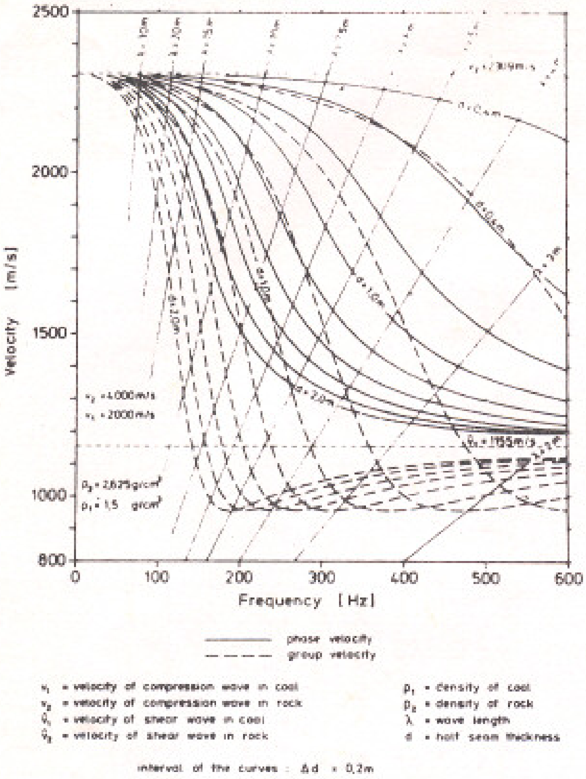

Fig. 6

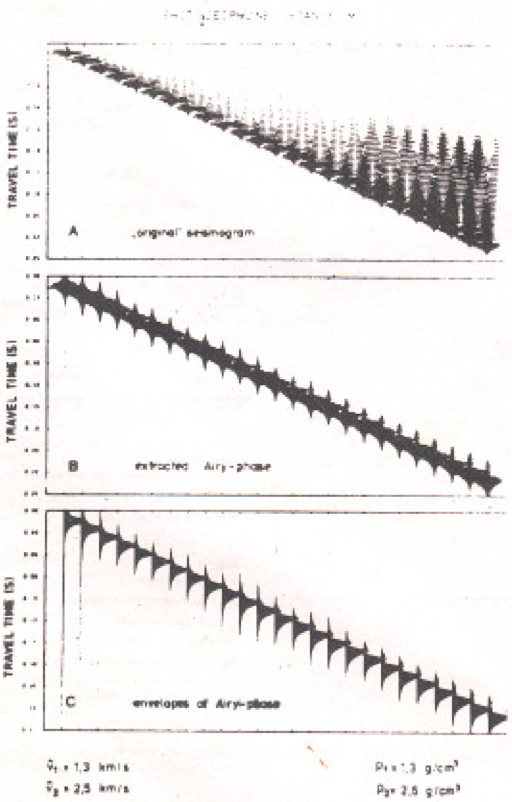

Fig. 7

to thinner seams. This fact is illustrated in Fig.6 for Love-type seam waves based on a shear wave velocity ratio of 1:2 and density ratio of 1:1:75.

The most important thing to be borne in mind for the use of 'in- seam seismic' in coal seam is that the above aspects of the seam waves are valid in coal measures or strata which are consolidated.

In-seam seismic methods

In the in-seam seismic studies for the detection of inhomogeneties in coal seams the properties of the Love-type waves are taken into account. The particle motion of the Love-type waves is aligned paralled to the centre plane of the seam and perpendicular to the direction of wave propogation (Fig.3) and these waves have their maximum amplitude in the centre of the seam (Fig.4C).

The method of in-seam seismic can be classified into two categories, namely, reflection methods and transmission methods. The reflection method is used for detection of faults and other disturbances/inhomogeneties in the coal seams while the transmission method is used to estimate the magnitude of the fault throw in comparison to the seam thickness. The principles behind the two methods are illustrated in Fig.8. Discussed below are the ways in which the inhomogeneties are detected.

Faults

When the seismic waves passing through a coal seam

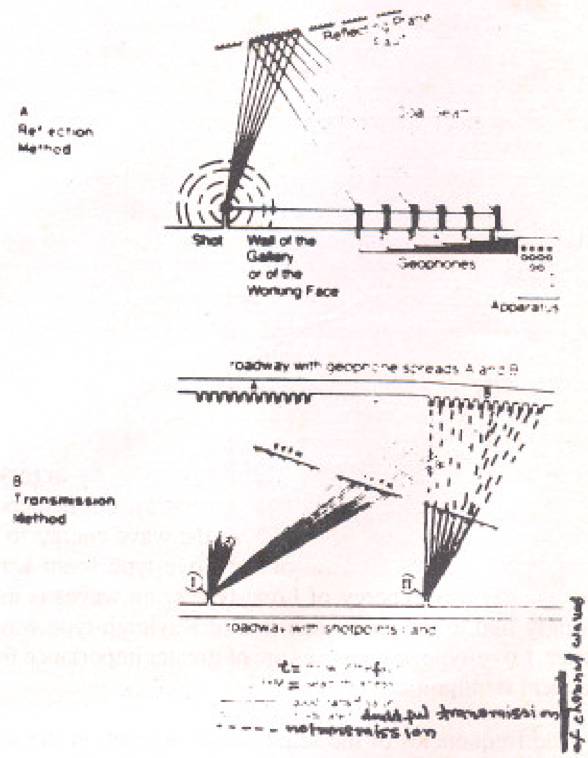

Fig. 8

come across a fault all or a part of the waves are reflected back, depending upon the extent of the throw of the fault. By receiving the reflected waves in the seam approximate distance of the fault from the source of emmission of the waves and also from the receiving point can be computed. The phenomenon of reflection of the waves from a fault is shown in Fig.9. In case the displacement due to fault is not up to full seam thickness some part of the waves will pass through.

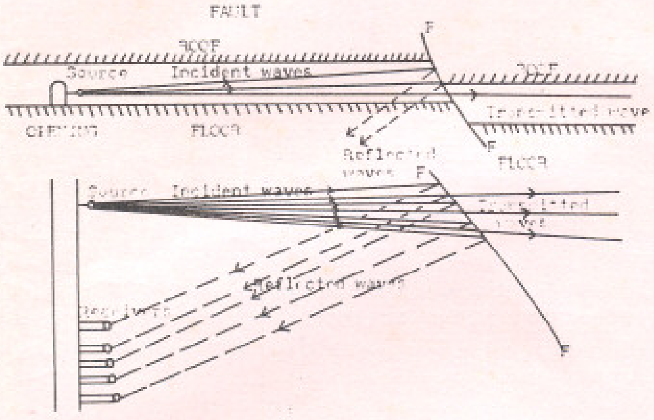

Fig. 9

DYKES

Like faults, dykes also reflect the seismic waves as seen in Fig.10 and in this case there is paractically no transmission of the waves.

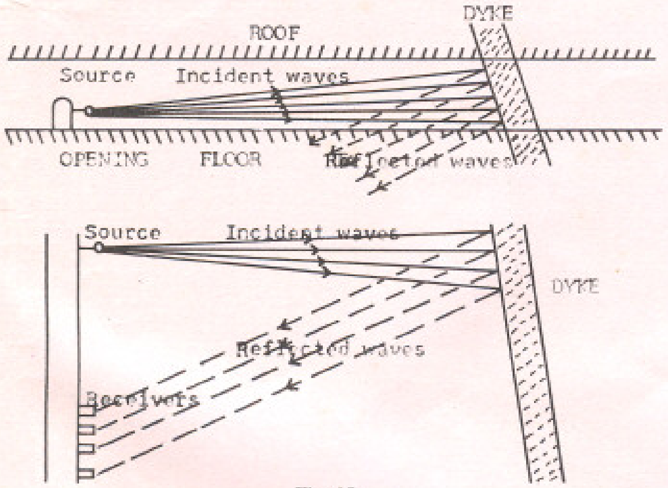

Fig. 10

THINNING OF SEAM

The phenomenon of thinning of coal seams can also be detected by using reflection method as shown in Fig.11, which is self- explanatory. In this case a part of the waves is reflected from the roof of the thinning zone while the remaining waves are transmitted further. The reflected waves are received and the distance of the thinning zone is computed.

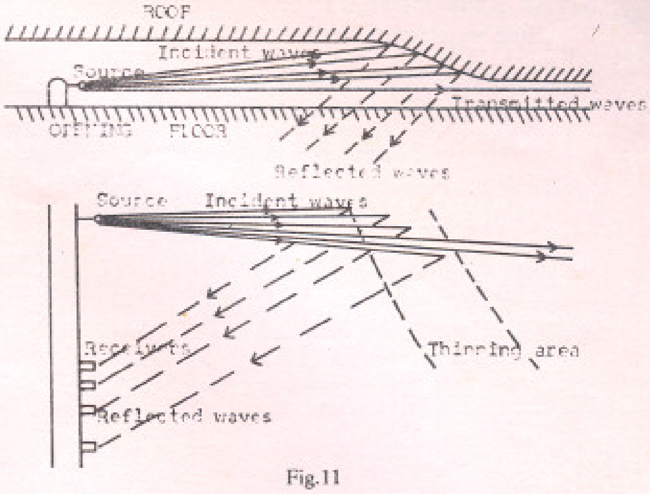

Fig.11

WASHOUTS IN SEAMS

Certain areas in coalfields have complete washouts of the seams. In such cases the process of detection by in-seam seismics is the same as for the dykes and faults as seen in Fig.12, which needs no explanation.

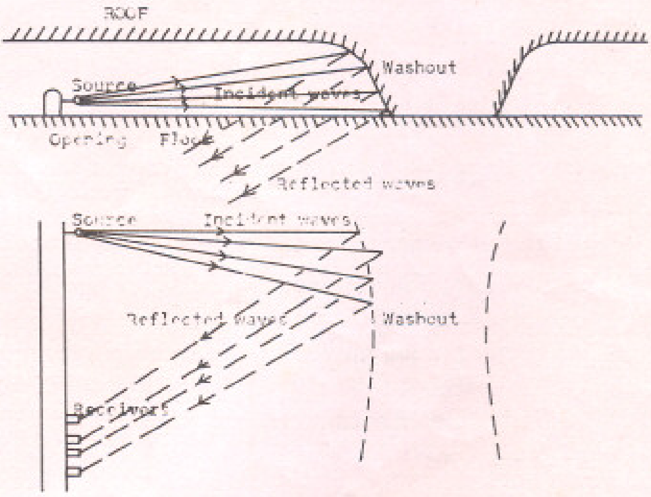

Fig. 12

CHANGE IN GRADIENT OF THE SEAM

In some cases, the gradient of the seam strata changes, this can also be detected by seismic-reflection method as shown in Fig.13.

INSTRUMENTATION

The following requirements are essential in coalfields :

1. The complete instrumentation should be fire-damp proof.

2. High-resolution digital recording with a signal frequency up to 720 Hertz using 24 seismic channels.

3. No signal attenuation and no frequency losses by using wall clamped borehole geophones.
4. Data storage on magnetic tape.
5. Immediate quality check by paper seismograms.
6. Remote firing, triggered by the control unit.
7. Easy transportation of the devices.

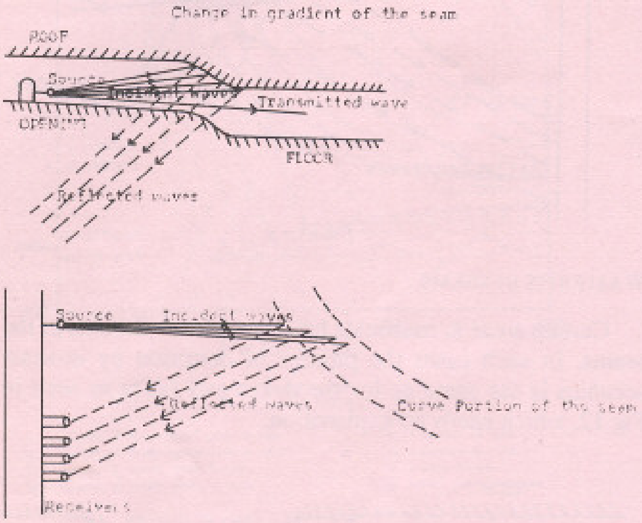

Fig. 13

DATA PROCESSING

The standard data processing contains the following important parts :

1. True amplitude recovery.
2. Frequency filtering to extract the higher frequencies of the airy-phase.
3. Stacking of the envelopes using dynamic corrections corresponding to the group velocity of the airy-phase.
4. Normalization of amplitudes.
5. Migration.
6. Deconvolution and recompression of wave trains.

Interpretation

The interpretation of processed data is quite simple if stacked envelopes occur after the stacking process. In this case, the reflection times of the maximum amplitude of envelopes are transformed to reflection distances using the group velocity. The actual position of the reflecting element is drawn on the map using the so-called "tangent method", corrections have to be applied when the seam inclines at an angle of more than 10 degrees to the horizontal.

PRECAUTIONS

i. Shot-point should be locked in the consolidated seam, fractured or weak-zone should not be present nearby the shot- point.
ii. No any other blasting should be done nearby this location where in-seam-seismic survey is going on.
iii. Continuous recording should be done. Dry-cell-battery system is essential for continuous power supply.

Acknowledgement

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