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Assessment of Rib Instability Hazards for Strata Management Systems

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INTRODUCTION

The support and control of unstable coal mine ribs is an on-going problem for the industry but in actual fact systematic research investigations were started almost 20 years ago in Australian Coal Industries Research Laboratory (ACIRL). This came about through the interests of the Australian Coal Association and the Queensland Coal Association Thick Seam Mining Committee. Some work was also carried out on coal mine rib mechanics under the NERDDC program in the mid 1980's. Several collieries were directly experiencing fairly acute rib control problems at this time and the research work was linked with these. A number of publications which have been largely forgotten resulted from this work: O'Beirne and Shepherd (1984), Shepherd *et al* (1984), O'Beirne *et al* (1985, 1986, 1987), but these and later studies form a good basis for the methodology of rib hazard identification. Other rib support research has also been carried out at the University of New South Wales: (Hebblewhite *et al,* 1998) have highlighted the need for matching the support to the dilational movements found in ribsides.

The assessment of rib conditions can be viewed as occurring in three broad phases during the life of mine workings as follows:

- as early as possible during the cutting of the development faces.
- continue through the formation of the pillars and while the pillars stand because there is often time dependent movement.
- during and after secondary extraction as stress abutments develop in both pillar and longwall extraction.

As a general rule in most seams rib instabilities are not problematical at cover depths of less than 100m unless the coal is particularly weak. However, during secondary extraction even shallow workings are subject to abutment stresses.

WHAT PRODUCES RIB HAZARDS?

Hazards are produced by the interaction of the natural coal seam variables and various mining-induced factors which can be modified according to the mine design (see Table 1). This paper is not examining the rib failure mechanisms in detail but will attempt to identify the principal types of hazards that should be accounted for in a strata management plan.

Table 1. List of factors influencing rib stability

Natural factors	*Mining induced/design factors*
Coal seam banding (plies) and their strength	Roadway width, first workings; stress abutments
Presence of dirt bands	Pillar size versus depth
Seam thickness	Roadway profile
Cover depth (stresses)	Mining direction
Seam dip gradient	Working height (in thicker seams)
Cleats	Straightness of ribsides

In general, rib instability hazards are produced by the coal fracture systems, some of which are cleats and some induced during the mining processes. Some early work on the interaction of cleat and mining induced fractures

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was carried out at Leichhardt Colliery by Hanes and Shepherd (1981). Mineralised cleats in the vitrinite (bright) bands were found to propagate through the dull bands to form induced fractures.

Later on, work by Shepherd *et al* (1984) and O'Beirne *et al* (1987) demonstrated an array of quite complex fracture interactions in ribsides that produced instabilities. The development of these induced fracture systems depends especially on cover depth, the ply banding in the coal and the distribution of dirt bands which have markedly different physical properties from the coal.

All the factors listed in Table 1 can play a role depending on the local circumstances and the mine layout and mining method.

ASSESSMENT OF RIB INSTABILITY HAZARDS

Assessment of rib instability should be carried out by competent geotechnical personnel and should generally consist of two types of activity:

- detailed rib mapping throughout the life of the workings, but especially starting at the development faces. This should include logging the coal brightness, strength testing and rib fracture identification. It is most important that the cleats are distinguished correctly from the induced fractures.
- installation of pillar rib instrumentation such as extensometers and instrumented rib bolts.

The aim of this work is to define the hazards for the purposes of risk assessment and it may initially determine the need for rib support. Instability of ribsides is a function of coal dilation, fracturing and the resultant size distribution of the detaching material. Dilation can occur by tensile extension in the ribs, or the combination of this and shear if there is sufficient confinement. Induced cracking can start ahead of a development face, interact with pre-existing cleats or joints and rapidly produce hazardous situations. A particularly useful hazard assessment scheme that can be incorporated in to hazard and risk assessments is given in Figure 1 (after O'Beirne *et al,* 1986).

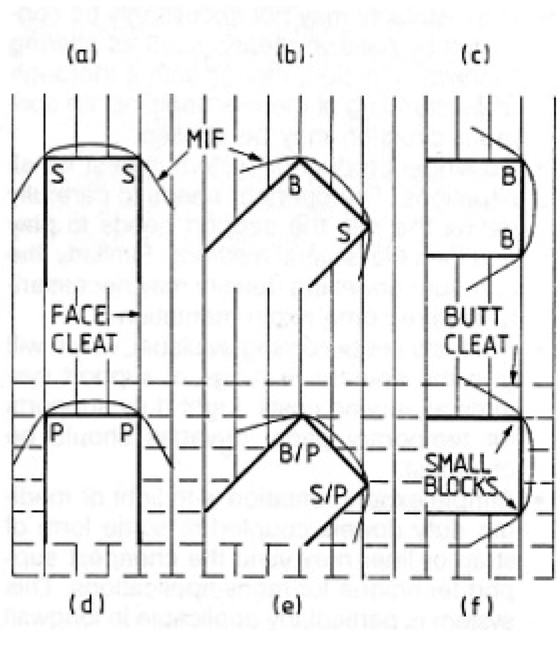

Fig. 1 Probable mode of rib spall according to drivage direction in first workings, cleat and MIF (Mining Induced Fractures) shown schematically in plans (a) to (f). S = slabs/plates (spot support), B = blocks/columns (extended spot support), P = particles (liner support)

If support is required, it should be installed as soon as possible. A common feature of underground workings is the accidental damage to rib support hardware and experience indicates that this is rarely fixed. Later on, this increases the hazard severity quite markedly and there are a number of cases where mine personnel have been severely injured precisely at the locations of damaged support.

For personnel protection, the main hazards are coal slabs and blocks and these commonly exist in ribsides as follows:

- undercut high blocky ribs
- large cleat-bounded slabs
- large cleat-bounded blocks and/or columns prone to toppling or sliding if unsupported.

In general, the panel layout will determine where the high risk places are, such as at pillar corners on intersections in first workings and in stress abutment zones in secondary extraction. During pillar extraction, the highest risk is in the fender ribs adjacent to the active lift and along the ribside opposite. In longwall retreat panels the highest risk places are generally within the front abutment zone at the maingate face corner and in the chain pillar ribside for some distance outbye from the chocks. This is a particularly hazardous area because it contains significant amounts of coal face clearance equipment.

In some seams, the risk from rib hazards can be reduced by limiting the working height to about 3m. This may work reasonably well in first workings but may be less effective in secondary extraction where abutment stresses may increase insidiously, resulting in sudden rib spall events that are notoriously unpredictable and have resulted in deaths and serious injuries.

CONTROLLING RIB INSTABILITY HAZARDS

Mapping at a large number of sites has resulted in the development of a simple classification system for rib spall material. The size of the material detaching is critical in terms of the risk to personnel and in Table 2 coal particle sizes are given. The small particle sizes are generally not hazardous unless unusually high stresses occur during development or extraction when it is possible to have non-gassy bursting during which the coal is forcibly ejected. The main risk stems from the larger material which needs pinning up to the ribs by support. A useful support system concept was published by O'Beirne *et al* (1986), and this is summarised as follows:

- spot support installation of bolts or dowels for slab and large column control
- extended spot support – bolts or dowels linked by strapping . These are particularly useful at pillar corners, in stooks or at any site containing narrow failure zones.
- Liner support – where full protection is required in high abutment zones or where the ribs disintegrate into particles. These can cover all or part of the working section.

In terms of a strata management plan, once the rib hazards have been assessed, it is preferable to relate the support needs to the hazard classes. In view of the regulations now in force, and OH & S principles, it is necessary to follow the guidelines laid down by the DMR (1999) and Standards Australia (2000). A generalised scheme to achieve this is given in Table 2. In reality, this would need to be site specific after geotechnical studies had been carried out, and it should only be used as a broad guide.

Table 2. Classification scheme for spalled blocks and outline of probable support needs.

Shape of hazard	*Smallest dimension in plane of ribside (m)*	*Rib support needs*
Blocks and slabs - very large - large	>1.0 >0.3-1.0	Close pattern of bolts or dowels and straps or mesh
Columns and small blocks – medium	0.1-0.3	As above, spacing to suit
Particles	>0.02-0.1 <0.02	Mesh or liner type

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