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GEOLOGICAL STRUCTURES IN RELATION TO OUTBURST EVENTS

Rod Doyle[1]

ABSTRACT: In Australia irrespective of coal seam or coalfield, geological structures play a crucial role in the experience of having Instantaneous Outbursts. Identification of geological structures through concerted exploration activities, including drilling and remote techniques, or through the observations of both operators and geological personnel can allow for hazards to be identified and for precautionary measures to be implemented. This paper reviews; geological structures known to be associated with outbursts, some techniques used in the definition of such structures, and touches on the current procedures in place at mines that experience outburst phenomena or are concerned about such risks.

INTRODUCTION

In reviewing this topic geological structures that should be of interest are briefly explained. An excellent summary of geological structures is presented in Lama and Bodziony (1996). The authors provide information of interest from the global database.

Anyone undertaking underground investigations cannot help but be concerned about the serious effects of outbursts; the loss of life, the impact that fatalities have on the immediate families, the workmates and the local community.

UNDERGROUND GEOLOGICAL MAPPING

Every geologist knows that it can be a difficult task to appropriately and routinely map roadways in the underground environment. Thousands of linear metres may need to be reviewed in a short space of time, often under adverse conditions and sometimes estimates on the significance of structures are rapidly made - these assessments can at times be arbitrary. In the case of an outburst investigation, the reverse is usually true; a detailed investigation can be undertaken for a small area known to be of great significance. It should also come as no surprise that different people put different emphasis on different structures that are observed. (This is probably true of any scientific endeavour.) Nevertheless, whilst geologists may disagree over some of the minor features, the majority would generally agree about the major aspects.

However, trying to assess the risk of outburst potential prior to an event, from underground mapping alone, is a big ask. In hindsight, it is easy to say that the difference should have been picked up and mining operations ceased. If the reader accepts this as a reasonable proposition, then we have to ask ourselves, 'Can we rely on mining operators to observe potentially dangerous situations associated with outbursts?' The answer to this is equivocal.

Without appropriate training could miners have much hope of identifying such structures? Yet with a modest level of training and appropriate underground experience, coupled together with a good sense of being aware of the mining environment in which they work, there is a real opportunity to give forewarning of 'changing conditions'. This aspect is without doubt one of the most important messages to get across to mining operators – the issue of changing mining conditions. What is different about our workplace today compared with yesterday?

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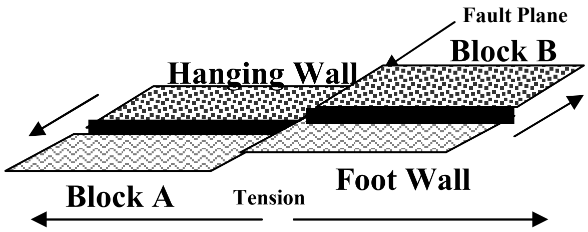
GEOLOGICAL STRUCTURES

The nature of geological structures that can have an impact on outbursting are varied. They range from the obvious structures such as faults and dykes to the not so obvious, including stress impacts, folding, shear zones. While it may and seem elementary there can be some benefit to the reader in having a simple description of structures in one small paper. Many of the deputy and undermanager exams often have such questions.

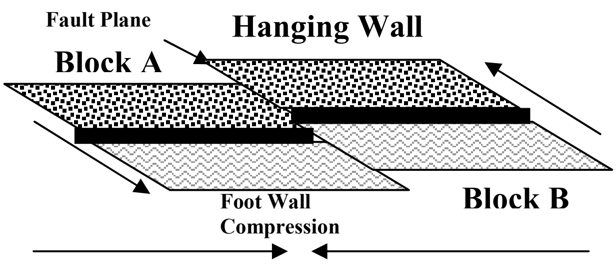
FAULTING

Normal
A fault is a planar structure with variable throw along its axis. It is helpful to visualise a fault in the following way – take a broadsheet of a newspaper and pinching it near the centre tear the sheet about 10cms in length so that the sides are still intact. This gives a 3D perspective of a normal fault plane. In the centre of the tear is the maximum throw of the fault and the throw of the fault diminishes towards its extremities.

In the 2D diagram below the Foot Wall (Block B) has moved or been thrown upward with respect to Block A (the Hanging Wall). The fault plane indicates that the two blocks have moved apart under tension. This fault is described as a normal fault.



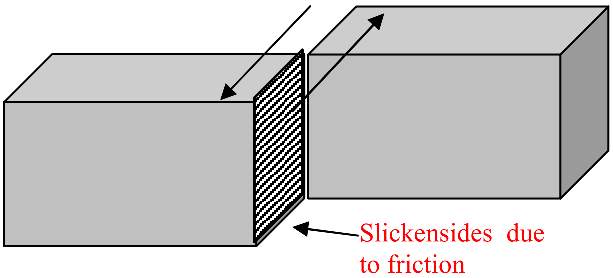
Reverse
In the 2D diagram below the Hanging Wall is upthrown with respect to Block A (Foot Wall). However, the angle of the fault plane indicates that the two blocks have moved towards each other under compression. If the angle of this fault plane is 30º or less with respect to the horizontal plane, the fault is termed a 'thrust fault'.



Strike Slip
In the 3D diagram below the two blocks shown indicate that the vertical movement is zero, while the horizontal movement could be significant.

Plate 1. A normal fault in the Bulli seam – Southern Coalfield - normally 2-3m thick. The effect of the fault has been to reduce the mining height to about 1m. The trace of the fault plane can be seen as the heavy black line (centre) with sandstone in both the roof and floor.

The level of horizontal movement may only be metres, but could be much more. At various collieries in the Sydney Basin movement at a scale of a few metres across dykes has been observed. At Dartbrook in the Hunter Tunnel there is also strike slip movement of a few centimetres across a dyke.

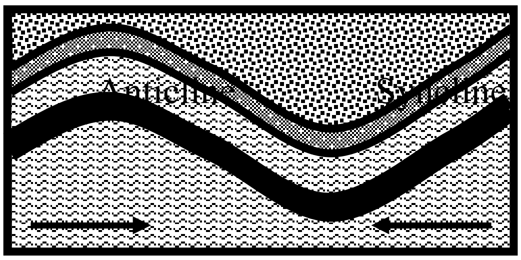


Mylonite, or more correctly fault gouge, is often associated with strike slip faults. Mylonite is the product of one block sliding against the other. This sliding movement naturally produces friction, which in turn produces the fault gouge material, which often displays slickensides. This crushed coal can easily be broken in the palm of an observer's hand. Generally, it is darker than the coal and stands out well in unstonedusted ribs. It varies in thickness from millimetres to decimetres. It can contain more moisture than the normal level of water inherent in the coal.

Mylonite tends to form a natural barrier to the migration of gas and under confinement this 'barrier' remains in place. When mining takes place and the confinement is reduced, the barrier, being weak, is readily ejected releasing the 'free gas' that is in its structure together with whatever gas has built up behind that barrier and is then available for rapid movement. In many respects shear zones are effectively equivalent to strike slip faulting and mylonite zones.

Anticline / Synclines

The 2D diagram below indicates the nature of anticlines – hill like, and synclines – valley like. Here the naturally flat sediments are 'folded' to represent hills and valleys. Seam rolls and steep dips can be associated with such structures. These structures can be formed from a compressional event of large magnitude, for example, basin wide tectonic events, but can also be associated with smaller localised events.



When mined these folded structures can exhibit high stress and cause difficult conditions requiring extra support. This is particularly true in and around the points of inflexion (bending). An analogy would be to take a wooden ruler and bend it to the point of failure – it would look like an anticline or syncline up to the point of failure, but prior to failure, stresses develop in the ruler at the points of inflexion and in a simple sense the same stress events occur in a coal seam.

Jointing – Fractures
Jointing is usually described as being associated with contraction of a rock mass during the process known as diagenesis or for coal, coalification. What these words simple refer to is the process of how sediments change from the state that they were originally deposited e.g. sands or muds, changing to the solid rocks that we see. Jointing can also form as a response to tectonic activity such as folding. In one sense joints are like the cracks we see in concrete, when there are inadequately spaced or no expansion joints.

Jointing often increases in frequency towards a geological structure. In particular not only can more joints be observed, but the orientation of these joints tends to be near parallel to the structure rather than following the direction or orientation of the normal joint pattern. This can be one of the most significant tell tale signs that operators have at their disposal to note that mining conditions have changed.

More should be done to explore for geological structures but where presentation of outburst incidents is dependent on assessment by mining operators they should be trained in methods of observation.

Why do joints increase in frequency and change in direction? This comes about because the joints are formed by two different processes. As discussed above the normal joint sets are formed during the process of diagenesis, i.e. early on. It is not until much later when a dyke intrudes or a fault occurs that this extra jointing is formed in association with the major geological structure. The new joints can develop nearly parallel to the structure as the ground accommodates the event. The frequency of the joints reduces away from the structure. This is why noticing changing ground conditions is so critical in trying to identify outburst potential.

Cleat
Jointing and cleat are pretty much formed by the same processes. Cleat refers to the 'fracture patterns' present in coal which are generally formed during coalification. People often talk about face and butt cleats. The face cleat being the dominant structure in coal, which to some extent is pervasive – i.e. extends for some distance, often throughout the coal seam. Whereas the butt cleat tends to only extend in length between two main/face cleats i.e. limited distance. Cleat can also be formed during tectonic activity.

INTRUSIONS

Dykes
Dykes form a vertical barrier in a coal seam much like a dam wall holding back a reservoir of gas. A dyke forms when there is movement of magma from within the earths crust towards the surface. It often forms a wall like structure of varying thickness. The breadknife in the Warrumbungle National Park is a great example of a dyke.

During the intrusion stage the hot gases and fluids that precede the magma act like a fracturing device and either push the country rock apart in a hydrofrac manner or ingest some of the country rock. Igneous activity has long been associated with the presence of carbon dioxide. During this process the coal is often coked to a moderate thickness away from the dyke material itself. Coked coal is clearly a very tell-tale sign of igneous activity.

Plate 2. An igneous dyke (white) on some 2-3m thick running near parallel to a longwall face line, AFC at base and chocks to right.

Sills
Silling is another form of igneous intrusion that intersec
ts strata in the horizontal plane. Silling can cause severe deterioration of coal and often leads to areas of coal being abandoned. Silling is common throughout the various coalfields in New South Wales, but silling has not been associated with outbursting.

Igneous Plugs and Diatremes
These geological structures are associated with igneous intrusive events. They are vertical in nature and are generally cylindrical in shape. While several have been identified in underground workings, none have been associated with outbursting. For a detailed account of diatremes the reader is referred to Crawford et al 1980.

FINDING GEOLOGICAL STRUCTURES

Surface drilling investigations allow for an overview of stratigraphy and seam continuity and can indicate major structures. However small scale structures, e.g. dykes and faults <2.0m are very difficult to identify with strike slip faulting all but impossible. This is particularly true in a moderately deep underground scenario where budgets may only allow for 250m grid spacing of boreholes which would generally be regarded as closely spaced.

In delineating geological structures in any mining area there are several tools that are of major use, in the first instance. These would be supplemented with an overview of existing structures in the near vicinity (Regional Tectonic Setting) and a literature survey. Examination of information from adjacent mines, if available is also essential. Ward (1984) provides an excellent overview of the geological investigations that should be routinely undertaken to assist in defining geological structures and coal reserves.

Gravity surveys and satellite imagery are other tools that can prove useful.

Geophysical logging tools are an absolute must for the majority of surface drilling activities. Resistivity can be used down hole as well as cross-country. The so-called acoustic sonic tool is making a slow introduction into the industry, but it can be a very useful tool for identifying small-scale structures. Green (2001) reviewed the success and value of this tool.

Magnetics is an essential tool for locating igneous activity. It has, also been used with some success in determining faulting. Either aero- or surface magnetics can identify areas of high magnetic susceptibility in the rocks close to the surface and at shallow depths. This information can then be transferred into high-resolution colour plots that identify the nature of structure. Moloney and Doyle (1996) identify the success of such techniques).

Further reviews using this approach and applying a detailed interrogation of the data is presented in Munroe et al (2001). Magnetics affords the opportunity to utilize drilling with specific targets in mind.

Seismic surveys have been of great value in interpreting faulted ground and can sometimes identify dykes and silling along with synclines etc. This type of survey can range from the 'wacker packer' style to 2D or 3D high-resolution dynamite surveys. Much has been written of the success and Peters and Hearn (2001) have reported on recent finding in the Bowen Basin. Results from this type of work allow for specific targets to be focussed on to gauge the accuracy of the interpretation.

The benefit of any of these techniques is in defining the presence, location and magnitude of geological structures. These structures can then be placed on a Hazard Map to be used when determining the likely impacts of both development and longwall extraction.

UNDERGROUND EXPLORATION ACTIVITIES

The impact of in-seam drilling has increased markedly during the last decade. Some of this improvement results from high quality survey tools giving rise to high-level confidence in the location of boreholes and their influence on surrounding strata.

The downside is that despite the obvious benefits of having geophysical logs run in these holes, the development of this technology for in-seam boreholes has not developed at an adequate pace. What also needs to go hand in hand with the use of this technology is the realisation by mining operators of how important is the information that the geophysical logs provide in locating geological structures. Ironically, for surface exploration boreholes, it is unlikely that any geologist would ever choose not to run geophysical logs – nor would they allow the drillers to write the borelogs for the hole, which is common practise throughout the in-seam drilling industry. I believe that geophysical techniques for in-seam work must be improved, further that it is critical in mines that have a specific outburst risk.

Remote techniques such as Radio Imaging (RIM) have a role to play. RIM can give varied results in different coal seams and in different coalfields. It is clear that in areas where it has been found to work, it can be employed to identify; geological structures, clean coal, areas of high moisture and potential zones of high gas content.

MANAGEMENT PLANS

Many mines have identified the need to implement Outburst Management Plans (OMP). The plans, if adequate, if followed and if audited, ensure that a specific process is in place to manage activities to avert the risk of having outbursts.

Most OMP rely upon a combination of determining the in-seam gas content and identifying geological structures. If the gas content falls below certain cut-offs, mining can progress without further work. If the gas content is excessive than further in-seam drainage is required to reduce the level of gas prior to mining commencing. If a structure is present then further drainage may be required.

Training of miners to identify geological structures, whilst essential, does not necessarily mitigate against an outburst event taking place. It is simply a means of detection and a limited one at that.

It is also important to assess the level of risk with a risk assessment of the potential at any site. A statistical analysis of the available gas data to assess the likely variability and determine the adequacy of the data should be conducted. Duke and Phillips (1993) describe statistical analysis of gas content testing.

CONCLUSIONS

Geological structures have a critical role in the outbursting events. In Australia outburst events without geological structures are extremely rare.

The role of structures appears to be twofold; providing disturbed ground and effectively creating a barrier to gas migration or drainage.

Ongoing research of outbursting, should be encouraged.

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