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Directional drilling in unstable environments

Hungerford Frank [a,b,*], Ren Ting [b]

[a] VLI Pty Ltd, Beresfield, NSW 2322, Australia
[b] Faculty of Engineering and Information Sciences, University of Wollongong, Wollongong, NSW 2522, Australia

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ABSTRACT

Directional drilling has been established in the coal industry as a viable means of gas drainage, exploration and water management. But the environment in and around coal seams is not always conducive to stable conditions while drilling and borehole stability after the drilling has been completed. This paper identifies the conditions which cause unstable drilling conditions and the various means which are used to attempt to manage or bypass those conditions. Ultimately, equipment does become bogged in these adverse environments and requires recovery by over-coring.

1. Introduction

Directional drilling has been developed and evolved as a safe and reliable means to position boreholes in coal seams and the surrounding strata to allow gas drainage, exploration ahead of development and water management [1–7]. But any drilling requires a stable environment to provide stable boreholes while drilling and for those boreholes to remain open through their functional life.

Coal seams have been subjected to numerous and various forces which create areas of fractured coal and unstable strata. Drilling into or through areas of unstable ground has always been a major problem for drillers. Even with precautions, caving can occur and bog the drill string in the borehole. This can result in the loss of drilling performance and equipment, project delays while attempts are made to retrieve the string, and steel left in the coal seam to be later intersected by mining.

The cost of equipment at risk is increasing as drilling technology improves and more expensive equipment is being used in-hole. Before any drilling is undertaken, it is logical to assess and define the potential drilling environment. Drilling projects can then be planned to manage the environment and to successfully complete the project while avoiding the adverse effects of intersecting unstable drilling conditions.

Unfortunately, even with the best planning and prior knowledge, drilling equipment does get bogged with potential loss at high expense. With increased exposure to adverse drilling conditions and bogging events, over-coring to recover bogged equipment has become an established practice.

2. Drilling environment

When drilling is penetrating strata, the strata is expected to be stable and competent enough to support the cylindrical opening of a borehole. The strata around the opening should be able to resist the surrounding stresses and any adverse effects that contact with water may have to that strata. But in the course of in-seam drilling, adverse and unstable environments are encountered and must be managed.

Several different forms of unstable ground have been encountered and defined with a variety of means developed to negotiate the zones [8].

2.1. Mylonite zones

Mylonite zones are areas of pulverised coal held in place by the surrounding coal and can be in small vertical or horizontal bands or in much larger volumes. This coal has no structural strength and collapses or can be propelled by gas pressure into any borehole intersecting it. The smaller bands can be negotiated usually with no indication at the drill site of the intersection. The problem exists with the larger volumes collapsing or being propelled into a borehole and jamming around the drill rods or blocking a borehole.

In some cases these areas can be cleared with very slow or no penetration and continual flushing until a stable cavity has been established. The areas can be bypassed by branching and choosing an alternate horizon or lateral position. If the rods do become

* Corresponding author. Tel.: +61 418 401 562.
E-mail address: FHungerford@vli.com.au (F. Hungerford).

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stuck, removing the water pressure may ease the pressure on the blockage and allow easier extraction.

2.2. Fractured coal

Boreholes intersecting areas of faulted coal can dislodge large volumes of fractured coal. This can jam around the drill string at the location of the faulting or be flushed out to settle in out-bye cavities or the standpipe and jam the rods there. The rods may jam only when feeding in as the debris is jammed against the in-bye edge of the cavity while being free to pull out. The reverse can happen with large pieces jammed against the out-bye edge of cavities by the flow of flushing water out of the borehole.

The mode of negotiating these conditions is usually the same as for mylonite zones. In most cases, working the bit back through an area helps to break up larger pieces for easier removal by flushing. If the area has been identified as extensive, it is better avoided with drilling.

2.3. Very high stress areas in coal

High stress concentrations can be present in the seam and surrounding strata due to abutment loading from longwall advances, new drivages or depth of the coal seam. This can cause the borehole to crush either as it is drilled or at some later stage. This has occurred while drilling a standpipe hole to 6 m, immediately after directional advances from the end of a standpipe or as it passes through a specific stress zone. Drilling through these zones is usually unsuccessful as it is difficult to stabilise them with flushing and reaming. When a zone is defined as localised around a panel, the initial section of hole can be drilled in stone to intersect the seam at some (trial and error) defined distance from the drill site to avoid the zone. Casing is not usually an option as the initial drilling can't complete the borehole into which the case is to be installed.

2.4. Fault zones

Fault zones usually contain components of all three previously described unstable environments. Where a seam displacement has occurred, the fault plane usually contains fault gouge similar to mylonite and the adjacent strata is likely to be disturbed to some extent. The surrounding strata is also likely to be under additional localised stresses. Reverse faults tend to be more disturbed than strike-slip and normal faults. The extent of disturbance and localised stresses is usually proportional to the magnitude of the fault displacement.

2.5. Dyke cinder

Cinder around dykes can be hard and presents drilling problems because of difficulty in penetrating the strata and the potential of damage to drill bits.

The common experience is for cinder to be in a granular form and to behave similarly to mylonite when penetrated by drilling. The extent of the cinder can vary from centimetres to several metres thick. The differences compared with negotiating mylonite zones are the light gritty nature of the drill cuttings and the flushing colour is light grey.

2.6. Soft clay dykes, sills and bands

The characteristics of the dykes present in coal seams vary greatly depending on the extent of weathering. Hard dykes can be very difficult to penetrate with Polycrystalline Diamond (PCD) bits and require diamond coring drilling. This material does not present unstable conditions after drilling.

Dykes which have undergone weathering have usually decomposed to a clay material which can be relatively firm when first penetrated but rapidly soften and can squeeze into the borehole after contacting with water. Some dykes can be stabilised by progressively flushing through to create a stable cavity. Boreholes drilled at an upwards angle through dykes are generally more stable as they do not have water lying in them to allow continual swelling of the clay.

Cases have been experienced where the dyke has been penetrated comfortably and the rods are free to push and pull until water pressure is applied and this forms a hydraulic clamp. Releasing the water pressure releases the rods. Drilling is very slow as penetration or rotation is difficult once the flushing water is applied.

Major clay bands within the seam are best treated as a boundary to the drilling as is the case with the seam roof. Intersections with a band are used for positioning the borehole within the seam with the borehole stopped at the intersection and continued after branching. Because of the likely low-angled intersection and prolonged contact, it is difficult to stabilise an extended length of borehole in clay with continual flushing and reaming.

Alternatives used to negotiate through clay strata have included:

- Drill HW casing through a dyke if close to the borehole collar and drill through the casing. This usually involves drilling the directional borehole through the clay structure, reaming and installing the casing before the clay swells to close the borehole. This is limited in depth due to the practicalities and expense. The casing may remain free or can possibly be cut and retrieved after the borehole is completed.
- Drill through then ream up to and through the dyke and try to position a short length of casing in that zone before it closes. Care must then be taken to insert the drill string through the casing for drilling beyond the zone.
- Branch and drill into the roof or floor strata across the dyke zone. This works on the assumption that most dykes are much thinner in the strata above and below the seam, have created less disturbance to the surrounding strata and present fewer problems.
- Use drilling water additives (muds) which stabilise the clay. Recirculation of the drilling fluid, which is the usual system for using drill muds on surface drilling projects, is not an established practice in underground in-seam drilling. Drill additives can be added continuously but are lost with the waste water, adding substantial cost to the drilling. It can be applied with occasional doses when conditions get "sticky".
- Avoid the zone and access the area beyond the dyke from another area of the mine if possible.

2.7. Flaking mudstone

Some boreholes deflect off the roof strata and continue to final depth. Some mudstones fret with water contact allowing large pieces of stone to drop into the borehole. Individual pieces may be flushed from the borehole but some can lodge in the borehole and either block water flow or jam the drill string when it is being withdrawn. If the surrounding roof or floor strata are suspect, deflecting off these stone intersections should be avoided, with branching being employed to continue drilling.

2.8. High gas content and pressure

In high gas content and pressure environments, most of the previously mentioned unstable environments become more unstable.