Horizontal heading

COAL operators have begun to realize the exploration potential of data obtained from horizontal directional drilling (HDD). Due to the erratic nature of localized anomalies such as channeling, splays and faulting, conventional vertical exploration drilling is not always successful.

Typically, high-density vertical exploration drilling patterns are necessary to reasonably map these anomalies for mine planning purposes. Yet for some mine operators focused vertical exploration drilling is cost prohibitive or difficult to implement due to depth or environmental drilling restrictions in certain areas, such as parts of the western US.

It is crucial that HDD data is recorded accurately by an experienced drilling crew and plotted and interpreted by a qualified geologist who can present useful interpretations of the anomalies. Wherever HDD is applied, as-mined data should be used to validate interpretations for future projections.

The HDD applications presented below are deployed by REI Drilling, which has provided directional drilling services to the coal mining industry since 1983.

Based in Salt Lake City, REI currently operates a fleet of seven underground longhole drilling units supported by professional geologic and mining engineering staff.

Horizontal directional drilling

Advances made in permissible downhole borehole survey technology in the 1990s has improved the accuracy of HDD performed for underground coal mining operations, and as a result, increased its application.

Initially performed for development of in-seam boreholes for methane drainage, HDD is now routinely used in geologic exploration and exploration of abandoned mine workings. Another application is in the development of targeted boreholes into surrounding mine workings (underlying, overlying, or adjacent) for water transfer or water drainage — draining overlying abandoned workings in advance of longwall mining, for example.

In coal mining operations, HDD is performed with high thrust, permissible drills, downhole mud-motor drilling technology, and state-of-the-art borehole surveying equipment. Clean circulating fluid is pumped through drill rods at rates of 50-100 gallons per minute at high pressures (1000psi), to power a hydraulic downhole motor which rotates a bit (typically 4in in diameter).

Directional control is achieved by the use of a bent housing installed behind the bit. The orientation of the "bend" (typically one to two degrees) is monitored by the borehole survey system and is positioned by the operator through rotation of the drill rods.

The bend and axial force produced by the drill (thrust) along the rods alters the track of the bit in a direction opposite to that of the bend. This also allows the development of multiple tangential boreholes (side-tracks).

Downhole magnetometers and accelerometers provide the drill operator with the azimuth and pitch of the drilling tools, in addition to the orientation of the bent housing. Steering is performed by the operator upon rationalization of the downhole data and orientation of the bent housing through rotation of the drill rods.

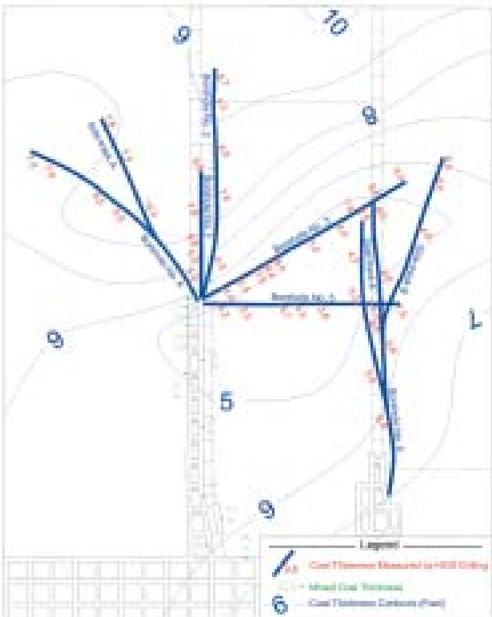
Experienced directional drillers use plots of rationalized downhole data, drilling thrust, downhole drilling water pressures, circulation volumes, and cuttings to accurately steer boreholes in coal seams, or interburden, to distances in excess of 5000ft.

Seam discontinuities

Seam discontinuities that compromise seam height, such as channeling, can be interpreted through the use of HDD with reasonable accuracy. The seam height is determined over an extended lateral length by physically contacting the mine roof at planned intervals.

Once the total depth of the borehole is reached, tangential boreholes, or side-tracks are developed to intercept the floor at locations that coincide with the roof contacts to provide a reasonable measure of coal thickness. Pending proper borehole planning, thickness measurements may be provided at intervals as frequent as 50ft for a typical 6ft coal seam.

Figure 1 — The results of HDD exploration to determine the extent of a post-depositional channel system.



This technique relies on coinciding roof and floor contact points, the use of proper borehole surveying techniques, and interpretation of the roof and floor through drilling thrust, downhole water pressures and cuttings. Using these parameters, REI has provided mine operators with reasonable predictions of the seam profile and the extent of post-depositional features which have been validated by subsequent mining.

Figure one shows the results of a HDD exploration program to determine the extent of a post-depositional channel system intercepted during gateroad development. In-place vertical drilling on this property indicated increasing seam height through projected longwall mining. However, when gateroad development commenced, the mine quickly encountered channeling that had scoured into the coal seam.

Seam height at the gateroad face was three feet, in order to advance this the mine was forced to cut the sandstone roof with a continuous miner. The trend of the channel was unknown and the mine was concerned all three of the longwall panels planned in the vicinity could be affected, compromising this part of the reserve.

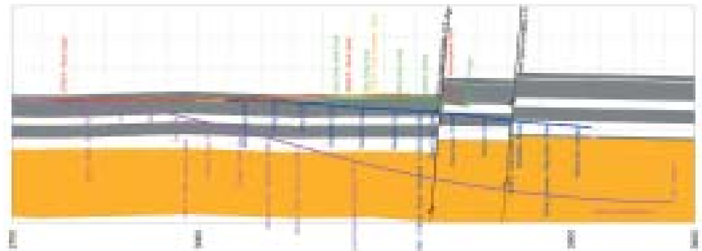


Figure 2 — A fault zone intercepted by HDD in advance of gate entry development.

Initial exploration drilling was along the gateroad projections (Borehole No.1 as indicated in figure 1). REI drilled Borehole No.1 to 1000ft bit depth, touching the roof at planned intervals of 100ft. REI pulled the downhole equipment back and developed side-tracks to contact the floor near the vicinity of the roof touches.

Through plotting and drill log interpretation REI determined that the channeling had lifted off the coal seam within 100ft from the current face location.

REI developed a total of six boreholes to determine the lateral extent and orientation of the sandstone body within the planned longwall panels in this mining district.

Further drilling and seam height characterization determined the channeling continued through three of the planned longwall panels. Figure 1 shows the isopachs derived from integrating the HDD results with as-mined and exploration data.

Following interpretation of HDD information, the mine elected to continue gate development and exploit this part of the reserve. As-mined surveys indicated that the seam heights determined from HDD exploration were consistently conservative but within 10% of as-mined measurements.

Fault detection and characterization

Concerns associated with mining into structural faults include determining the trend and lateral extent of the fault, the amount of offset, the volume of rock excavation required for mine-through, roof control impacts, and the potential emission of any associated water or methane.

Be it gateroad development or longwall mining, advancing through an unexpected fault can require a significant, capital intensive effort.

Horizontal directional drilling can be utilized to identify faults, quantify their characteristics and extent, and relieve associated water and gas. Properly performed borehole surveys and drilling logs provide information to derive projections of seam offset, the presence of fault gouge, and the lateral extent of faulting in advance of mining.

Such information is invaluable as it provides a mine operator with valuable time to revise mining plans, develop contingency plans, or derive fault interception plans.

The location of the fault is determined by ascertaining the continuity of coal during drilling. This is achieved through monitoring drilling thrust, downhole water pressures, changes in circulation volumes, and cuttings.

Where faults are encountered, carefully surveyed side-tracks placed into the roof, floor, or fault gouge determine the orientation of the displacement and its magnitude. Side-tracks developed to further intercept the discontinuity along its lateral length characterize its extent.

A profile of a fault zone intercepted by REI in advance of gate entry developments is illustrated in figure 2. This fault zone, when intercepted by mining in an adjacent gateroad produced a tremendous volume of water which significantly impeded mining development. Drilling indicated the anticipated fault zone was further outbye than anticipated, while exploratory side-tracks and associated drilling logs indicated the fault was comprised of multiple "en echelon" step faults.

REI projected the offsets were 4 and 11ft, respectively. Water production from encountering the fault was less than 50gpm, indicating that the interception from prior mining had discharged the fault zone.

Based on the results derived from HDD exploration, the mine elected to proceed with bleeder development and prepared rock excavation and gob disposal plans.

Other applications

HDD provides the coal mining industry with an effective and practical geological exploration tool. Applications by REI have established the approach for characterization of channeling, faults, coal burn, and intrusive anomalies.

Coal Burn, or "Clinker", is common in western US coal basins near outcrops. Burn characteristics include oxidized, or burned coal, which affects roof stability in proximate entries and condemns reserve areas. In some instances, oxidation is still active. From a mine planning perspective, burn is sporadic and unpredictable. REI has applied HDD to effectively determine the lateral extent of burn and identify active oxidation.

Other applications practiced by REI include core sample recovery from directionally drilled boreholes for characterization of mine roof or floor, partings, and coal, for the purposes of integrity planning (roof control) and determining coal quality.

Applications include the use of geophysical instruments downhole (natural gamma to characterize the immediate roof conditions in advance of mining), and experimentation with borehole radar.

Future developments for HDD and its application to exploration focus on bringing geophysics to the bit face.