MineVue radar for delineation of faults in underground coal mines of India

Faults pose potential problems in mining coal. Therefore, coal companies prefer to deal with the effects of faults in coal mining at the early stages of development, effects that sometimes include stability of roof and ribs in underground workings. Due to the presence of faults in underground coal mines, the seam may be significantly displaced, depending upon the type of fault. During the extraction of coal from underground coal mines, mining machineries may not be able to reach the displaced seam, if the displacement is too large. Presence of faults in underground coal mines may affect the production, safety and other associated mining activities such as the following.

1. Production: In underground coal mines, fault and fracture networks can result in significant geotechnical, production and safety hazards. Ground control strategies typically include mine designs that minimize fault exposure[1]. Physical displacement of coal seams due to fault can cause major interruptions to production (making it difficult or impractical to mine) and can affect the economic viability of a coal mine[2–4].

2. Opening of pathways for the influx of water and gas into underground workings: Some faults are pathways for water which can carry large amounts of clay and dissolved mineral matter and deposit these materials in the coal seam. The deposits are usually inconspicuous and widely dispersed, so they do not have much effect on the overall quality of coal shipped from a mine. Occasionally, difficulties are caused by the flow of water or flammable gases into underground workings along faults. Some faults provide natural pathways for the movement to fluids through the crust of the Earth, while others act as barriers to the movement of water. Faults can also act as trap zones for gas, which can result in bursts during mining, again posing significant risks to production and the safety of mining personnel.

3. Weakening of roof in underground mines: Any fault or fracture tends to decrease the stability of the roof and ribs in underground coal mines, and produces added danger to the workers, decreased production of coal and increased expense for supports and for cleaning of roof falls. Occasionally, zones of highly crushed or pulverized coal are encountered in a faulted area. Mining such coal produces large amounts of dust and fine 'slack'.

4. Introduction of impurities into coal seams: Various impurities detrimental to coal mining and coal quality are introduced into coal seams along faults. The most common unwanted materials are gouge and breccia, sand, clay, pyrite and other sulphides, calcite and quartz. These minerals increase the ash and sulphur contents of coal and may cause accelerated wear and tear on mining equipment.

5. Subsidence and fault reactivation: The existence of faults within the influence of coal depillaring zone affects the ultimate surface subsidence profile. Faults located in areas undergoing mining subsidence during extraction of coal seams may undergo reactivation. The impact of subsidence-induced fault reactivation may cause moderate to severe damage to foundations, houses, buildings, structures and underground services, as well as to agricultural land through disruption of drainage and alteration of the gradient. Fault reactivation that is contemporaneous with mining subsidence occurs because of the release of strain accumulation along the fault zone. The mechanisms involved in mining-induced fault reactivation have been reviewed by Donnelly[5].

6. Coal mine fire control: Sometimes the existence of fault in a mine becomes a blessing in disguise. The fault acts as a barrier in coal mine fire areas due to upthrow or downthrow of coal seam. It prevents the burning of *in situ* coal seam beyond fault.

Drilling is the most common method used in coal exploration and most coal companies rely heavily on drill-hole data for evaluating their mine properties. Evaluation by drilling is expensive and offers only limited information because drilling provides single data points. Considering the above problematic issues, the MineVue radar has been developed by the Central Institute of Mining and Fuel Research (CIMFR), Dhanbad which provides a continuous subsurface profile.

The radar system can be used for delineation of different inhomogeneities like faults, slips, galleries, etc. in underground coal mines. The MineVue radar survey which was developed was used for delineation of faults and galleries in underground coal mines of Tetulmari Colliery, Sijua area of Bharat Cocking Coal Limited (BCCL), Dhanbad. Interpreted MineVue data for faults and galleries were confirmed by the mine managements using existing mine plans of the concerned underground mine sites for checking the reliability of the developed radar system and to mine the coal safely.

Delineation of mine galleries or faults by conventional surveying is arduous and time-consuming. Also proving the same by means of long bore holes, drilled by safety boring machines, requires special machinery, skilled operators and adequate arrangements at the colliery. Various government agencies in India have experimented with a number of geophysical methods over the last 20 years in an effort to replace exploratory drilling. Ground penetrating radar (GPR) technology has shown the greatest potential to provide rapid, a priori information ahead of a working face. Since the 1970s, GPR has been used extensively mainly in solving different types of civil engineering problems, some of which were like the problems of the mining industry. Geophysical methods can give better but indirect solutions after delineating different geotechnical problems in the mining areas[6,7]. Among the geophysical methods, GPR, barring some limitations, is the most feasible technique for shallow workings[8].

The GPR technique depends on the emission, transmission, reflection and reception of an electromagnetic pulse. Depending on geological conditions of the area it can produce continuous high-resolution profiles of the subsurface rapidly and efficiently[9–11]. The GPR is also used for delineation of underground structures[12,13]. Nowadays, the GPR is significantly used in identifying and locating subsurface features such as cavities, conduits, fractures and buried caves[6,14]. A literature survey indicates that presently no GPR system is

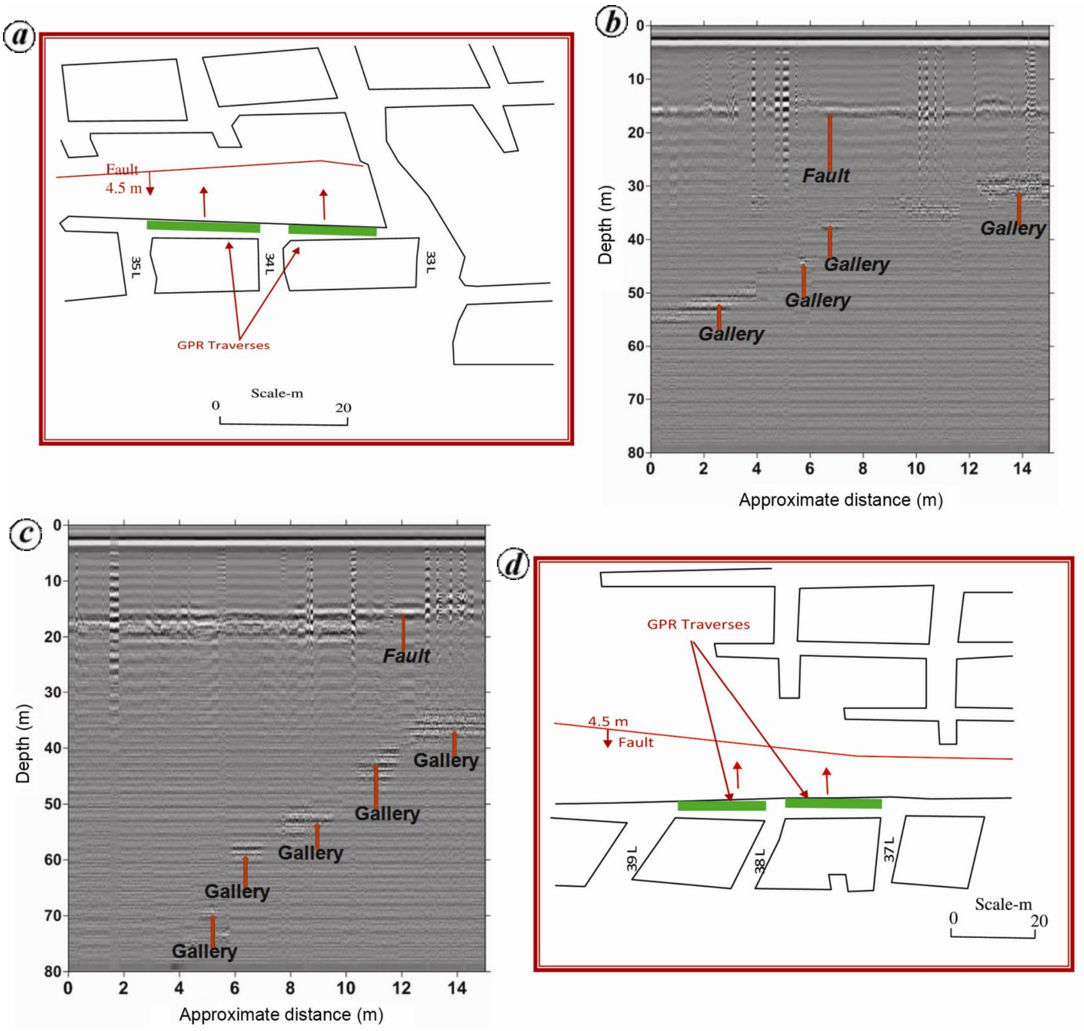

Figure 1. ***a***, Radar traverse between levels 34 and 33 as well as levels 35 to 34 in seam III of Tetulmari Colliery (dry gallery and fault). ***b***, ***c***, MineVue data between levels 38 and 37 (***b***) as well as levels 39 and 38 (***c***) at Tetulmari Colliery. ***d***, Radar traverse between levels 39 to 38 as well as levels 38 and 37 in seam III of Tetulmari Colliery (waterlogged gallery and fault).

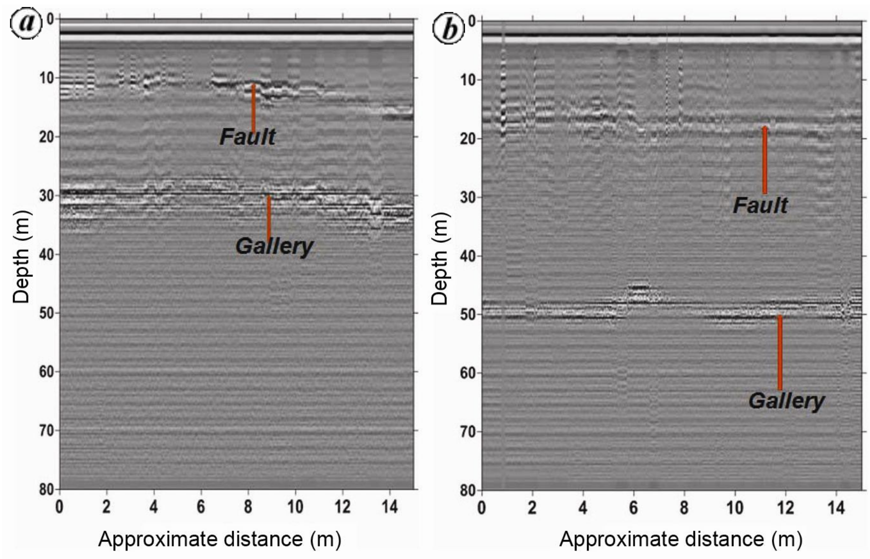

Figure 2. MineVue data at Tetulmari Colliery between levels 35 and 34 (***a***) as well as levels 34 and 33 (***b***) showing gallery and possible fault.

commercially available to penetrate 50–60 m in coal.

Considering the above facts the MineVue radar system has been developed, having the world's longest range depth of penetration of 60 m and lowest frequency (40 MHz) shielded radar system; it has been designed specifically for underground coal mines. The primary aim of the MineVue system is to delineate the mine galleries and faults up to 60 m in underground coal mines to avoid inundation hazard and other related mining problems for the safety of the mine and mining machinery used in underground coal mines. This paper deals with the study of the MineVue survey to delineate faults and mine galleries in underground coal mines, correlation and confirmation of the MineVue data with existing mine plans of the concerned collieries to check the efficacy of the developed MineVue radar system.

The Tetulmari Colliery is situated at about 0.5 km south of Tetulmari railway station of Grand-Chord line and about 15 km west of Dhanbad railway station. The colliery is surrounded by Sendera Bansjora and Nichitpur collieries in the east, Amalgamated Keshalpur and West Mudidih collieries in the west, non-coal bearing area in the north and Mudidih Colliery in the south. Total coal reserve of the colliery is 62.8 Mt having Washery-IV and Grade-D quality coal. At present, total lease-hold area of the colliery is 3.17 sq. km. There are many different coal seams, starting from seam I to seam VIIIA and all are outcropping in the property. General gradient of seams is 1 in 8, except at the OCP patch where the gradient of seam has changed to 1 in 4 due to strike fault. There are four dip-rise faults of 3.0, 4.5, 1.2 and 4.5 m, and one strike fault of 0–24 m throw occurring in the property.

The MineVue radar survey was carried out in seam III in the underground coal mine as shown in Figure 1 *a–d*. Average thickness of seam III is 4.5 m and dipping in 1 in 8. The entire property is developed and it is waterlogged on the dip side.

Two panels were surveyed between levels 35 and 34 as well as levels 34 and 33 at the first survey site of Tetulmari Colliery. The radar scans of these two panels are shown in Figure 2 *a* and *b* respectively.

The part-plan shown in Figure 1 *a* illustrates the actual locations of these radar surveys and those of faults and galleries. Examination of the radar data with the part-plan indicates a close correlation between the radar interpretations and actual locations of faults and galleries. Interpreted MineVue data indicate faults and galleries at depths of 12 and 30 m between levels 35 and 34 as well as 18 and 50 m between levels 34 and 33 respectively, which have been confirmed by the concerned colliery part-plan (Figure 1 *a*).

A second underground site was surveyed at Tetulmari Colliery between levels 38 and 37 as well as levels 39 and 38. The resultant data were not typical of strong reflections from a parallel gallery, as seen at the other sites surveyed. The data appear to be disconnected with small reflections at various points along the profile, as shown in Figure 1 *b* and *c*. An examination of the mine plan of this area explains the unusual radar reflections, as shown in Figure 1 *d*.

In this case, the radar imaged multiple 'point-sources' of reflection, because small galleries were present at different depths rather than a complete gallery wall. After interpreting MineVue data as shown in Figure 1 *b* and correlating with the mine part-plan (Figure 1 *d*), it may be concluded that a fault exists at a depth of 16 m from the coal seam face and four short galleries are present at depths varying from 30 to 55 m. Similarly, after interpreting MineVue data as shown in Figure 1 *c* and correlating with mine part-plan (Figure 1 *d*), it may be concluded that a fault exists at a depth of 18 m and five galleries are present at depths varying from 35 to 70 m. All the above MineVue data were confirmed by the concerned mine managements using the respective mine part-plans of the sites.

Thus the radar survey resulted in the followings conclusions:

1. Interpreted MineVue data from the first site confirmed that faults and galleries were present at depths of 12 and 30 m between levels 35 and 34 as well as 18 and 50 m between levels 34 and 33 respectively.
2. MineVue data from the second site also confirmed that a fault exists at a depth of 16 m from the coal seam face and four short galleries are present at depths varying from 30 to 55 m between levels 38 and 37. Similarly, after interpreting MineVue data and correlating with mine part-plan, it is concluded that a fault exists at a depth of 18 m and five galleries are present at depths varying from 35 to 70 m between levels 39 and 38.
3. All the above MineVue data are confirmed by the concerned mine managements using the respective mine part-plans of the sites.
4. After confirmation of survey results with the concerned mine managements, it is concluded that MineVue radar system is a useful technique for delineating faults and mine galleries for safe and productive coal mining.

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