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Application of Ground Penetrating Radar for Mining Hazards

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खनन क्षेत्र में विभिन्न समस्याओं का पता लगाने के उपरांत भूभौतिकीय विधियों द्वारा इन समस्याओं का परोक्ष रूप से बेहतर समाधान किया जा सकता है। विभिन्न भूभौतिकीय विधियों में ग्राउण्ड पेनेट्रेटिंग रडार (जी. पी. आर.), कुल मूल परिसीमाओं को छोड़कर भूमिगत खानों के विवरों एवं जलप्लावित क्षेत्रों के निरूपण के लिये संभवतः, सबसे सुसंगत उपकरण है। इन समस्याओं के कारण भूमिगत खानों से कोयले को निकालना बहुत कठिन होता है।

इस आलेख में खानों की कुछ समस्याओं के साथ ही साथ उपरोक्त वर्णित तकनीक की अनुप्रयोज्यता को कुछ केस स्टडी के साथ प्रकाशित किया गया है।

INTRODUCTION

There is pressing need for better means of exploring ground conditions ahead of mining and tunnelling. Exploration drilling suffers from the drawbacks of high cost and a seriously restricted sampling zone. Traditional geophysical exploration methods including gravity, magnetic, resistivity, induced-polarisation, and inductive electromagnetic techniques have been used with some success underground, but all suffer from poor target resolution relative to range, since they depend upon the minor distortions of a potential force field.

Much greater ratios of resolution to range can, in principle, be obtained by employing radiation as the exploring agent. This is because propagation time delays can be used to measure range accurately and to separate the small effect of a distant target from the much larger effects of nearer targets and of the transmitter. There are only four types of radiation capable of substantial penetration through rock: neutrinos, hard cosmic rays, seismic waves, and electromagnetic waves. The first two are not easy and a technology for their application to exploration has not yet been developed. Seismic waves have long been used with great success in exploration for petroleum, but the development of underground seismic methods is in its infancy. Electromagnetic (radar) waves have been very successfully used for detection and location through the air and outer space, and have also explored through polar icecaps more than a mile thick. Unfortunately, the bodies of water and the soil mantle covering most of the earth are essentially radar–opaque because of their high electrical conductivity. It is generally not realised that below the soil many rocks are somewhat radar–transparent and that electromagnetic waves can be used for exploring such rocks, once a quarry, a mine, a borehole, or other means of access has been opened.

Electromagnetic waves are reflected by any boundary or object where they encounter a pronounced change in electrical properties. In rocks, the usual cause of such a change is a difference in moisture content. Hence, radar waves passing through tight dry country rock are reflected by a fault filled with gouge clay or with wet broken rock, for example. Other possible reflections are metallic masses and interfaces with air, as at the adjacent mine opening. Since the rock properties governing the propagation and reflection of radar waves are quite different from those governing seismic waves the two methods of exploration should supplement one another.

There are so many mining problems like unapproachable old workings, water–logged areas and cavities. Due to this reason, it is very difficult to extract the coal from underground mines. In accord with its mission to assist the mining industry in developing technology to deal with problems caused by abandoned mines, an electromagnetic instrument, Ground Penetrating Radar System has been used for assessing the hazards of abandoned underground mine workings in Jharia coalfield, Dhanbad, India.

Jharia township is the most important part of Bharat Cocking Coal Limited (BCCL) having 2 sq. km. Area. There are so many mining problems like unapproachable old workings, water–logged areas and cavities. Due to this reason, it is very difficult to extract the coal from underground. Underground mining (mainly partial extraction by development) below Jharia town has been carried out through three collieries namely East Bhuggatdih and Simla Bahal of Kustore Area and Kujama colliery of Bastacola Area of the B. C. C. L. Chouthaikulli, Hussainabad and Katras More localities of the town witnessed extensive subsidence and cracks in the buildings and roads in March, 1996 and subsequently in October, 1996. After that, problem arises for the stability of dwellings in the whole leasehold area of the BCCL. A burning problem arises about the stability of the area between Bata More and 4 No. Bus Stand in Jharia Town. Now, this challenging work is also sponsored to CMRI for study the stabilisation of Jharia Town between Bata More and 4 No. Bus – Stand. For this purpose, Ground Penetrating Radar (GPR) is used for detection of unapproachable underground workings.

METHODOLOGY

Geophysical methods can give better solutions indirectly after locating the different problems in the mining areas. Among geophysical methods, GPR (Geo–radar) barring some limitations is the most feasible technique for shallow workings. Geo–radar is the modern surface–geophysical method that depends on the emission, transmission, reflection and reception of an electromagnetic pulse and can produce continuous high resolution profiles of the sub–surface rapidly and efficiently.

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OPERATING PRINCIPLE

A very short time impulse (ns) is generated at a very high frequency (25 Mhz to Ghz) and radiated by an antenna, called transmitter. When the signal encounters an anomaly, it is reflected and picked up by a receiver which transmits it to a magnetic and graphic recorder, this constitutes a "scan" or radar echo. This is shown in Fig. 1. The waves reflected by anomalies in the subsurface are observed successively with the regular displacement of antenna along the profile studied. The data is presented as a "time section" or radar propice.

The records shows the total travel time for a signal to pass through the subsurface, reflect from an inhomogeneity, and return to the surface. The two-way travel-time is measured in nanoseconds (1ns = 10^{-9} seconds). Determining to the depth to a reflector involves using the basic equations :

$$D = T.V/2 \qquad \text{........ (i)}$$

$$V = C/\varepsilon^{0.5} \qquad \text{........ (ii)}$$

where,

D = depth to the reflector, in feet;

T = two-way travel time, in nanoseconds;

C = velocity of light in free space = 0.98 foot per nanosecond;

ε = relative dielectric permitivity, a dimensionless ratio;

V = electromagnetic wave velocity, in feet per nano-second

The depth of exploration varies between 1 and 40 meters for both natural soils and construction materials. The depth of penetration depends on the following :

1. the capacity of the equipment;
2. the emitted wave frequency;
3. the electric properties of the materials (dielectric and conductivity);
4. moisture content.

Scope and Limitations

The principle limiting factor in depth of penetration of the GPR method is attenuation of the electromagnetic wave in the earth materials. Studies show that in areas having material of low electrical conductivity, such as clay-free sand

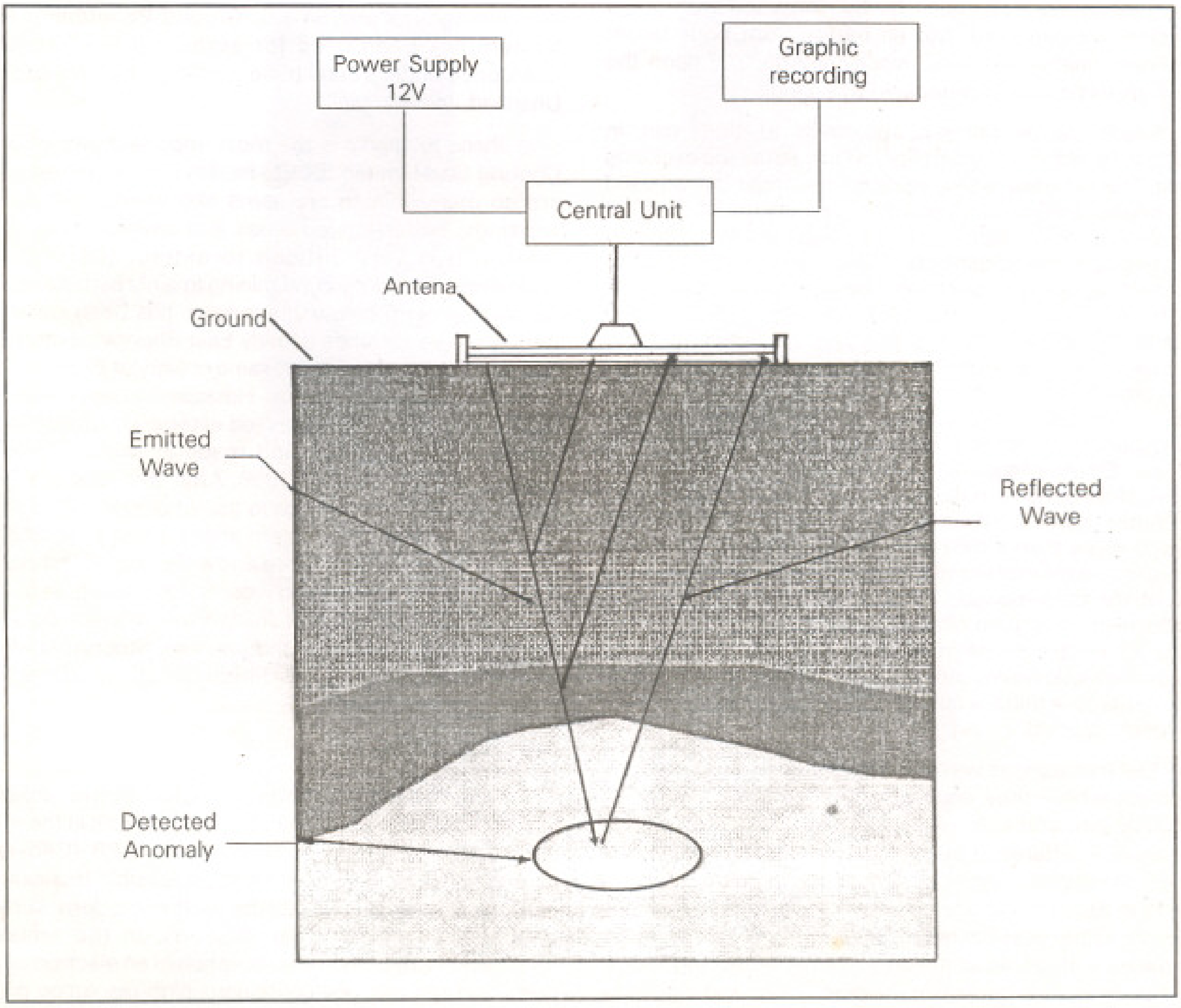

Fig. 1 : Operating principle of the GPR

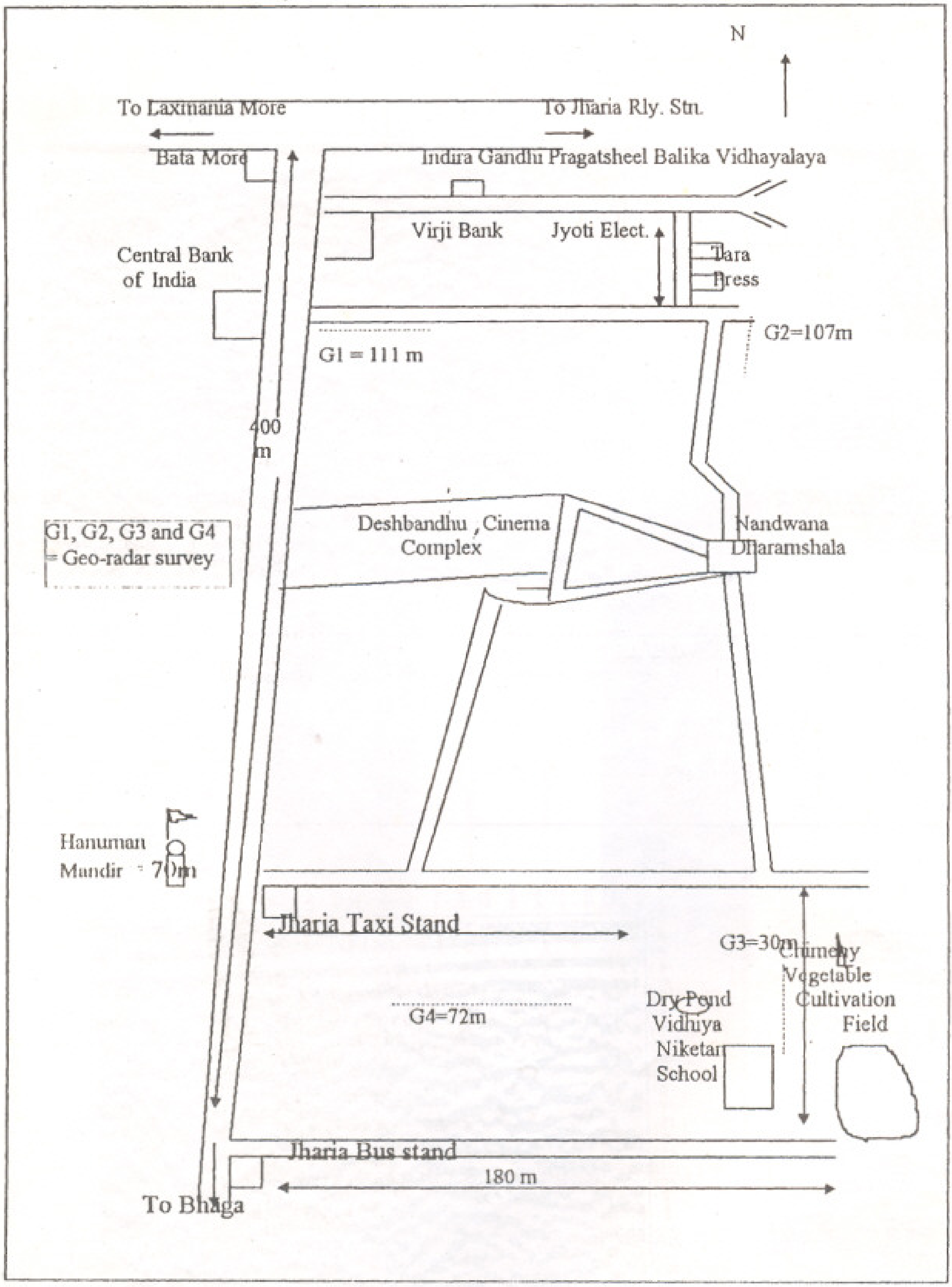

Fig. 2 : Field sketch for GPR survey sites towards unapproachable area

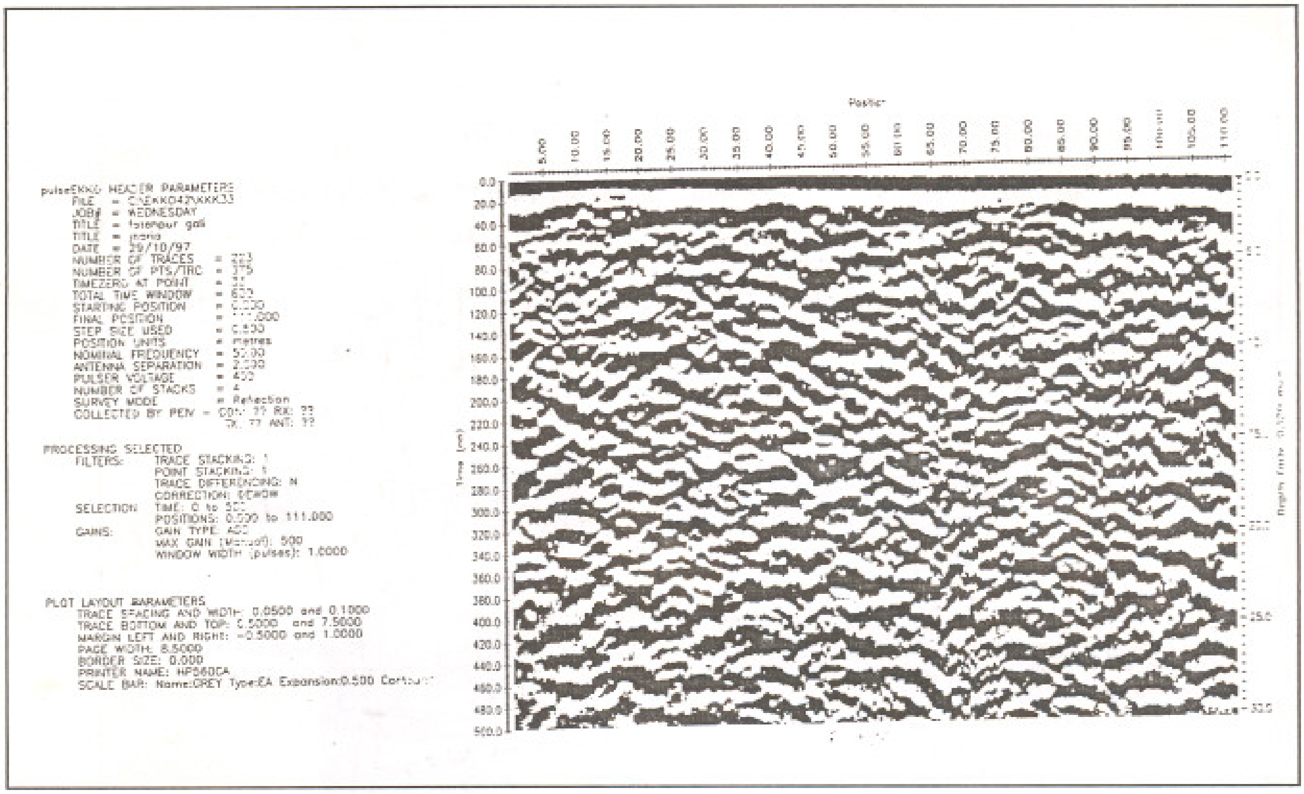

Fig. 3 : Radar signatures for subsurface features along Fatehpur Gali

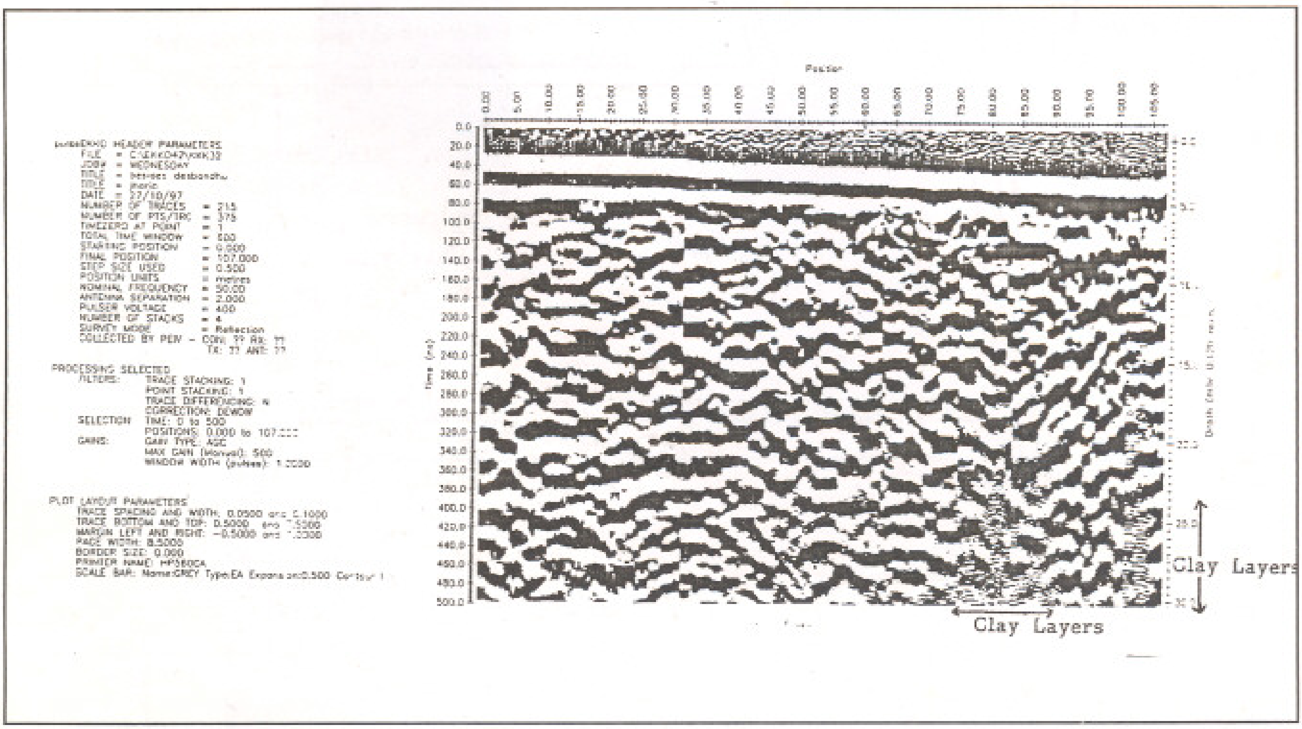

Fig. 4 : Radar signatures for subsurface features in the back side of Desbandhu cinema Hall

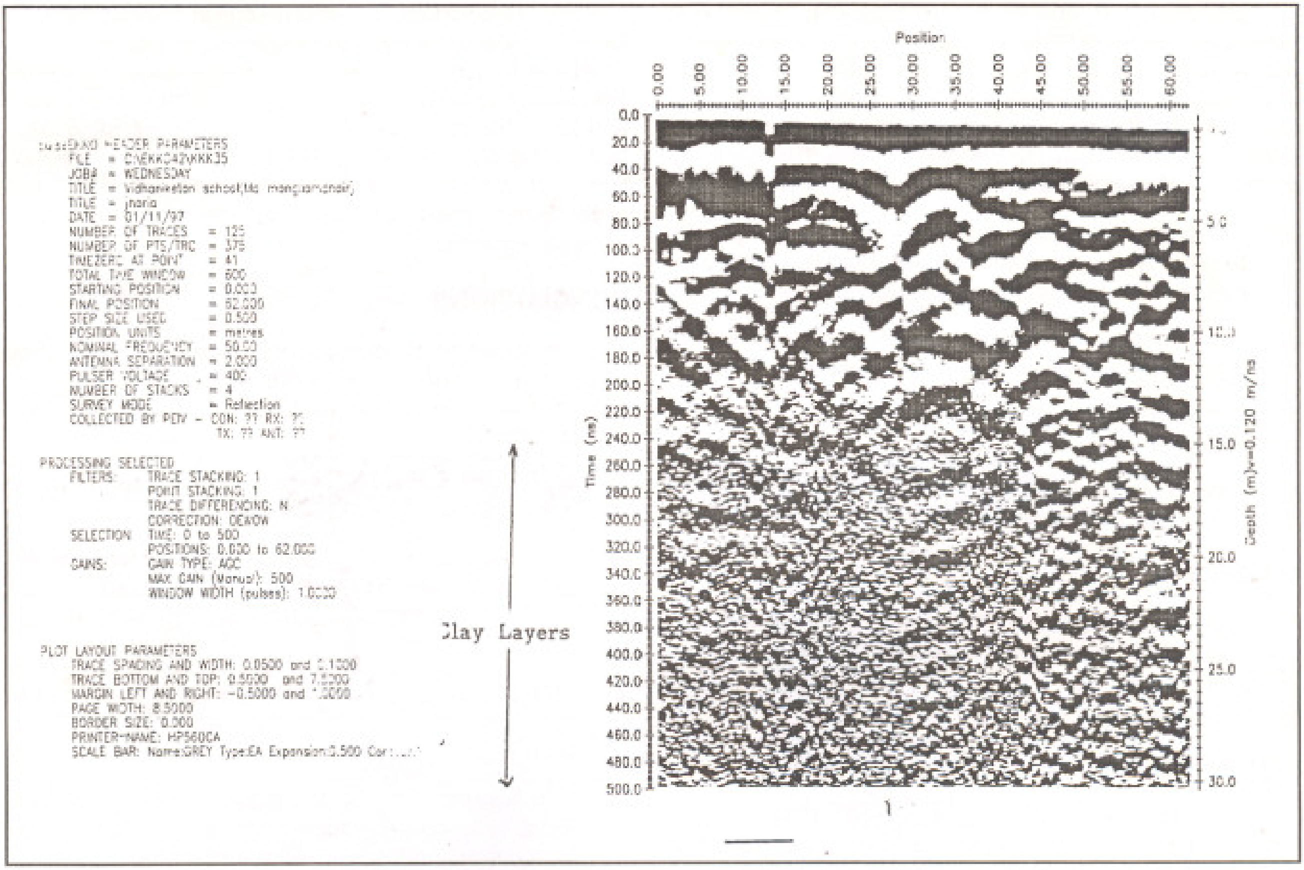

Fig. 5 : Radar signatures for subsurface features in front of Bidya Niketan School

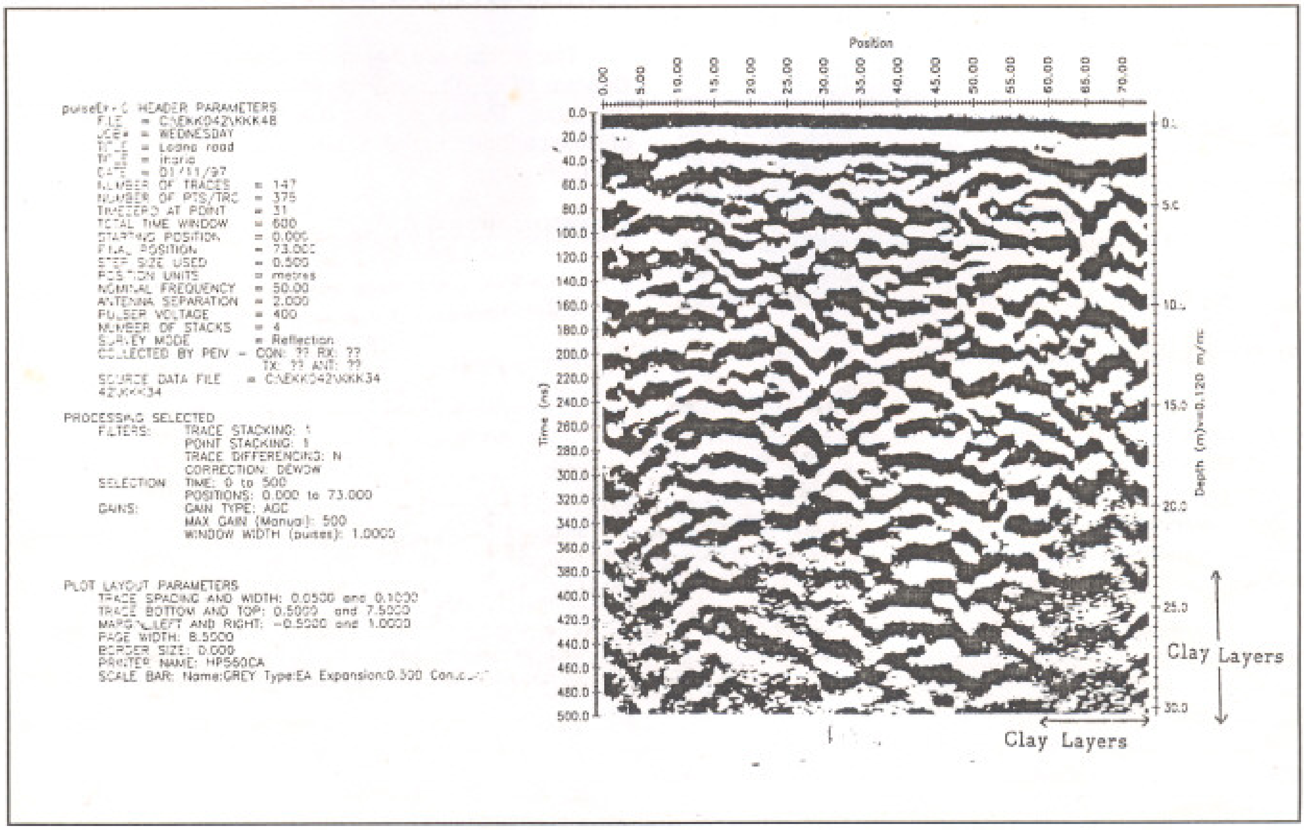

Fig. 6 : Radar signatures for subsurface features along Lodna Road

and gravel, low frequency electromagnetic waves can penetrate to depth of 90 feet (Olhoeft, 1986). In areas having highly conductive materials, such soils with a high percentage of clay minerals and water having conductivity less than 10 ms/m, the penetration depth of electromagnetic waves can be less than 3 feet (Olhoeft, 1986). The following points may always be taken care while carrying GPR survey:

1. The transmitted wave must be at a sufficient power to reach the buried object and return to the surface to be detected by the receiver.
2. The impedance contrast of the buried body must be high enough to cause a sufficient reflection.
3. The object must be large enough to be detected at the specified depth.
4. Other objects must not interfere with the reflection emanating from the buried object.

OBJECTIVE

The objective of GPR survey is to delineate unapproachable underground workings, cavities and solid layers between Bata More and 4 No. Bus-stand in the leasehold area of Kujama colliery in Jharia Town.

STUDY AREA

The study area extends between Bata More and No. 4 Bus-stand. The total width and length of this area is 300m and 440m respectively. Width of 200m and 100m of study area lies in the West and East of Bata More-Sindri Road mostly within the leasehold of East Bhuggatdih and Kujama collieries respectively (Fig. 2). The study area of East Bhuggatdih colliery is approachable whereas the study area of Kujama colliery is unapproachable, where GPR survey was conducted. GPR survey sites (numbered as G1, G2, G3, G4) are shown (Fig. 2). Study site G1 located between Virji Bank and Deshbandhu cinema is called Fatehpur Gali. Study site G2 lies in the backside of Deshbandhu cinema. Study site G3 is located in the ground of Bidya Niketan school lying close to Lodna Road whereas last Study site G4 lies on Lodna Road passing just opposite to Dharamsala Road.

RESULTS AND DISCUSSIONS

GPR survey has been carried out along Fatehpur Gali (G1), backside of Deshbandhu cinema (G2), in the front of Bidya Niketan School (G3) and Lodna road (G4) in Jharia town. Figs. 3 through 6 show the Radar Signatures for substance features of Fatehpur Gali, backside of Desbandhu cinema, in the front of Bidya Niketan School and Lodna road respectively.

Fig. 3 shows the Radar Signatures along Fatehpur Gali. In this figure, there are solid black lines upto 30 metres depth from the surface indicating solid strata in underground. Fig. 4 shows the Radar Signatures of the backside of Desbandhu Cinema. There are so many solid black lines along with some breakage in solid lines in this figure. These breakage in lines are existing at the depths of 25 metres to 30 metres and at the positions from 80 metres to 84 metres on the surface. These breakage in lines indicate clay layers. Similar solid lines and breakage in solid lines have also been found in Fig. 5 and Fig. 6 respectively. Solid lines are existing upto the depth of 16 metres from the surface and after that breakage in lines or layers indicating clay-layers in Fig. 5. There are so many solid layers in underground except at depths varying from 25 metres to 30 metres and at positions from 60 metres to 68 metres where clay-layers are existing in Fig. 6.

CONCLUSIONS

The following conclusions are drawn after conducting GPR survey at four different locations between Bata More and No. 4 Bus-stand within the leasehold of Kujama colliery in Jharia town :

1. Solid layers are existing upto a depth of 30m from the surface in Fatehpur Gali.
2. There are solid layers upto a depth of 30m at the backside of Deshbandhu cinema. Clay layers are also found at 25-30m depth between 80-84m surface position.
3. Solid layers are present upto 16m depth and below clay formation exists in the ground of Bidya Niketan School.
4. Solid layers are found upto a depth of 30m below Lodna Road. But again clay formations are detected at 25-30m depth and from 60-68m surface position.

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