Utility of magnetic data in delineation of groundwater potential zones in hard rock terrain

Exploration and management of groundwater in hard rock terrain is a challenging task, as the potential groundwater zones are associated with fractured and fissured zones. Identification of such features in subsurface is a difficult task. The groundwater potential in such an environment depends upon the thickness of the weathered/fractured layer overlying the basement rocks. An integrated geoscientific study has been carried out to understand the aquifer set up, especially the groundwater flow system in weathered fractured granitic zone in Maheshwaram watershed, having an areal extent of ~55 km^2 situated at about 30 km south of Hyderabad, India. The area under study lies between longitudes 78°24′30″ and 78°29′00″E as well as latitudes 17°06′20″ and 17°11′00″N (Figure 1). The weathered zone extends to a depth of 20 m followed by fracturing at many places[1] and shows variable density of fractures. The nature and degree of weathering are observable from a number of defunct dugwells that are generally truncated by erosion and overlain by a few decimetres of red soil; the weathered mantle has quite homogeneous thickness of less than 3 m throughout the watershed[1].

Dolerite dykes are seen in the northern, northeastern and western parts of the basin. Due to over-exploitation of the groundwater resources, the water level has gone down and presently the groundwater occurs mainly in the fractured/fissured rock under unconfined conditions[1]. As the aquifer is unconfined in nature, it gets recharged from the top surface during precipitation. In such a case the knowledge of the depth to the interface between the hard rock and weathered/fractured zones gives an idea regarding the availability of groundwater and its percolations and accumulation within the subsurface. In the present study the interpretation of ground magnetic data in conjunction with the resistivity and borehole results provided information regarding the interface and dyke intrusion that helped in delineating the groundwater potential zones.

The magnetic materials present within the weathered zone are depleted due to the weathering process during the geological time. This depletion of magnetic minerals reduces the susceptibility of the weathered zone whereas it is unaltered in hard rock. Thus the geological contact between overlying weathered/fractured zones and underlying hard rock becomes a good magnetic interface with considerable susceptibility contrast. So, the delineation of such an interface using magnetic data yields information regarding groundwater potential of the area.

In the present study 18 magnetic profiles were selected for ground magnetic survey using a Proton Precession Magnetometer (PPM), totalling 10-line km with a station interval of 5 m and 10 m. The study is concentrated mainly across the exposed dolerite dykes and traverses are laid perpendicular to its strike. To do the diurnal correction, we have recorded the time varying magnetic field with the

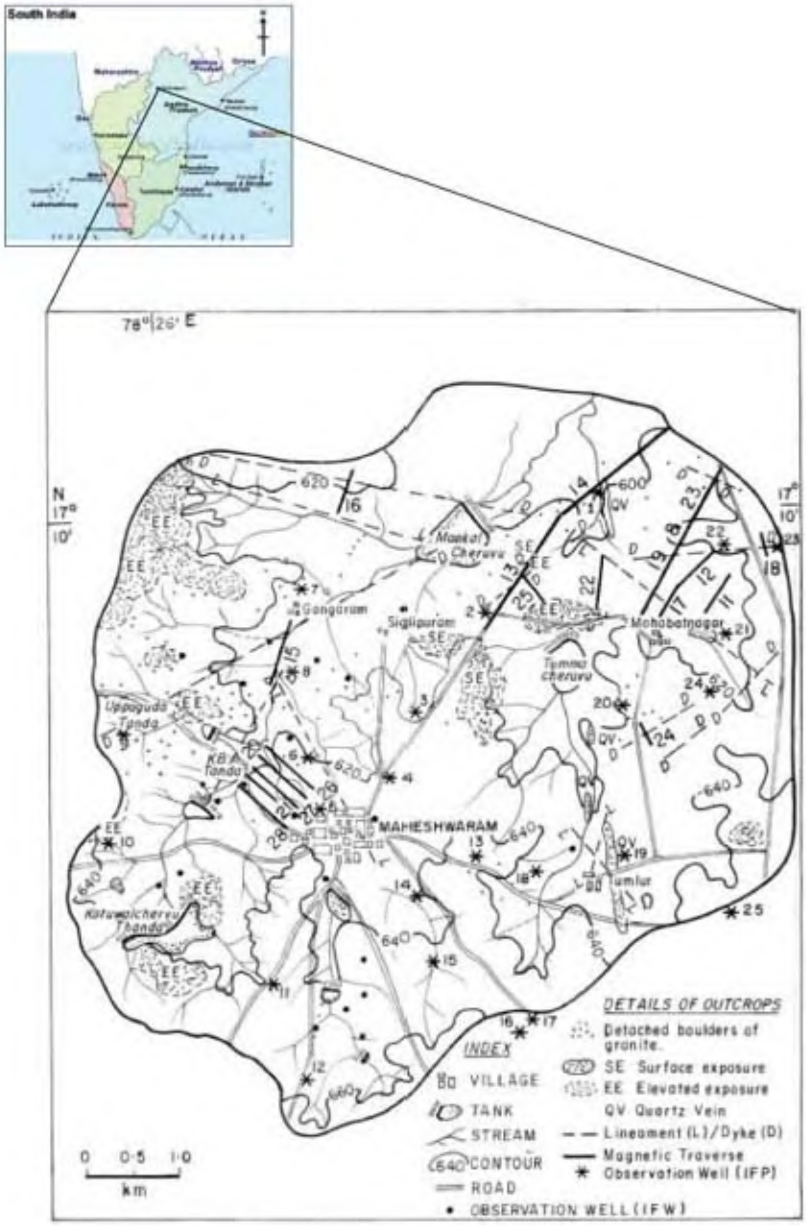

Figure 1. Location map of study area showing magnetic traverses.

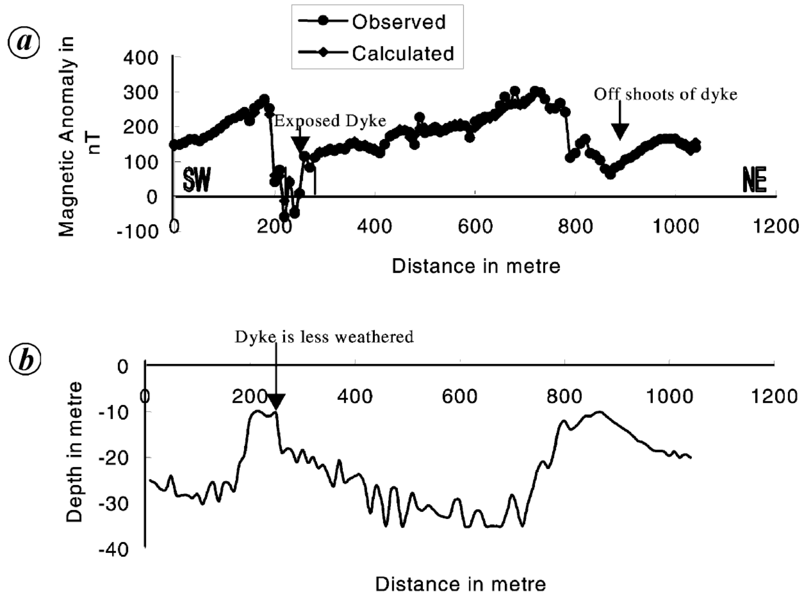

Figure 2. Observed and calculated magnetic anomaly along with inverted depth model (Profile-13).

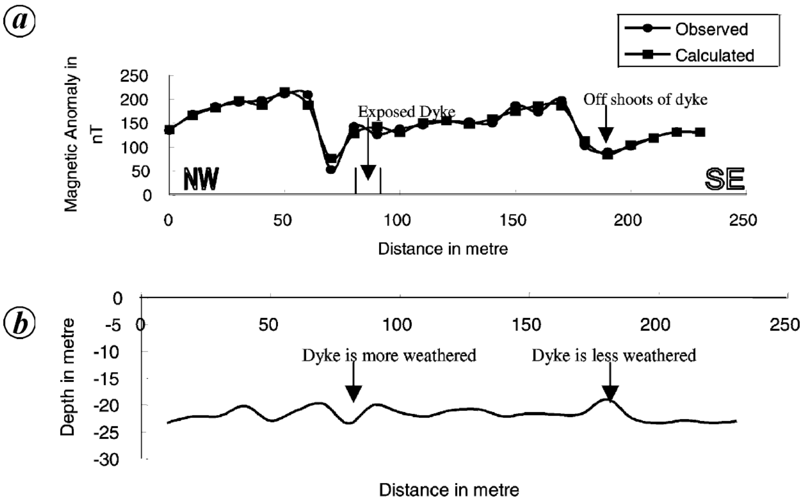

Figure 3. Observed and calculated magnetic anomaly along with inverted depth model (Profile-24).

same magnetometer with a repeated time interval of 2 h. The observed magnetic reading is corrected for International Geomagnetic Reference Field (IGRF) and the diurnal corrections and then plotted all along the 18 profiles. This plotted data is digitized at an interval of 10 m and a database is prepared, to be used for 2D magnetic inversion[2,3] to obtain the depth to the interface of hard and fractured rocks. The other parameters required are minimum and maximum depths to bedrock along the individual profiles which are taken from the results of nearby resistivity soundings[4] and intensity of magnetization.

The depth to the interface between hard and the fractured rocks obtained using this method corroborates well with the results obtained from resistivity and litholog data over the entire study area. For instance, two cases are presented here. Profile-13 (Figure 2) orients along SW–NE direction and it starts from SW direction. It crosses a dyke at 200 m from the starting point of the line (Figure 1) and perhaps crosses another concealed off-shoot of dyke at the NE end of the profile. Modelling of the anomaly along this profile indicates that the interface of the hard rock varies from 10 m to about 35 m (Figure 2 *b*), with minimum at the exposed dyke and concealed offshoots and maximum depth to the interface is between these two dykes. This indicates that the bedrock is deeper between the two dykes and the unweathered part of the dyke is shallower. So, the zone between these two dykes is likely to have good groundwater potential. A drilled well (IFP-2, Figure 1) close to starting point along west side of the profile indicates interface of the fracture zone and bedrock is at a depth of ~27 m, which confirms well with the present model. In another case, the observed data along profile-24 (Figure 3 *a*) and its inversion shows less variation of interface with two humps (Figure 3 *b*), one over the dyke and another along the SE end of the profile. The hump in the SE end may be due to shallow depth to the bedrock in this part or due to the concealed offshoots of another dyke, which is exposed at an offset of 100 m. The modelled depth to bedrock obtained is ~24 m. In general, the depth to bedrock obtained in the northern part of the watershed is ~17 m while in the northeastern part it ranges from 10 to 35 m. In the western part, the minimum counts to around 14 m but maximum depth of interface is about 18 m while in the eastern part it is estimated to be ~24 m. The interface between hard and fractured granite is estimated away from the dyke also. In profile-24 (Figure 3) the dyke is more weathered with respect to country rock as compared to offshoots that are less weathered. It is observed that within the dyke, there are variations in depth levels of the interface which behave as a groundwater potential zone. Thus, these dykes act as groundwater flow channels at shallow levels and barriers at deeper depth levels. The present study identified the thickness of the weathered/fractured zones and boundaries of the dyke intrusion and thus helped in selecting favourable groundwater potential zones. Hence the method suits well in the present conditions and could be used as a useful tool to be applied in similar geological environment, because it is fast and economical[5] as compared to other geophysical methods such as resistivity imaging and seismic technique in determining the depth to bedrock. Thus the present results are useful in identification of new potential well sites as well as in calibrating the numerical aquifer model of the groundwater flow.

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Suppression of deleterious bacteria by rhizobacteria and subsequent improvement of germination and growth of tomato seedlings

Saprophytic bacteria in soil include beneficial and deleterious species that have the potential to influence plant growth and crop yields significantly. The deleterious bacteria affect plant growth negatively through production of phytotoxins[1], but they do not necessarily parasitize the plant tissue. Other deleterious activities include alterations of the availability of water, ions and plant growth promoting substances by changing the root functions and/or by limiting root growth[2]. Beneficial bacteria on the other hand, promote plant growth and are referred to as 'plant growth promoting rhizobacteria' (PGPR)[3]. The PGPRs affect plant growth positively by enhancement of availability and uptake of plant nutrients[4], production of plant growth promoting substances[5] and suppression of deleterious bacteria[6].

In a field experiment, tomato seedlings in the nursery exhibited stunted growth. Microbiological analyses of the histosphere of such stunted plants yielded two predominant and distinct bacteria[7]. Based on morphological, physiological and biochemical tests[8], both were identified tentatively as *Bacillus* sp. and designated as DHBL and DHBS.

In order to study further the role of these bacteria, they were tested for the influence on germination and growth of tomato *in vitro*. Germination of tomato was tested following the petri plate pairing technique[9]. Interestingly, the histosphere bacteria were found to significantly inhibit seed germination as evidenced by the reduced length of radicle of tomato, presumably by producing volatile metabolites. *Bacillus* DHBL inhibited radicle length by 37% while *Bacillus* DHBS inhibited it by 48%. When examined, both the deleterious bacteria did not produce

Table 1. Plant growth response of tomato after bacterization with DBHS in an axenic culture at 30 days after sowing

Treatment	Germination (%)	Mean root length (cm)	Mean shoot length (cm)	Vigor index
Uninoculated control (UIC)	92	5.9	8.4	13.16
PGPR (RDV 108)	100	8.8 (+ 49.15)	8.9 (+ 5.95)	17.70
DHBS	90	5.1 (– 13.56)	4.4 (– 47.6)	08.55
PGPR + DHBS	98	7.6 (+ 28.8)	8.3 (– 1.19)	15.58
CD at 1%	1.88	2.37	2.28	

Values in parentheses indicate per cent increase or decrease over UIC.