Exploration for groundwater in the basaltic Deccan traps terrain in Katol Taluk, Nagpur District, India

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This communication describes the results of vertical electrical soundings carried out at 12 sites for delineation of deeper aquifers in the Deccan traps terrain in Katol Taluk, Nagpur District, Maharashtra, India. Interpretation of sounding data suggests the presence of water-bearing intertrappeans/vesicular and fractured zones within the trap sequence and sedimentary formations below the traps, which are considered to be a potential source of groundwater for meeting the increasing demand for water supply.

Keywords: Deep aquifers, exploration, groundwater, vertical electrical sounding.

ABOUT two-thirds of the Indian territory comprising the central, western and southern peninsula is covered by different types of hard rocks such as basalts, granites, gneisses, etc. Western and central India are occupied by tholeiitic basaltic lava flows of the Deccan traps sequence. The Deccan traps occupy a vast terrain between 69°–79°E long. and 16°–22°N lat. and constitute one of the largest volcanic provinces on the earth. In the map of India (Figure 1), the territory occupied by the Deccan traps is shown in green colour and that occupied by the other types of hard rocks is shown in brown. The Deccan traps sequence consists of multiple layers of solidified lava flows. It is more than 2000 m thick on its western margin near the Mumbai coast and decreases in thickness eastward. It is about 50–100 m on its eastern margin west of Nagpur city in central India, and occupies ~ 500,000 sq. km area spread over parts of Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh and Karnataka. Most of the area of Maharashtra is covered by the Deccan traps. The basaltic flows vary in colour from dark grey to purple and pink. Each lava flow consists of an upper vesicular unit and a lower massive unit which may or may not be fractured/jointed. Two lava flows at some places are separated by intertrappean sedimentary beds. Therefore, unlike other hard rocks, the Deccan traps behave as a multi-aquifer system, somewhat similar to a sedimentary rock sequence. Acute shortage of groundwater in hard-rock areas, such as the Deccan traps, is well known. Groundwater occurs in limited quantity in unevenly distributed aquifers with secondary porosity caused by weathering, faulting and fracturing of the trap rocks. Accumulation and movement of groundwater in the Deccan traps is controlled by lithology, degree of weathering, and nature and intensity of the openings (faults, fractures, joints, etc.). Hydrogeological characteristics of Deccan traps have been described in detail in the literature[1–3]. Groundwater available in shallow, weathered mantle under unconfined condition above the Deccan traps, is inadequate to meet the ever-increasing demand of water supply. This necessitates the need for groundwater exploration from deeper aquifers occurring within and below the traps.

The area under study is ~ 20 sq. km, forming a part of the Katol Taluk, Nagpur District, Maharashtra, India, located close to the eastern margin of the Deccan traps terrain about 30 km NW of Nagpur city (78°46′–78′48°30″E long. and 21°12′–21°15′N lat.). It encompasses Kotwalbardi and Raulgaon villages of Katol Taluk and some areas of the adjacent Pohi village of Kalmeshwar Taluk situated towards the east (Figure 1). Nagpur city derived its nickname ‘orange city’ because of the large production of orange in the rural areas of Katol and Kalmeshwar taluks. Semi-arid climatic condition prevails in this region. The average annual rainfall is ~ 950 mm. The southwest monsoon (during middle June to September) contributes more than 70% of the rainfall. Rainwater is the main source for recharging of groundwater.

The region is drained by four creeks flowing in the west to east direction. Two of the creeks located on the southern side of Kotwalbardi emerge from the Kondhali Reserve Forest and join Mortham Talav (reservoir) at the boundary with Kalmeshwar Taluk. The other two creeks flow between Raulgaon and Kotwalbardi and converge at the boundary with Kalmeshwar Taluk north of Mortham Talav (reservoir) to form a single channel within the Kalmeshwar Taluk. Shallow aquifers discharge groundwater into these creeks resulting in the lowering of the water table in the dug wells during non-rainy season. At the same time, nearby deeper aquifers hydraulically connected to these water courses are getting continuously recharged. Thus these water courses significantly affect the geo-hydrological conditions of the area.

The entire area under study is covered by Deccan traps below a thin soil cover which is produced by weathering of the traps. In some places at a higher elevation, highly weathered/massive basalts are exposed. The soil-covered area constitutes about 70% of the total area and is being used for agriculture and development of orange orchards. The remaining area is wasteland. Below the soil layer is the weathered/fractured basalt layer. Groundwater of limited quantity occurs in this weathered/fractured mantle at shallower depth under unconfined conditions. This zone is the main source of groundwater supply to the dug wells. Below this zone lie the lava flows. Each lava flow consists of an upper vesicular subunit and a lower massive subunit which may or may not be fractured. Two lava flows are separated by intertrappean sedimentary

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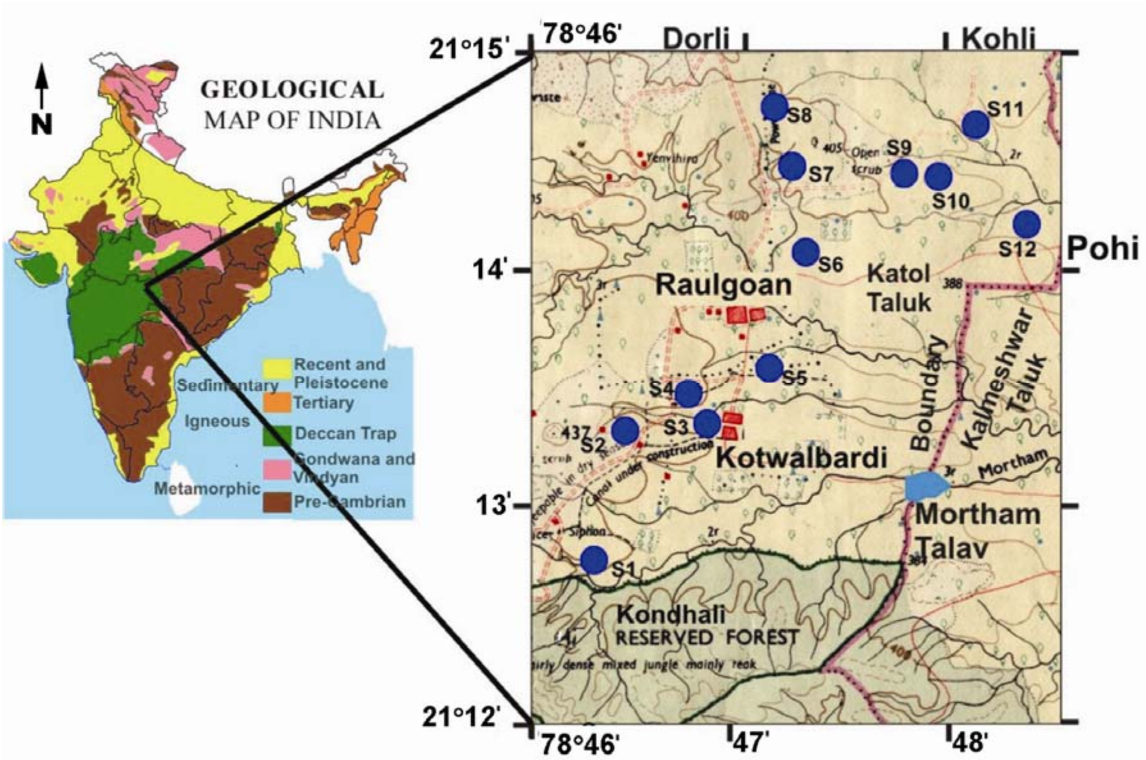

Figure 1. Location map of the study area and sites of vertical electrical sounding with sounding numbers (modified after SOI Toposheet No. 55 K/6).

Table 1. Regional stratigraphy

Formation	Age
Alluvial	Recent to Quaternary
Deccan lava flows with intervening intertrappean sedimentary beds	Lower Eocene to upper Cretaceous
Lameta beds (infratrappeans)	Cretaceous
Gondwana formations	Permian

beds, which together with the underlying vesicular basalt layer form a potential groundwater zone between two compact basalt layers at a deeper level. Groundwater occurs in confined conditions in this composite unit of intertrappeans and vesicular basalt layers, and in the joints and fractured zones of massive basalts at a deeper level. At places clay-rich bole beds occur between lava flows. They are red or green coloured. The colouration is caused by the presence of variable amounts of Fe_2O_3 or MgO (ref. 4). Bole beds are poor aquifers because of their clayey nature.

An interesting geological feature of this region is the presence of Gondwana sedimentary formations of Kamthi Group underlying the traps. They are exposed near Bazargaon village south of the area and near Adasa to the north. Occurrence of Gondwana formations on both sides of the study area suggests that they may underlie the traps within the study area and serve as a potential source of groundwater. At places, between massive basalt layers and Gondwana formations occur the Lameta beds, a suite of sedimentary rocks of Cretaceous age. Regional stratigraphy is given in Table 1 (refs 4 and 5).

In this region water supply for irrigation and domestic use is mostly from dug wells of 10–15 m depth penetrating the top weathered/fractured zones. Water available in the dug wells is inadequate to meet the present demand for irrigation and domestic use. Most of the dug wells dry up in the beginning of summer, causing enormous damage to the crops and orange plantation. Increasing demand of water supply can be met from deeper aquifers. This communication presents a case study in which the electrical resistivity method has proved to be useful for identifying deeper aquifers in the form of fractures, faults, joints, intertrappeans and infra trappean Gondwana sedimentary formations.

The presence of groundwater in geological formation leads to distinctive reduction in the resistivity value. This characteristic of geological formations makes the geo-electrical survey more suitable than any other geophysical method for delineation of potential groundwater zones. Geo-electrical surveys are conducted to find out variation of resistivity either with depth or laterally. The former type of survey is called vertical electrical sounding (VES) and the latter is called profiling. Many configurations have been developed to carry out profiling and VES. Wenner and Schlumberger configurations are widely used for profiling and VES respectively[6–8]. Earlier, geo-electrical surveys have been carried out by several workers in different parts of the Deccan traps terrain for groundwater exploration. Bose and Ramkrishna[9] have carried out geo-electrical survey in Sangli District, Maharashtra. Gangadhar Rao *et al.*[10] have carried out integrated geophysical surveys consisting of geo-electrical and magnetic surveys for groundwater exploration in the Deccan traps covered Godavari–Purna basin in Aurangabad District, Maharashtra. Murthy *et al.*[11] have carried out geophysical studies for the delineation of Gondwana formations below the Deccan traps in Umrer, Bander, Kamthi and Katol troughs in Nagpur District. Kumar *et al.*[12] have carried out geo-electrical survey to decipher potential groundwater zones around Aurangabad. Muralidharan *et al.*[5] have carried out deep resistivity surveys for mapping Gondwana sedimentary rocks at depths below the traps for selecting suitable sites for bore wells in the Jam river basin of Katol Taluk. The area studied by them lies to the west of the present study area.

As the objective of the present work was to find out the depth of the aquifers within the traps and below them VES survey using Schlumberger configuration has been carried out at 12 sites in part of Katol Taluk. Apparent resistivity (ρ_a) for Schlumberger configuration was computed using the following expression:

$$\rho_a = \frac{\pi(L^2 - l^2)}{2l}\frac{\Delta V}{I},$$

where L is half the distance between the current electrodes, l half the distance between the potential electrodes; ΔV the potential difference and I the current applied through the current electrodes.

Locations of the sites are shown in Figure 1. Sites S1–S4 are in the Kotwalbardi village limits, sites S5–S11 are in Raulgaon village and site S12 is in Pohi village of Kalmeshwar Taluk.

A computer program 'Resist' was used to process the measured apparent resistivity data. This program is designed to process data obtained with Wenner, Schlumberger and dipole–dipole array. Data processing and interpretation is accomplished in three stages: (i) smoothening of noisy field data; (ii) accurate computation of apparent resistivity models; and (iii) inversion of resistivity data[13]. The output is obtained in the form of layered resistivity model consisting of the layer thicknesses and the corresponding true resistivity values. Based on the resistivity surveys carried out in parts of Nagpur, Amaravati, Akola and Jalgaon districts, the following resistivity values have been suggested for the different litho-units of the Deccan traps region by the Central Groundwater Board (source: CGWB website).

Alluvial, black cotton soil (Al): 5–10 Ohm-m; weathered/fractured/vesicular basalt saturated with water: 20–45 Ohm-m; moderately weathered/fractured/vesicular basalt saturated with water (MWFVB): 40–70 Ohm-m; massive basalt (MB): > 70 Ohm-m; water-saturated Lameta bed: < 10 Ohm-m; water-saturated Gondwana formation: < 30 Ohm-m, and Gondwana formation without water: > 50 Ohm-m.

Approximately similar values of resistivity were taken as guidelines for the interpretation of computed resistivity models. From the measured resistivity data, it is difficult to distinguish the water-saturated Lameta and Gondwana sedimentary formations. However, our experience from bore-well lithologs of this region suggests that the resistivity value of water-saturated Gondwana sedimentary formation is < 30 Ohm-m and that of water-saturated Lameta bed is < 10 Ohm-m. The resistivity value for the highly fractured saturated basalt formation is more or less similar to that of the water-saturated Gondwana formation. Hydrogeological interpretation of the computed true resistivity model for each site village-wise is presented.

In the Kotwalbardi village limits four soundings were carried out at sites S1–S4 (Figure 1). Computed true resistivity models for these sites are presented in Figure 2. Interpretation of the true resistivity model for site S1 suggests the occurrence of a thin soil column (17.8 Ohm-m) of 1.5 m thickness underlain by 22.9 m thick layer of massive basalt (119.2 Ohm-m). This is followed by a 33.1 m thick column of moderately fractured/vesicular basalt (58.3 Ohm-m) which could be a poor to moderate source of groundwater. At this site, the Gondwana sedimentary formation (19.3 Ohm-m) seems to lie at a depth of 57.5 m. All depths are measured from the ground surface. At site S2, which is located in barren land, presence

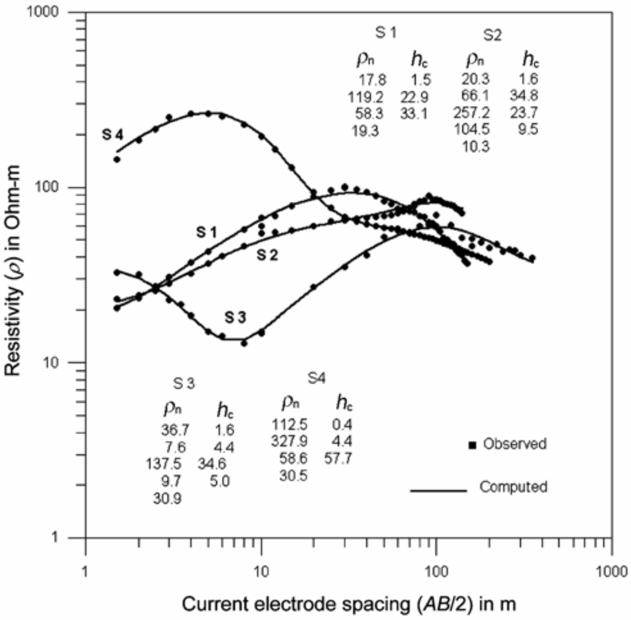

Figure 2. Resistivity models for sites S1–S4, Kotwalbardi village.

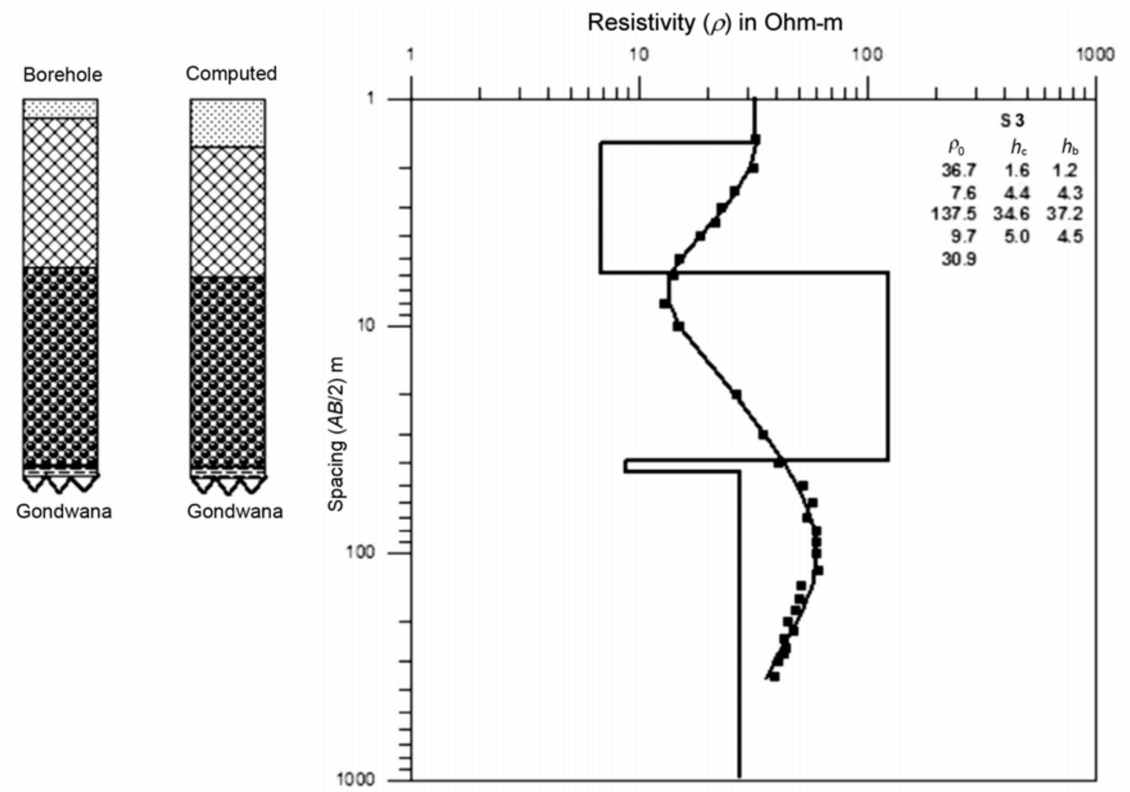

Figure 3. Comparison of computed thickness of layers (h_c) with the thickness obtained from bore well (h_b) at site S3, Kotwalbardi village.

of a 34.8 m thick layer of MWFVB (66.1 Ohm-m) is indicated between a 1.6 m thick soil cover and 33.2 m thick layer of massive basalt (104.5–257.2 Ohm-m). Below this massive basalt layer is the water-saturated Lameta bed (10.3 Ohm-m) which may be followed by the water-saturated Gondwana formation. Thus at this site groundwater potential zone is below 70 m.

Resistivity model for site S3 indicates the presence of a 4.4 m thick weathered formation (7.6 Ohm-m) below the 1.6 m thick alluvium. This is underlain by 34.6 m thick layer of massive basalt (137.5 Ohm-m). This massive basalt layer is underlain by 5 m thick Lameta bed with 9.7 Ohm-m resistivity. Below it is the water-saturated Gondwana sedimentary formation (with 30.9 Ohm-m) at 45.6 m depth. A bore well was drilled at this site to verify the interpreted results. A comparison between the computed stratigraphy and the bore well stratigraphy is presented in Figure 3. Here, h_c represents computed thickness of the layer and h_b represents layer thickness observed from the bore well. Bore-well stratigraphy reveals 1.2 m thick soil cover. Below this is the 4.3 m thick column of weathered formation, which forms the unconfined aquifer at shallow depth. This layer is underlain by a 37.2 m thick layer of massive basalt. Below this a 4.5 m thick Lameta bed of black colour is found and further down lies the Gondwana sedimentary formation at a depth of 47.2 m below ground level. Thus the stratigraphic sequence obtained from the bore well is in close agreement with the computed one. The bore well yield is 750 gph (1590 lph), which is considered as moderate.

Site S4 located in a barren land is on a massive basalt layer (112.5–327.9 Ohm-m) exposed on the surface and it extends up to a depth 4.4 m. This layer is underlain by a 57.7 m thick layer of moderately fractured basalt (58.6 Ohm-m). At this site, Gondwana sedimentary formation (30.5 Ohm-m) appears to be at 51.7 m depth. Suitability of this site for groundwater development needs verification by drilling.

Seven soundings, S5–S11 were carried out in Raulgaon village. Their locations are shown in Figure 1. Computed true resistivity models for the first four soundings, i.e. S5–S8 are presented in Figure 4 *a*, whereas results of the remaining three soundings are presented in Figure 4 *b*. Computed resistivity model for site S5 suggests the presence of a 8 m thick layer of alluvium and weathered basalt (30.2 Ohm-m). This is followed by a 13.1 m thick water-saturated weathered basalt formation (15.1 Ohm-m), a 22.4 m thick water-saturated fractured massive basalt (41.8 Ohm-m), a 5.7 m thick Lameta bed (12.9 Ohm-m) and another layer of Gondwana formation (46.2 Ohm-m) at a depth of 49.2 m. This site is close to a creek. Therefore, low resistivity (12.9–46.2 Ohm-m) indicative of the presence of groundwater throughout the investigated depth may be due to leakage of water from the water course. It appears to be a site suitable for groundwater exploitation.

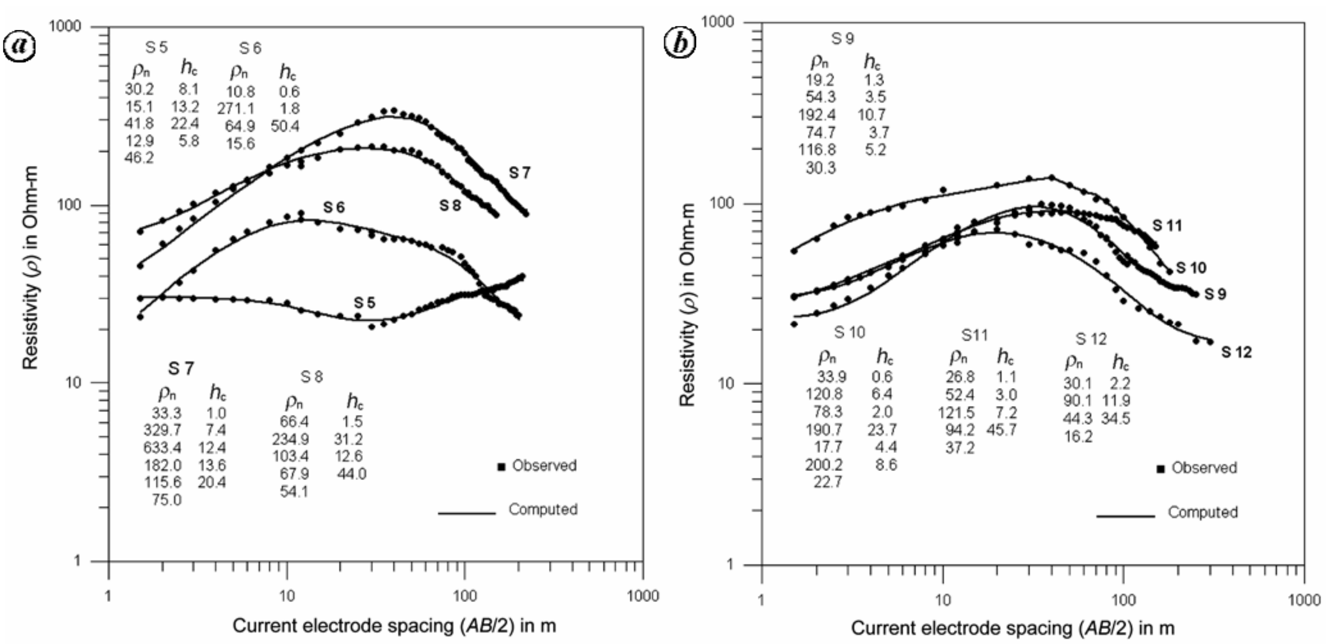

Figure 4. Resistivity models for sites S5–S8 sites (***a***) and sites S9–S12 (***b***), Raulgaon village.

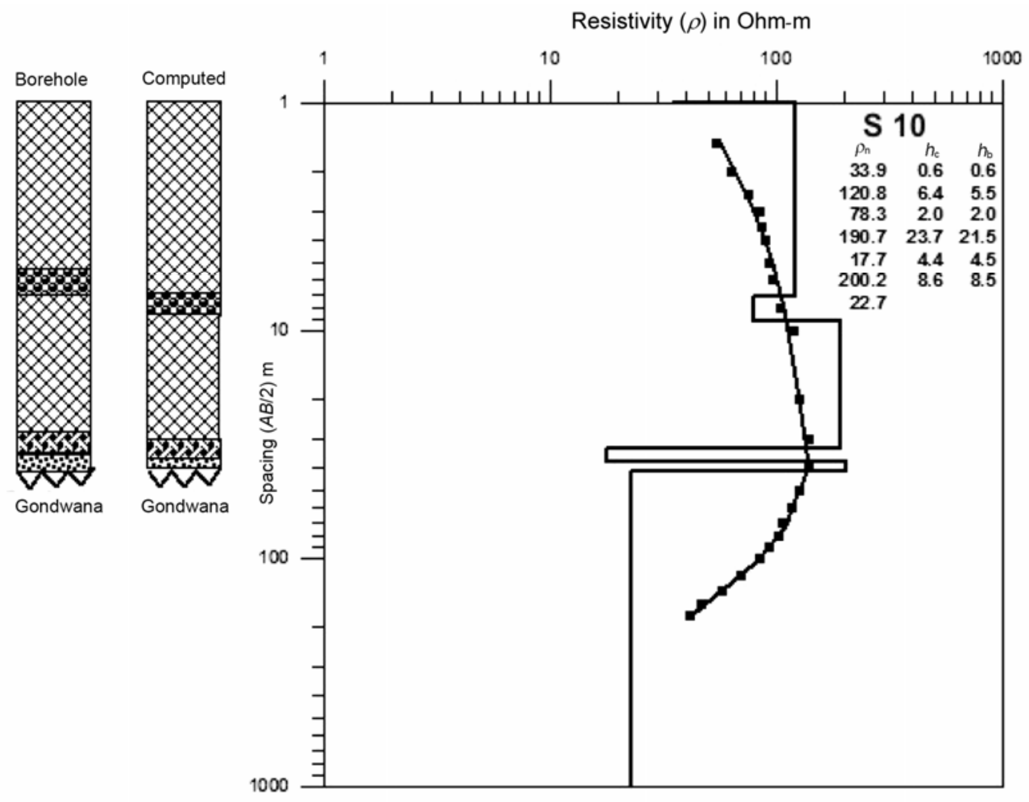

Figure 5. Comparison of computed thickness of layers (h_c) with the thickness obtained from bore well (h_b) at site S10, Raulgaon village.

The resistivity model for site S6 indicates the presence of a 50.4 m thick, moderately fractured basalt layer (64.9 Ohm-m) below a 1.8 m thick layer of massive basalt (271.1 Ohm-m). Gondwana sedimentary formation (15.6 Ohm-m) is indicated at 52.8 m depth. Resistivity model for site S7 suggests the presence of massive basalt (75.0–329.7 Ohm-m) throughout the investigated depth of 54.8 m. But the downward trend of computed resistivity curve indicates the probability of occurrence of Gondwana sediment below the present depth of investigation.

Table 2. Hydrogeological interpretation of vertical electrical sounding (VES) data from parts of Katol Taluk, Nagpur District

VES No.	Location (East longitude; North latitude)	Interpretation					
		Number of layers	Resistivity (ρ) (Ohm-m)	Thickness (h) (m)	Depth (m) from ground surface	Lithological classification	Groundwater prospects
S1	78°46′2.7″;	1	17.8	1.5	0.0	Al	–
	21°12′40″	2	119.2	22.9	1.5	MB	–
		3	58.3	33.1	24.4	MFB	Poor
		4	19.3		57.5	GS	Good
S2	78°46′30″;	1	20.3	1.6	0.0	Al	–
	21°13′15.6″	2	66.1	34.8	1.6	MWFVB	Poor
		3	257.2	23.7	36.4	MB	–
		4	104.5	9.5	60.1	MB	–
		5	10.3		69.6	L	Good
S3	78°46′36.7″;	1	36.7	1.6	0.0	Al	–
	21°13′19.2″	2	7.6	4.4	1.6	WB	Good
		3	137.5	34.6	6.0	MB	–
		4	9.7	5.0	40.6	L	Good
		5	30.9		45.6	GS	Good
S4	78°46′44.3″;	1	112.5	0.4	0.0	MB	–
	21°13′26.4″	2	327.9	4.4	0.4	MB	–
		3	58.6	57.7	4.8	MFB	–
		4	30.5		51.7	GS	Good
S5	78°47′.9″;		30.2	8.0	0.0	Al	–
	21°13′3.5″		15.1	13.1	8.0	WB	Good
			41.8	22.4	21.1	FB	Moderate
			12.9	5.7	43.5	WVB	Good
			46.2		49.2	FB (or GS)	Good
S6	78°47′6.6″;	1	10.8	0.6	0.0	Al	–
	21°14′15.6″	2	271.1	1.8	0.6	MB	–
		3	64.9	50.4	2.4	MFB	Poor
		4	15.6		52.8	GS	Good
S7	78°47′13.2″;	1	33.3	1.0	0.0	Al and WB	–
	21°14′27.5″	2	329.7	7.4	1.0	MB	–
		3	633.4	12.4	8.4	MB	–
		4	182.0	13.6	20.8	MB	–
		5	115.6	20.4	34.4	MB	–
		6	75.0		54.8	MB	–
S8	78°47′9.6″;	1	66.4	1.5	0.0	WB	–
	21°14′42″	2	234.9	31.2	1.5	MB	–
		3	103.4	12.6	32.7	MB	–
		4	67.9	44.0	45.3	MWFVB	–
		5	54.1		89.3	MWFVB	–
S9	78°47′47.5″;	1	19.2	1.3	0.0	Al	–
	21°14′33″	2	54.3	3.5	1.3	WFB	Poor
		3	192.4	10.7	4.8	MB	–
		4	74.7	3.7	15.5	FB	Good
		5	116.8	5.2	19.2	MB	–
		6	30.3		24.4	GS	Good
S10	78°47′47.5″;	1	33.9	0.6	0.0	Al	–
	21°14′37.8″	2	120.8	6.4	0.6	MB	–
		3	78.3	2.0	7.0	FB	Good
		4	190.7	23.7	9.0	MB	–
		5	17.7	4.4	32.7	WVB	Good
		6	200.2	8.6	37.1	MB	–
		7	22.7		45.7	GS	Good

(*Contd*)

Table 2. (*Contd*)

VES No.	Location (East longitude; North latitude)	Interpretation					
		Number of layers	Resistivity (ρ) (Ohm-m)	Thickness (h) (m)	Depth (m) from ground surface	Lithological classification	Groundwater prospects
S11	78°48′1.6″;	1	26.8	1.1	0.0	Al	–
	21°14′42.6″	2	52.4	3.0	1.1	WFB	–
		3	121.5	7.2	4.1	MB	–
		4	94.2	45.7	11.3	MB	–
		5	37.2		57.0	GS	Good
S12	78°48′25.9″;	1	30.0	2.2	0.0	Al and WB	–
	21°14′10.2″	2	90.1	11.8	2.2	MB	–
		3	44.3	34.5	14.0	FVB	Moderate
		4	16.2		48.5	GS	Good

Al, Alluvium; WB, Weathered basalt; FB, Fractured basalt; WVB, Weathered/vesicular basalt; MWFVB, Moderately weathered/fractured/vesicular basalt; MB, Massive basalt; FMB, Fractured massive basalt; GS, Gondwana sandstone/sand/bole bed; WVB represents intertrappean beds; MFB, Modified fractured basalt; L, Lameta bed; and FVB, Fractured/vesicular basalt.

Similarly, downward trend of the resistivity curve for site S8 indicates the presence of Gondawana formation below 89.3 m depth. Both S7 and S8 do not appear to be favourable for groundwater exploration.

The resistivity model for site S9 shows the presence of a 3.5 m thick fractured basalt layer (54.3 Ohm-m) below a layer of alluvium 1.3 m thick. A 3.7 m thick water-bearing fractured layer (74.7 Ohm-m) sandwiched between two layers of massive basalts (190.7–200.2 Ohm-m) of 10.7 and 5.2 m thickness can be also seen in the model. The lower massive basalt layer is underlain by Gondwana sedimentary formation (30.3 Ohm-m) at 24.4 m depth, which is surprisingly at a shallow depth compared to other sites. This site is located in an elevated barren land.

In the case of site S10 two water-bearing formations in the form of a fractured basalt layer of 2 m thickness and intertrappeans of 4.4 m thickness sandwiched between two successive pairs of massive basalt layers are delineated at 7 m and 32.7 m depth respectively. Thickness of the three massive basalt layers with resistivity values of 120.8, 190.7 and 200.2 Ohm-m is 6.4, 23.7 and 8.6 m respectively. The first layer of massive basalt occurs below the topsoil layer of 0.6 m thickness. The last layer of massive basalt is underlain by Gondwana formation (with 22.7 Ohm-m resistivity) at a depth of 45.7 m. At this site a bore well was drilled up to a depth of 45 m, penetrating 3 m basement below the traps. Groundwater at high pressure was struck in the fractured basalt layer at 7 m depth as well as in intertrappean bed at 29 m depth. A comparison of the computed thickness of different litho units with the bore well litholog is presented in Figure 5. Both stratigraphic sequences are found to be in close agreement. This validates our interpretation of VES data. The bore-well yield is 4200 gph (15,900 lph), which is good.

Computed resistivity model for site S11 indicates the presence of a 3 m thick fractured basalt layer (52.4 Ohm-m) which is underlain by a 53 m thick massive basalt layer (94.2–121.5 Ohm-m). Gondwana sedimentary formation (37.2 Ohm-m) at this site is indicated at 57 m depth. This site is considered as unfavourable for groundwater exploitation.

Site S12 is located near Pohi village in Kalmeshwar Taluk (Figure 1). Computed resistivity model for this site suggests the presence of a water-saturated fractured basalt layer (44.3 Ohm-m) of 34.5 m thickness below a 11.9 m thick layer of massive basalt (90.1 Ohm-m). At this site, water-saturated Gondwana sedimentary formation (16.2 Ohm-m) is indicated at 48.5 m depth below the fractured basaltic layer. This site appears to be suitable for groundwater development. A summary of the interpreted results is given in Table 2.

Interpretation of computed resistivity models for all investigated sites, except S7 and S8, indicates the presence of deeper aquifers within the traps and Lameta/Gondwana sedimentary formations. In this region trap thickness varies from 24.4 to 57.5 m, except at sites S2, S7 and S8, where trap thickness is > 70 m. This suggests the undulating nature of palaeo-topography on which Deccan lavas were pored out. Except sites S2, S7, S8 and S11, the remaining eight sites appear to be favourable for groundwater exploration. Potentiality of groundwater reservoirs at sites S3 and S10 was verified by bore-well drilling.

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Stable isotopes study on geothermal waters in eastern India

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An experimental study on stable-isotopes (δD, δ^{18}O) of thermal waters as well as non-thermal waters, from different geothermal springs in the Ganga–Mahanadi basin is reported. A total of 38 water samples were collected during September 2010 and analysed by elemental analyser followed by stable isotope ratio mass spectrometer. The isotopic composition for oxygen indicates that the water rock interaction is insignificant for the springs in the study area whereas the δD values indicate blending between thermal and non-thermal waters. The results reveal that the origins of the thermal spring waters are primarily meteoric origin.

Keywords: Geothermal water, meteoric water, stable isotope.

IN the present communication, we report the results of stable isotopic study (δD, δ^{18}O) on thermal waters as well as non-thermal waters, collected from different geothermal springs located in eastern India. Variations in stable isotopic composition of oxygen and hydrogen constituting the water molecule have been used in several studies to identify geothermal resources[1]. This has been possible because stable water isotopes are influenced directly by several processes, including mixing and dispersion. In the case of geothermal springs where water circulation takes place at great depths and at temperatures that are substantially high, physical separation processes such as evaporation and condensation, responsible for fractionating the isotopes are practically absent. On the other hand, thermal waters, during their passage through subterranean regions, come into association with minerals containing variable amounts of natural radionuclide which may, upon disintegration, interact with nuclei of some of the elements within the water and cause a change in their relative isotope ratios[2]. Most of the previous works have remained confined to the chemical characteristics of the springs. The hydrological aspects pertaining to the source and age of the thermal waters and their relationship with local non-thermal waters, especially with groundwater, are not well understood[3]. Moreover, the isotopic composition, particularly deuterium provides the best indication of the origin of thermal springs. This communication applies stable isotope techniques to offer direct constraints on the origin, recharge and movement of thermal water of geothermal areas in the Ganga–Mahanadi basin.

The Geological Survey of India (GSI) has identified about 340 geothermal hot springs throughout the country. The Bakreswar (23°52′00″N : 87°25′00″E) and Tantloi (24°23′00″N : 87°16′00″E) geothermal areas are located in the Birbhum District of West Bengal and Santhal Parganas District of Jharkhand respectively. The average temperature of the springs is around 45–71°C. They belong to several groups of geothermal areas occurring in an E–W belt along the trend of Gondwana sedimentary basin in the central part of the Precambrian Chotanagpur Gneissic Complex. Geothermal activity in Bakreswar is represented by a cluster of seven thermal springs scattered over an area of 3500 sq. m. The emergence of the springs is mainly controlled by a nearly N–S trending buried fault[4], which is likely to extend through the Tantloi geothermal

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