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The Groundwater modelling and resource management by geological mapping: A case study from Ambaji basin, Gujarat NW India

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Abstract- In 21st century water is the main socioeconomic problem due to increasing demand of fresh water particularly in hard rock terrain. In hard rock terrain groundwater plays the vital role for fresh water exploration. For groundwater exploration the hydrogeological fractures has been mapped in the study area by geological field work. The objective of this study is to search for the hydrogeological potential areas from which the ground water can be explored economically. The field work has been done in Ambaji basin of Aravalli Delhi fold belt. Aravalli Delhi fold belt is a Proterozoic fold belt running 700- 800 km in NE- SW direction and situated in NW India. The Aravalli Delhi fold belt had undergone multiple phases of deformation. The field area contains gabbro norite basic granulite series, granite, cataclasite and mylonitic type of rocks and due to late stage brittle fracturing these rocks have been fractured. These fractures are mainly reactivated fractures which are controlled by pre-existing fractures in the shear zone.

The fractures control the groundwater circulation in hard rock terrain. The fractures in the study area are oriented in mainly NNW-SSE, NE-SW and E-W directions. These fractures are also visible on the Google Earth map. And during the field work it has been found that around the Ambaji basin the groundwater flows around NNW-SSE, NE-SW fractures. At intersection point of the NNW-SSE, NE-SW fractures we get a good water reservoir and the flow of these water reservoirs are blocked by E-W fractures. So the occurrence of block wise or sector wise water reservoir is observed in the field. Also the multi electrode resistivity test has been done along and across the fractures. The occurrence of groundwater is 10-15 meter as observered in pseudosections of resistivity profiles. At some places we get deeper conductive zones due to presence of deep seated shear zones.

Keywords**:** Groundwater, Multi electrode resistivity, Fracture, Hard rock terrain, Aravalli

1. Introduction

Water is the main problem in the 21st century. We always face some socioeconomic problem due to groundwater. India is a country of urban and village population. Particularly in the hard rock terrain fractures controls the groundwater flow. The fractures may be polygenetic in the origin. The mapping of fractures is very important in the management of groundwater exploration. The previous study of fractures shows the importance in petroleum, nuclear energy, water resource and mineral exploration studies. Mapping of fractures is also important in management and development of water resources. Generally the occurrences of fractures are at weathered rocks. Due to presence of fractures the porosity and permeability also increases in these zones which is good for groundwater circulation. In this way where fracture density is more we get more groundwater. The fracture in the study area develops due to the brittle deformation.

In the present study, the field work data and Google Earth has been used for the groundwater exploration sites. The result was analysed on the basis of field truth of water wells as on the intersection point of two fractures the water reservoir has been observed. Also the resistivity data has been taken at the sites along and across to fractures.

2. Regional Geology

The Aravalli mountain belt of NW India occurs as NE-SW trending synclinorium and extended from Delhi in the north through Ajmer, Marwar to Idar and Palanpur in south covering ~800km. The mountain belt is stretched through Delhi, Rajasthan to northeastern part of Gujarat and is bounded by Marwar craton in the west and Mewar craton in the east. The Marwar craton is composed of Mesoarchean tonalite-trondhjemite-granodiorite (TTG) gneisses and some distribution of greenstone belt rocks while Marwar craton has intrusion of Erinpura and Malani granite in some parts and some parts are covered by volcano sedimentary sequences of younger age which belong to Sindreth, Punagarh and Marwar groups (Singh et al. 2010 and Biswal et al. 1998a). Precambrian rocks of Rajasthan and Gujarat have overprinting of multiple tectonic events. Aravalli craton manifests complete succession of rocks ranging from Archean (3.2 Ga) to Paleoproterozoic (2.5 Ga). It is comprised of three major groups of rocks: Bundelkhand gneissic complex of Archean age, Aravalli Supergroup of Paleoproterozoic and Delhi Supergroup of Meso- Neoproterozoic age. Aravalli craton is underlain by Banded gneissic complex of 3.3–2.5 Ga. Metamorphism of sediments and intrusions of granitic, basic and ultrabasic rocks associated with various deformational events have been recorded here. According to Roy et al. (2005) the major metamorphism took place between 1725 Ma to 1621 Ma at beginning of the Delhi orogenic cycle. Two distinct ages of granitoid intrusion is reported from north Delhi Belt. These events took place between 1711Ma and 1660Ma while granitoid intrusion in southern Delhi Fold Belt is much younger than the of northern Delhi Fold Belt and ages recorded are 800 Ma-860 Ma for granitoid (known as Erinpura granite), 750 Ma G3 granite and nearly 1Ga for calc-alkaline Granite intrusion. Some minor dyke intrusions are also reported in Aravalli craton like norite dyke of Sandmata Complex, felsic dyke swarm of Sirohi and Albitite dykes in the NW Aravalli Mountain. These all are believed to be of Neoproterozoic age.

3. Geology of the Study Area

The study area is located at the southwestern end of the Ambaji basin of South Delhi Terrain. Tectonically our present study area has been subdivided into a number of longitudinal shear zones which are dominated by arenaceous facies in the east and calcareous facies in the west (Heron, 1953; Sen, 1981). The rocks of the South Delhi terrain are marked by amphibolite facies metamorphism and possessed three phases of folding. However, the terrane shows sporadic occurrence of granulite, (Desai et al., 1978; Naha et al., 1987; Biswal, 1988; Tobisch et al., 1994; Biswal et al. 1998a, b; Singh et. al; 2014, Tiwari et. al; 2015). The rocks of Ambaji area have undergone three phases of folding (F1, F2 and F3). F1 are tight, isoclinals and recumbent folds having Class 1C geometry. F2 folds are open to tight and upright to inclined folds of Class 1C to Class 2 geometry, developed on the F1 axial planar fabric (S1). F1 and F2 are coaxial along NE-SW axis and produced from buckling by a sub-horizontal compression along NW-SE direction. Superimposition of F2 on F1 produced Type 3 (hook shape) interference pattern. F3 folds are puckers, kink bands and crenulation folds. F3 conjugate kinks have dominant axial planes striking NNE-SSW and NW-SE. Superimposition of F3 on F2 produced Type 1 (dome and basin) interference pattern. The morphology and dynamics of the kink bands suggest that F3 kink bands were formed towards the end of the last phase of deformation. The Ambaji Granites have also been identified to consist of three phases of granitic intrusion. The G1 phase is closely associated with pelitic granulites, carries undigested paleosome patches bearing spinel, cordierite and sillimanite and shows similar deformational structures as migmatites. Thus, it is interpreted that the G1 phase has been produced from the melting of the pelitic rocks during synkinematic F1 folding and high-grade metamorphism. The G2 phase is very coarse-grained, with quartz, alkali feldspar and biotite, and rare garnet, muscovite and zircon. The granites occur as batholiths, intruding into the metasedimentary rocks along the axial planes of F2 folds, and shear zones producing extensive metasomatic alteration in country rock. The G3 phase is synkinematic to F3 folding and it is generally medium grained and occurs as dykes, veins or lensoidal bodies. In contrast to these high-grade rocks, the low-grade rocks in the Ambaji basin consist of mica schist, quartzite, calcareous schist, pillow-bearing meta-basalt and meta-rhyolite. These are intruded by amphibolites dykes and G2 and G3 phases of granites. The age of G1, G2 and G3 granites are observed 860, 800 and 750 Ma respectively (Singh et. al; 2010, Tiwari et. al; 2015).

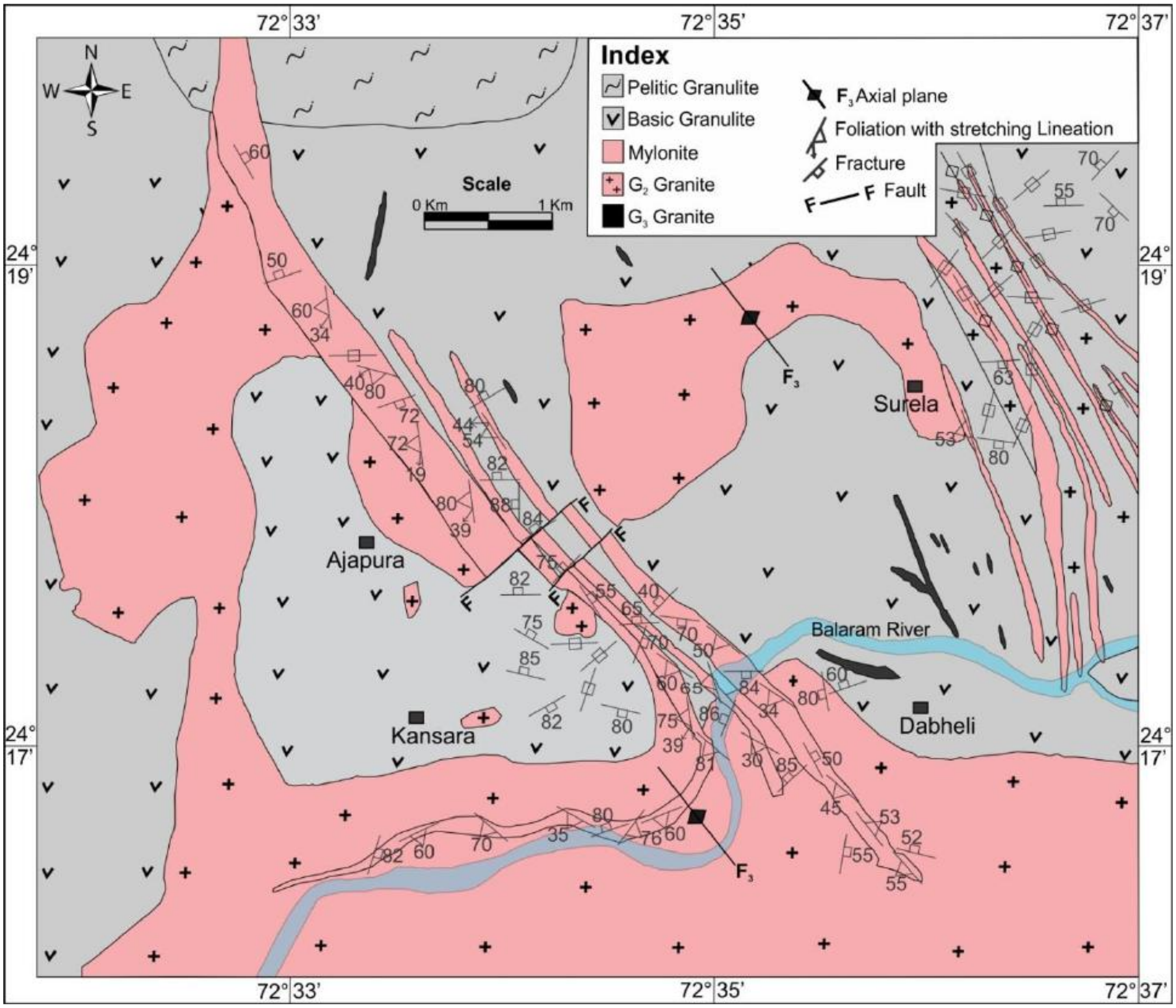


Figure 1: Lithological and structural map of study area (Modified after Biswal et. al. 1998.)

Dips of mylonitic foliation are more or less sub-vertical to vertical, i.e. about 60°-90°. Foliations are dipping mostly SW but in some places it shows dipping in the opposite direction i.e. in the NE. This variation may be due to non-uniform stress distribution during deformation. Stretching lineations are plunging in opposite direction, i.e. towards SW onwards NE. Along one limb of folded mylonitic belt of Jogdadi shear zone we get cataclasites. Three sets of fractures are identified in the study area which are controlled by major fractures present in the study area. Petrographically mylonite contains mainly biotite, quartz and K- feldspar. In thin section biotite and quartz are foliated and swears around K- feldspar. The lithological and structural map of the study area is shown in figure 1.

4. Methodology

4.1 Statistics of fractures

During field work, fracture and foliation data were collected by measuring the attitudes of fracture planes and foliation planes at each location from the field area. There are 3 major sets of fracture are found in this area, the trends of theses fractures are NNW-SSE, NE-SW and E-W. The dip angle ranges from 40^o to 90^o. The latitude and longitude of each fracture location noted down. Total number of ninety-six fracture data collected from field shown in figure 2a, 2b.

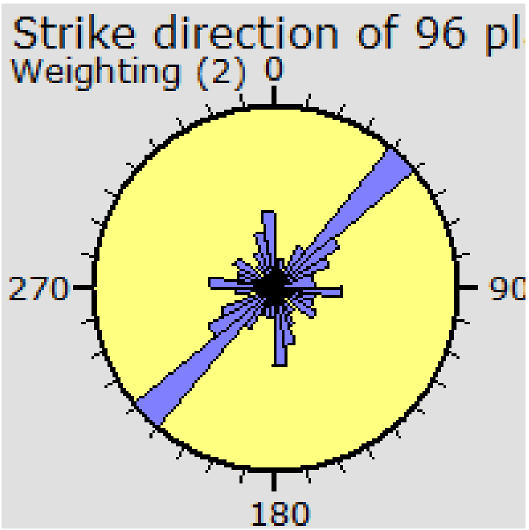


Figure 2a: Strike directions of shear planes presented in the form of Rose diagram (using Win –Tensor 5.0.8 software). The major trends of theses fractures are NE-SW, SSE-NNW and ESE-WNW.

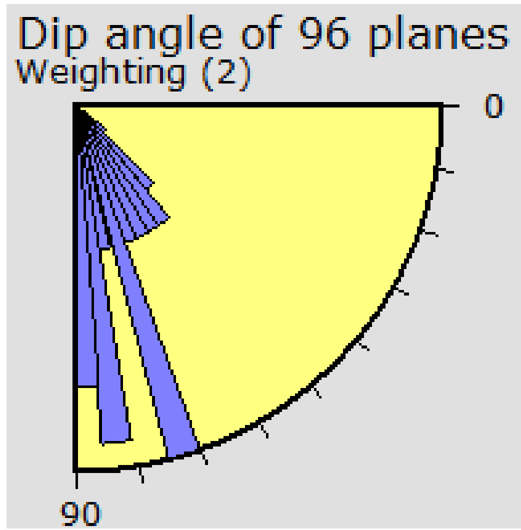


Figure 2b: Dip directions of fracture planes presented in the form of Rose diagram (using Win –Tensor 5.0.8 software). The dip angle ranges from 40^o to 90^o.

In the Google Earth image it has been observed that major lineaments are in NNW-SSE, NE-SW and E-W directions. The lineaments in the Google Earth image are showing the same pattern as observed during the field mapping. The all three lineaments are cutting each other making intersection points. Two Google Earth image have been taken here so that the lineaments are clearly observed as shown in figure 3a, 3b.

Figure 3a: The Google Earth image of the study area, the orientation of the fractures in the field are same as major lineaments present on the Google Earth image. (Near Ajapura Mota and Dabheli)

Figure 3b: The Google Earth image of the study area, the orientation of the fractures in the field are same as major lineaments present on the Google Earth image. (Near Surela).

4.2 Principle of Multi electrode Resistivity Imaging (MERI)

In a normal electrical resistivity survey, we use two electrodes for current transmission and two electrodes for potential measurements. With this setup we can design only a Wenner or Schlumberger or dipole-dipole configuration at a time. However MERI includes a large number of electrodes located along a line at the same time, and which carries out an automatic switching of these electrodes for acquiring profiling data. This technique is called Resistivity Imaging or electrical resistivity Tomography (ERT). The subsurface image can be obtained by combining electrical sounding (1D vertical) and electrical profiling (1D horizontal) data to give two dimensional cross- section, which can in turn be combined to give 3D model of ground (Figure 4). Manually this method is both laborious and time consuming, so that computer-controlled multielectrode resistivity systems (Dahlin 1993) had been developed. This entails the use of multiple electrodes, connected via multicore cables to a switching box, which in turn is connected to a DC resistivity meter. The switching box is automatically selects combinations of electrodes as instructed by computer protocol file at a time, according to the survey design, and the resistivity meter takes readings for each set of selected electrodes, thus producing a 2D data set. The procedure for acquiring resistivity imaging includes the following four successive steps. (1) Creating the sequence of measurements with a ElectreII software; the sequence depends on the number of electrodes, their spacing, the type of array (Wenner- Schlumberger, Dipole-Dipole, Pole-Dipole, Pole-Pole, etc.). (2) During the measurements, the output voltage of the equipment is automatically adjusted to the level of the signal measured. (3) Transferring the data from the resistivity meter to PC and process the data with ProsysII software, filtering of noisy data in relation with their standard deviation or on the level of the signal, introduction of the topography (electrode elevation), and visualization of the results bring a level of investigation depth. (4) Inverting the data with a Res2DINV software, which, after a certain number of iterations, gives the values of the interpreted resistivities (through a colour scale), and depths various types of electrode combinations can be used, such as Dipole-Dipole, Wenner-Schlumberger, Pole-Pole arrays.

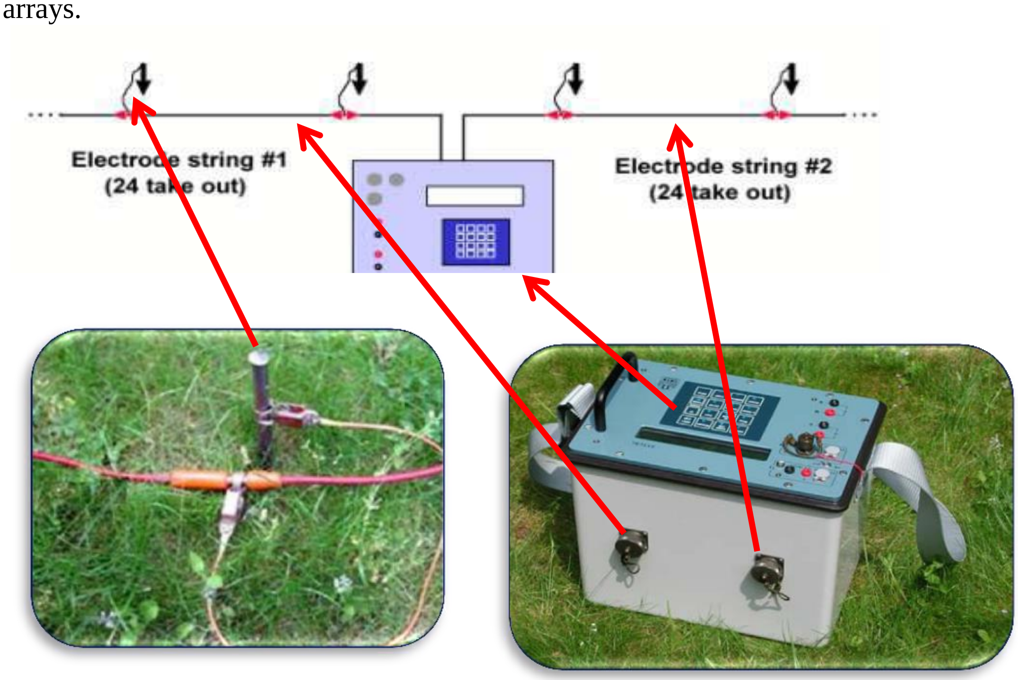


Fig. 4: Field layout of 2D resistivity imaging system.

The Multi electrode Resistivity Imaging (MERI) data of 2D and 3D can be processed by ProsysII Software. The Data points have corresponding deviation values. In this data keep the readings which have a deviation value less than 3. Remove the Data points which have deviation value greater than 3. After removing the highly deviated data points there is noticeable change in the values of resistivity, current and voltage. This software converts the bin format data into data format data.

5. Results and Discussion

The electrical resistivity imaging surveys were conducted in the Ambaji region with profile length of 15 km along 14 different sites as listed in table 1.

Table1: Coordinates of Electrical resistivity survey in Ambaji (Gujarat) and Rajasthan

Site No.	Site Name	Latitude	Longitude
1	Kansara	240 17’ 25.0’’	720 34’ 621’’
2	Ajapur	240 18’ 10.5’’	720 35’ 23’’
3	Ajapur-2	240 17’ 47.0’’	720 34’ 50.2’’
4	Surela	240 18’ 32.0’’	720 35’ 01.3’’
5	Surela-2	240 18’ 19.8’’	720 36’ 04.9’’
6	Surela-3	240 18’ 17.9’’	720 36’ 11.2’’
7	Surela-4	240 18’ 16.8’’	720 36’ 20.0’’
8	Surela-5	240 18’ 12.7’’	720 36’ 28.9’’
9	Surela-6	240 18’ 06.7’’	720 36’ 39.1’’
10	Surela-7	240 18’ 03.5’’	720 36’ 49.4’’
11	Bhadala	240 17’ 54.2’’	720 37’ 09.7’’
12	Near Kansara	240 17’ 41.4’’	720 42’ 27.3’’
13	Baisa singha	240 24’ 46.5’’	720 43’ 37.3’’
14	Baisa singha-2	240 24’ 53.6’’	720 43’ 32.3’’

From the psuedsections of site 1 to site 14 (figure 5), the variance of conductive zone is located within shallower depths and resistive zone is located at deeper depths. The sites 3, 13, 14 are showing fold type structures. The site 5 shows the high resistivity nature at intermediate depths due to presence of basic granulite. The sites 10, 11 show the patches of highly resistive zones at different depths due to presence of basic granulite. In the site 12 shearing type structures are observed at a depth of 30 m.

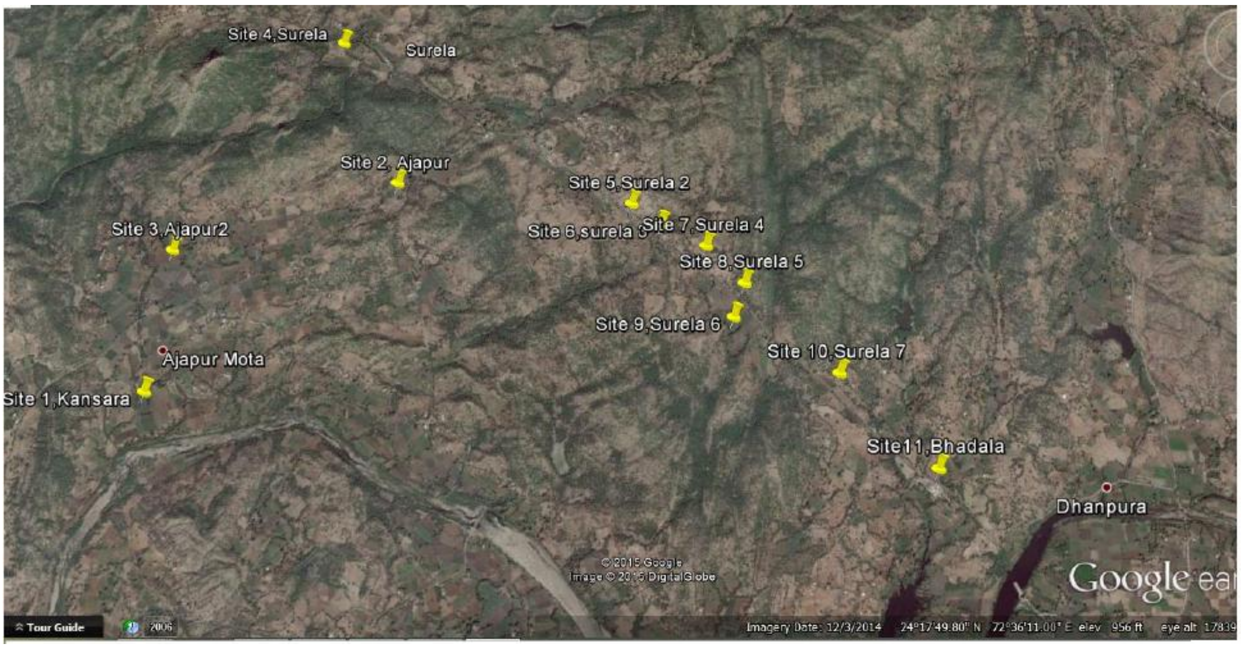
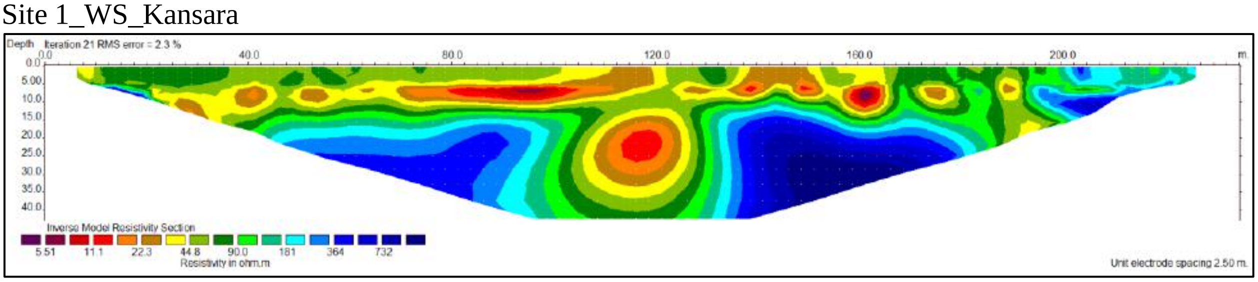


Figure 5: Geographical distribution of sites for Electrical Resistivity surveys have recorded in Ambaji. It is located in the Banskantha district, Gujarat. Total profile length of 15km at 14 Sites with an Average Site spacing of 1 km.

The resistivity range change from one site to another site but an average the resistivity range 3-30000 ohm-m (figure 6). Conductive zone with in shallower depths is due to sediments such as clay particles or water present below the subsurface. Resistive zone at deeper depth is due to the presence of metamorphic rocks such as basic granulite and mylonite.

Site 1_WS_Kansara



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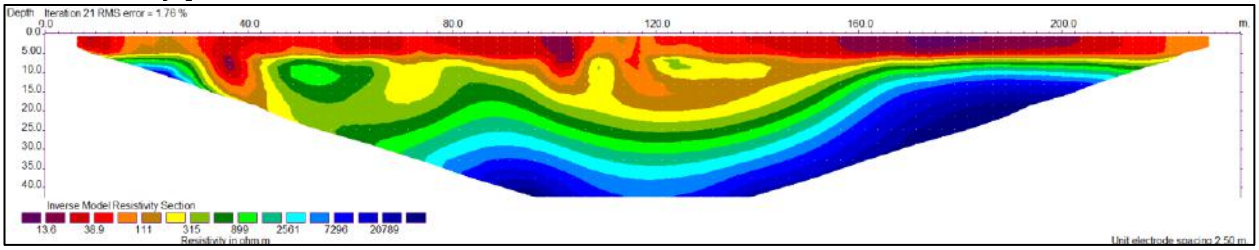
Site 2_WS_Ajapur



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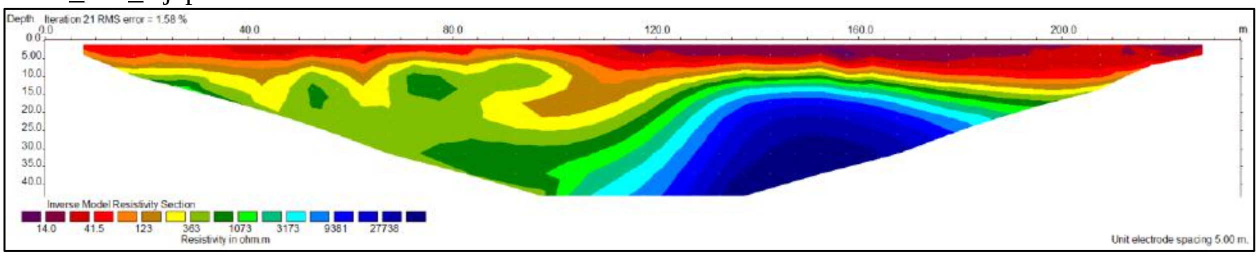
Site 3_WS_Ajapur 2



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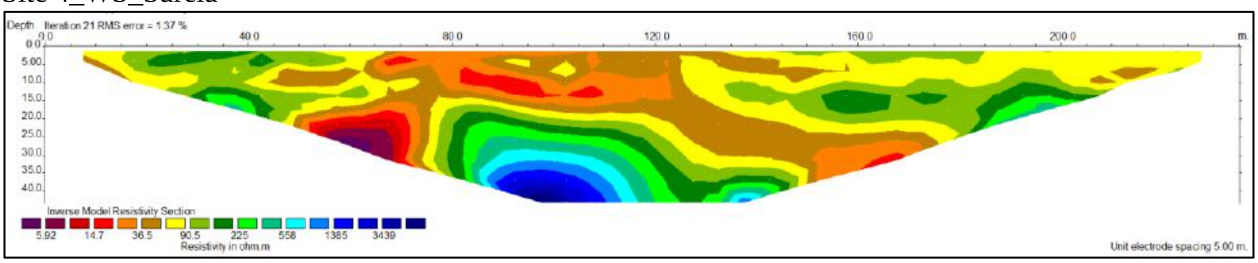
Site 4_WS_Surela



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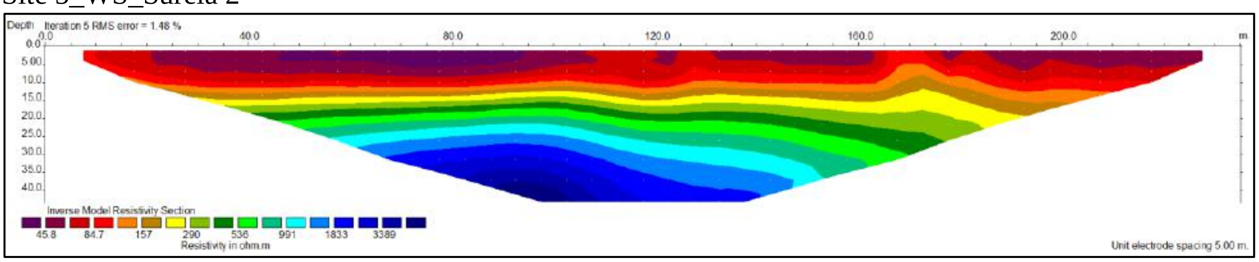
Site 5_WS_Surela 2



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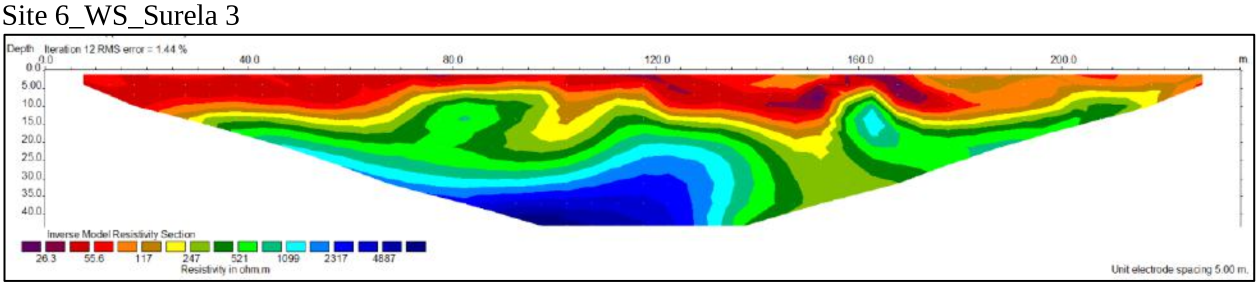
Site 6_WS_Surela 3



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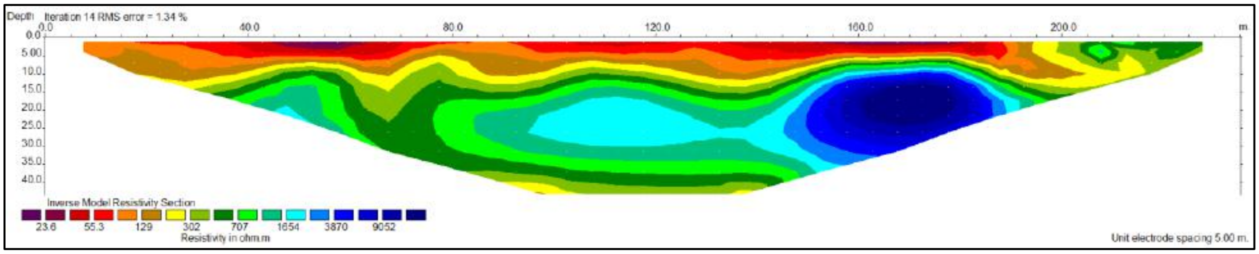
Site 7_WS_Surela 4



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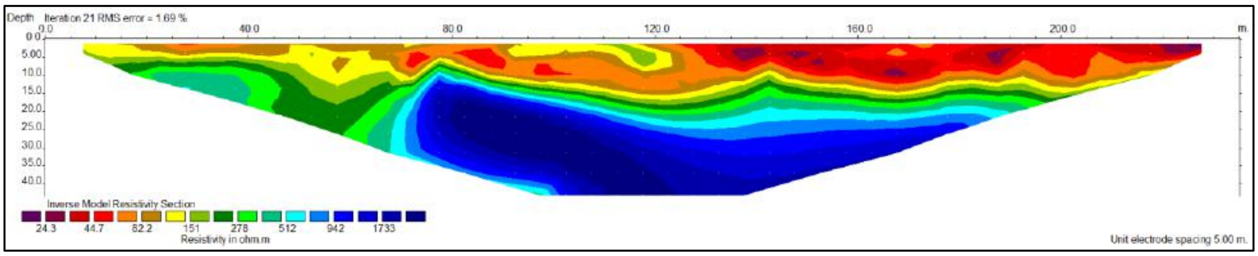
Site 8_WS_surela 5



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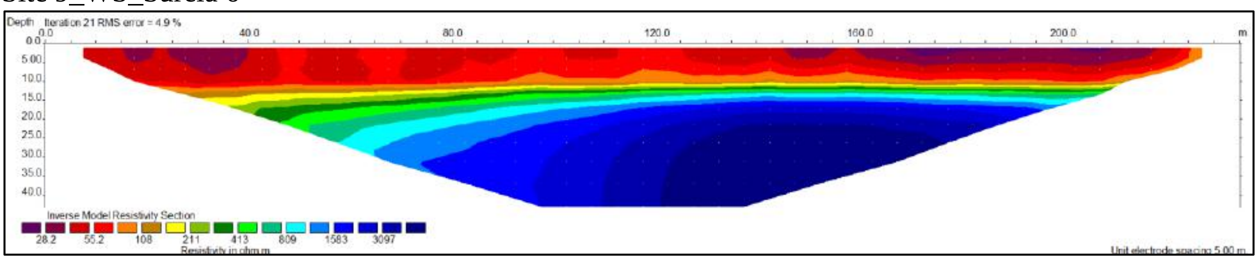
Site 9_WS_Surela 6



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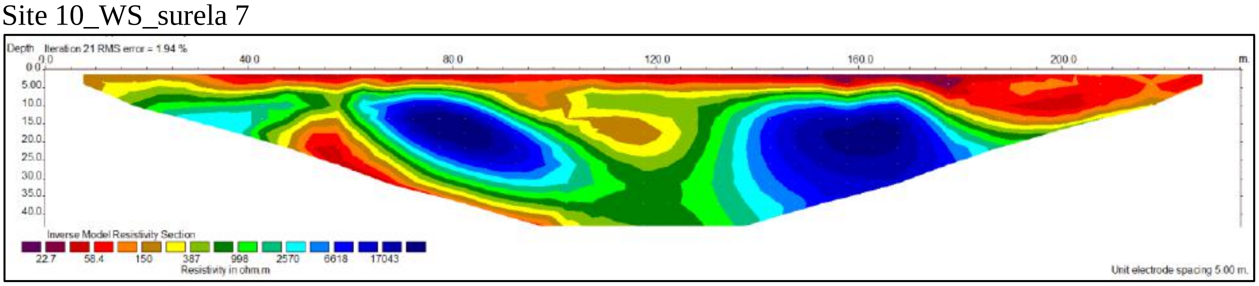
Site 10_WS_surela 7



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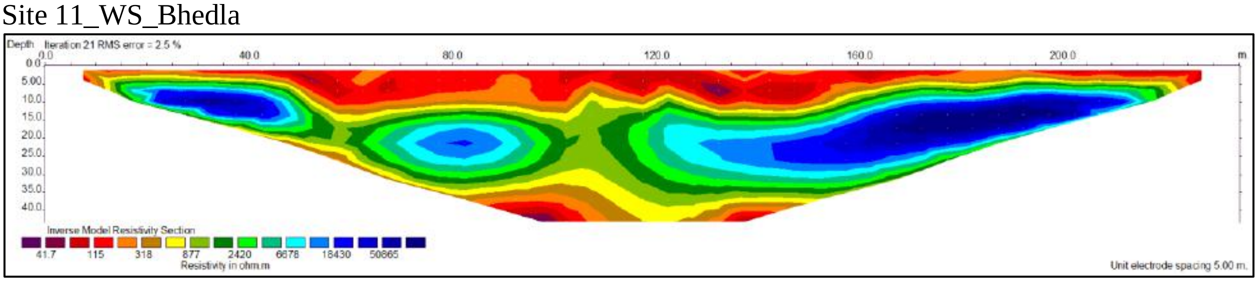
Site 11_WS_Bhedla



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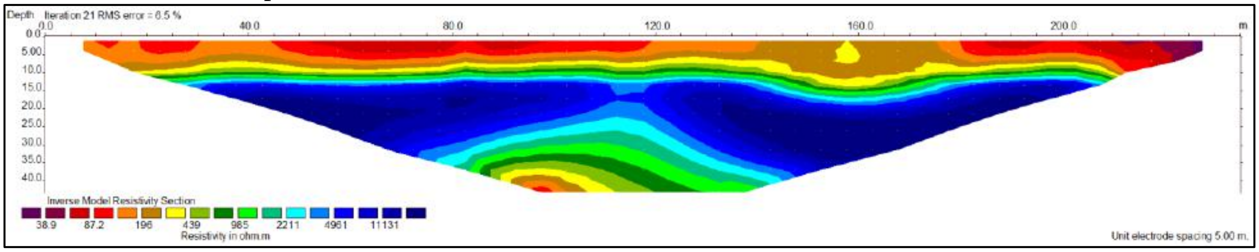
Site 12_WS_Near kanpura



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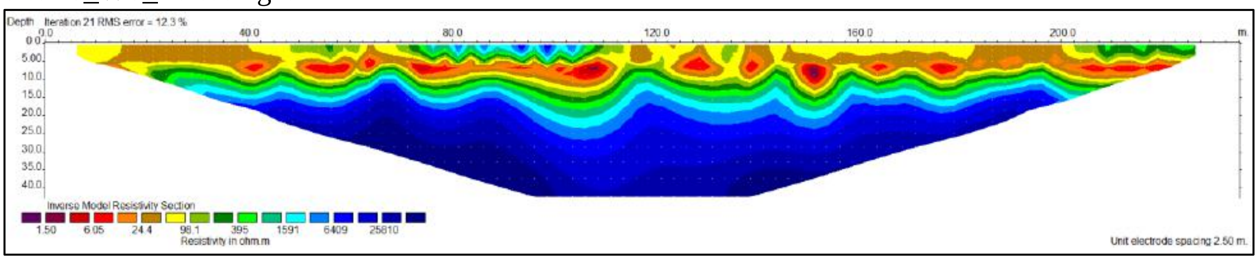
Site 13_WS_Baisasingha



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Site 14_WS_Baisasingha

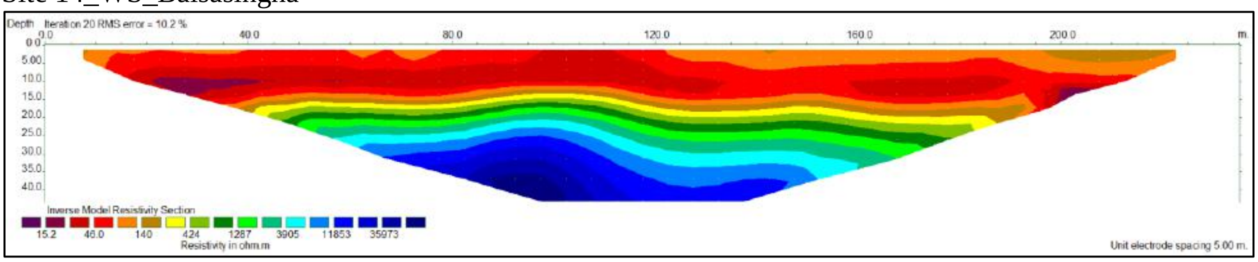

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Figure 6: Pseudosections of electrical resistivity profile of 14 sites taken at Ambaji basin Gujarat and Rajasthan for groundwater survey in hard rock terrain.

6. Conclusion

The study is carried out with special reference to groundwater circulation in fractures. For this purpose resistivity survey and detailed field mapping is done. From the field mapping and resistivity survey it has been interpreted that the groundwater circulates in NNW-SSE, NE-SW oriented fractures. The flow of groundwater is blocked by E- W fractures and this makes the grid wise system for groundwater occurrence in the fractured hard rock terrain. The intersection points of NNW-SSE (green colour lines as shown in figure 7), NE-SW (red colour lines as shown in figure 7) oriented fractures are highly potential (blue colour points as shown in figure 7) for groundwater Exploration. The occurrence of groundwater is up to 10- 15 meters depth as observed in the pseudosections from the multi electrode resistivity test. At some places we get deeper conductive zones due to the presence of deep seated shear zones.

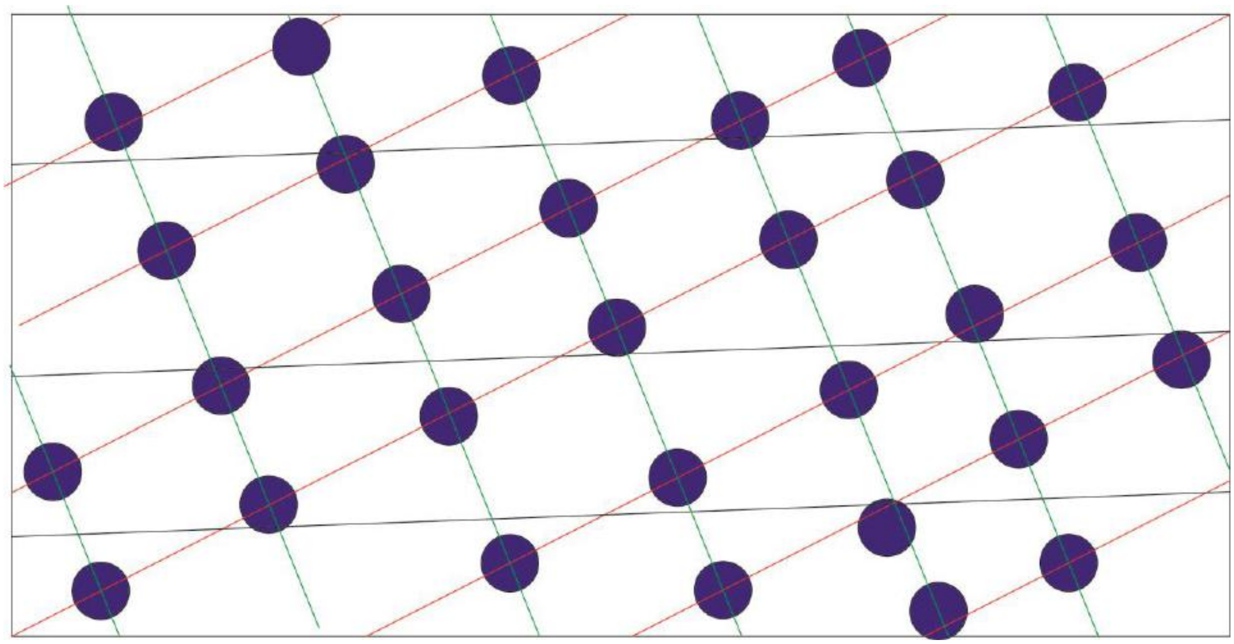

Figure 7: A groundwater model for Ambaji area. The intersection point of NNW- SSE (Indicated as green lines in the figure) and NE- SW (Indicated as red lines in the figure) oriented fractures are highly potential areas for groundwater exploration indicated as dark blue circles in the figure. The E-W oriented (Indicated as black lines in the figure) fractures block the circulation of groundwater. So the potential areas for groundwater exploration occurs sector wise in the study area.

In the future we can use this method for the exploration of groundwater in other hard rock terrains to reduced cost and time in search of it.

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