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# Detection of Fractures for Groundwater Development in a watershed of Vedavathi River basin using Remote Sensing and High-Altitude Aeromagnetic Data

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## Abstract

Remote sensing satellite data and high-altitude aeromagnetic data have been used to detect fractures for groundwater development in hard rock formation. A watershed of Vedavathi River located in the upper parts of the basin has been selected for this study. The applications of remote sensing satellite data have been proved useful for selecting feasible sites for drilling the borewell. The high-altitude aeromagnetic data is used in general for mineral exploration, geological mapping and deriving the tectonic set up of the regions. An attempt has been made to use the aeromagnetic data along with the remote sensing data for groundwater exploration in the study area.

**Keywords**: Fracture; Groundwater; Remote Sensing



## 1. Introduction

In the recent years, mapping and analyses of lineaments have gained popularity with the increasing availability of satellite and high-altitude aircraft images. Lineaments are mappable linear surface features, which differ distinctly from the patterns of adjacent areas and presumably reflect subsurface phenomena (O'Leary *et al.*, 1976). The remotely sensed linear features are largely a reflection of rock fractures, emphasized by vegetation and topography. Lineament analysis has been successfully used in exploration for oil and gas traps, and to select drilling locations for maximum porosity in tight formations (Peterson, 1980; Mah *et al.*, 1995).

Regional aeromagnetic anomaly maps bring out the regional pattern of the structural features among other things and provide an exceptional background for interpretation to be made for specific purposes (Sharma, 1986). The usefulness of the aeromagnetic data for geological studies is summarized in the Project Vasundhara publication (1994) of Geological Survey of India. The study shows that aeromagnetic data clearly defines the major crustal shear zones. Occurrence of groundwater in hard rock is confined to litho-contacts, faults/shear and joints. Remote sensing techniques and aeromagnetic surveys are of immense use in delineating these structural features. A study has been carried in a watershed (Fig-1) of Vedavathi River basin to find out potential fractures for ground water development using geology, lineament interpreted from remote sensing data and aeromagnetic anomaly map.

### 1.1 Study Area

The watershed mainly drained by Veda River, which is a tributary of Tungabhadra River and is designated as Veda watershed (4D3E6) as per watershed atlas of India. The total geographic area of the watershed is 1547 sq.km, lies between longitude of 75° 52' 20" E and 76° 21' 19" E and latitudes of 13° 05' 54" N and 13° 33' 45" N (Fig.1). The watershed is the uppermost catchment of Vedavathi River basin

Fig-1

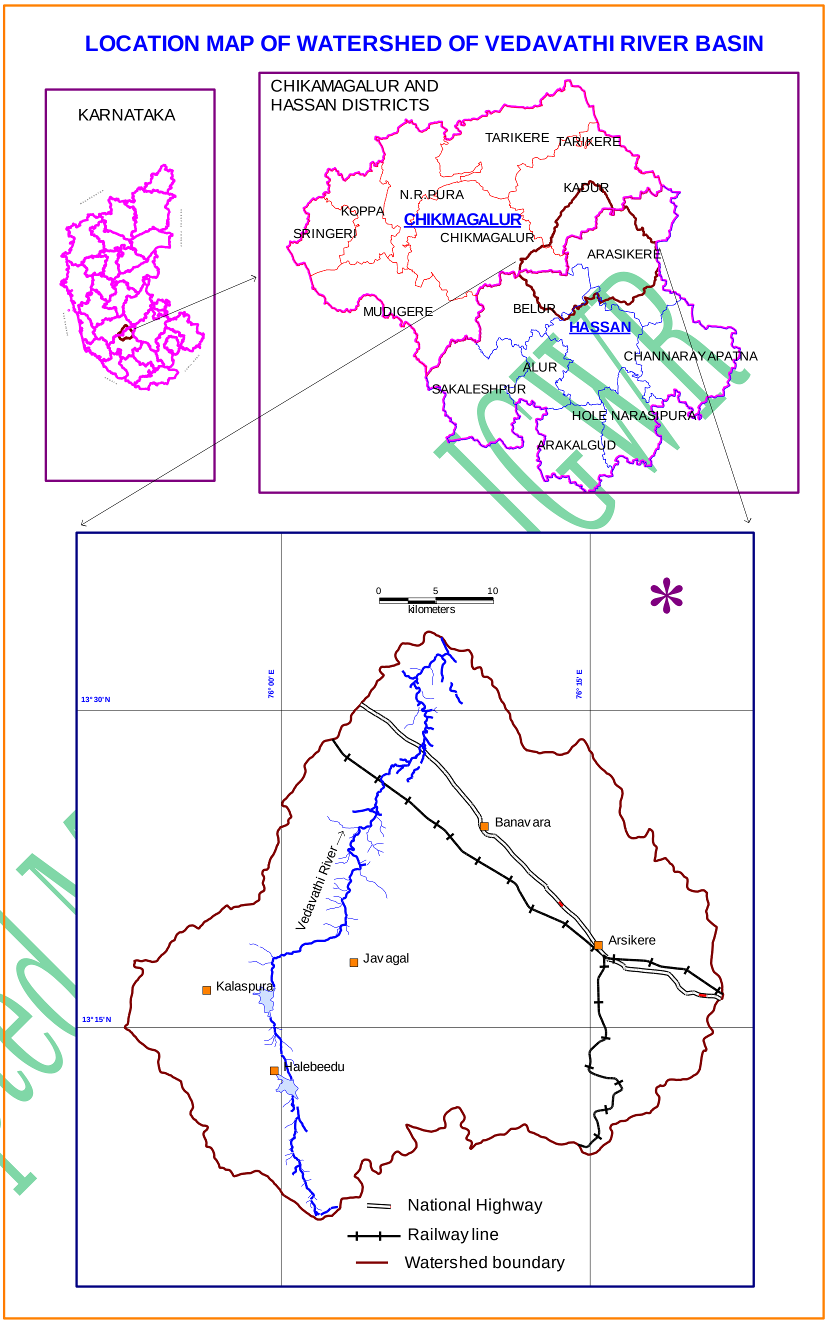





Fig.1. Location map of the study area

and located in parts of Chikmagalur and Hassan districts. The Veda River originates in southern part of the study area. The study area falls in three taluks of Hassan district and two taluks of Chickmagalur districts. In Hassan district, the study area is falling in part of

Arsikere, Belur and Hassan taluks covering area of 1137sq.km. The major part of the study area falls in Arsikere taluk, representing 52 % of the total geographic area. The watershed comprises of 544 villages falling in village panchayats. The study area is not having any major irrigation system and it is totally depending on groundwater sources for the domestic and irrigation purposes.

## 2. Geology

Based on the visual interpretation of the satellite data (IRS-1D, LISS-III), lithological boundary has been demarcated and updated with help of limited field checks and existing Geological information, published geological map on 1: 250000 scale (Fig-2). Geologically, the area is mainly underlain by Sargur and Peninsular Gneisses Complex of Archaeans age, followed by the Dharwar Super Group and closepet granite of lower protozoic age. The details of lithounits are discussed below.

The ultra-mafic schist is confined only in southern part of the study area and found only in Peninsular Gneissic complex and at places in closepet granite. This is generally trending NW- SE direction except in pockets of central part of the study area where it is trending NE-SW direction. Thin bands of Amphibolitic Metapelitic Schist/Pelitic Schist, Calc-Silicate Rock are unconformably overlained by ultra-mafic schist of Sargur rock type and found in the southwest of Hallabedu. It is mainly confined in the peninsular gneiss and granite (Shimoga). Peninsular gneisses mostly form pediplain. The foliation trend is generally NW-SE direction and dipping on either direction. The ground water condition of this formation is good. Granite (Shimoga) is conformably overlain by peninsular gneiss and is of Archaean age. It is exposed in the northwest and northern parts of the study area. It is mainly consists of quarts, feldspar and biotite minerals.

Basal oligomictic conglomerate is marker bed for unconformity between Peninsular gneiss basement and Dharwar Super group. It consists of quartz pebble and is occurring in the extreme southwest of the study area. Metabasalt is a supracrustal rocks of the Bababudan group, which constitutes the older group of the Dharwar Super Group. This group rests unconformably on peninsular gneiss basement and the unconformity is marked by an oligomictic quartz-pebble conglomerate. It is forming as narrow range of hills trending NW- SE direction. The closepet granite is exposed in the eastern part of the study area and this is forming as denudational hills.

### 2.1 Lineament

Lineaments of different lengths are identified by visual interpretation techniques using tone, texture, pattern and association (Fig-2). A total of 1195 lineaments have been mapped in the study area using IRS-ID, LISS-III satellite data. They are generally varying in length ranging from 0.002 to 7.07 km. The mean length of the lineaments is 0.79 km. Five sets of lineaments are found in the area and are trending E-W, NE-SW and NW-SE, N-S and ENE-WSW directions. Based on the length of the lineaments, four length classes such as <1km, <2km, <3km and >3 km were classified in the study area (Plot-1 and Table-1). <2km length of the lineaments are generally found in the southern part of the study area and are mainly controlled by streams with no tributaries drain in the study area. Streams are generally controlled by lineaments. It is predominantly confined in the ultra-mafic schist, metabasalt & tuff and closepet granite.

Fig - 2

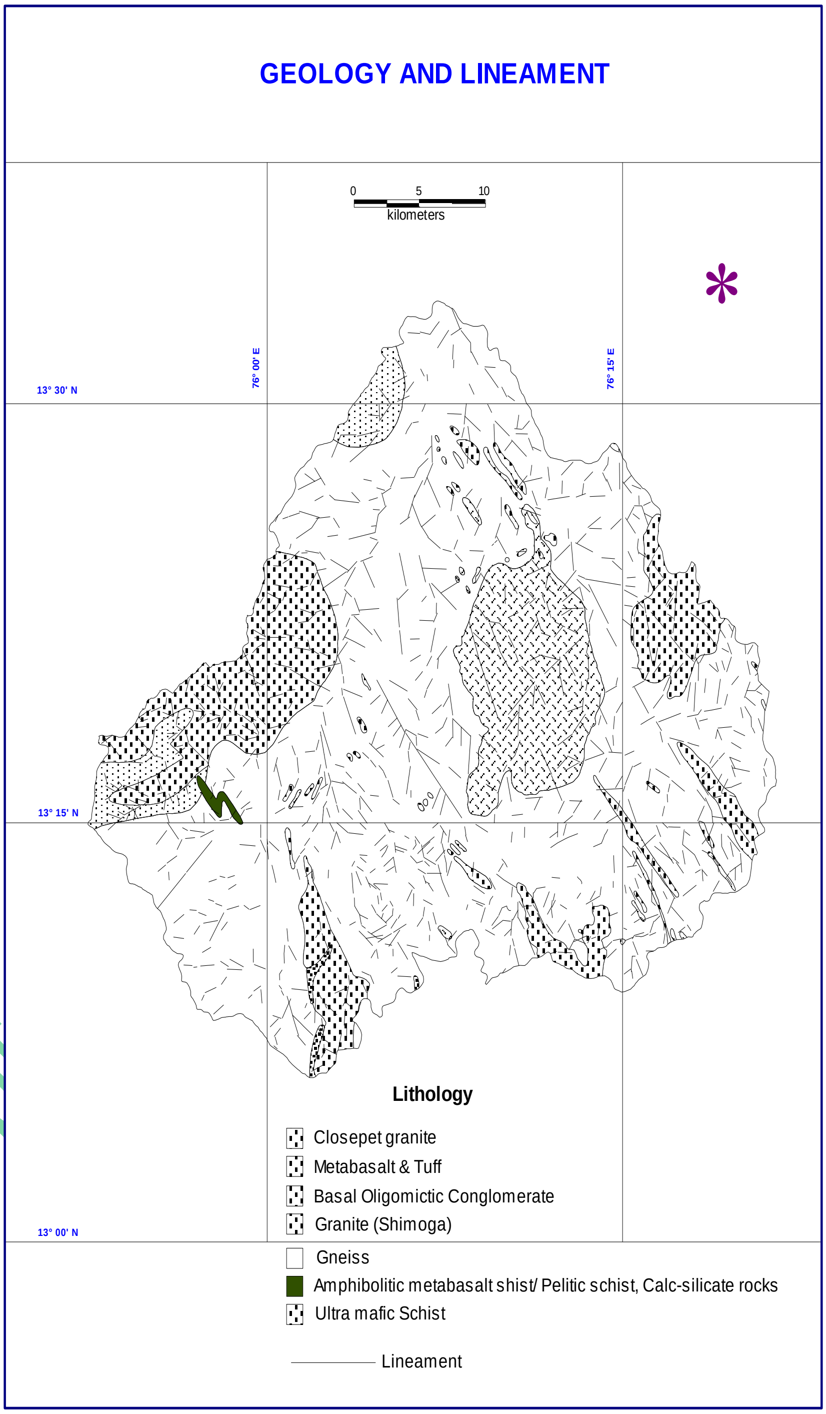
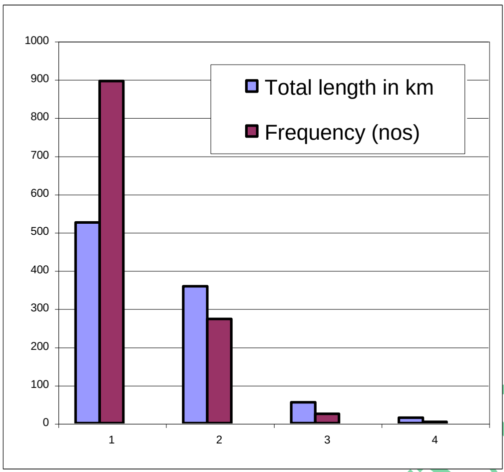





Fig.2. Geology and lineament map of the study area




Plot No: 1 Plot of length and frequency of lineament against length class

Table No :1. Details of the lineament interpreted through remote sensing data

| Sl.No | Total length in km | Frequency (nos) | Length class in km |
|---|---|---|---|
| 1 | 525 | 895 | <1 |
| 2 | 358 | 273 | <2 |
| 3 | 54.14 | 24 | <3 |
| 4 | 14.4 | 3 | >3 |
| **Total** | **951.54** | **1195** | **4** |

2 to 3 km lengths of lineaments are predominantly seen in the central and eastern parts of the study area and are generally trending NE-SW direction. The streams with tributaries of the watershed are mainly controlled by these lineaments. >3km lengths of lineaments predominantly exist in the central parts of the study area and are generally trending NW-SE direction. The main river and its major tributaries of the study area are mainly controlled by these sets of lineaments and are generally found in colsepet granite. The lengthiest lineament is observed in the east of the Javagal, trending NW-SE direction and running for 7.07 km.

The NW-SE lineament is shear fractures running parallel to general trend of rock formation whereas the NE-SW and E-W lineaments are tensional fracture. The shear joints indicate movement against each other and are tight joints. Due to the shearing these joints are generally filled with clay material and are not very potential from groundwater point of view. The tensional fractures are open in nature. Therefore, the ground water potential of tension fractures are higher than the shear fractures. Lineament intersections are considered as potential site for groundwater exploration.

### 3. Aeromagnetic Data

The contour maps of aeromagnetic total intensity and analytical signal covering sheets 57C and 57D were published in the technical report of GSI, prepared under the joint study carried out between GSI and CGWB. The aeromagnetic data was collected at 4km line interval and 2121m altitude. In the present study, the total intensity aeromagnetic contour map and analytical signal map were digitised and analysed quantitatively and qualitatively for the study area.

### 3.1 Aeromagnetic Anomaly

The aeromagnetic data collected from the field was not corrected for the normal field. To correct for the contribution from main core field, International Geomagnetic Reference Field (IGRF) was used. The total intensity aeromagnetic anomaly contour map was prepared. The anomaly map shows irregularly oriented elliptical to elongated magnetic contour patterns with high, gradient and amplitude in the eastern part. It is predominantly correlated with part of closepet granite, ultra mafic schist and contact zones of granite and gneiss. The magnetic anomaly axes are trending in N-S direction at the center of the study area and in the remaining area, the axes are trending E –W direction. The magnetic axes represent the direction of orientation of the anomalies and broadly define the regional structural fabrics. Negative magnetic anomaly occurring in the northern part is not showing any surface manifestation. In the western part, it represents irregularly oriented anomalies with high intensity, gradient and amplitude. This zone falls over the granite (Shimoga), metabasalt and tuff and contact zone between metabasalt &tuff / gneiss and between gneiss /and granite (Shiomga).

### 3.2 Aeromagnetic Breaks

Linear features including magnetic axis and breaks are interpreted from aeromagnetic anomaly map, based on the shape, size, orientation, intensity, gradients, frequency and amplitude (Babu Rao et al. 1987). Magnetic breaks signify the direction along which there is discordance in the pattern of the anomalies and indicate faults/ shears/ fractures (Paterson and Bosschart 1987). Manifestations of faults/shears/dykes in aeromagnetic maps have following manifestation (Astier and Paterson, 1989) as given below:

i. Sharp gradients forming a linear boundary between areas of different magnetic level and relief. These may be fault contacts (Magnetic breaks)

ii. Disruptions and/or deflections of magnetic contour lines. These are commonly wrench faults or shears, often with distinguishable lateral movement (Magnetic breaks).

iii. Linear magnetic lows within country rocks of moderate or high magnetic relief. These are usually zones where surface weathering or hydrothermal alteration has oxidized magnetite to hematite or limonite (Magnetic zones and trend of magnetic zones represents by axis). The zones are generally due to rock formation.

iv. Narrow, linear features with direct magnetic expression. The magnetic response in these features may be due to secondary magnetite resulting from metamorphism or narrow dykes intruded in pre-existing faults.

Based on the above criteria, a total of 28 magnetic breaks have been marked which are indicative of faults/shears/fracture zones and lithological contact zones. The magnetic breaks trend along NE-SW, NW-SE, NNE-SSW and WNW-ESE.

The aeromagnetic breaks identified on the aeromagnetic map are shown in the Fig.3. The magnetic breaks have been classified into minor (<10 km), intermediate

(10-20 km) and major (> 20 km). The above study has clearly indicated i. total length of magnetic breaks (230 km), ii. total number of magnetic breaks:28, iii. minimum and maximum length of the magnetic breaks (1 km & 25 km) and iv. Prominent trend direction of magnetic breaks is NW-SE, which is parallel to major shears zone trend (Chitradurga Boundary Shear - S.P.Anand, 2002). The NE-SW trend magnetic breaks are parallel to the major river trend flowing in the area.

Table 2 Results of magnetic break trend analysis

| Sl. No. | Trend of magnetic breaks | No. of magnetic breaks(N) | Cumulative length in km. (L) | Average length (L/N) | Freq-uency (%) | Remarks |
|---|---|---|---|---|---|---|
| 1 | NE-SW | 9 | 51 | 5.6 | 32.14 | **River trend** |
| 2 | NNE-SSW | 7 | 46 | 6.5 | 25.00 | |
| 3 | NW-SE | 8 | 111 | 13.87 | 28.57 | **Shear zone trend** |
| 4 | WNW-ESE | 4 | 22 | 5.5 | 14.28 | |
| | **Total** | **28** | **230** | **8.21** | **100** | - |

Field studies were carried out to identify ground manifestations/ causative sources of 28 magnetic breaks. The magnetic breaks in most of the places are characterized by shears/faults/fractures and litho-contacts. There are emplacements of quartzo-feldspathic/ pegmatite/epidote veins in some of these breaks. The magnetic breaks, which were interpreted in the peninsular gneissic terrain, does not have any ground manifestation. The causative sources for these magnetic breaks may occur below thick overburden. The magnetic breaks running from Bikanahalli in the south to Karadigavi in the north over a distance of 25.48km trending NW-SE is not having any surface manifestations. In general, NW-SE breaks are highly comparable with the Chitradurga Boundary shear/fault. In the granitic terrain, found in the eastern part of the study area, magnetic breaks are indicating the litho-contacts between the granite and peninsular gneiss. The NE-SW trending breaks are responsible for the subsurface fractures system and it is generally found in the southern part of the study area.

## 4. Groundwater Potential

Groundwater potential of the fractures are inferred through ground water exploration. Central Ground Water Board has drilled 22 borewells during 1978-79, 1991-92, 1997-98 and 2008-10 under ground water exploration programme. The borewells drilled during 2008-10 were located based on the aeromagnetic breaks. During the drilling, drilling discharges were estimated by V- notch 90° methods in the drilling site itself. Hence, the discharge of each fracture is estimated (Table 3). The drilled depth of the borewells was ranging from 48 to 200mts. The drilling feasible sites were selected based on the aeromagnetic breaks coupled with Vertical Electrical Sounding method. The borewells drilled close to aeromagnetic breaks are yielding ranging from 1.75 liter per second (lps) to 24.00 lps (Fig-3). The maximum yield of 24.00 lps is encountered in Manakattur borewells which is located WNW-ESE trending aeromagnetic break representing contact between granite and granite gneiss formation. The NE-SW and NW-SE trending aeromagnetic breaks are having the potential fractures with ranging from 1.75 to 4.45 lps. The general trend of the fracture zones in the watershed is NW-SE direction, which is highly parallel to the Chitradurga shear zones and general strike of the rock formation.

Table: 3 Details of the borewell drilled in the watershed

Note : PW- Pumping well, OW- Observation well and EW- Exploratory well

| Sl.no | Location | Drilling Discharge (lps) | Year of drilling | Depth (mts) | Distance of observation well (mts) |
|---|---|---|---|---|---|
| 1 | Undiganalu (PW) | 14.93 | 2008-09 | 128.24 | 15 |
| 2 | Undiganalu (OW) | 12.93 | 2008-09 | 143.52 | - |
| 3 | Manakattur (PW) | 24.00 | 2008-09 | 138.52 | 29.70 |
| 4 | Manakattur (OW) | 11.76 | 2008-09 | 162.44 | - |
| 5 | Jajur (PW) | 4.26 | 2008-09 | 200.00 | 23.00 |
| 6 | Jajur (OW) | 3.28 | 2008-09 | 200.00 | - |
| 7 | Tirupati (PW) | 8.2 | 2009-10 | 174.08 | 30 |
| 8 | Tirupati (OW) | 0.01 | 2009-10 | 200.00 | - |
| 9 | Diggenahalli (PW) | 6.41 | 2009-10 | 200.00 | 30.00 |
| 10 | Diggenahalli (OW) | 4.42 | 2009-10 | 200.00 | - |
| 11 | Adaguru | 2.4 | 2009-10 | 200.00 | - |
| 12 | Ghattadahalli | 1.75 | 2009-10 | 165.00 | - |
| 13 | Kalasapur (PW) | 2.69 | 1997-98 | 187.00 | - |
| 14 | Kalasapur (OW) | 2.46 | 1997-98 | 100.23 | |
| 15 | Devanur | 4.25 | 1997-98 | 171.99 | - |
| 16 | Shanegere | 0.5 | 1991-92 | 56.25 | - |
| 17 | Kallanayakanahalli | 4.0 | 1978-79 | 48.00 | - |
| 18 | Mududi EW | 4.04 | 1978-79 | 82.05 | - |
| 19 | Mududi OW | 0.75 | 1978-79 | 35.00 | |
| 20 | Javagallu EW | 2.5 | 1991-92 | 70.65 | - |
| 21 | Javagallu OW | 1.45 | 1991-92 | 55.00 | |
| 22 | Banavara | 0.21 | 1991-92 | 90.00 | - |

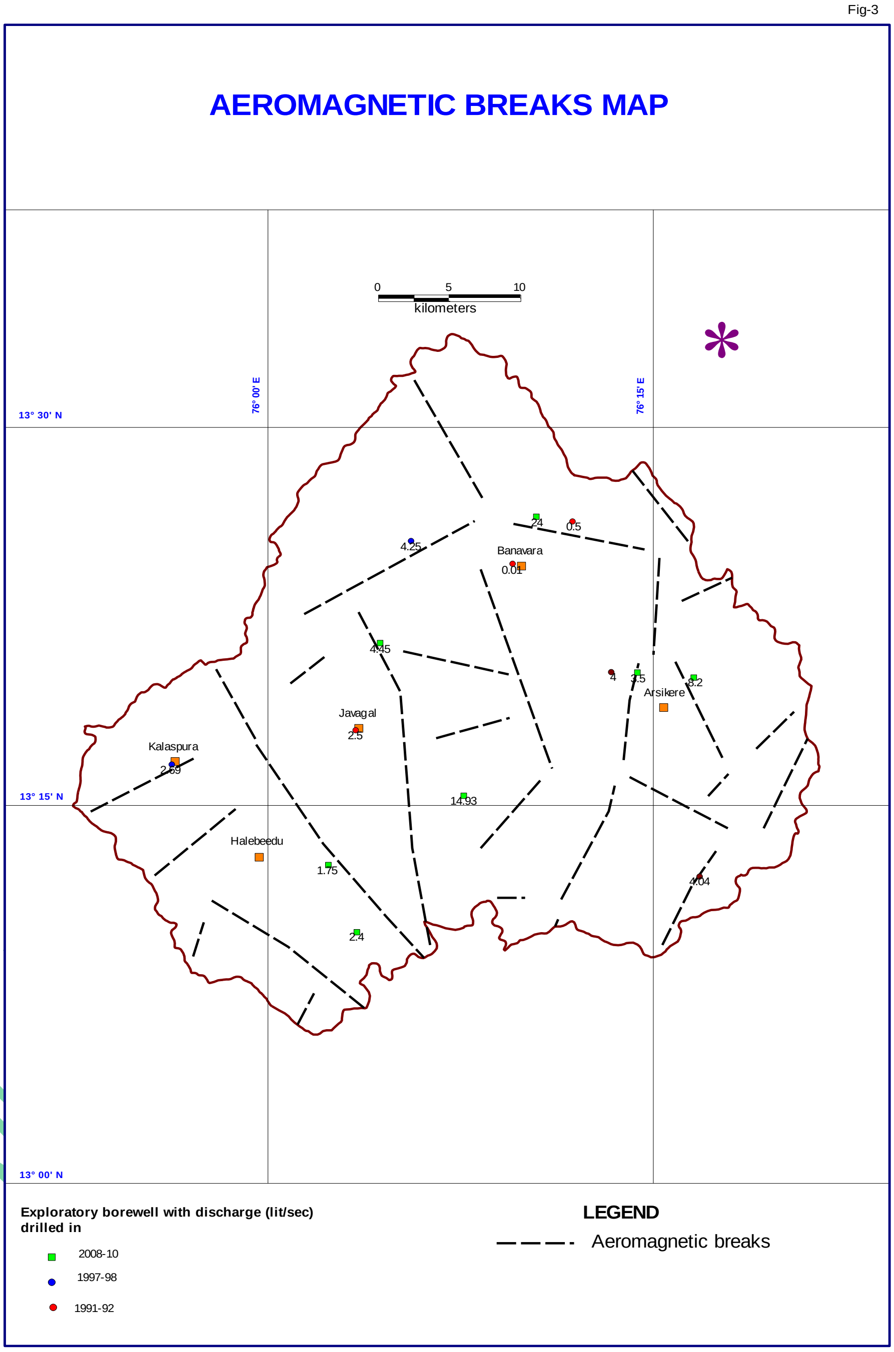





Fig-3 Aeromagnetic breaks map of the study area

Table 4. Fracture zones depth vs yield of borewell drilled during 2008-10 in the study area.

| Sl.no | Fracture Zones depth (Mts) | | Discharge of Zone(lps) | Cum.Discharge ( litre/sec) |
|---|---|---|---|---|
| | From | To | | |
| **i) Manakattur Exploratory Well** | | | | |
| 1 | 92.68 | 94.68 | 0.08 | 0.08 |
| 2 | 113.96 | 115.6 | 0.35 | 0.43 |
| 3 | 130.88 | 132.88 | 1.56 | 2.44 |
| 4 | 136.88 | 138.52 | 9.32 | 11.76 |
| **ii) Manakattur Observation Well** | | | | |
| 1 | 20.28 | 22.28 | 0.08 | 0.08 |
| 2 | 25.92 | 27.92 | 2.36 | 2.44 |
| 3 | 33.56 | 35.56 | 1.82 | 4.26 |
| 4 | 37.56 | 39.2 | 3.96 | 8.22 |
| 5 | 50.84 | 52.84 | 1.68 | 9.90 |
| 6 | 52.84 | 54.48 | 1.86 | 11.76 |
| 7 | 69.76 | 71.76 | 1.00 | 12.76 |
| 8 | 77.4 | 79.4 | 1.04 | 13.8 |
| 9 | 136.88 | 138.52 | 2.28 | 16.08 |
| 10 | 161.44 | 162.44 | 7.92 | 24.00 |
| **iii) Jajur Exploratory Well** | | | | |
| 1 | 33.56 | 34.56 | 0.13 | 0.13 |
| 2 | 87.04 | 89.04 | 3.15 | 3.28 |
| 3 | 119.2 | 121 | 1.11 | 4.26 |
| **iv) Jajur Observation Well** | | | | |
| 1 | 92.68 | 94.98 | 0.03 | 0.03 |
| 2 | 127 | 129 | 0.18 | 0.21 |
| 3 | 136 | 138 | 0.22 | 0.43 |
| 4 | 140 | 142 | 1.32 | 1.75 |
| 5 | 188 | 190 | 1.09 | 2.84 |
| 6 | 196 | 198 | 0.44 | 3.28 |
| **v) Undiganalu Exploratory Well** | | | | |
| 1 | 22.28 | 23.92 | 3.75 | 3.75 |
| 2 | 25.92 | 27.92 | 1.79 | 5.54 |
| 3 | 100.32 | 102.32 | 1.19 | 6.73 |
| 4 | 121.6 | 123.24 | 3.17 | 9.9 |
| 5 | 123.24 | 125.24 | 2.86 | 12.76 |
| **vi) Undiganalu Observation Well** | | | | |
| 1 | 19.4 | 21.4 | 0.43 | 0.43 |
| 2 | 25.92 | 31.56 | 8.6 | 9.03 |
| 3 | 48.84 | 50.84 | 0.81 | 9.9 |
| 4 | 119.96 | 121.6 | 0.9 | 10.8 |
| 5 | 129.2 | 130.88 | 1.96 | 12.76 |
| 6 | 142.42 | 143.52 | 2.17 | 14.93 |

**vii) S.Digganahalli Exploratory Well**

| | | | | |
|---|---|---|---|---|
| 1 | 22.28 | 22.35 | 0.01 | 0.01 |
| 2 | 46.84 | 48.84 | 4.41 | 4.42 |

**viii) S.Digganahalli Observation Well**

| | | | | |
|---|---|---|---|---|
| 1 | 62.12 | 64.12 | 0.01 | 0.01 |
| 2 | 100.96 | 101.96 | 0.07 | 0.08 |
| 3 | 140.52 | 147.00 | 2.38 | 2.45 |
| 4 | 182.72 | 184.36 | 2.42 | 4.87 |
| 5 | 186.36 | 188.36 | 2.46 | 6.41 |

**ix) Malaikallu Tirupathi Exploratory Well**

| | | | | |
|---|---|---|---|---|
| 1 | 50.84 | 51.15 | 2.44 | 2.44 |
| 2 | 129.24 | 130.5 | 3.75 | 3.75 |
| 3 | 161.44 | 162.5 | 7.85 | 7.85 |
| 4 | 173.08 | 174.05 | 8.2 | 8.2 |

**x) MalaikalluTirupathi Observation Well**

| | | | | |
|---|---|---|---|---|
| 1 | 33.56 | 35.56 | 0.1 | 0.1 |

**xi) Adaguru Exploratory Well**

| | | | | |
|---|---|---|---|---|
| 1 | 31.56 | 32.05 | 0.43 | 0.43 |
| 2 | 69.76 | 70 | 7.02 | 7.45 |
| 3 | 93.68 | 94.25 | 1.18 | 8.2 |
| 4 | 138.52 | 139 | 0 | 0.75 |
| 5 | 165.04 | 166 | 4.66 | 6.41 |
| 6 | 169.08 | 171.08 | 0 | 1.75 |
| 7 | 198 | 199.64 | 0 | 1.19 |

**xii) Ghatadahalli Exploratory Well**

| | | | | |
|---|---|---|---|---|
| 1 | 33.4 | 35.5 | 1.75 | 1.75 |

The discharges of fractures encountered in borewells drilled during 2008-10 are presented in the table 4. The shallow fracture is encountered at the depth of 20.28 mts in Manakattur location whereas the deeper fracture is encountered at the depth of 198.00 mts in Adaguru location. Based on the plot of discharge vs depth of fractures results, the highly fractured zones are found between 110-160 mts depth in the confined aquifer system with the discharge ranging from 1 to 3 lps (Fig-4). The moderately fractured zones and low fractured zones are found between 60 to 110 mts and 160 to 200 mts. respectively. It is clearly indicating that the fracture occurring between 110 to 160 mts are running long distance and having good connectivity. The intensity of the fractures is also high between those depths. Due to this, the ground water condition is excellent. The fractures are also encountered between the depths from 20 to 60 mts and ground water condition are highly influenced from the top weathered zone. The ground water in these fractures occurs under unconfined to semi-confined aquifer system. The discharge of the fractures is ranging from less than 1.00 lps to 4.5 lps. But the majority of the fractures are having the discharge between 1 to 3 lps. This zone also clearly indicates that the fracture is having good connectivity and running laterally for long distance.  The fractures occurring between 20 to 60 mts and

110 mts to 160 mts depths are not having any connectivity vertically. The breaks, which are not showing any surface indications, trending NW-SE direction occurring in the western part of the watershed are the resultant of the shearing thereby creating thick zone of weathering. It is mostly responsible for the shallow potential aquifers. The WNW- ESE and NE-SW trending breaks are generally responsible for the deeper aquifer system.

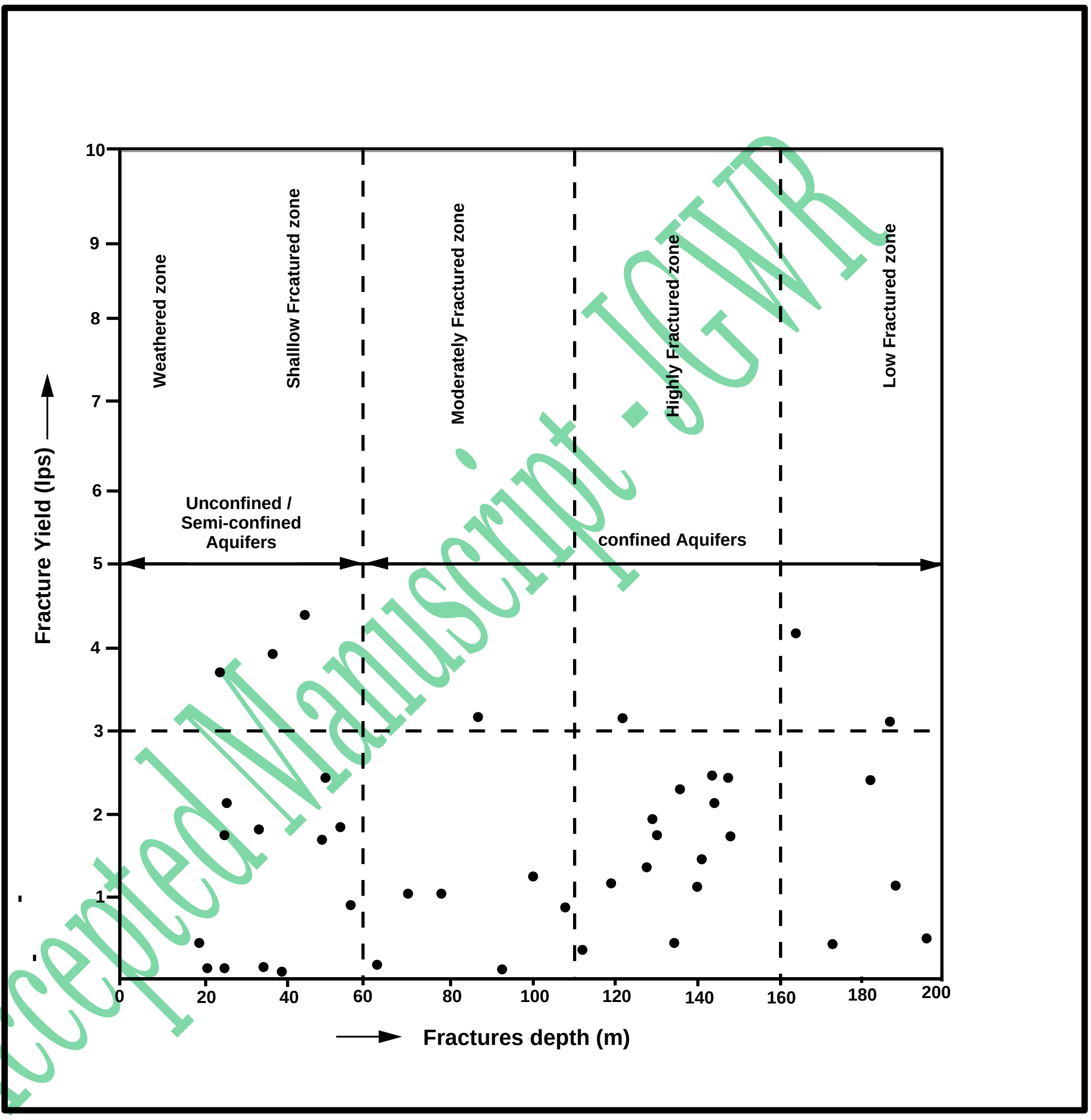




Fig-4 Borewell Yield vs Fracture depth

## 5. Conclusion

The high-altitude aeromagnetic anomaly and signal maps are used to interpret the aeromagnetic breaks. The interpreted aeromagnetic breaks in the watershed are mainly characterised by geological contact between closepet granite and granite gneiss and subsurface structural trend traced mainly in the southern part of the watershed. The aeromagnetic breaks are examined through ground water exploration. The wells drilled on WNW – ESE breaks, which indicate the geological contact, have encountered the fractures in the depth range of 110mts to 160mts. In the southern part of the watershed, breaks that are not showing any surface manifestation are indicating the fractures depth between 40mts to 60mts. They are mostly the resultant of shear fractures. These two fracture systems are not having any interconnectivity. The yields of these two fracture systems are not showing any significant changes falls between 1lps to 3lps. The present study reveals that the aeromagnetic data in conjunction with remote sensing data is useful in detecting ground water potential fractures systems in the hard rock formation.

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