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A qualitative approach of VLF (EM) data for groundwater exploration in a hard rock terrain, Osmania University Campus, Hyderabad, Telangana state, India

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Abstract
Very Low Frequency (EM) investigations were carried out in the Osmania University Campus, Hyderabad to delineate structural configuration and trace subsurface fracture zones at depth could represent groundwater potential zones. A qualitative interpretation of VLF-EM data along the AA^1 to SS^1 traverses is based on the crossover point, amplitudes of filtered real and imaginary components are appears as positive peaks in the Fraser filter real curve. This region constitutes anomalous zone which can be attributed the presence of vertical conductive or lateral contacts of different conductivity beneath the surface. Qualitative maps tilt derivative and analytical signal trends lows and highs are mapped which are reflecting similar trends of fractures, which are indicating structural configuration, conductive subsurface conductors at depth representing the groundwater potential zones.

Keywords: Very Low Frequency Electromagnetic Method (VLF-EM); Fracture zones; Fraser filter; Conductivity; Groundwater.

1. Introduction

The Osmania University Campus ($78^0 31'00''$ E Longitude to $78^0 32'30''$ E Longitude and 17^0 $23'48''$ N Latitude to 17^0 $25'42''$ N Latitude) is situated in an area of approximately 6.58 sq. km (1627.32 acres) lies in Hyderabad metropolitan city (SOI). The maximum elevation observed is 535m and minimum elevation is 503 m with respect to mean sea level. Here three types of granites exist–pink, grey and the leucogranites (Balakrishana and Rao, 1961; Sitaramayya, 1968, 1971) [1, 2, 3] and some pegmatite patches traversed by narrow white apatite veins, which intersect each other randomly. The granitic host rocks are intruded at places with doleritic dykes. The general geological section consists of soil layer underlain by weathered rock, which is in turn followed by the fractured rock at a few places. The basement, occurring at an average depth of 15 m consists of hard impervious granite.

Groundwater occurrence in the hard rock terrain can be vary irregular due to abrupt discontinuity in lithology, thickness and electrical properties of the overburden and weathered bed rock (Udaya Laxmi and Ramadass 2013) [4]. Many researchers (Kelly and Mares, 1993[5], Koefed 1979) [6], Parasnis (1973) [7], Zohdy (1964, 1965 and 1975) [8, 9, 10] have employed electrical methods of prospecting comprise a wide variety of techniques which utilize different electrical properties and their related phenomena to distinguish between different geological formations or to delineate structures. Subsurface characteristics are deduced from measured electrical properties of the earth such as resistivity. Though several geophysical methods are applicable for weathered zone studies under various geological conditions. Very Low Frequency Electromagnetic Method (VLF-EM) is passive methods from ground based military radio transmitters as the primary EM field for Geophysical survey. VLF ground surveys a quick and powerful tool for the study of geologic features within about 100m of the surface.

In the present paper emphasis the results of VLF-EM surveys. VLF (EM) are carried out in the hard rock terrain in Osmania University Campus, Hyderabad, to delineate the structural configuration and trace subsurface conductive zones at depth, could represent groundwater potential zones.

2. Drainage

The drainage is mostly dendritic which is characteristic of the granitic country and becomes radial at some places. The general trend of the drainage is towards the south joining the Musi River. There is nallah running parallel to the road leading to Elegugutta hill, which takes many turns and finally attains north-south trend. There are three tanks in the area – Mohini Cheruvu, Landscape Garden tank and Ramanthapur Cheruvu (Figure: 1). The last one falls outside the university area, which was once part of it.

The Landscape Garden tank was formed due to the construction of a small dam like bund which is in a valley across the nullah. The tanks total areal extent is about 1/2 sq.km. Under normal rainfall, the tank gets overflowed. However, due to the continuous drought for the last few years it does not contain much water. Of the three tanks, the major one is MohiniCheruvu which gets filled with most of the University's run off water.

3. Data Base

The VLF-EM profiling (traverse) was carried out with structural geophysical objectives with appropriate measurement of geometrics and procedure, by using ABEM WADI instrument at 10m interval along nineteen traverses which give a direct measure of ground conductivity. Seven traverses (AA^1, BB^1, CC^1, DD^1, EE^1, HH^1 and KK^1) were approximately in N-S direction and remaining twelve traverses (FF^1, GG^1, II^1, JJ^1, LL^1,MM^1, NN^1, OO^1, PP^1, QQ^1, RR^1 and SS^1) approximately in E-W direction (Figure: 2). The VLF-EM traverses range from 500 m to 2500 m, along the roads (about 10m away from the roads to avoid the cultural noise) with orientation at high angles to the direction of the transmitter. The frequency used for this survey was 22.5 KHz. A total of 2137 station positions were occupied for VLF-EM profiling. The WADI VLF-EM equipment detects the ratio (in percentage) between the vertical and horizontal components of the EM signal. The primary field is horizontal; the normal reading on the WADI will be zero even when horizontal lying conductors are present. The VLF method is very sensitive to small changes in ground conductivity.

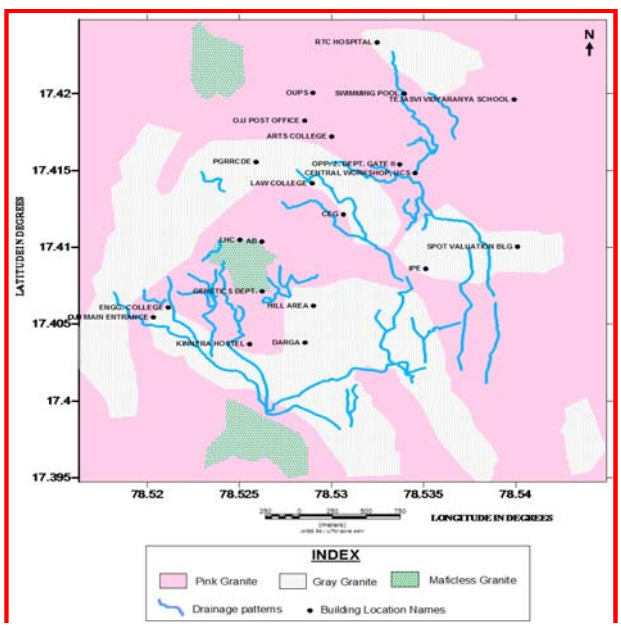


Fig 1: Drainage Patterns and Geology of the Study area.

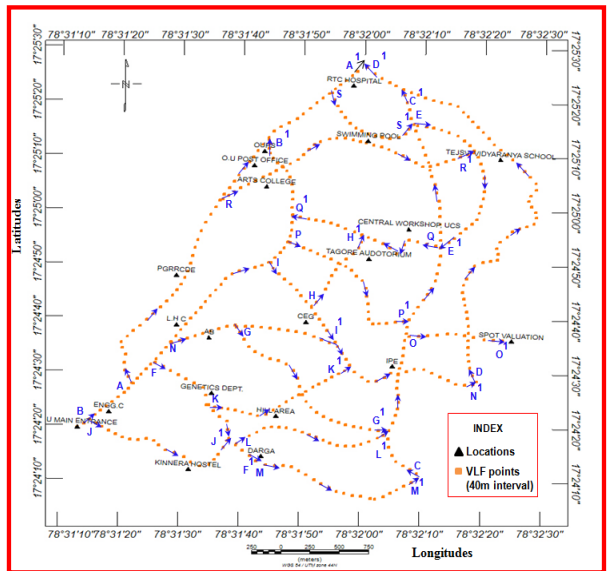


Fig 2: Locations of VLF traverses (AA^1, BB^1, CC^1, DD^1, EE^1, FF^1, GG^1, HH^1, II^1, JJ^1, KK^1, LL^1, MM^1, NN^1, OO^1, PP^1, QQ^1, RR^1 and SS^1)

4. Analysis of VLF-EM Data.

A qualitative interpretation of VLF-EM data is based on the cross-over point between the real and imaginary data which appears as positive peaks in the Fraser-filtered real curve, these regions constitute anomalous zones which can be attributed to the presence of vertical conductor or lateral contacts of different resistivities beneath the surface (Srigutomo *et al.*, 2005) [11]. This, therefore, ascertains a simple fact that the analytical signal of the real component takes off the Fraser filtered off the real component. The Fraser Filter (Q) (Fraser, 1969[12]) was computed using a filter operator as;

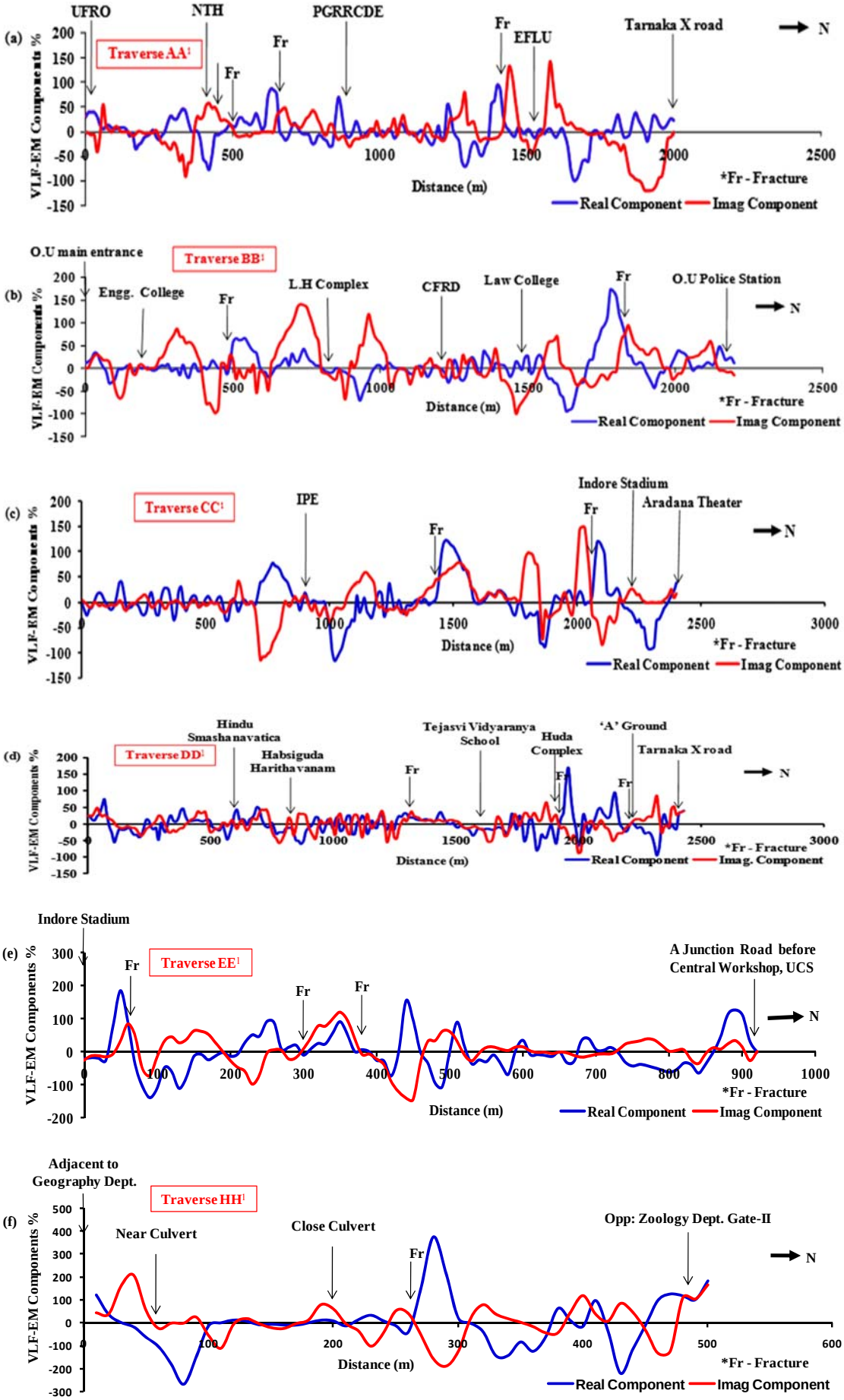
$$Q = (Q_4+Q_3) - (Q_2 + Q_1) \ldots (1)$$

Where Q is EM data and the subscript is station positions. This was applied to the real component VLF data to transform the data set to the filtered real VLF data.

5. VLF – EM Traverses

Electromagnetic VLF traverses (AA^1 to SS^1) are carried all along parallel to the roads (away from the roads) in the N-S & E-W direction. Nineteen traverses in all were taken up. Plots of the filtered real and imaginary parts were produced for every profile and they were interpreted in view of the existence of conductive zones that could be related to tectonic faults.

Fraser filtering (Fraser, 1969) [12] responses ranged in value from 100 % to 98% along the traverse. Figure: 3 & 4 (AA^1 to SS^1) shows the Fraser filtered data (real or in-phase component and imaginary or quadrature component). The in-phase traverses show positive peaks of different values of relative current density correspond to higher values of resistivity. All the VLF-EM intensities and sharpness were suggesting the presence of shallow and deep conductors. With such equivalent current density cross-section plots, it is possible to qualitatively discriminate between conductive and resistive structures where a high positive value corresponds to the conductive subsurface structure and low negative values are related to resistive materials. In addition, equivalent current density cross-section also gives an idea about the dip direction; however, exact dip angle cannot be estimated due to the vertical axis variable being a pseudo depth only.


(a)
Traverse AA¹
UFRO
NTH
Fr
PGRRCDE
EFLU
Tarnaka X road
N
VLF-EM Components %
Distance (m)
*Fr - Fracture
Real Component
Imag Component
(b)
Traverse BB¹
O.U main entrance
Engg. College
L.H Complex
CFRD
Law College
O.U Police Station
Real Comoponent
(c)
Traverse CC¹
IPE
Indore Stadium
Aradana Theater
(d)
Traverse DD¹
Hindu Smashanavatica
Habsiguda Harithavanam
Tejasvi Vidyaranya School
Huda Complex
'A' Ground
Tarnaka X road
Imag. Component
(e)
Traverse EE¹
Indore Stadium
A Junction Road before Central Workshop, UCS
(f)
Traverse HH¹
Adjacent to Geography Dept.
Near Culvert
Close Culvert
Opp: Zoology Dept. Gate-II

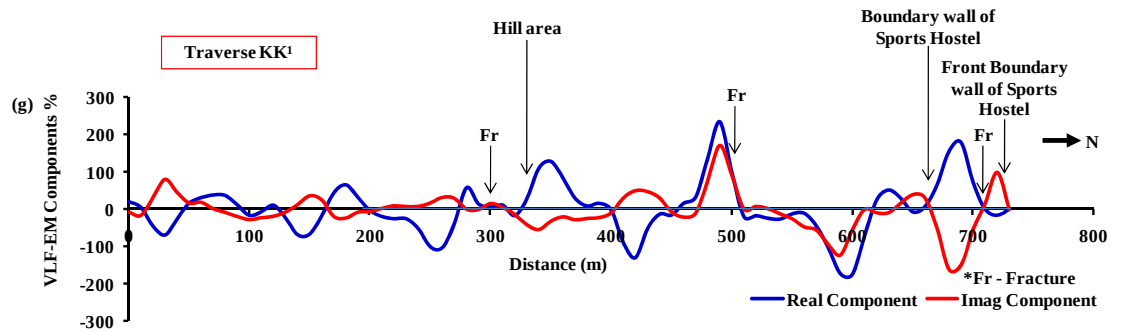
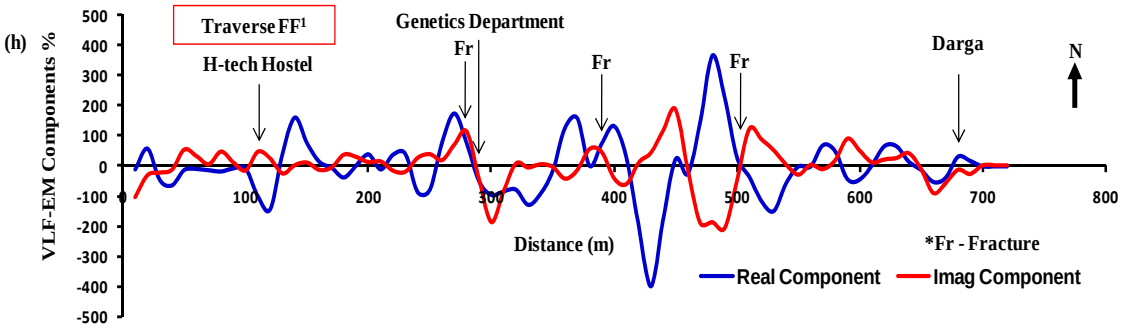
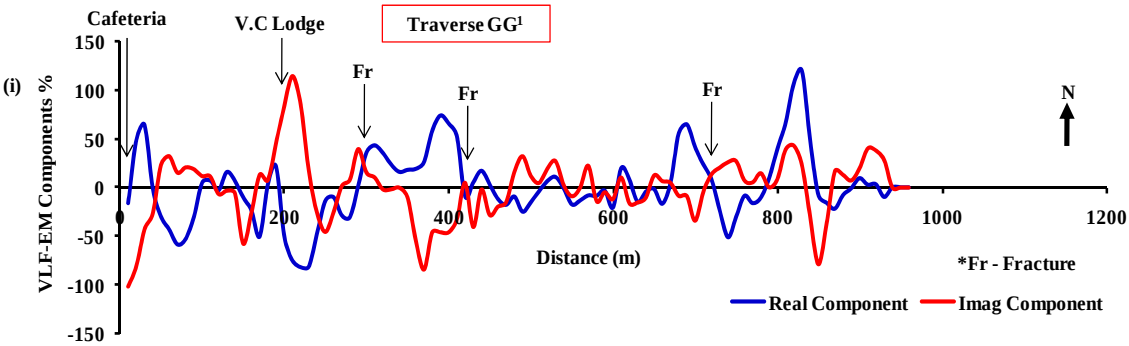
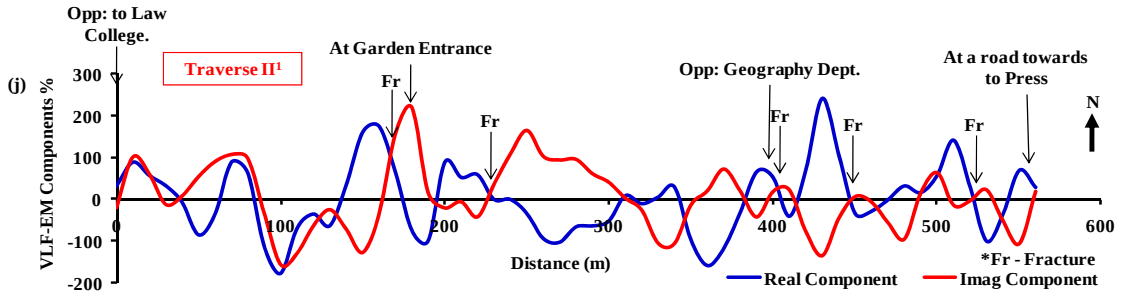
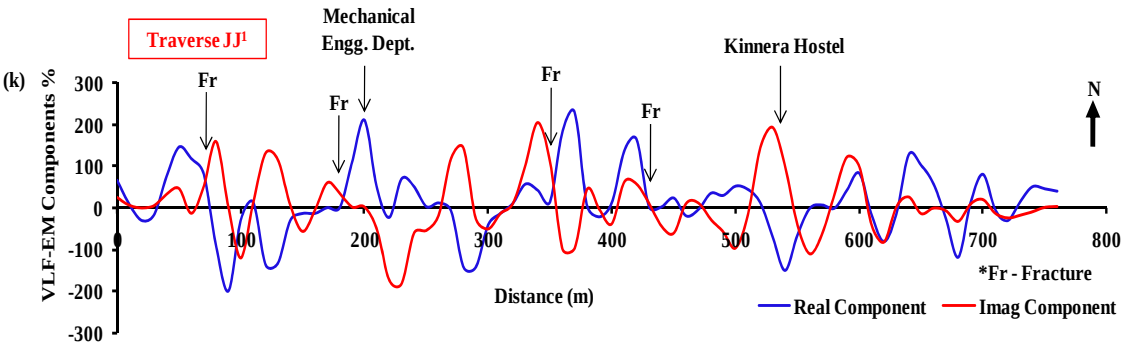


Fig 3: Fraser filter graph of Traverses (N-S direction) of a) AA¹, b) BB¹, c) CC¹,d) DD¹, e) EE¹, f) HH¹ and g) KK¹









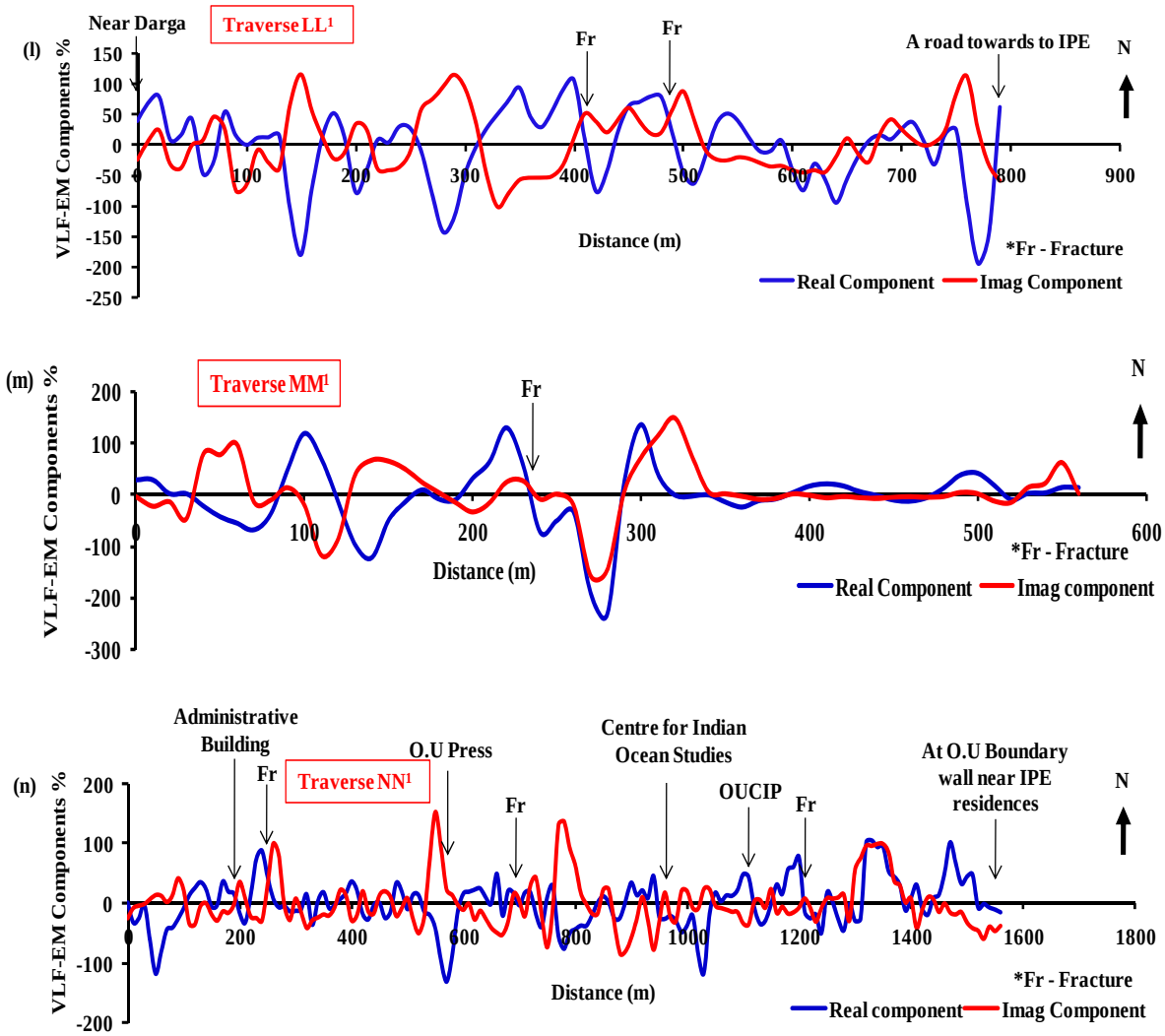
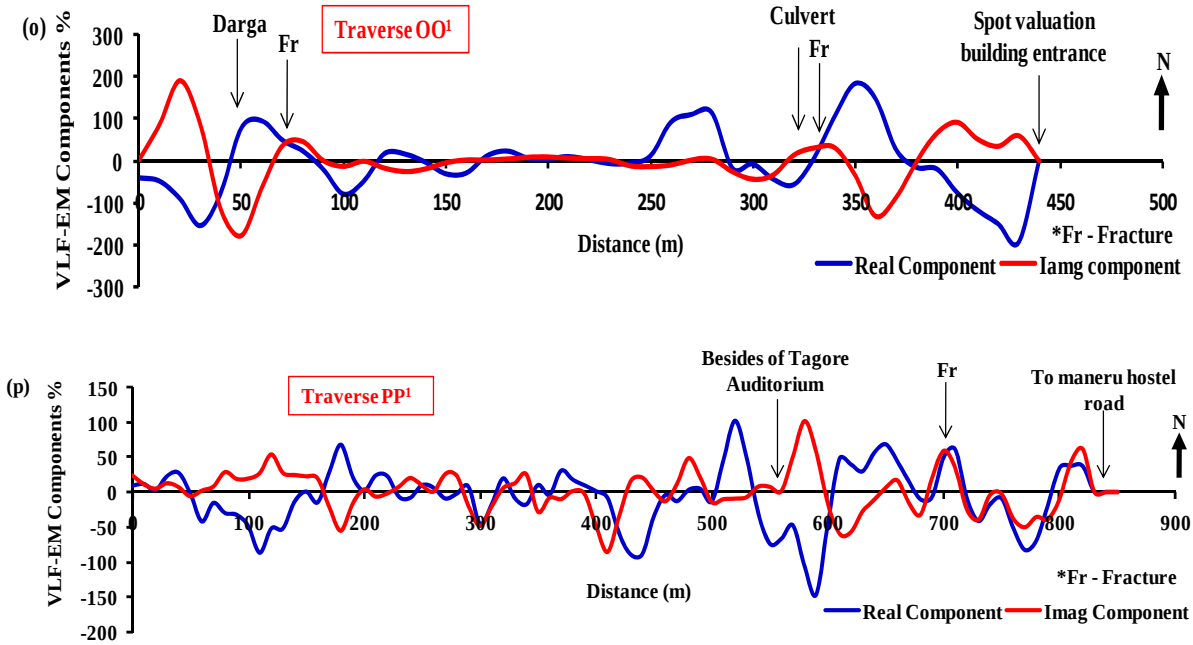


Fig 4: Fraser filter graph of Traverses (E-W direction) of h) FF¹, i) GG¹, j) II¹, k) JJ¹,l) LL¹, m) MM¹, n) NN¹, o) OO¹, p) PP¹, q) QQ¹, r) RR¹ and s) SS¹



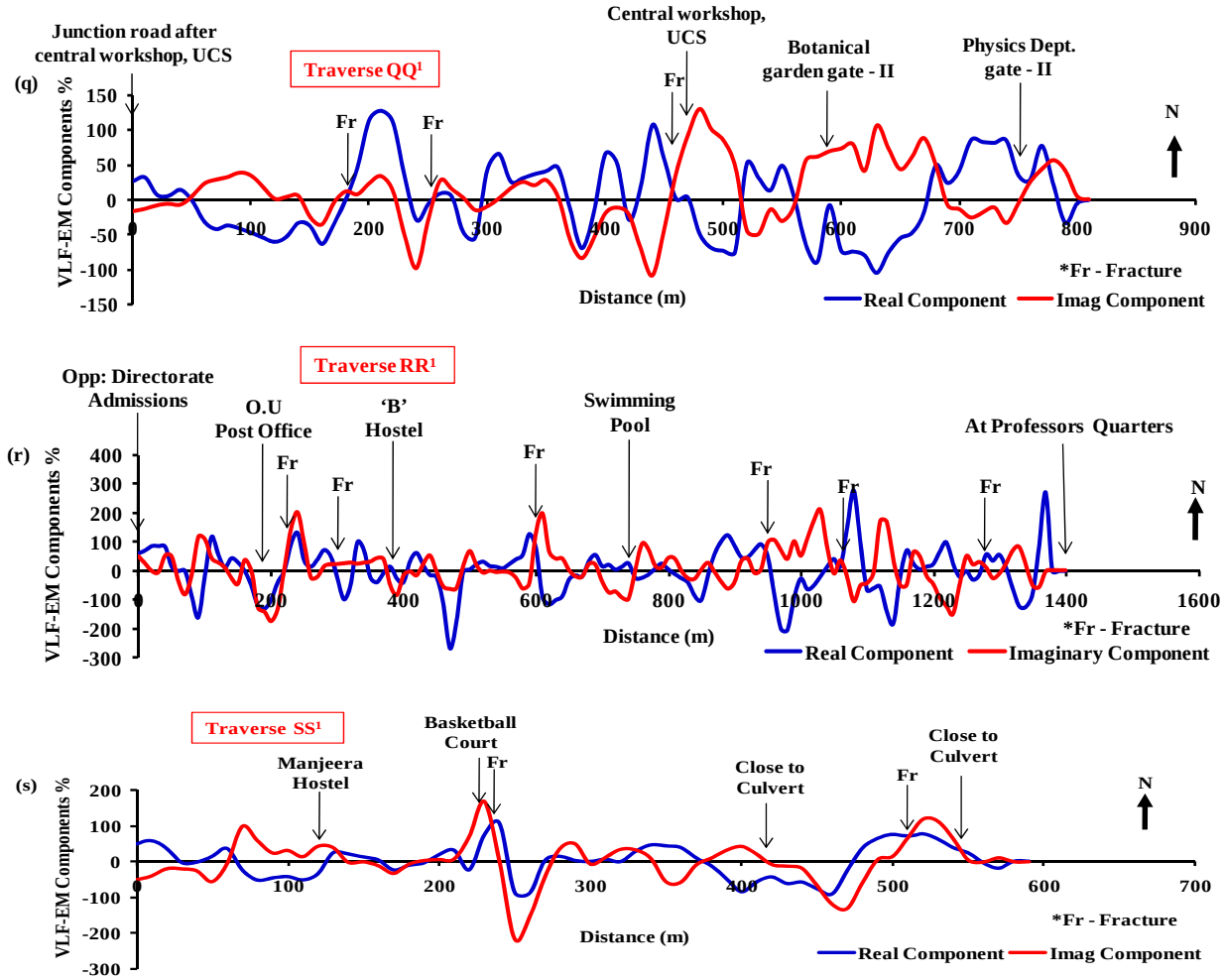


Fig 4: Continued

Table 1: VLF method Fractures details

S.No.	Traverse/Total Length (m)	Identified Fracture Locations co-ordinates		Fractures along the Traverse (m)
		Longitude in Degrees	Latitude in Degrees	
1	**AA¹(N-S)**-From UFRO to Tarnaka Junction/2000	78.52461	17.41222	500
2		78.52527	17.41335	640
3		78.52918	17.42070	1450
4	**BB¹(N-S)**-From O.U main entrance to O.U Police Station/2200	78.52347	17.40852	490
5		78.53003	17.41808	1850
6	**CC¹(N-S)**-From Behind the Genetics Dept, to Aradana Theatre/2400	78.53679	17.41352	1470
7		78.53616	17.41945	2070
8	**DD¹(N-S)**-From IPE residences to Tarnaka Junction/2430	78.54131	17.41785	1350
9		78.53754	17.42218	1950
10		78.53526	17.42283	2200
11	**EE¹(N-S)**-From Indoor Stadium Entrance to near central workshop/920	78.53627	17.42101	70
12		78.53820	17.42008	300
13		78.53857	17.41953	370
14	**FF¹(E-W)**-From Ganga Hostel to Darga/920	78.52614	17.40748	270
15		78.52635	17.40657	390
16		78.52727	17.40567	500
17	**GG¹(E-W)**-From Cafeteria to IPE/960	78.52947	17.40896	300
18		78.53042	17.40795	440
19		78.53242	17.40573	720
20	**HH¹(N-S)**-From Geography Dept. to Botanical Garden II Gate/490	78.53222	17.41386	260
21	**II¹(E-W)**-From Opposite to Law College to a road towards to O.U Press/560	78.53004	17.41288	170
22		78.53066	17.41210	230
23		78.53156	17.41080	410

24		78.53177	17.41051	450
25		78.53211	17.40992	530
26	**JJ[1](E-W)**-From Opposite to Telangana Mahila Sabha to behind the Genetics Dept., close to Darga/760	78.52133	17.40556	60
27		78.52241	17.40496	190
28		78.52381	17.40476	350
29		78.52458	17.40424	440
30	**KK[1](E-W)**-From Behind the Genetics Dept., close to Sports Hostel/730	78.52911	17.40625	300
31		78.53090	17.40746	500
32		78.53236	17.40833	710
33	**LL[1](E-W)**-From Darga to (Forest) towards to IPE road/790	78.53108	17.40515	410
34		78.53172	17.40484	490
35	**MM[1](E-W)**-From Near Darga to a road up to a point of N-S direction/560	78.53095	17.40302	240
36		78.52688	17.41054	250
37	**NN[1](E-W)**-From R Y Temple to dead of IPE residences/1560	78.53132	17.41012	700
38		78.53505	17.40831	1200
39	**OO[1](E-W)**-From O.U Darga (IPE) to Spot valuation Building/440	78.53607	17.41027	70
40		78.53880	17.41015	330
41	**PP[1](E-W)**-From Opposite to O.U Library to Maneru Hostel road/850	78.53431	17.41092	700
42	**QQ[1](E-W)**-From After Central workshop to Arts College road/810	78.53532	17.41501	170
43		78.53508	17.41445	250
44		78.53347	17.41534	460
45	**RR[1](E-W)**-Opposite to directorate admissions to Professors quarters/1400	78.52860	17.41832	240
46		78.52904	17.41852	300
47		78.53116	17.42015	600
48		78.53399	17.42000	950
49		78.53495	17.41959	1060
50		78.53669	17.41906	1280
51	**SS[1](N-S)**-From Near Shivalayam to Indoor Stadium/590	78.53293	17.42101	240
52		78.53510	17.42052	510

6. Real and Imaginary Components

A popular method of presenting traverse data along single or parallel traverses is by drawing the graphs of the parameters measured against the locations. In the present study area, nineteen (19) traverses are available maps of the variation in parameters are constructed showing by means of contours the locations of anomalous points. During the record of data and under the field conditions data have been affected by noise hence applying the Fraser filter and noise has been removed. Real and imaginary data has plotted as contours shown in the Figures 5 and 6. These Figures representing lateral and vertical variation in conductivity when the conductivity of the source of the interest is more than that the adjoining the rocks, positive real anomalies are observed. It is possible to demarcate the approximate boundary conductive and nonconductive bodies. It is interesting to know that where real and imaginary both positive indicating the conductive fracture zones.

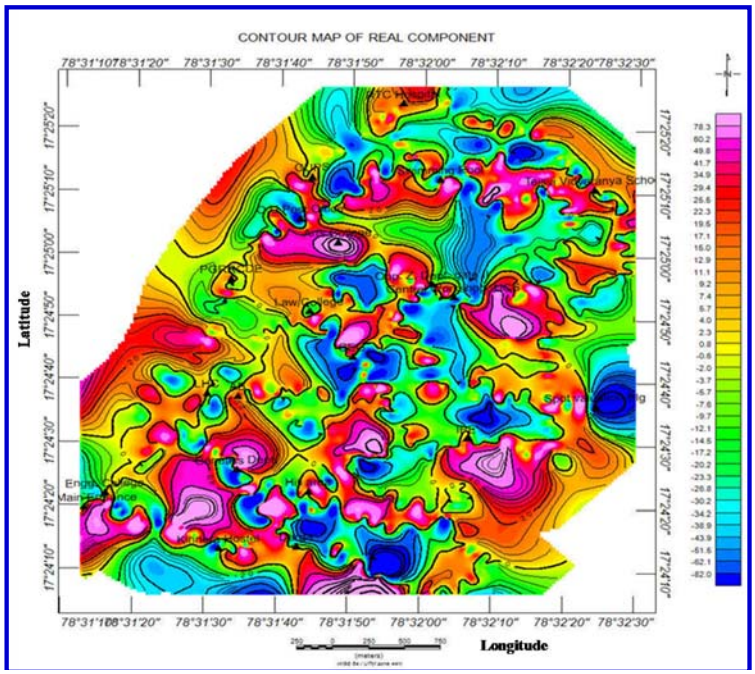


Fig 5: Contour map of Real Component (Contour Interval 2.5)

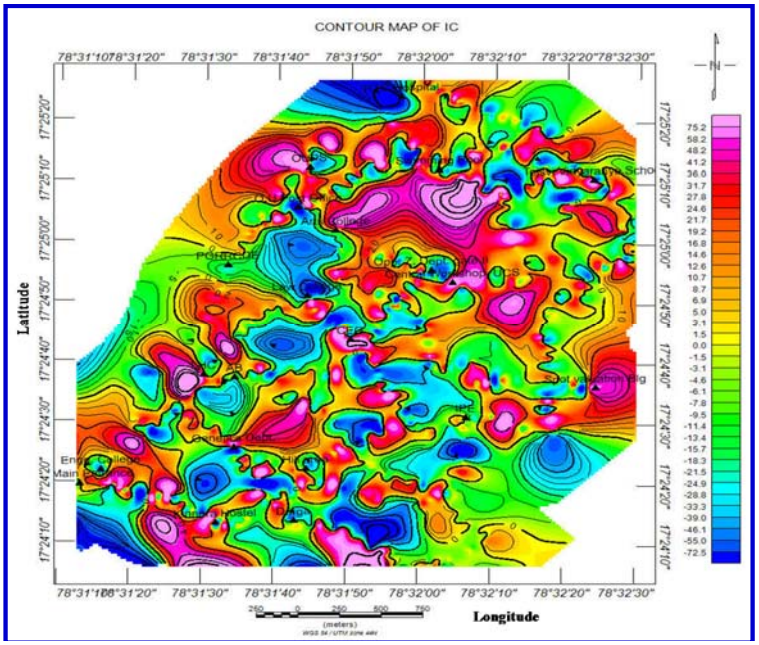


Fig 6: Contour map of Imaginary Component (Contour Interval 2.5)

7. Analytical Signal

The amplitude of the analytical signal gives a symmetrical curve and in general attains its maximum exactly over the origin of regular geometrical structures (Sinha 2003, Sundararajan and Srinivas 1996. and Lazarus *et al*., 2013) [13, 14, 15], however, the peak of the amplitude corresponds to the origin for all structures. For VLF-EM anomaly, if f(x) is the in-phase component and H(x) its Hilbert transform, then the analytical signal can be expresses as

$$A(x) = f(x) - iH(x) \qquad \ldots (2)$$

Whereas H(x) = {IF (w) Cos (wx) – RF (w) Sin (wx) z}dw, RF (w) and IF (w) are real and imaginary part of the Fourier transform off(x) expresses as

F (w) = f(x) e dx = RF (w) – iIF(w)

and the amplitude of the analytical signal is

$$AA(x) = f(x)^2 + H(x)^2 \qquad \ldots (3)$$

When the filter is apply to the real component data aimed at simplifying the fact that conductive bodies have positive and negative peak associated with, it may take difficult to determine the exact location of the positive conductive body, instead of this N-S and E-W trends have been observed. This function and it derivatives are independent of the strike, dip conductive bodies.

The VLF data Figure: 7, the range from 0.1 to 5.3, the area is marked by both high and low conductive closures which could be attributed to several factors such as

1) variation in depth to difference in conductivity
2) difference in lithology
3) degree of strike. Several trends within the study area are N-S and E-W, are observed, and are Figure: 6 high-frequency signatures are observed at the northern and southern portion of the study area.

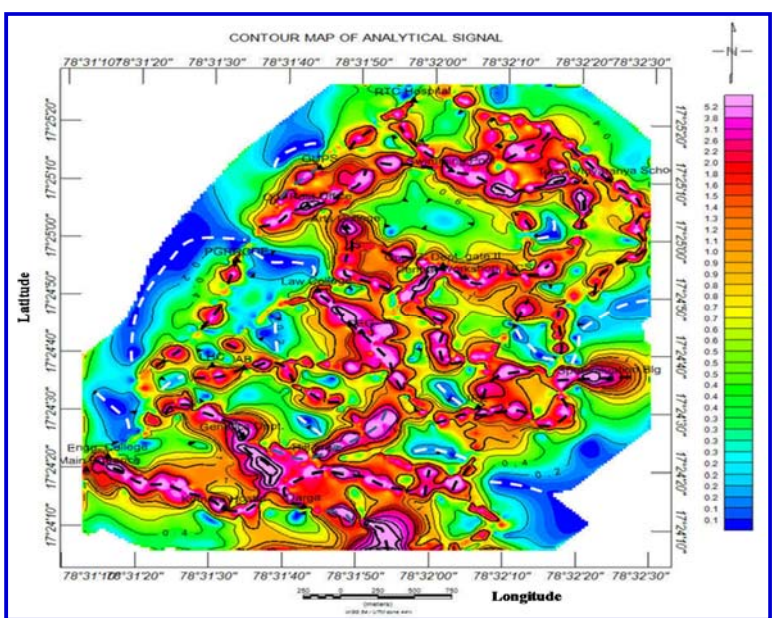


Fig 7: Contour map of Analytical Signal of Real Component (Contour Interval 0.1)

8. Tilt Derivative

The tilt derivative, first reported in 1994 and more recently used to derive the local wave number (1997), it will show that the combination of the tilt derivative and its total horizontal derivative are highly suitable for mapping shallow basement structure and mineral exploration targets and that they have distinct advantages over many conventional derivatives.

The tilt derivative opting calculates the tilt derivative of a grid and optionally, the total horizontal derivative of the tilt derivative grid using the convolution method saves a lot of processing memory and time.

The tilt derivative is defined as:

$$\textbf{TDR} = tan^{-1}\left(\frac{VDR}{THDR}\right)\ldots \qquad (4)$$

Where VDR = First vertical derivative

THDR = Total horizontal derivative

$$\textbf{VDR} = \frac{dT}{dZ}\ldots \qquad (5)$$

$$\textbf{THDR} = \sqrt{\left(\frac{dT}{dX}\right)^2 + \left(\frac{dT}{dY}\right)^2}\ldots \ (6)$$

The total horizontal derivative of the tilt derivative defined as

$$\textbf{HD-TDR} = \sqrt{\left(\frac{dTDR}{dX}\right)^2 + \left(\frac{dTDR}{dY}\right)^2}\ldots \ (7)$$

The results of the tilt derivative shown in Figure: 8 narrow over merging for minimum and maximum values of tilt, therefore, the edges of real anomalies are better resolve and the tilt derivative, shows the structured fabric of the region, this special distribution of aquifers and VLF real data highs and lows are demarcated.

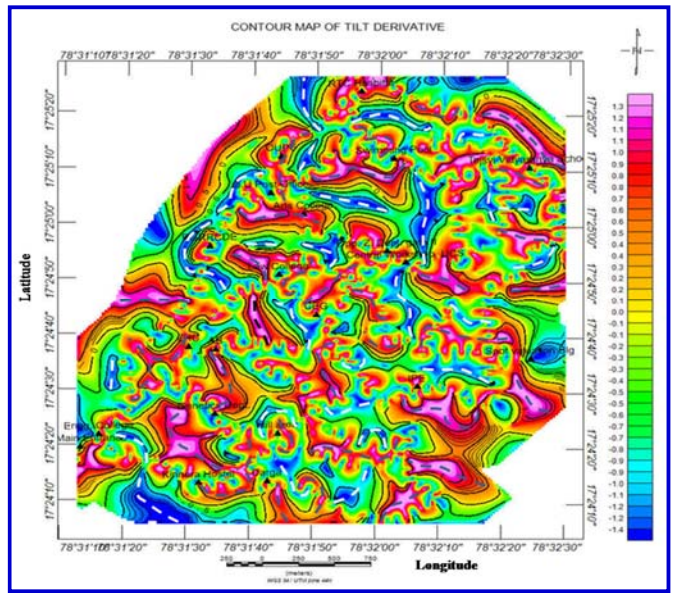


Fig 8: Contour map of Tilt Derivative of Real Component (Contour Interval 0.1)

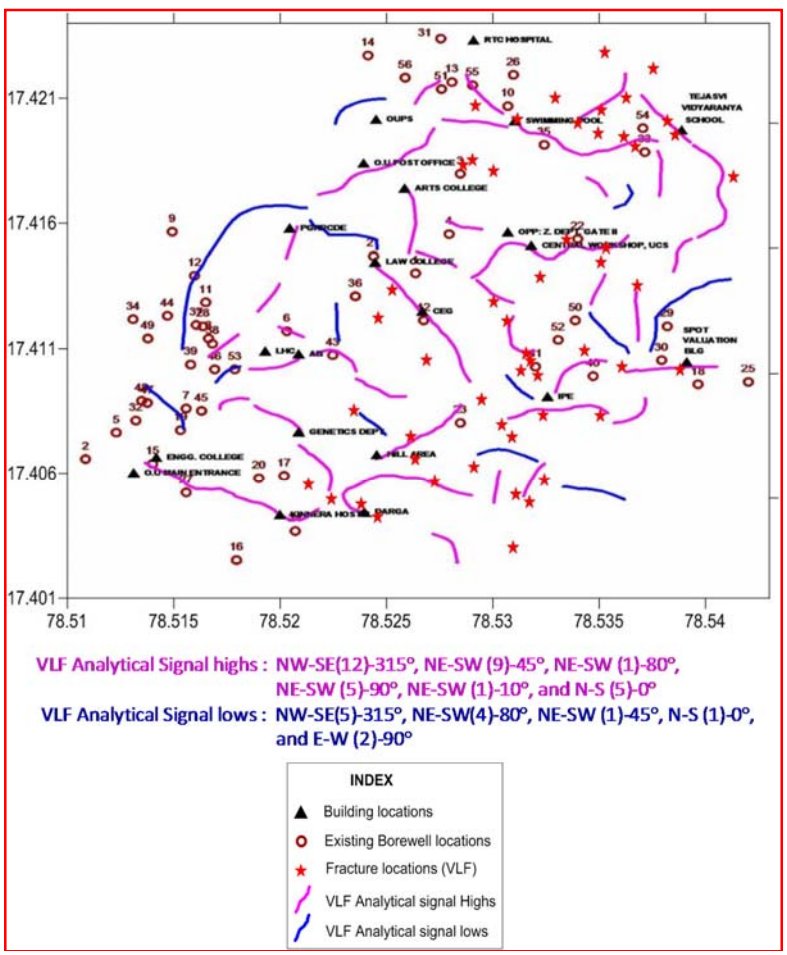


Fig 9: Map of VLF Analytical Signal lineaments with Fracture locations

9. Conclusions

An attempt has been made to identify groundwater potential zones in hard rock terrain in Osmania University Campus. Very Low Frequency (VLF) electromagnetic survey has been conducted in this study for the purpose of delineating subsurface features in the study area, Osmania University Campus. A total of nineteen (19) VLF - EM profiles are acquired using ABEM WADI VLF instrument at every 10m interval. The VLF-EM result mapped shallow linear conductors that are suspected fracture zones of varying length in the area.

The VLF-EM techniques as clearly demarcated the fracture system associated with crossover points at positive amplitude peaks of filtered real and imaginary components along the traverses shows 52 fracture zones were delineated in the study region, which are capable of holding significant quantity of groundwater. These zones were shown in table: 1 and presented in figure 9. A qualitative analysis of VLF-EM data of real and imaginary are subjected to gradient techniques to identify structural trends as well as groundwater potential zones in the O.U campus granitic terrain Hyderabad, mapping of the fracture points following the same trends.

10. Acknowledgment

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11. References

1. Balakrishna S. Raghava Rao M., Pink and grey granites Hyderabad, Current Science, 1961; 30:264.
2. Sitaramayya S. Structure, Petrology and Geochemistry of Granites of Ghatkesar, A.P., and Ph.D. Thesis (unpublished), Osmania University, Hyderabad, 1968.
3. Sitaramayya S. The Pyroxene Bearing Granodiorites and Granites of Hyderabad Area, (the Osmania Granites): Quarterly Journal of the Geological, Mining and Metallurgical Society of India. 1971; 43:117-129.
4. Udaya Laxmi, Ramadass, Environmental studies & Groundwater Quality Assessment Approach through integrated studies in parts of Hyderabad, A.P, India, International Journal of Advances in science and technology, 2013; 6(4):85-102.
5. Kelly WE, Mares S. Applied geophysics in hydrogeological and engineering practice, Elsevier, Amsterdam, 1993, 289.
6. Koefed O. Geosounding principles, I-Resistivity Sounding Measurements, Elsevier, Amsterdam, 1979, 276.
7. Parasnis DS. Methods in Geochemistry and Geophysics, 3, the mise-a-la-masse method, Mining Geophysics, 2nd revised edition, 1973, 195-202.
8. Zohdy AAR. Earth resistivity and seismic refraction investigations in Santaclara country, California: Ph.D dissertations, Stamford University, Publ. by University Microfilms, A Xerox company, Ann Asbar, Michigan, U.S.A, 1964.
9. Zohdy AAR. The auxiliary point method of electrical sounding interpretation and its relationship to Dar Zarrouk parameters. Geophysics, 1965; 30(4):644-660.
10. Zohdy AAR. Automatic interpretation of Schlumberger sounding curves using modified Dar Zarrouk functions. Geological Survey Bulletin 313E, Washington, 1975.
11. Srigutomo W, Harja A, Sutarno D, Kagiyama T. VLF data analysis through transformation into resistivity value: Application to synthetic and field data, Indonesia Journal of Physics. 2005; 16(4):127-136.
12. Fraser DC. Contouring of VLF-EM data: Geophysics, 1969; 34(6): 958- 967.
13. Sinha PK, Surenendra Nath M, Sikhendu De, Murlidharan PK, Ravi Shankar Misra. A GIS approach in mineral targeting with Narayanpet Kimberlite spatial dataset. Presented at the Map India Conference, 2003
14. Sundararajan N, Srinivas Y. A modified Hilbert transform and its applications to self-potential interpretations. Journal of Applied Geophysics. 1996; 36:137-143.
15. Lazarus G. Ndatuwong, GS Yadav. Analysis and Interpretation of In-Phase Component of VLF-EM Data using Hilbert Transform and the Amplitude of Analytical Signal. Journal of Environment and Earth Science. 2013, 3(11).