IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 9, Issue 3 Ser. II (May – June 2021), PP 31-37
www.iosrjournals.org

Identifying Potential Aquifers Using Landsat Images, Aeromagnetic And Resistivity Responses In Panyam, Plateau State, Nigeria

Umbugadu A A[1] & Ancho M I[2]
Department of Geology & Mining,
Nasarawa State University, Keffi

Abstract
The study involves delineation of aquifers in Panyam and its environs, North Central Nigeria. This study can serve as a useful guide for groundwater development projects which may be put in place to cater for water needs of dwellers. Methods employed include; geological mapping of the area, field acquisition of electrical resistivity data using 1D vertical electrical sounding of nine (9) stations, acquisition of aeromagnetic data and interpretations of total magnetic intensity (TMI) maps, as well as analysis of lineaments generated from remotely sensed aerial photographs of the area. Exposed in the study area are basement rocks comprising of granitic gneisses, basalts and granites with evidence of deformation shown as joints, fractures and veins in places. Interpreted resistivity data shows a three layer case for VES 1 to 5, comprising of topsoils, weathered regoliths and fresh basement with resistivity ranges of 321 Ωm to 1572 Ωm, 126 Ωm to 365.1 Ωm and over 290000 Ωm respectively. VES 6 to 9 comprise of five layers, with the presence of a fractured zone, with resistivity range of 59.4 Ωm to 676 Ωm. The weathered and fractured layers constitute the aquiferous units in the area with the fractured zone being the main aquifer, owing mainly to its appreciable thickness of up to 30 to 50 m. TMI maps classify the study area as a magnetic high area, showing evidence of uplift in surrounding basement rocks which could have lead to the development of structures as depicted by abundance of NE-SW trending lineaments derived from aerial photographs. The occurrence of lineaments correlates with electrical resistivity data, which points to deep sited fractures as main aquifers in the area. Based on the study, the area has moderate to high groundwater potential. Groundwater exploitation in economic quantity will be more feasible for fractured aquifers at depths of up to 30 to 50 m.
Keywords: *groundwater, aquifer, resistivity, fractures, magnetic susceptibility*

Date of Submission: 08-06-2021 Date of Acceptance: 21-06-2021

I. Introduction

Groundwater constitutes one of the main sources of fresh water for consumption and other vital uses. In Nigeria, there are about 200 million people and a vast number of this population in both rural and urban areas depend on the availability of groundwater for their day to day life and as time passes by, demand increases (Healy et al, 2020). Unfortunately, groundwater is a scarce resource because it is not accessible everywhere, hence the need for a deliberate and focused scientific exploration of the resource to help provide precise drilling points thereby preventing wasteful abortive drillings which could result to waste of resources and may cause some adverse effect on the earth.

The aim of this study is to delineate aquifers from which potable groundwater can be exploited to cater for the dare water needs for inhabitants of Panyam and its surrounding areas. Electrical resistivity survey method has been extensively used as a viable tool in identifying suitable aquifer locations beneath the surface owing to its ability to detect difference in resistivity of various rock formations and structural conditions (Battacharya, 1968 & Melanchthon, 1988). Magnetic methods of geophysics have also proven to be helpful in groundwater exploration. Air borne magnetic data are processed and interpreted to portray the occurrence of structures in rocks which are crucial to the occurrence and distribution of groundwater in rocks (Oni *et.al,* 2020).

The study area forms part of the Pankshin Sheet 190 NE, North Central Nigeria. It is precisely sited within latitude 9°21'0"N to 9°26'0"N and longitude 9°11'0"E to 9°16'0"E (Figure 1), covering an area extent of about 72 km^2. Highest points within the study area stands at 1240 ft appearing as hills, while lowest points have elevation values of 1100ft (Figure 1). The area is drained in a dendritic pattern by several minor streams. It is interconnected with major towns such as Bokkos, Shendam and Barkin Ladi through a number of major roads. Foot paths linking various adjourning locations also abound.

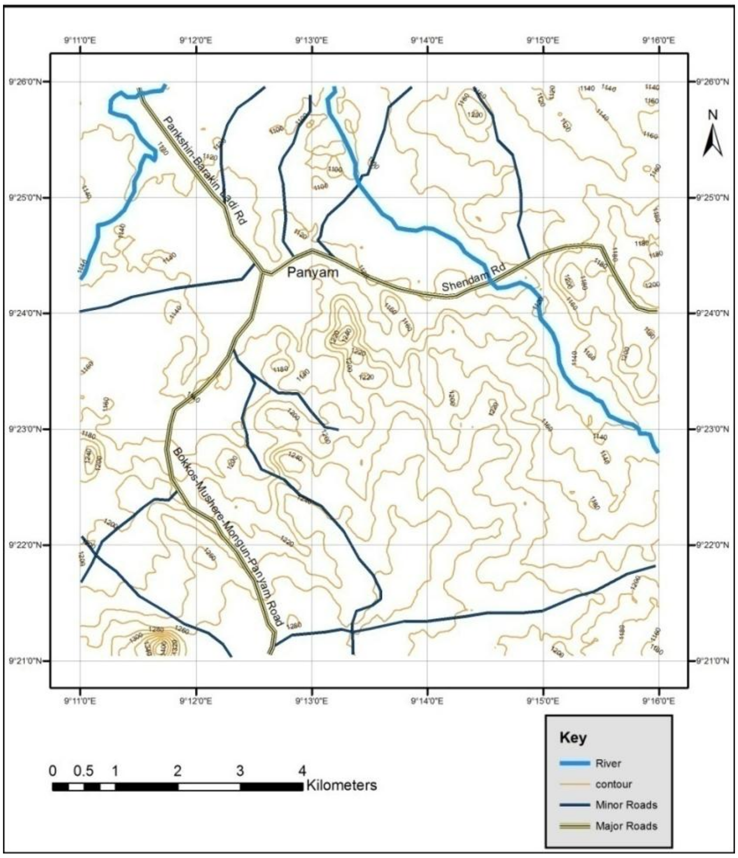

Fig. 1: Location, Relief and Drainage Map of Study Area

II. Materials And Methods

This research incorporates acquisition, processing and interpretation of landsat images, geo-electrical resistivity and aeromagnetic data as well as field geological investigation to depict the presence of structures and depth of various geological formations beneath the ground surface, with specific target being the aquiferous zones. Geological mapping was achieved by traversing the area on foot and observing the rocks megascopically at locations where they are exposed. Such locations were plotted on a base map, alongside measurements of joint trends, strike and dip values, amount of displacement of minor faults as well as trends and approximate extent of exposures among other features. The electrical resistivity survey data was acquired using the Schlumberger field configuration to carryout 1D vertical electrical sounding (VES) of nine (9) points spread evenly across the study area (Figure 2). Data were acquired by the use an Omega Ohms Terrameter on which wires were connected for transmission and retrieval of electrical signals. Current is sent into the ground by connecting wires to the top of a pair of current electrodes hammered into the ground. Different values resistance for various underground units are picked as signals and transmitted onto the screen of the Terrameter through wires connected to a pair of potential electrodes also hammered into the ground. The process is repeated for each current electrode spacing (AB/2) and potential electrode spacing (MN/2) on a profile until the desired distance is attained where the survey terminates. A distance of 100 m was used in this study. The apparent resistivity data acquired from the survey were interpreted using the WINRESIST software which has been widely employed in groundwater geophysical studies. Remotely sensed LandSat images covering Panyam and its environs were acquired and processed to produce a lineament map of the area using the Arc GIS 10.3 software.

High resolution aeromagnetic data employed for this research are subset of data acquired in 2006 and 2007 by Fugro Surveys for the Nigerian geological survey Agency (NGSA). The data were obtained along a 80 m high, NW-SE flight trend. The following corrections were done on the data:

a. Removal of the geomagnetic gradient using standard model of the International Geomagnetic Reference Field (IGRF) with respect to World Geodetic System 1984 ellipsoid.

b. Georeferencing of data using UTM (Universal Transverse Mercator) coordinate system.

c. Gridding of data using bi directional gridding technique (Akima, 1970; Geosoft Inc., 2012a).

Further processing of the corrected aeromagnetic data involved the production of a total intensity map for the study area by the use of Oasis Montage soft.

III. Results and Discussions

a. Geology

Panyam and surrounding areas studied are part of the Basement Complex of Nigeria, consisting of the Migmatite-Gneiss Complex, Schist Belts, Older Granites Suits and other minor rock units. Rock units particularly present in the study area includes: basalts (older and newer basalts), biotite granites and granitic gneiss. Major structural trend of joints and fractures in the area trends in the NE-SW direction, which is in tandem with the major structural trend of basement rocks in Nigeria as outlined by Rahaman 1988. Biotite granite, rising to a height of about 1200 ft intrudes into the gneiss and basaltic rocks on the south eastern portion of the area mapped around Nyes (Figure 2). It is expected that the aquifers in the area should exhibit secondary porosity; derived from structures present in the rocks.

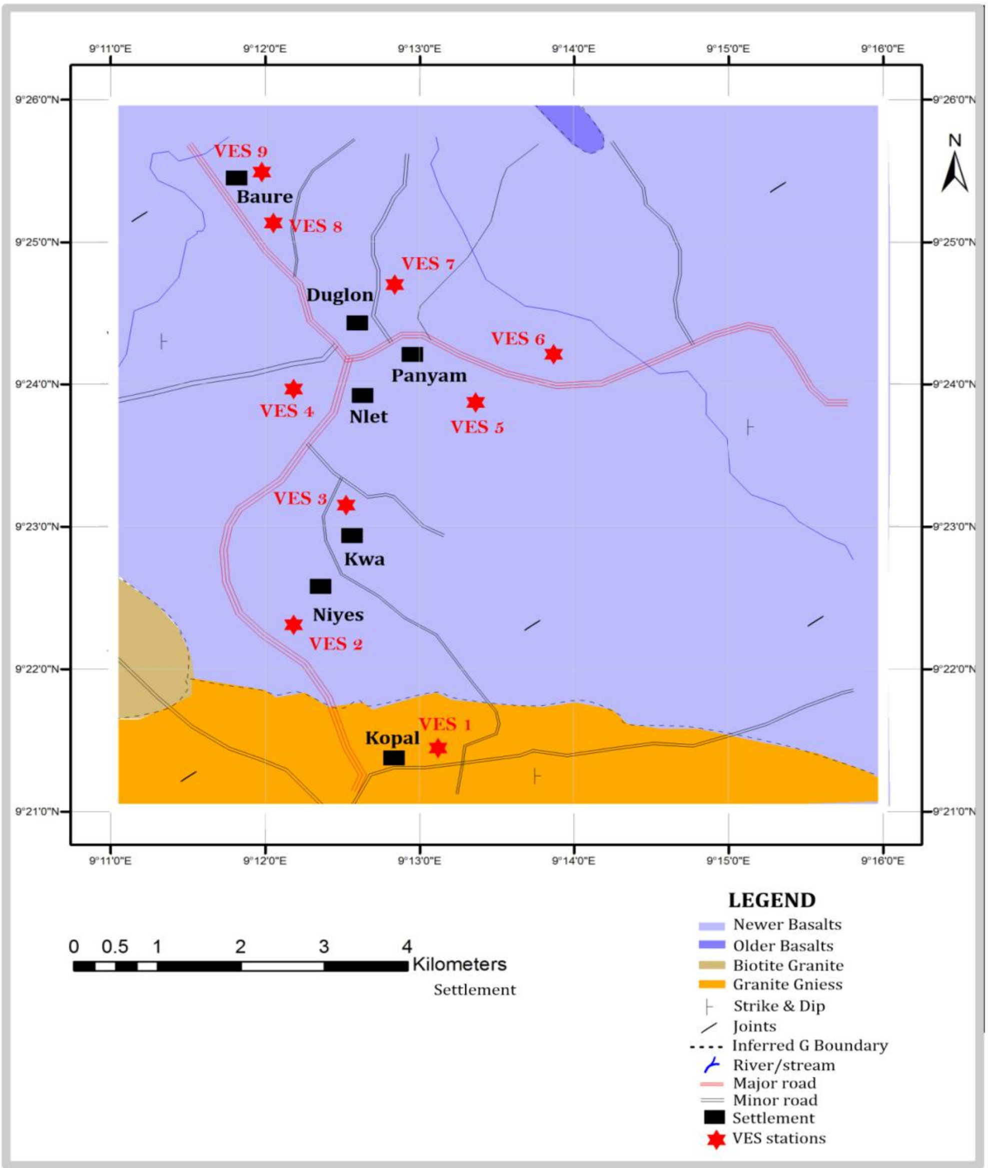

Figure 2: Geological Map of Panyam and its environs

b. Aeromagnetic Data

Figure 3 indicates the Total Magnetic Intensity (TMI) map of Panyam and its environs. This depicts the variation in magnetic susceptibility of rocks in the area (Boubaya, 2017). For the study area, as observed on the map (Figure 3), the area can be classified as magnetically high, with a value range of 1090 to 1437 Tesla. Qualitatively, these high areas correspond to typical basement terrains (Joel *et al*, 2016) which in the case of this study comprises of the granitic gneiss at the southernmost portions and predominantly basalts covering over

75% of the total area, to the north. TMI patterns follow a similar fashion with the geology of the area (Fig 2), pointing out that basaltic rocks, dominant in the area are less susceptible compared with the gneisses.
The occurrence of a wholly positive anomaly indicates that basement rocks in the study area has probably undergone uplift, thereby inducing faulting which is evident in the occurrence of multiple fractures in rocks. Also, it is likely that the uplift of the granitic intrusion on the south-western portion of the area triggered deformation, leading to the formation of structures that would serve as groundwater aquifers.

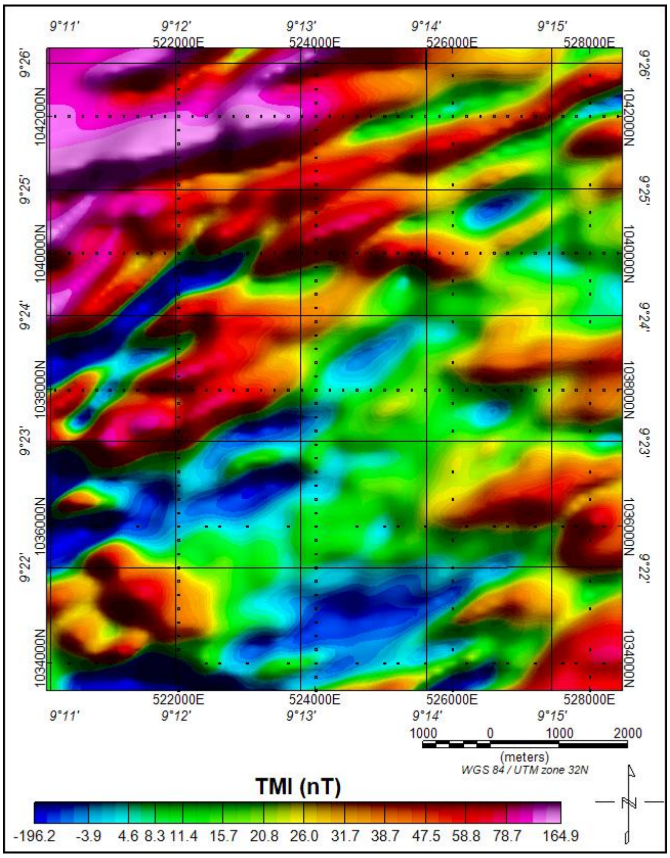

Figure 3: Total Magnetic Intensity (TMI) map of Panyam and its enivirons

c. Resistivity Data

Nine VES points were sounded within the research area. VES 1 - 5 were taken in Nyes and its environs while VES 6 – 9, around Panyam, Duglon and other adjoining areas. Interpreted result of the geo-electrical soundings is presented in table 1. On the basis of geo-electric units detected, the area generally consists of shallow top soils, which are lateritic in nature with depth range of 1.12m to 2.97m with varying resistivity values ranging between 321 to 1572 Ωm; weathered regoliths layer with depth range of 4.08m to 7.43m and corresponding resistivity range of 126 to 365.1 Ωm. At this layer, groundwater could be exploited via shallow hand dug wells. However, water at this depth range may not be sustainable in terms of quantity. The fractured layer over the study area ranges in depth from 10 m to 50 m with corresponding resistivity range of 59.4 to 676Ωm. This constitutes the main aquifer from where groundwater can be obtained in economic quantity. The fresh basement layer extends downward as from 50m with resistivity values reaching 29000 Ωm. VES 1 to 5 constitute a three layer case, with weathered zones constituting the main aquifers. VES 6 to 8 constitute a six layer case, with thick fractured layers constituting a more prolific aquifer. VES 9 consists of six layers, also bearing the fractured layer as its main aquiferous zone. Probable rock units may include highly fractured/jointed basalts or granitic gneiss. For optimum groundwater derivation in the study area, it will be more feasible for VES 6 to 9 as compared with VES 1 to 5, which are shallow and of less economic quantity.

Table 1: Interpretated Geo-electric Data

VES	Layers	Resistivity (Ωm)	Curve Types	Layer Thickness (m)	Depth (m)	Lithology
1	1	861	H	2.15	2.15	Top soil/Laterite
	2	126		1.93	4.08	Weathered Regoliths
	3	290000		∞	∞	Basement
2	1	321	Q	1.538	1.538	Top soil/Laterite
	2	3527		4.105	5.643	Basement
	3	15953		∞	∞	Crystalline Basement
3	1	1181	H	2.965	2.965	Top soil/Laterite
	2	175.6		3.451	6.416	Weathered Regoliths
	3	2026		∞	∞	Basement
4	1	1572	H	2.281	2.281	Top soil/Laterite
	2	166.3		1.6972	4.254	Weathered Regoliths
	3	1329		∞	∞	Basement
5	1	1112	H	0.2943	0.2943	Top soil/Laterite
	2	365.1		3.258	3.553	Weathered Regoliths
	3	3047		∞	∞	Crystalline Basement
6	1	23.2	HK	1.4	1.4	Top soil/ laterite
	2	11		4.64	4.64	Clayey laterite
	3	170		0.98	7.02	Weathered layer
	4	11799		16.9	23.9	Crystalline Basement
	5	676		Infinity	Infinity	Fractured layer
7	1	28.4	HK	1.73	1.73	Top soil/ laterite
	2	6.63		1.94	3.66	Clayey laterite
	3	281		1.5	5.17	Weathered layer
	4	90705		0.67	5.83	Crystalline Basement
	5	59.4		Infinity	Infinity	Fractured layer
8	1	2.58	AH	1.12	1.12	Clayey laterite
	2	34.5		3.29	4.40	Laterite
	3	10957		2.09	6.05	Crystalline Basement
	4	395		43.5	50.00	Fractured layer
	5	554		Infinity	Infinity	Fractured layer
9	1	328	HA	1.16	1.16	Top soil
	2	37.22		6.27	7.43	Weathered layer
	3	503		1.46	8.89	Fractured layer
	4	10491		15.04	23.92	Hard Basement
	5	12518		26.08	50.00	Fresh basement
	6	16554		Infinity	Infinity	Fresh basement

d. Landsat Imagery

To complement geophysical assessments, RGB 742 remotely sensed photograph of Panyam and its environs (Figure 5) was processed to portray lineament density and orientations. The lineament density map of the area is shown in figure 5.

Lineaments have proven to be a reliable tool in deciphering underground structures due to their correspondence in most cases with subsurface structural features which may have some form of external surface expression (Caran *et al* 1981, Selvarani *et al,* 2016, & Ilugbo *et al,* 2017). Usually, they are pictured as patterns of stream flow, vegetation, topography, etc (figure 4). The patterns of appearance of these features may be influenced by a buried structure, such as a joint. Several previous works have shown a correlation between lineaments and underground structures. From figure 5 below, Panyam and its adjoining area are dominated by a NE-SW trending fractures with very few showing a NW-SE trend. The presence of interconnected fractures indicates good permeability which favours groundwater movement in pore spaces. This means that the fractures may be quite deep sited and further corroborates why the fractured layers depicted from resistivity data were seen at higher depths of up to 50 m and are said to constitute the main aquifers in the area owing from high interconnectivity of pore spaces.

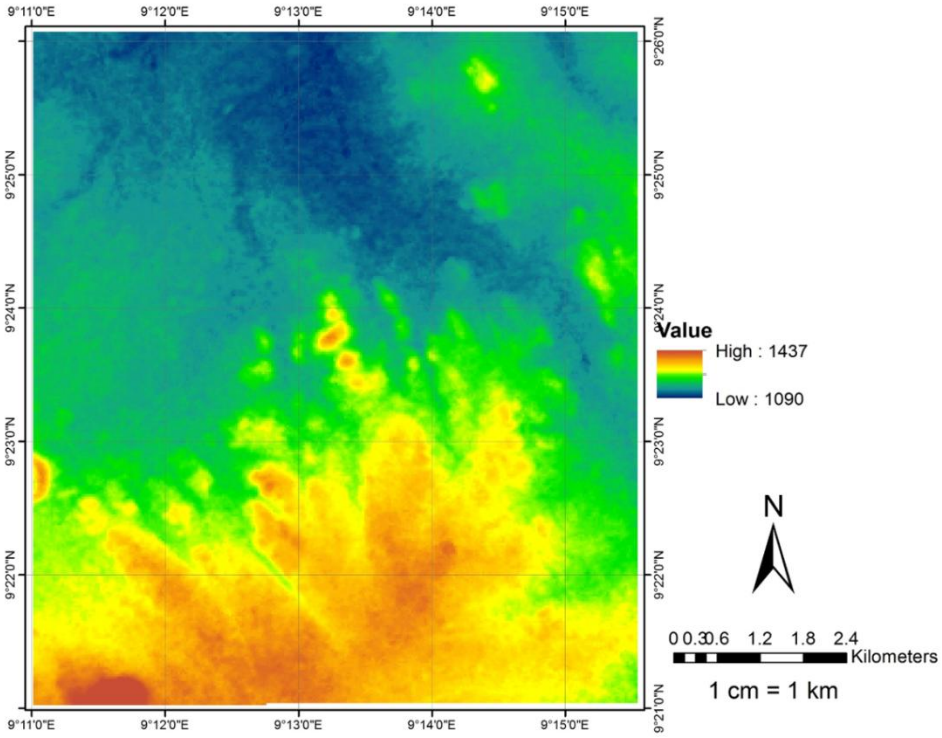

Figure 4: RGB 742 LANDSAT image of the Study area

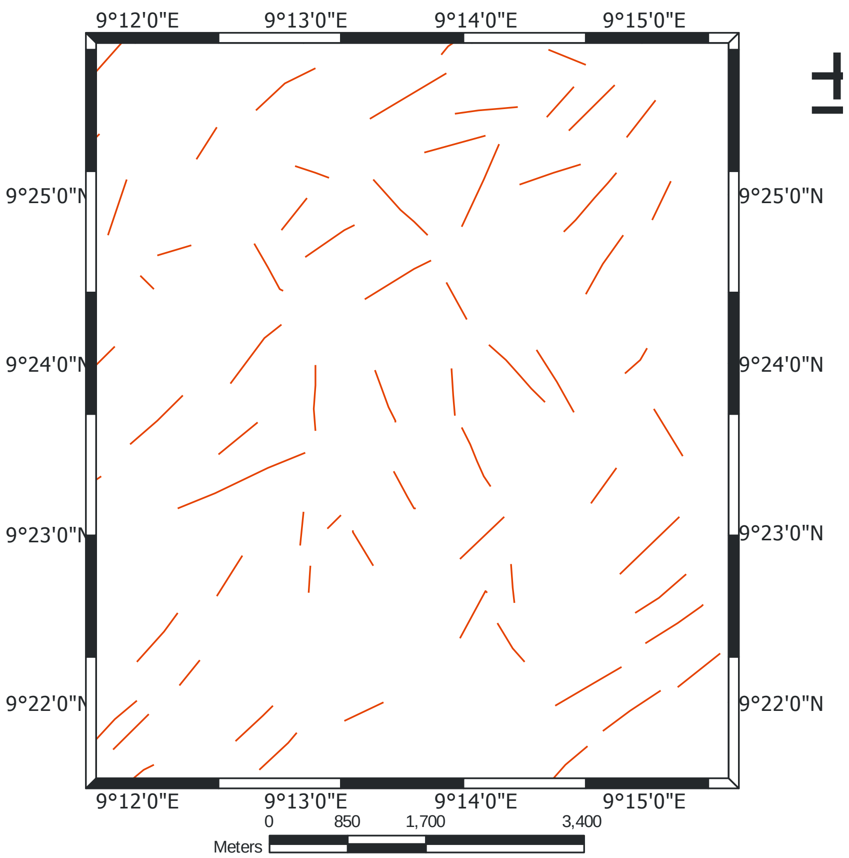

Figure 5: Lineament density map of Panyam and its adjoining areas

IV. Conclusions

This study portrays the usefulness of resistivity data and lineament patterns, coupled with geology and aeromagnetic maps in identifying aquifers in Panyam and its adjoining areas. Particularly, the study demonstrated that:

a. Weathered layer constitutes an aquiferous zone within the area, with shallow depths ranging between 4.08m to 7.43m and corresponding resistivity range of 126 Ωm to 365.1 Ωm. Here groundwater is obtained through shallow hand dug wells. This layer exists for all VES points sounded.

b. The thick, deep sited fractured layer constitutes the main aquifer in the study area. It layer has thickness of 10 m to 50 m, mostly around Panyam, Duglon and Baure areas, which geologically compose of basaltic rocks.

c. The study area dominantly consist of NE-SW trending lineaments, spread over it, an evidence of the occurrence of deep sited structures perceived to make up the main aquifers, as suggested by resistivity data. Total Magnetic Intensity map of the study gives indications of existence of basement rocks (granitic gneiss, basalts and granites) which have undergone some uplifts, resulting in the formation structures to serve as favourable conduits for groundwater.

d. Panyam and it adjoining areas generally have moderate to good groundwater potential. For an appreciable quantity of groundwater for industrial use, the best target should be the fractured zones, extending to a depth of 30 to 50 m

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