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The Challenges of Borehole Drilling in A Mixed (Heterogeneous) Geologic Terrain of Larding, Quaan-Pan, Plateau State North-Central Nigeria

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ABSTRACT: *The study area lies within a mixed terrain of basement (Older Granite and gneisses), and volcanic (Basalts). Vertical Electrical Sounding (V.E.S) was conducted using ABEM terrameter SAS 4000 to investigate the groundwater potentials of the area. Twenty-seven geo-electrical soundings were carried out, twelve from the mixed terrain and five from a nearby homogenous terrain for comparison. Comparative analysis showed that resistivity values from the mixed terrain were inconsistent, having highs and lows, ranging from 34.7 to 365 ohm meter, while those from the homogenous terrain were consistent, with resistivity ranging from 14.84 to 74.41 ohm meter. Eight boreholes were drilled, four each on either terrain. Drilling was easier on the homogenous terrain, with total drilled depth ranging between 30 to 35 meters, with a good yield, while a lot of challenges were encountered during drilling on the mixed terrain ranging from difficulties in penetrating through the overlying basaltic boulders to the basement, to loss of water into dry fractures, and the collapse of the drilled hole during development. Only one borehole was successfully drilled in the mixed terrain to a depth of 35 meters. The studies revealed that the area is a poor hydro-geological terrain due to its mixed geology.*

Keywords: *ABEM terrameter SAS 4000, hydro-geological, borehole, drilling and hydro-geophysical*

I. INTRODUCTION

The study area is located in Quaan-Pan Local Government Area of Plateau State, North Central Nigeria. It lies between latitudes $08^0 57'$ and $09^0 03'$N and longitudes $09^0 12'$ and $09^0 10'$ E (Fig.1). The area lies on a mixed terrain of basement (Older granite and gneisses), close to it lies a homogenous volcanic (basaltic) terrain particularly the newer basalts of the Jos Plateau which occur as cones and lava flows and are mainly built of basaltic scoria and pyroclastics (Lar and Tsalha, 2005).

There are few rivers and streams within the study area, and the area falls within the tropical Savannah environment with prolonged dry season during which all the streams are dried up, subjecting the community to serious water shortage. Thus in a effort to provide the community with potable water, various government agencies and individuals have taken strong initiatives to exploit the subsurface water for the populace which has resulted to little success due to the heterogeneous nature of the area.

The successful exploitation of basement terrain groundwater requires a proper understanding of the geo-hydrological characteristics. This is particularly important in view of the discontinuous (localized) nature of basement aquifers (Satpathy and Kanungo, 1976). Therefore, the drilling process for groundwater development in a heterogeneous terrain such as Lardang, should be preceeded by detailed hydro-geophysical investigations.

The groundwater in the basement terrain is mainly contained in the porous and permeable weathered basement zones. The groundwater yielded from the weathered horizon is often supplemented by the accumulated groundwater in the fractured and or jointed column of the basement rocks. The highest groundwater yield in basement terrains is found in areas where thick overburden overlies fractured zones (Olorunniwo and Olorunfemi, 1987 and Olorunfemi and Fasuyi, 1993). In the study area, the overburden is usually less than 1m thick. The electrical resistivity method is one of the most relevant geophysical methods applied in groundwater investigation in the basement terrain (Ako and Olorunfemi, 1989; Limaye 1989; Owoade and Moffat 1989,). The relevance of the method is based on the usually significant resistivity contrast between the weathered zone and or fractured column and the very resistive fresh bedrock (Olorunfemi and

Fasuyi, 1993). The development of groundwater in Lardang is beset with problems of failed (abortive) hand dug wells and boreholes arising from poor knowledge of the hydro-geophysical characteristics of the heterogeneous basement aquifers. To provide background information for future groundwater development as a way of reducing cases of borehole failures, a hydro-geophysical investigation of the area was conducted using the electrical resistivity method.

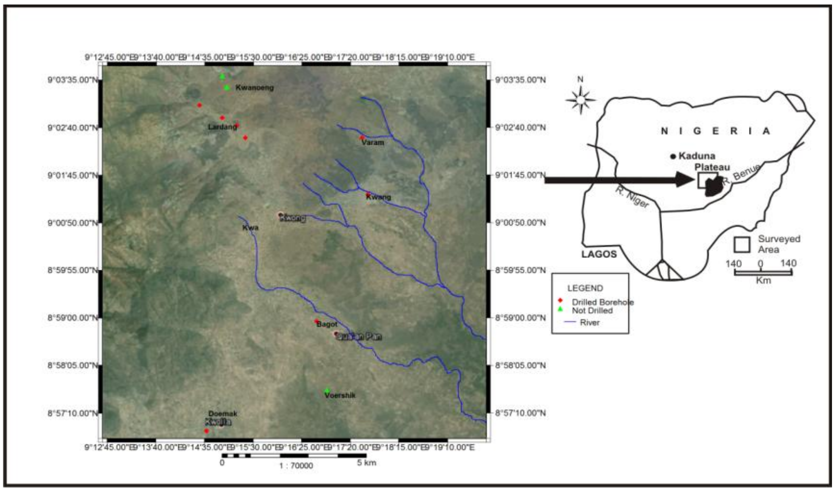


Fig. 1. Location map of the study area showing geophysical surveyed stations

II. Materials And Methods

A total of twenty-seven (27) Vertical Electrical Sounding (V.E.S) was conducted using ABEM Terrameter SAS 4000 to investigate the groundwater potential of the area, involving the Wenner electrode array. Field data were obtained from eleven (11) points which was interpreted using manual curve matching and IPI2WIN computer software. Six (6) of the points investigated were on the heterogenous terrain, while the other five (5) were on the homogenous basaltic terrain for comparison. Eight (8) boreholes were drilled four (4)each on either terrain using an India drilling machine (Rig) employing air drilling method from surface simply because of the thin overburden in this area, less than 1m in all cases.

1.2 Geology

The area is underlain by the Pre-Cambrian basement complex rocks of Nigeria which was intruded by the newer basalts of the Jos Plateau in the Cenozoic (Wright, 1985). The identified lithological limit includes Older Granite, gneisses with few occurrences of pegmatites, basalt in form of boulders scattered on the surface (Fig. 2).

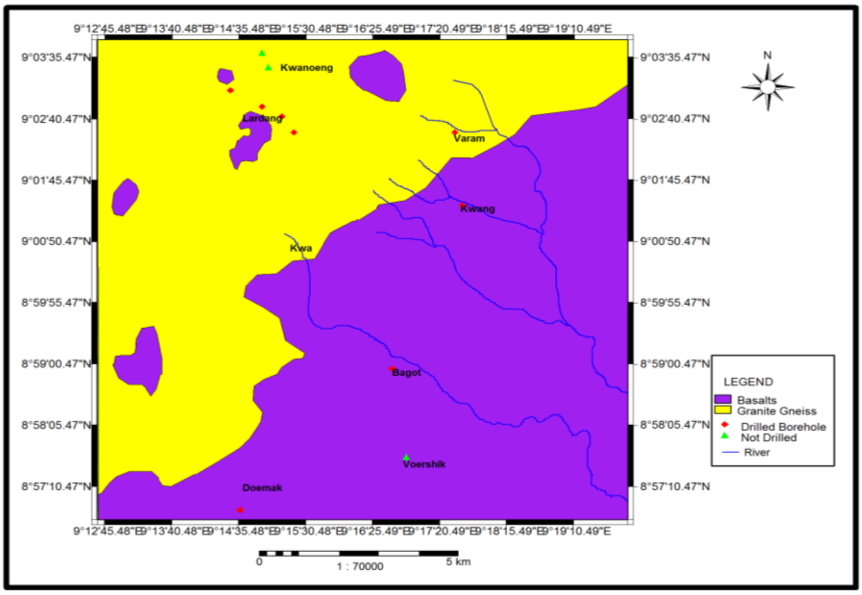


Fig.2 Geologic Map of the surveyed area

III. Results and Discussion

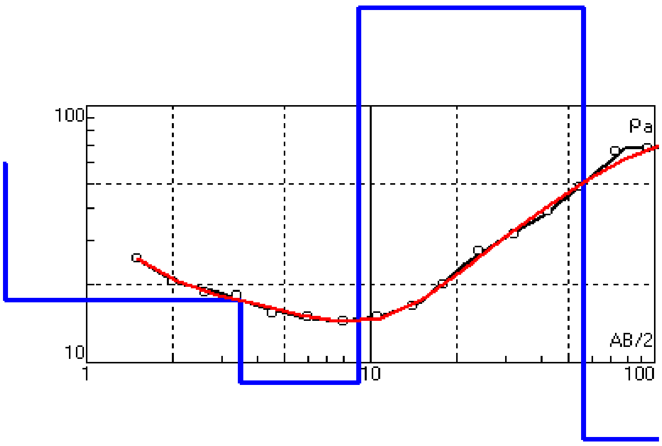
The points investigated are presented in table 1 and the interpreted resistivity values and curves are presented below.

Table 1. Investigated points

S/No	Locality and coordinates	Drilling depth	Result
1	Lardang 1 N $09^0$02'.846" E N $09^0$14'.939" Elevation 454m	70m	Collapsed
2	Lardang 2 N $09^0$02'.940" E $009^0$14'.705" Elevation 469m	40m	Abortive
3	Lardang 3 N $09^0$02'.475" E$009^0$15'.342" Elevation 432m	40m	Abortive
4	Kwanoeng 1 N $09^0$03'.049" E$009^0$14'.499" Elevation 476m	35m	Good yield
5	Kwanoeng 2 N $09^0$03'.650" E$009^0$14'.425" Elevation 432m	Not drill	-
6	Kwanoeng 3 N $09^0$03'.437" E$009^0$14'.971" Elevation 424m	Not drill	-
7	Varam N $09^0$02'.490" E$009^0$17'.532" Elevation 327m	30m	Good yield
8	Kwang N $09^0$01'.380" E$009^0$17'.638" Elevation 319m	30m	Good yield
9	Bogot N$08^0$58'.959" E$009^0$16'.655" Elevation 319m	30m	Good yield
10	Doemak N $08^0$56'.837" E$009^0$14'.599" Elevation 310m	35m	Good yield
11	Voershik N $08^0$57'.587" E$009^0$16'.584" Elevation 320m	Not drill	-

Comparative analysis from the above results shows that the resistivity values from the mixed terrain were inconsistent, having highs and lows ranging from 34.7 to 365 ohm meter, while those from the homogeneous terrain were consistent, with resistivity ranging from 14.84 to 74.41 ohm meter. Drilling was easier on the homogeneous terrain, with total drill depth ranging between 30 to 35m with good yield, while a lot of challenges were encountered during drilling on the mixed terrain ranging from difficulties in penetrating of the drill bit through the overlying basaltic boulders to the basement, to loss of water into dry fractures, and the collapse of the drilled hole during development.

Bogot

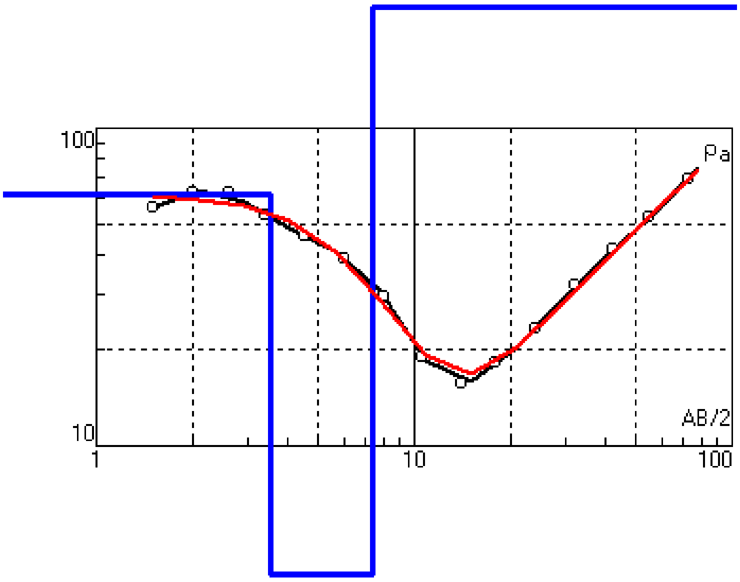


Model	
D	Ro
0.5	59.7
0.434	59.7
0.434	17.5
3.504	17.5
3.504	8.42
9.034	8.42
9.034	251
56.434	251
56.434	5.02
169.3	5.02

Field curve	
AB/2	App.Resistivity
1.5	25.4
2	20.8
2.6	18.8
3.4	18.4
4.5	15.6
6	15
8	14.5
10.5	15.1
14	16.5
18	20
24	27.2
32	31.7
42	38.6
55	48.5
72.5	66.3
95	68.4

Synthetic curve	
AB/2	App.Resistivity
1.5	25.318
2.0842	20.589
2.896	18.221
4.024	16.729
5.5914	15.374
7.7692	14.419
10.795	14.839
15	17.562
20.842	22.802
28.96	30.252
40.24	39.641
55.914	50.562
77.692	61.818
107.95	
70.835	

Doemak



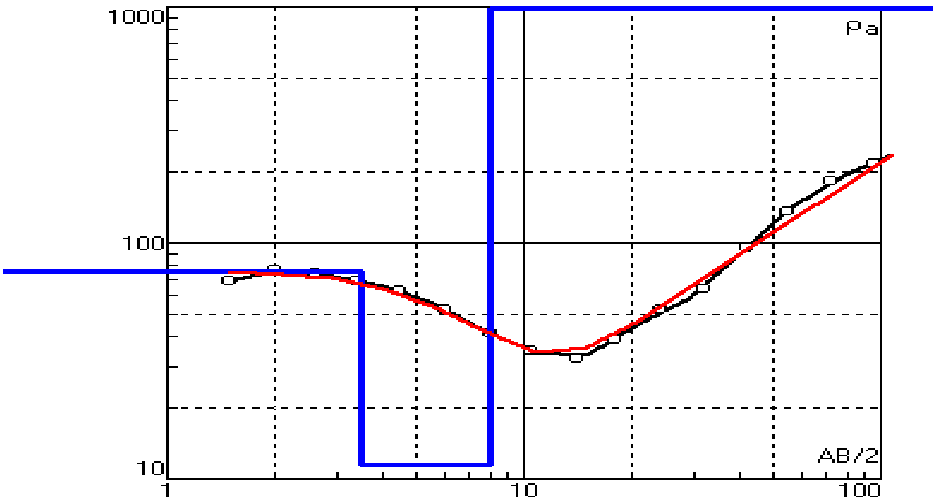
Model	
D	Ro
0.5	61.9
3.54	61.9
3.54	3.96
7.39	3.96
7.39	5437
22.17	5437

Field curve	
AB/2	App.Resistivity
1.5	56.3
2	63
2.6	62.4
3.4	52.9
4.5	45.7
6	39.1
8	29.7
10.5	19.1
14	15.7
18	18.2
24	23.3
32	31.9
42	41.5
55	52.7

72.5	69.5

Synthetic curve	
AB/2	App.Resistivity
1.5	61.045
2.0842	59.752
2.896	56.785
4.024	50.776
5.5914	40.821
7.7692	28.682
10.795	19.306
15	16.743
20.842	20.429
28.96	27.981
40.24	38.787
55.914	53.75
77.692	74.413

Kwanoeng 1

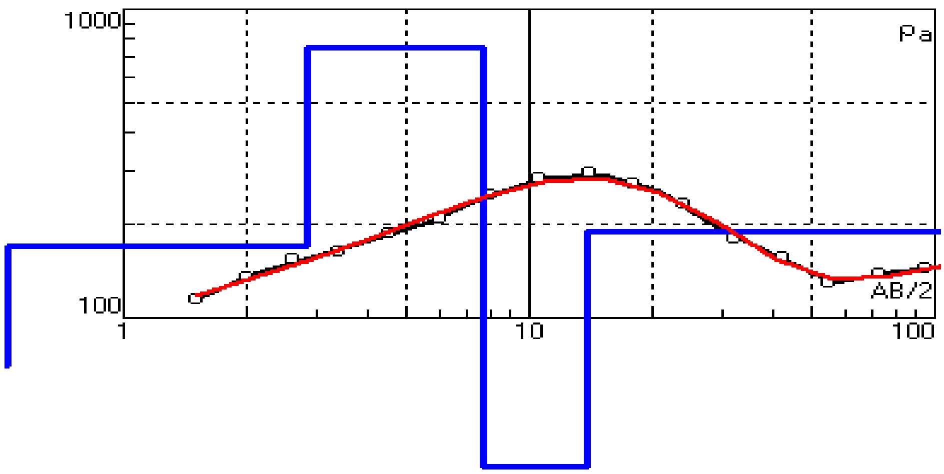


Model	
D	Ro
0.5	76.2
3.47	76.2
3.47	11.5
8.07	11.5
8.07	17740
24.21	17740

AB/2	App.Resistivity
1.5	69.1
2	76.4
2.6	74.2
3.4	69
4.5	63
6	52.3
8	41.4
10.5	35.1
14	32.4
18	39.1
24	51.9
32	63.5
42	96
55	137
72.5	182

Synthetic curve	
AB/2	App.Resistivity
1.5	75.27
2.0842	73.873
2.896	70.693
4.024	64.34
5.5914	54.083
7.7692	42.253
10.795	34.695
15	36.289
20.842	46.968
28.96	64.73
40.24	89.795
55.914	124.53
77.692	172.58
107.95	238.94

Kwanoeng 2

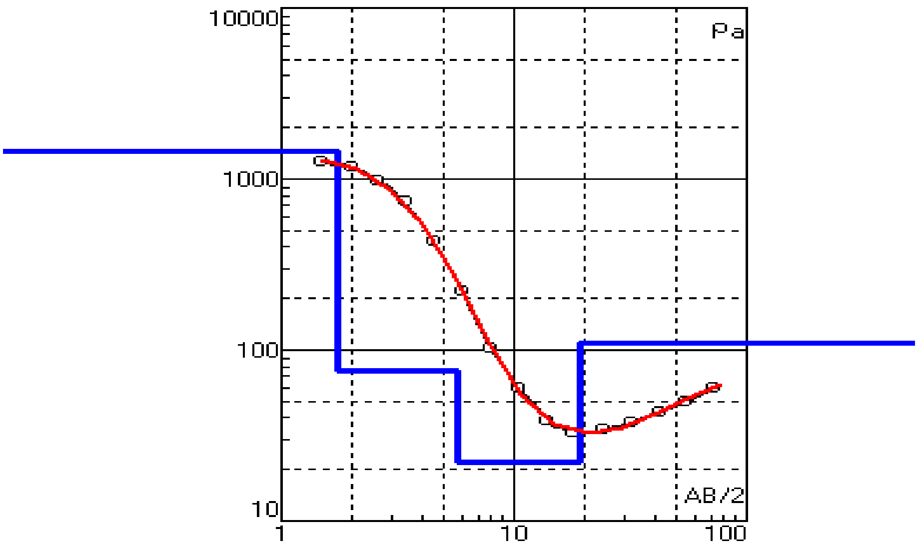


Model	
D	Ro
0.5	70.3
0.447	70.3
0.447	170
2.837	170
2.837	747
7.757	747
7.757	26.1
13.827	26.1
13.827	191
41.481	191

Field curve	
AB/2	App.Resistivity
1.5	115
2	136
2.6	154
3.4	163
4.5	189
6	210
8	252
10.5	282
14	295
18	272
24	235
32	180
42	157
55	129
72.5	139
95	145

Synthetic curve	
AB/2	App.Resistivity
1.5	117.52
2.0842	135
2.896	155.12
4.024	180.32
5.5914	212.47
7.7692	248.22
10.795	276.4
15	281.84
20.842	255.17
28.96	204.54
40.24	156.05
55.914	133.44
77.692	136.33
107.95	149.22

Kwanoeng 3

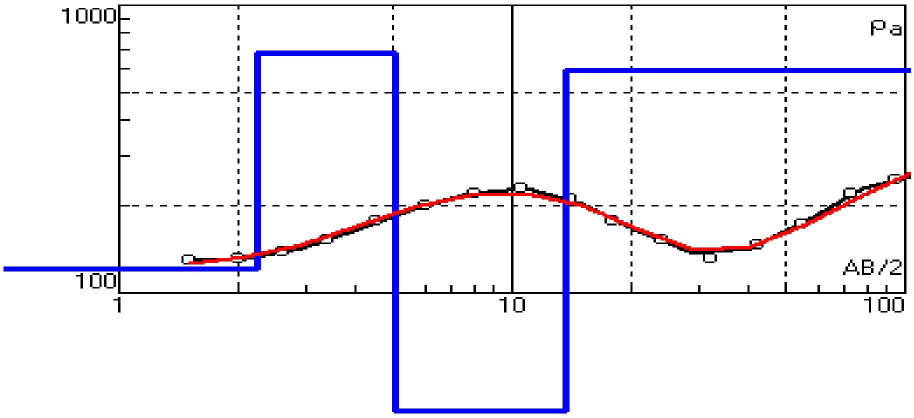


Model	
D	Ro
0.5	1448
1.75	1448
1.75	76.3
5.68	76.3
5.68	21.8
19.18	21.8
19.18	110
57.54	110

Field curve	
AB/2	App.Resistivity
1.5	1255
2	1189
2.6	987
3.4	743
4.5	434
6	221
8	102
10.5	59.9
14	38.4
18	32.7
24	34
32	37.6
42	43.4
55	50.2
72.5	60.2

Synthetic curve	
AB/2	App.Resistivity
1.5	1306
2.0842	1141
2.896	872.82
4.024	544.31
5.5914	265.84
7.7692	111.98
10.795	54.996
15	36.986
20.842	32.58
28.96	35.483
40.24	42.621
55.914	51.925
77.692	62.171

Lardang 1



Model

D	Ro
0.5	121
2.25	121
2.25	685
5.03	685
5.03	38.9
13.72	38.9
13.72	593
41.16	593

Field curve

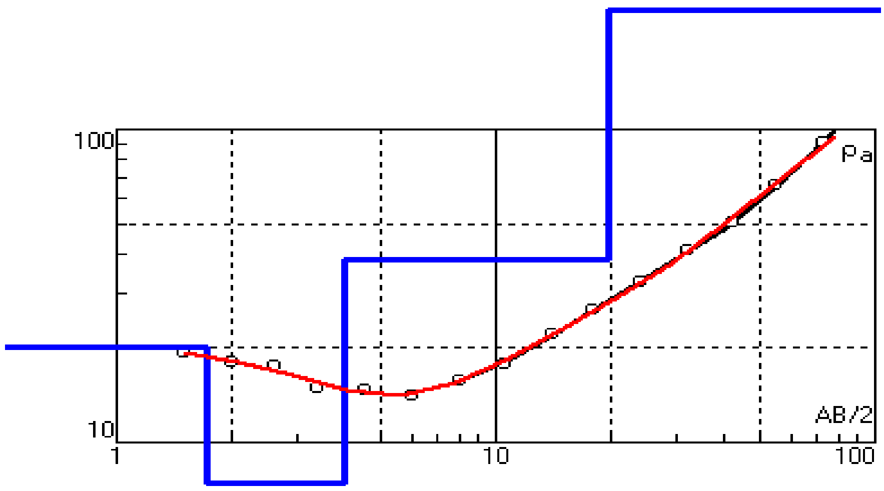
AB/2	App.Resistivity
1.5	130
2	131
2.6	139
3.4	152
4.5	178
6	200
8	222
10.5	232
14	213
18	177
24	153
32	132
42	147
55	174
72.5	222

95 248

Synthetic curve

AB/2	App.Resistivity
1.5	126.33
2.0842	133.5
2.896	147.56
4.024	170.08
5.5914	197.14
7.7692	218.12
10.795	220.86
15	200.17
20.842	165.92
28.96	141.11
40.24	144.24
55.914	173.84
77.692	218.18
107.95	270.01

Lardang 2

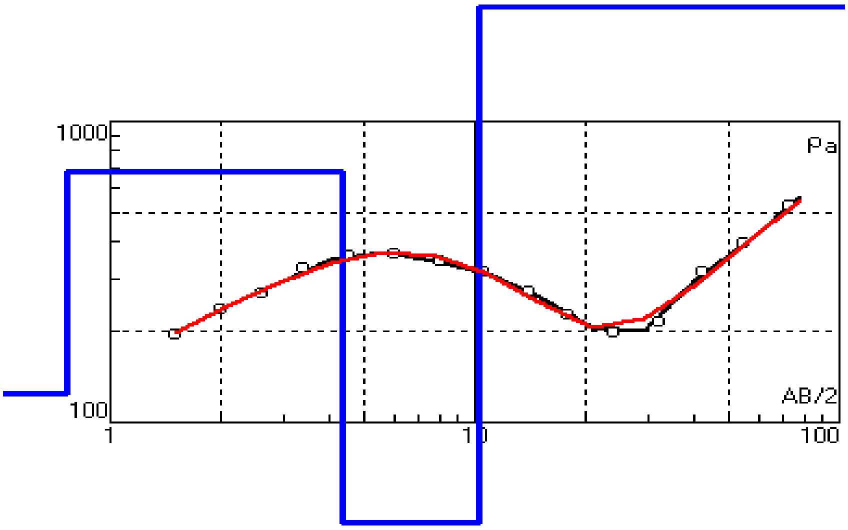


Model	
D	Ro
0.5	20.16
1.731	20.16
1.731	7.432
3.99	7.432
3.99	38.19
19.91	38.19
19.91	6770
59.73	6770
Field curve	

AB/2	App.Resistivity
1.5	19.21
2	18.01
2.6	17.61
3.4	14.91
4.5	14.75
6	14.07
8	15.69
10.5	17.9
14	22.02
18	26.43
24	32.58
32	40.85
42	50.3
55	66.44
72.5	90.85
Synthetic curve	
AB/2	App.Resistivity

1.5	19.181
2.0842	18.094
2.896	16.428
4.024	14.722
5.5914	14.103
7.7692	15.411
10.795	18.517
15	22.973
20.842	28.969
28.96	37.52
40.24	50.208
55.914	68.764
77.692	94.982

Lardang 3

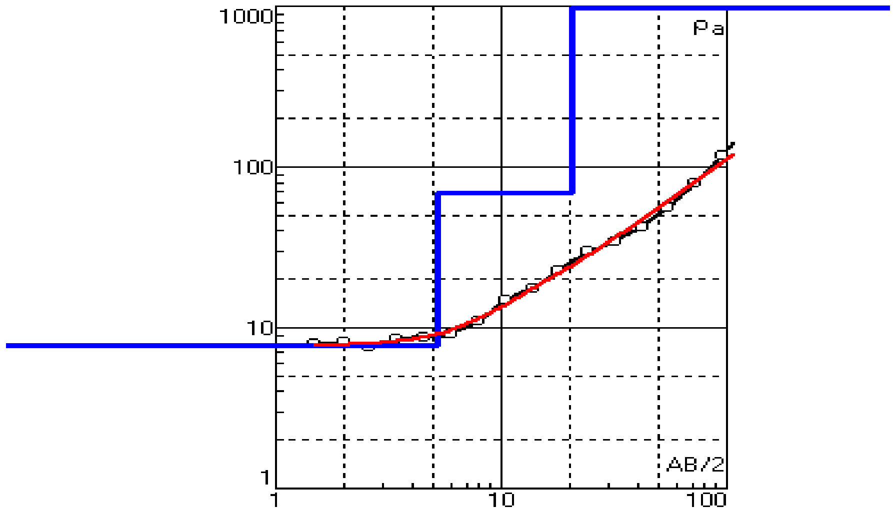


Model	
D	Ro
0.5	125
0.757	125
0.757	679
4.307	679
4.307	46.1
10.247	46.1
10.247	79405
30.741	79405

Field curve	
AB/2	App.Resistivity
1.5	197
2	238
2.6	268
3.4	326
4.5	358
6	365
8	342
10.5	315
14	273
18	227
24	198
32	214
42	317
55	394

72.5	523
Synthetic curve	
AB/2	App.Resistivity
1.5	197.41
2.0842	242.24
2.896	292.37
4.024	338.19
5.5914	365.86
7.7692	359.71
10.795	314.04
15	249.15
20.842	207.34
28.96	220.53
40.24	287.64
55.914	396.79
77.692	550.2

Varam

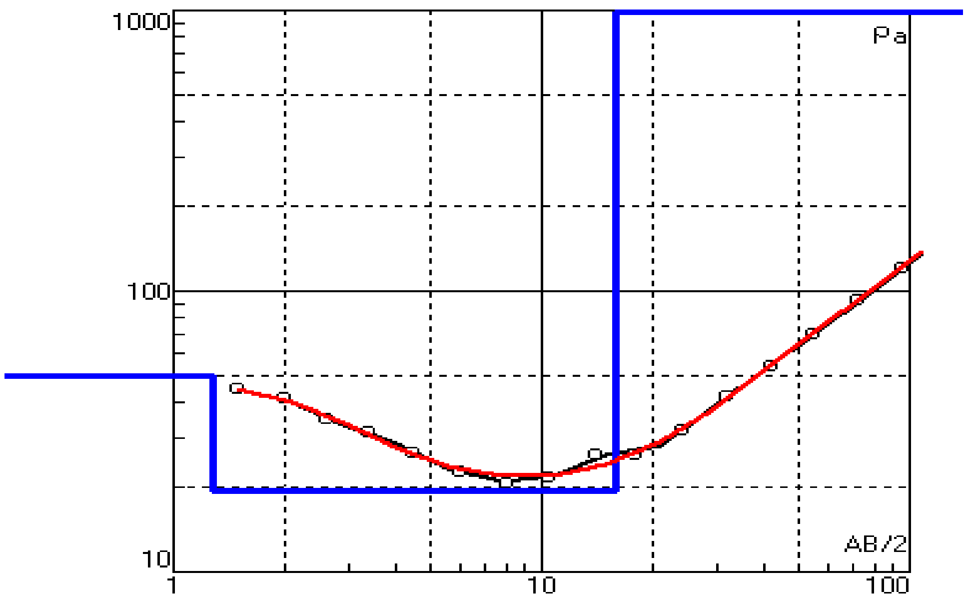


Model	
D	Ro
0.5	7.79
5.16	7.79
5.16	69
20.66	69
20.66	14482
61.98	14482

Field curve	
AB/2	App.Resistivity
1.5	8.01
2	8.1
2.6	7.53
3.4	8.55
4.5	8.79
6	9.17
8	10.9
10.5	14.9
14	17.6
18	22.6
24	29.8
32	34.2
42	42.7
55	55.9
72.5	78.9
95	118

Synthetic curve	
AB/2	App.Resistivity
1.5	7.8315
2.0842	7.9004
2.896	8.0756
4.024	8.4959
5.5914	9.4245
7.7692	11.233
10.795	14.265
15	18.728
20.842	24.907
28.96	33.483
40.24	45.617
55.914	62.845
77.692	87.03
107.95	120.63

Voershik

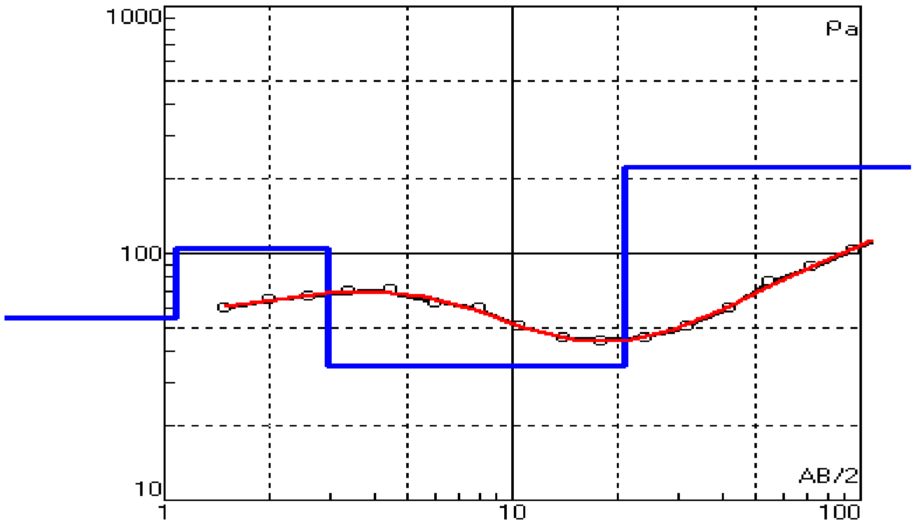


Model	
D	Ro
0.5	50
1.29	50
1.29	19.5
15.89	19.5
15.89	29510
47.67	29510

Field curve	
AB/2	App.Resistivity
1.5	44.5
2	41.5
2.6	34.8
3.4	31.5
4.5	26.6
6	22.7
8	20.8
10.5	21.7
14	26.1
18	25.9
24	32.1
32	42
42	54.2
55	70.2
72.5	92.6
95	121

Synthetic curve	
AB/2	App.Resistivity
1.5	44.801
2.0842	40.008
2.896	33.721
4.024	27.713
5.5914	23.687
7.7692	21.963
10.795	22.099
15	24.159
20.842	29.028
28.96	37.944
40.24	51.917
55.914	71.96
77.692	99.887
107.95	138.61

Kwang



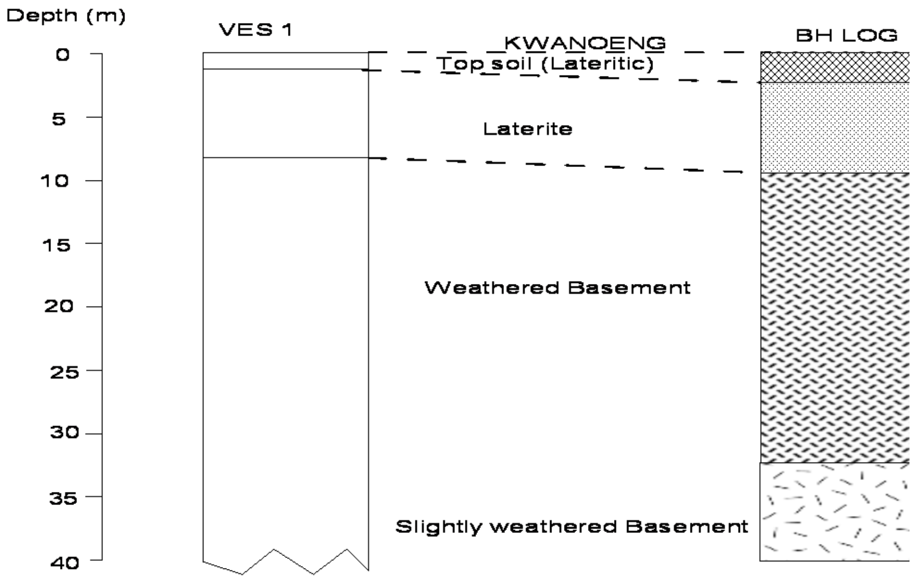
Model	
D	Ro
0.5	54.77
1.082	54.77
1.082	104.1
2.939	104.1
2.939	34.87
21.079	34.87
21.079	223.3
63.237	223.3

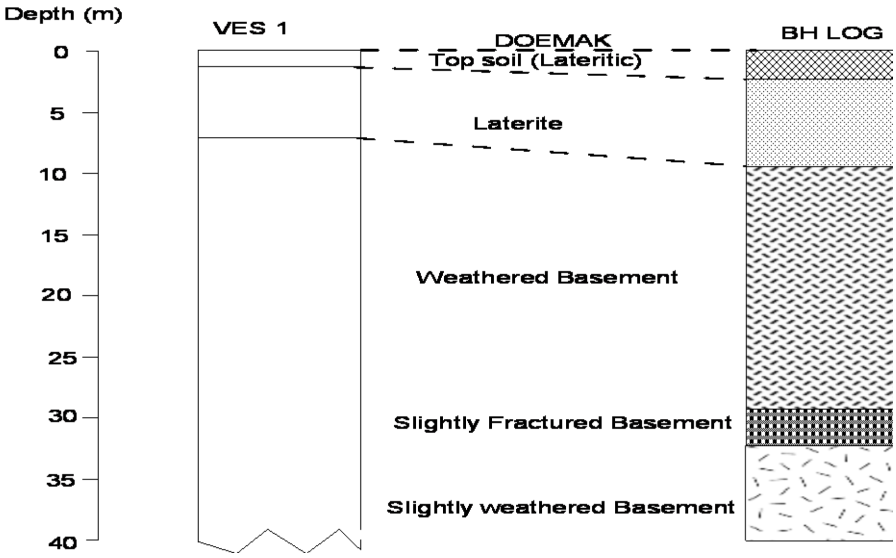
Field curve	
AB/2	App.Resistivity
1.5	60.49
2	64.44
2.6	67.19
3.4	70.2
4.5	70.78
6	62.65
8	59.87
10.5	50.57
14	45.43
18	44.04
24	45.72
32	50.51
42	59.8
55	76.82

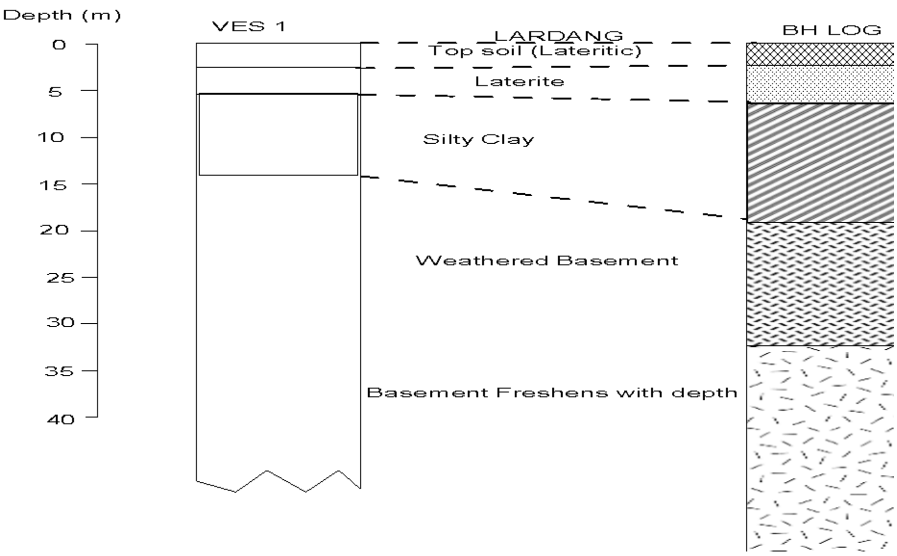
72.5	87.7
95	103.3

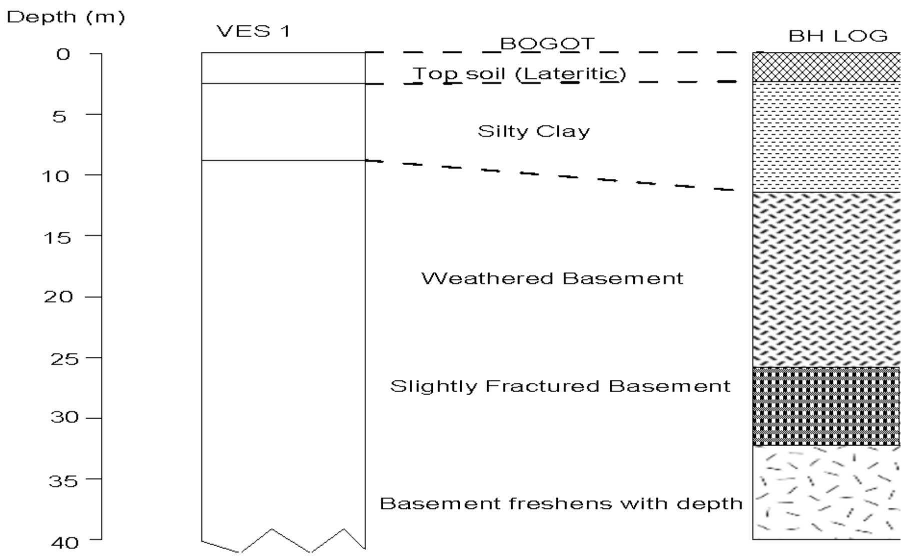
Synthetic curve	
AB/2	App.Resistivity
1.5	60.521
2.0842	64.732
2.896	68.794
4.024	70.107
5.5914	66.627
7.7692	58.878
10.795	50.257
15	44.678
20.842	44.153
28.96	49.049
40.24	59.269
55.914	74.088

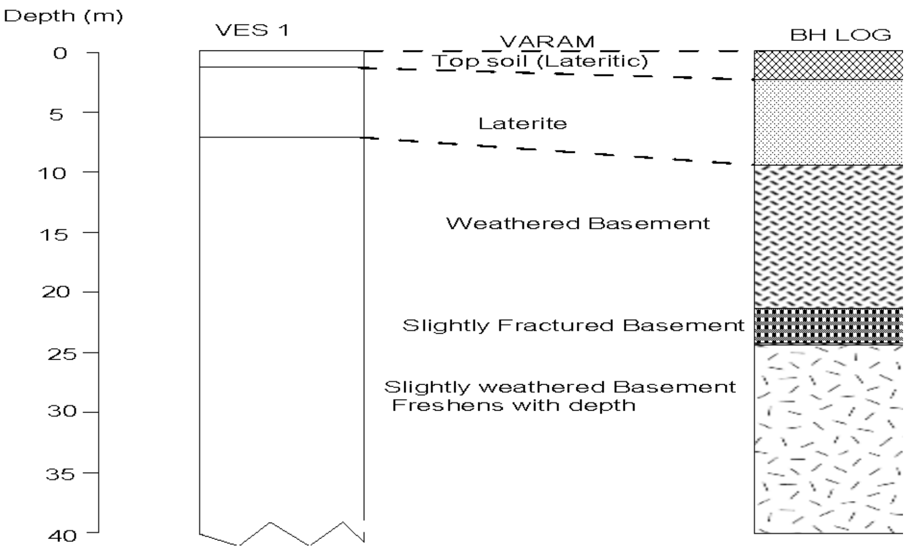
WELL LOG FOR THE DRILLED BOREHOLES

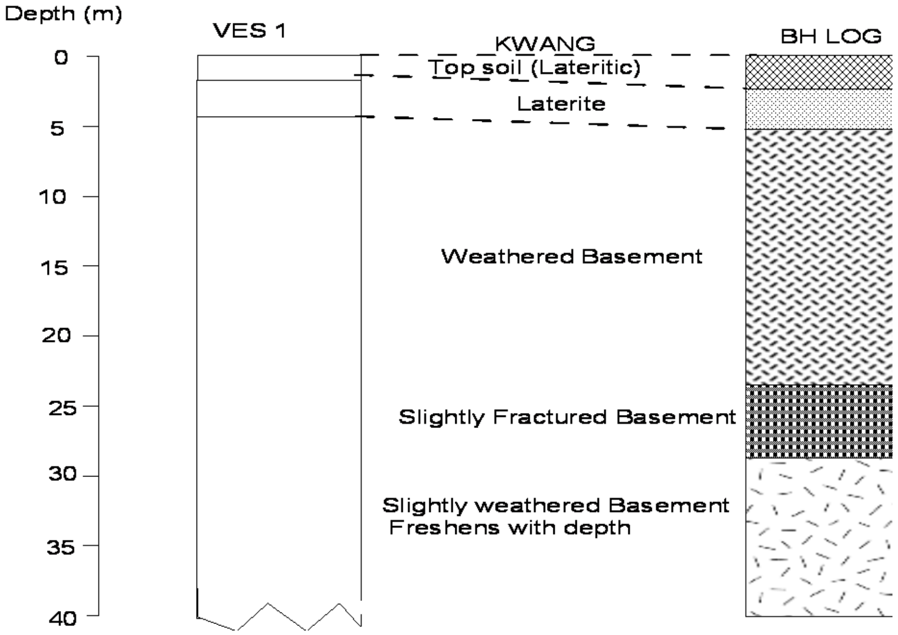







Depth (m)
VES 1
BOGOT
BH LOG
0
5
10
15
20
25
30
35
40
Top soil (Lateritic)
Silty Clay
Weathered Basement
Slightly Fractured Basement
Basement freshens with depth


Depth (m)
VES 1
VARAM
BH LOG
0
5
10
15
20
25
30
35
40
Top soil (Lateritic)
Laterite
Weathered Basement
Slightly Fractured Basement
Slightly weathered Basement
Freshens with depth


Depth (m)
VES 1
KWANG
BH LOG
0
5
10
15
20
25
30
35
40
Top soil (Lateritic)
Laterite
Weathered Basement
Slightly Fractured Basement
Slightly weathered Basement
Freshens with depth

Pump testing at Bogot @ 4Litres per Minute

Pump testing at Kwang

Team carrying out pump testing @ Kwang

Pumping rate @ 3Litres per Minute

Pump testing at Varam @ 6Litres per minute

Pump testing at Varam @ 6Litres per minute

IV. CONCLUSION

The hydro-geophysical investigation and the challenges encountered during drilling revealed that Lardang area is a poor hydro-geological terrain due to its mixed geology. It is not far from the fact that the fractures, joints created by the volcanic activities are dry in most cases leading loss of water into such openings during drilling. The studies also revealed that the homogeneous basalts seems to be interlocking underground making it easier to drill without falling as is the case with the mixed terrain, and a good hydro-geological terrain.

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