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Central Longitudinal Traverse Data-field Analysis of a 4 km^2 VES study at the Southern Phase II Development, Gidan Kwano Campus, Minna, Nigeria

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Abstract
When carrying out the data-acquisition phase of the 4 km^2 areal extent VES survey at the southern Phase II Development, Gidan Kwano Campus, Minna, Nigeria, concomitant VES-IP surveys were ignored for the points of Profile 11 because the results of the dual VES-IP surveys for these points already existed in the longitudinal traverse (LT) format beyond the northernmost 21st 2 km linear extent station of the 4 km^2 areal extent grid. The aim of this study is to process and interpret the central longitudinal traverse data-field of the 4 km^2 VES study at the southern Phase II Development of the Gidan Kwano Campus in order to gain insight into the hydro-centric nature of the material along this mid-profile. The VES survey for the mid-profile of interest in this study was carried out over the spread of P11-1 to P11-34 in no particular order but a survey point being determined by the convenience and logistics of getting to that point on the day of survey. Essentially, the log-log plots show more three-layer geological formations along the line of study but there are points where a four-layer formation can also be discerned.; this three-layer structure is the expected norm at the local basement province of which this line of study is a part. The geologic cross-section shows the conventional and dominant three-layer representation of "top soil," "weathered basement/laterite," and "partly-fractured (fresh) basement." The pseudosection plot shows that, at the lower slope of the line of survey, low-resistivity materials of the sub-300 Ωm range dominate at comparatively shallower depths; as the survey-station designation increases in numerals as one proceeds upslope of the line of survey, dominant higher-resistivity material of a uniform kind are noticed at depth-points deeper than the 20 m mark and this is prominent between P11-20 and P11-30; still higher-resistive materials are noticed at the 40 m depth-mark downwards between P11-15 and P11-32 as they are noticed at the 30 m depth-mark downwards at P11-8 and P11-9. Overall, there is concentration of more prospect locations at the lower slope of the line of survey (P11-1, P11-2, P11-3, P11-4, P11-5, and P11-7) and at the northern end of the line of survey (P11-30, P11-31, P11-32, and P11-34). It is recommended that the groundwater prospect locations at P11-1, P11-2, P11-3, P11-5, P11-7, and P11-12 be integrated into the database of the existing 57 definite groundwater prospect locations inferred from the 4 km^2 areal extent VES survey. As was done for the 4 km^2 areal extent VES survey, the VES points that are flagged as prospects for this study should be subjected to an even more stricter control on their hydro-centric nature by making recourse to the concomitantly-acquired induced polarisation (IP) data at coincident points of surveys as those for the VES.

Keywords: *traverse; georeferencing; VES; resistivity; psedosection; hydro-centric; groundwater*

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I. Introduction

The work of Jonah and Olasehinde (2017A) was a dual vertical electrical sounding (VES)-induced polarisation (IP) survey completed in the transverse traverse (TT) designation, specifically along east-west direction; the 4 km^2 areal extent of Jonah and Olasehinde (2017A) at 100-m VES-IP station-spacing results in 21 longitudinal (north-south) traverses and 21transverse (east-west) traverses. However, when carrying out the data-acquisition phase of Jonah and Olasehinde (2017A), concomitant VES-IP surveys were ignored for the points of Profile 11 because the results of the dual VES-IP surveys for these points already existed in the longitudinal traverse (LT) format beyond the northernmost 21st 2 km linear extent station of the 4 km^2 areal extent grid; this dedicated survey was completed a couple of years before the broad-area survey of Jonah and Olasehinde (2017A).

The Phase II Development is an 8 km^2 swath of land of the Gidan Kwano Campus, Federal University of Technology, Minna, that is ideal for the University's near-term and mid-term facility expansion programmes (Jonah, 2016C; Jonah and Adamu 2017B; Jonah and Jimoh, 2016A; Jonah and Olasehinde, 2015B; Jonah and Olasehinde, 2017A; Jonah and Saidu, 2016B; Jonah and Saidu, 2018C; Jonah and Saidu, 2018D; Jonah *et al.*, 2015A; Jonah *et al.*, 2015C; Jonah *et al.*, 2015D; Jonah *et al.*, 2015E; Jonah *et al.*, 2018A; Jonah *et al.*, 2018B). On the ground, this 8 km^2 areal extent is a perfect rectangle with its ends corresponding to the following georeferenced co-ordinates: 09^{0}30′57.8″N, 006^{0}25′39.0″E (most extreme southwest); 09^{0}30′57.8″N, 006^{0}26′43.8″E (most extreme southeast); 09^{0}33′07.4″N, 006^{0}26′43.8″E (most extreme northeast); 09^{0}33′07.4″N, 006^{0}25′39.0″E (most extreme northwest). Accurate traverse fixing is desirable to build a grid for the 8 km^2 swath and georeferencing of survey stations is desirable to independently verify the results of this study. At 100 m separation, a total of 21 profile lines were identified in the longitudinal traverse sense and a total of 41 profile lines were identified in the transverse traverse sense. This traverse fixing scheme results in 21 x 41 = 861 principal survey stations. Station-designation format for this survey follows a two-dimensional spatial awareness: principal profile lines are in the north-south direction, with the first profile line being the westernmost line of longitude; numerical station-designation is from west to east. Thus, the first assigned station of survey based on this format is the most extreme southwestern point in the 4 km by 2 km grid appropriately called P1-1; that is, Station 1 of Profile 1. Station 2 of Profile 1 (P1-2) is exactly 100 m to the north of Station 1; Station 3 of Profile 1 (P1-3) is exactly 100 m to the north of Station 2 and exactly 200 m north of Station 1, and so on. P2-1 means Station 1 of Profile 2; this is exactly 100 m to the east of P1-1; P3-1 is exactly 100 m to the east of P2-1 and exactly 200 m to the east of P1-1. Each of these principal survey stations was visited whence its latitude, longitude, and elevation information (x, y, z) were measured and duly recorded. On the ground, against the backdrop of a satellite imagery map showing Phase I (obviously, the present developed portion), the locations of the principal stations are as shown in Figure 1.

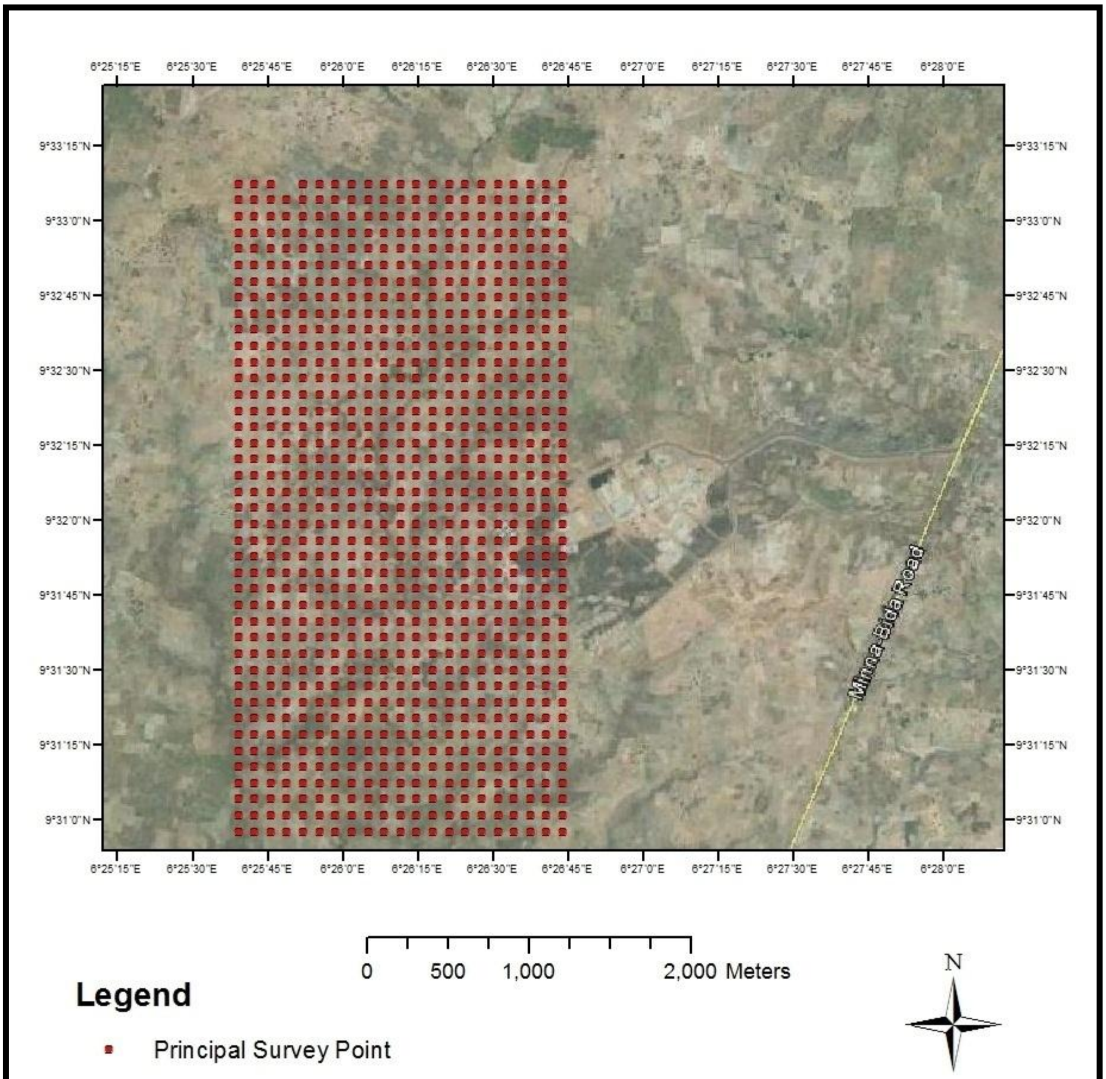


Figure 1. Locations of the principal stations against the backdrop of a satellite imagery map showing Phase I

The southern 4 km^2 areal extent at the Phase II Development of the Gidan Kwano Campus where a full-body VES study was completed (Jonah and Olasehinde, 2017A) is shown as Figure 2. There are 441 principal stations in the grid of Figure 2: not all the 441 principal survey stations of the 4 km^2 areal extent were occupied during the course of the VES survey because of barriers encountered at coincident points of surveys; the barriers are those due to wet-stream, outcrop, thicket, built-up area, instrumental error (that is, “Error 12” of the ABEM Terrameter 4000), and raw sewage. The schedule of Figure 2 has been colour-coded to indicate the stations that were occupied for data collection during the course of this survey, see Figure 3. The pattern of field VES data collection for the work of Jonah and Olasehinde (2017A) was a transverse traverse format; in the year 2011, a longitudinal traverse format VES data-collection exercise was completed for the central longitudinal traverse only of the 4 km^{2}areal extent shown in Figure 2. The points of this central longitudinal traverse were ignored during the data-collection phase of the work of Jonah and Olasehinde (2017A), completed in the year 2014 and that is why this central longitudinal traverse can be easily traced in Figure 3 as the straight line of red dots from the southernmost LT11-1 to the northernmost LT11-41.

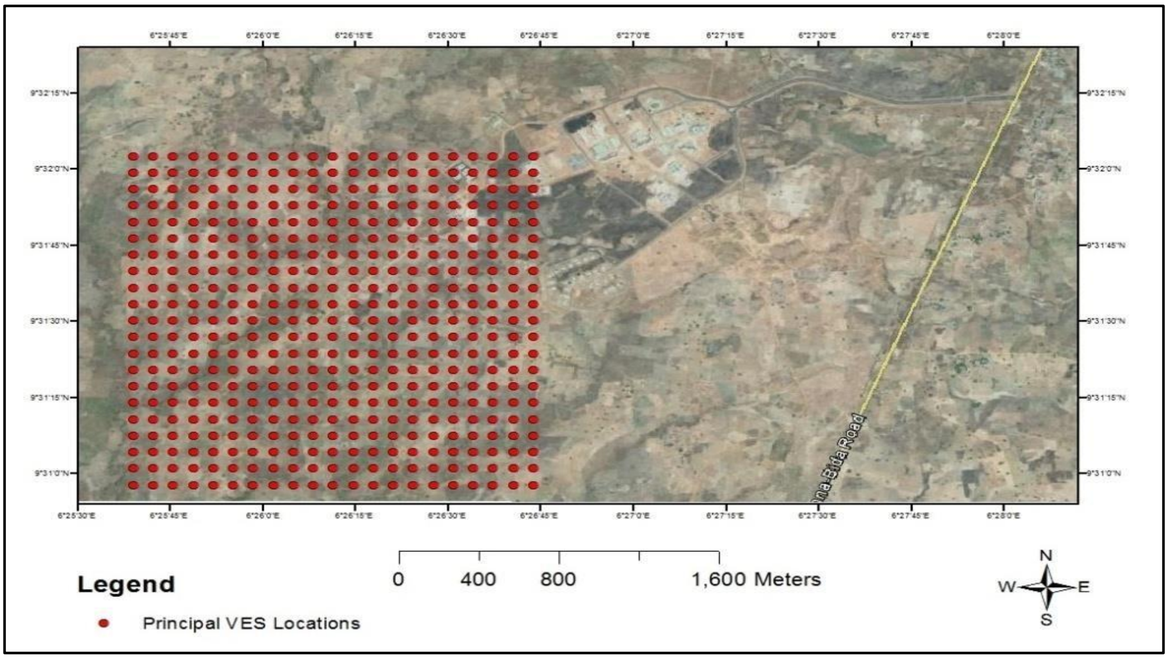


Figure 2. Grid of the 4 km^2 tranche of Phase II Development of the Gidan Kwano Campus at 100 m station-spacing. (The tadpole-shaped feature is Phase I, the present developed portion of the GKC, seen to the northeast of the red-dotted grid of the 4 km^2 areal extent; the Minna-Kateregi-Bida Road is seen as the linear slope to the far east of the grid.)

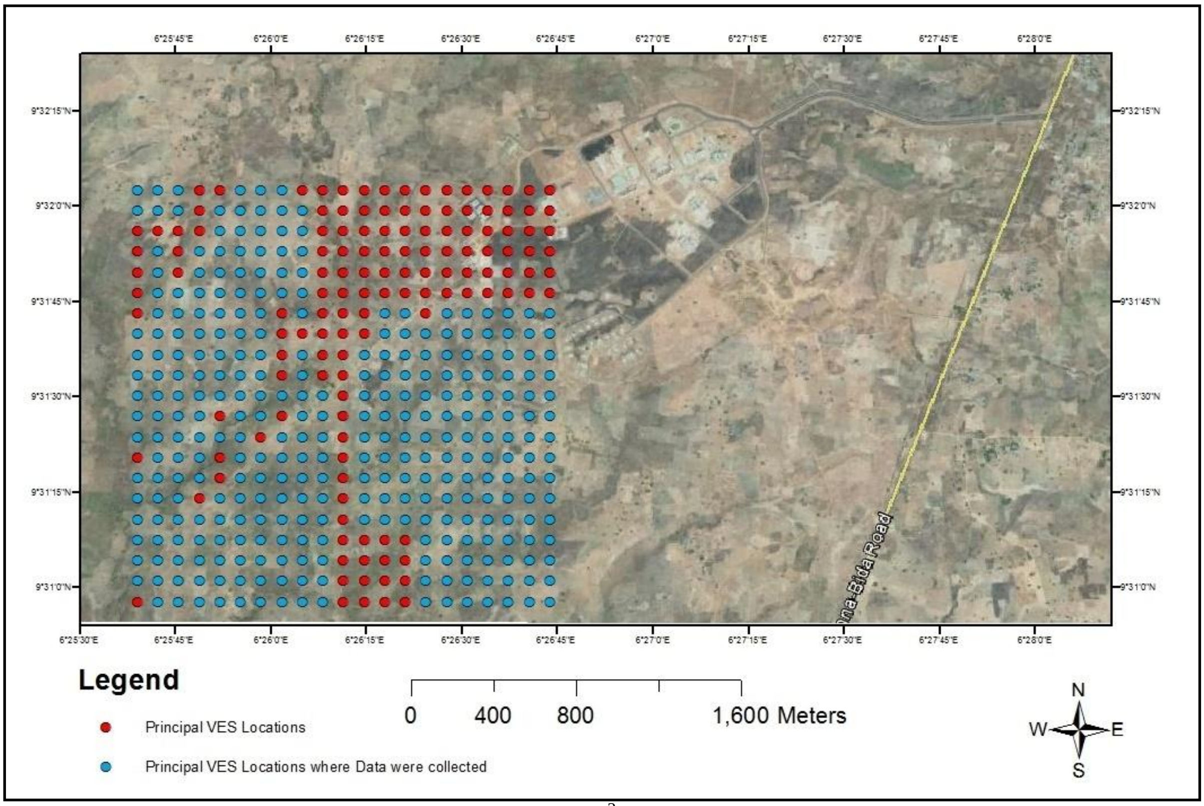


Figure 3. Locations of the principal stations of the 4 km^2 tranche of the Phase II Development colour-coded for locations where data was collected for Jonah and Olasehinde (2017A). (The central longitudinal traverse, for which data-collection was ignored for the work of Jonah and Olasehinde (2017A) and for which data was acquired in 2011, can be easily traced in this figure.)

One of the limiting factors of Jonah and Olasehinde (2017A) was incurred expenses that ensured that the original targeted geoelectrical survey over the larger 8 km^2 areal extent of the Phase II Development was only completed for the half-scale 4 km^2 areal extent in the transverse traverse format. However, longitudinal traverse format geoelectrical survey data-set beyond the 4 km^2 areal extent envelope, albeit on a single straight line only, exists in the archive; since the northern half of this single straight line passes very close to the students' hostel facilities, and the result of Jonah and Olasehinde (2017A) reveals a paucity of groundwater prospect locations at this northern segment of the greater 8 km^2 areal extent of the Phase II Development, it is now of great interest to process the VES information from this single straight line so as to make further inference about the groundwater prospect locations distribution at this vexing northern sector. The aim of this study is to process and interpret a central longitudinal traverse data-field of a 4 km^2 VES study at the southern Phase II Development, Gidan Kwano Campus, Minna, in order to gain insight into the hydro-centric nature of the material along this mid-profile; the objectives of this study are achieved by the routes of production of log-log plot for each survey point along this mid-profile, production of pseudosection along this mid-profile, production of geoelectric cross-section along this mid-profile, and production of geologic cross-section along this mid-profile. At the completion of this study, any VES location that is flagged for groundwater prospect at the northern half of the 4 km^2 areal extent envelope and beyond would be designated "location of high priority" in view of the fact that this location should be closer to the students' hostel facilities compared to the clusters of groundwater prospects at the lower-half northeast-southwest (NE-SW) diagonals of the 4 km^2 areal extent that were duly mapped by Jonah and Olasehinde (2017A); this "high priority" marker is so that drilling should commence immediately at that location. If VES survey of this study had been completed for the mid-profile of the wider 8 km^2 Phase II Development of which the 4 km^2 areal extent of Jonah and Olasehinde (2017A) is only a half-scale, then 41 stations would have been occupied in total. Of these designated 41 stations (P11-1 too P11-41), only 34 were occupied for this study and just two of these (P11-25 and P11-26) could not be surveyed because of barriers resulting from mounds or heaps of soil that were readied for yam crop. Thus, only 32 separate VES sequence of readings along the mid-profile (P11) are available for this study. Although, the focus of this study is solely the processing and analysis of the 32 separate VES sequence of readings along the mid-profile of the area of study herein, a longer spread of the longitudinal traverses over a broader swath of the 8 km^2 Phase II Development would have provided a basis to compare interpretation results with those of Jonah and Olasehinde (2017A).

II. Method

The VES survey for the mid-profile (actually, the westernmost first profile during the schedule of that 2011 work) of interest in this study was carried out over the spread of P11-1 to P11-34 in no particular order but a survey point being determined by the convenience and logistics of getting to that point on the day of survey; the survey time-frame was from the 11th May 2011 to 27th May 2011. For each VES sequence of measurements carried out at a station of interest occupied in the course of this survey a corresponding induced polarisation sequence of measurements was also carried out.

III. Result

The acquired resistance values at each survey point out for the available 32 VES locations need to be converted to the true resistivity values of the inhomogeneous earth known as the apparent resistivity values; the apparent resistivity value (that is, the resisitivity) for each survey point was determined by multiplying the acquired resistance value with its corresponding geometric factor. The abridged VES data-set (for P11-1, P11-4, P11-5) for the line of survey of this study is presented in the Appendix. Usually, after determining the resistivity values from the field resistance values, it is desirable to generate curves, commonly log-log plots, showing the variation of resistivity values with the effective depth surveyed at that particular sequence for each VES station. It is recognised that the effective depth of penetration is equal to half the current electrodes spacing (if the current electrodes are separated by distance AB, then this AB/2). According to Zohdy (1989), a continuous variation of resistivity with depth curve is easily derived from multilayer step-function curve by drawing a curve that passes through the logarithmic midpoint of each vertical and horizontal line on the multilayer step function model. In view of the fact that the layer depths are logarithmically closely-shaped, the derived continuous variation of resistivity with depth model is equivalent to the original model. This approach makes it easy to construct maps of contoured resistivity values at different depths and to construct contoured geoelectric sections. The field resistivity values were initially subjected to the log-log plot routine of the Windows-compatible IP2Win® software whence corresponding field curves for all the stations occupied were produced; the initial outputs were the "default" graphs. These were further smoothed by iterations which were done in layers, thus resulting in final "modelled" outputs. The smoothed graphs are those that have connections to all the plotted points on the graph, and these are presented as Figures 4 to Figure 35. Each of the IP2Win® log-log plot provides information on the numbers of layers, the average resistivity values of these layers, their depths of occurrence, and their approximate thicknesses.

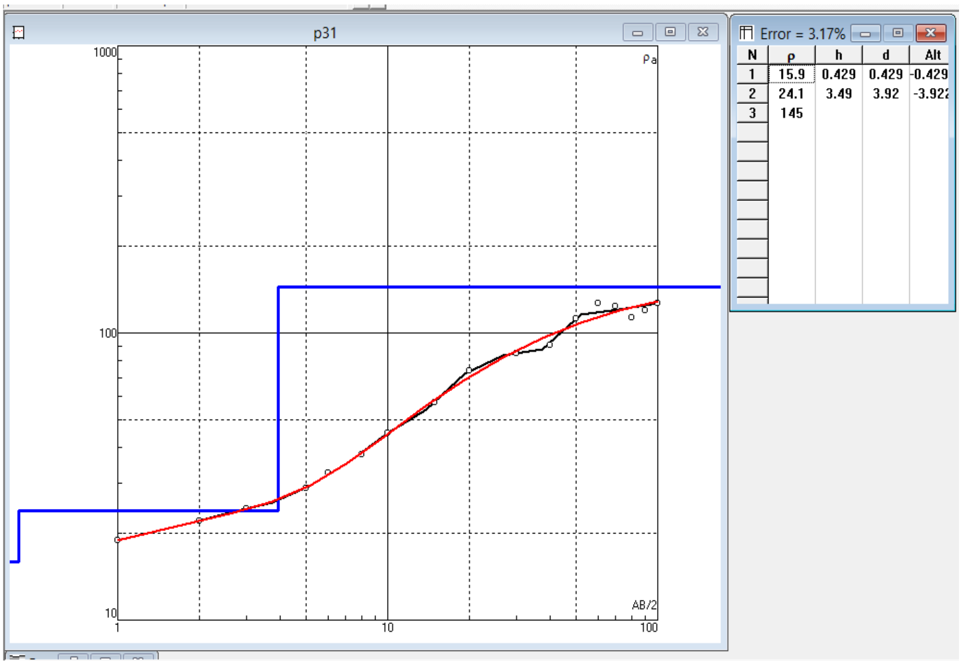


Figure 4. Log-log plot and corresponding data-field of P11-1

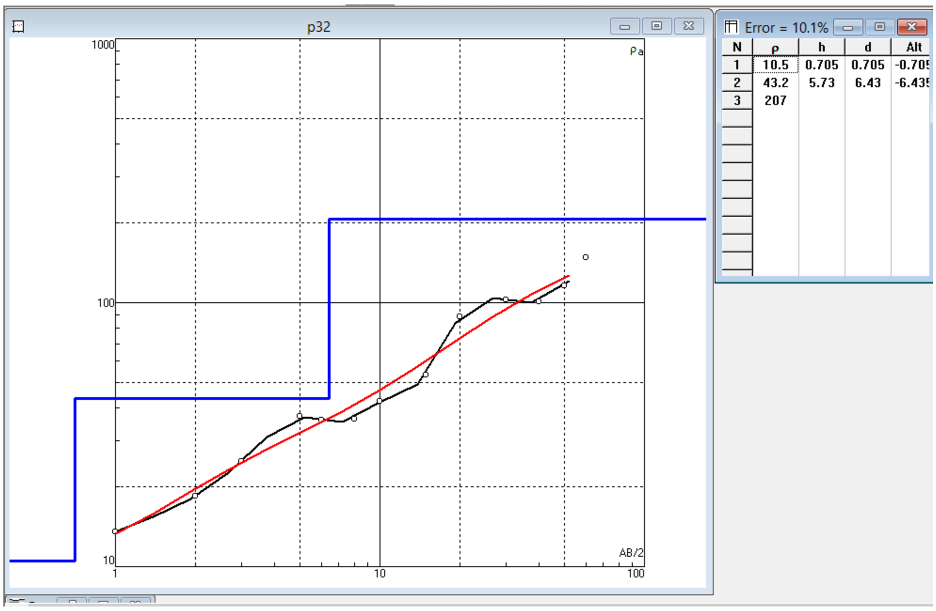


Figure 5. Log-log plot and corresponding data-field of P11-2

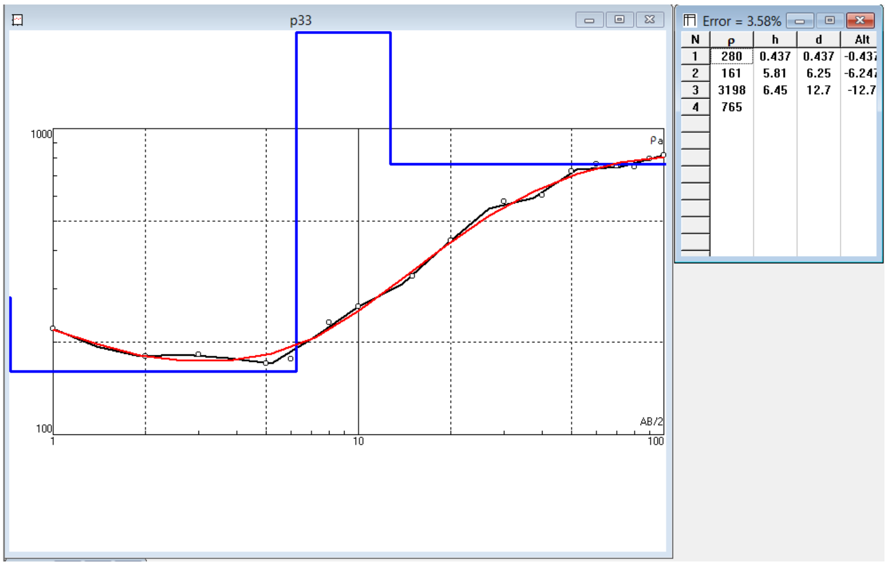


Figure 6. Log-log plot and corresponding data-field of P11-3

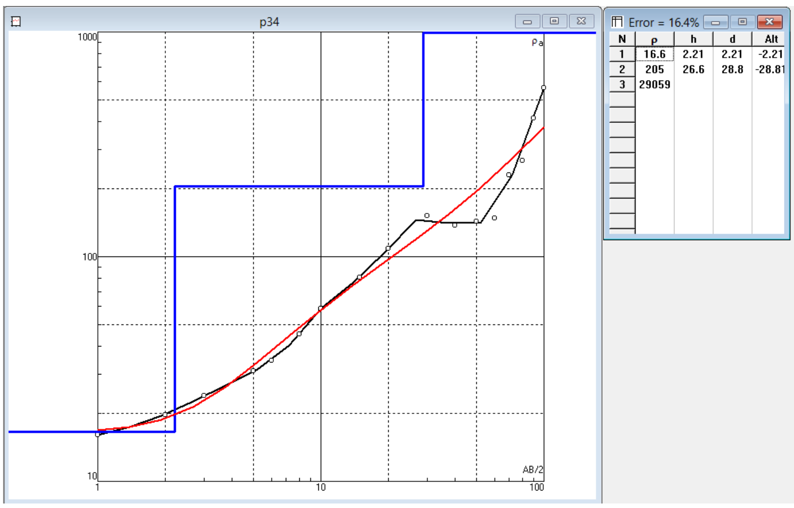


Figure 7. Log-log plot and corresponding data-field of P11-4

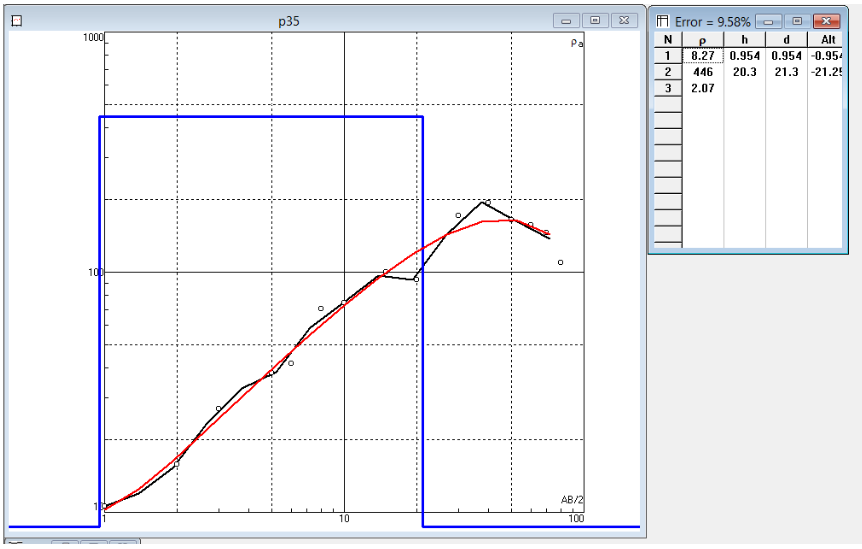


Figure 8. Log-log plot and corresponding data-field of P11-5

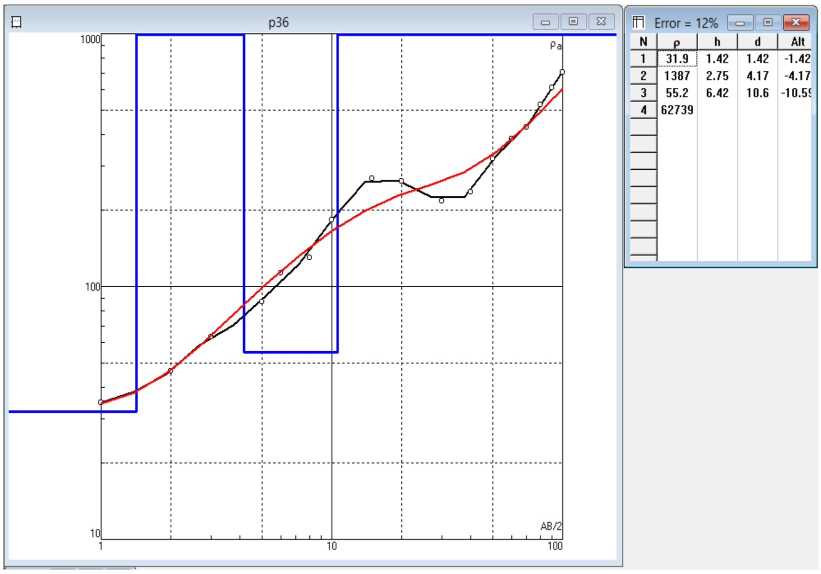


Figure 9. Log-log plot and corresponding data-field of P11-6

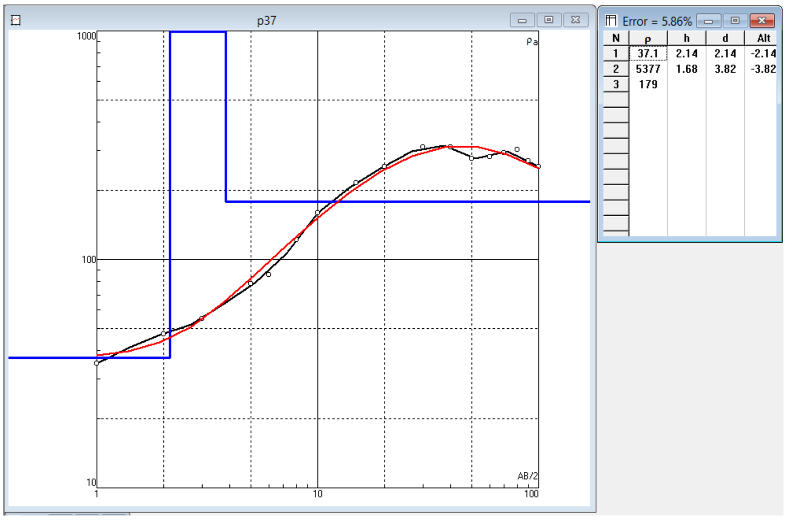


Figure 10. Log-log plot and corresponding data-field of P11-7

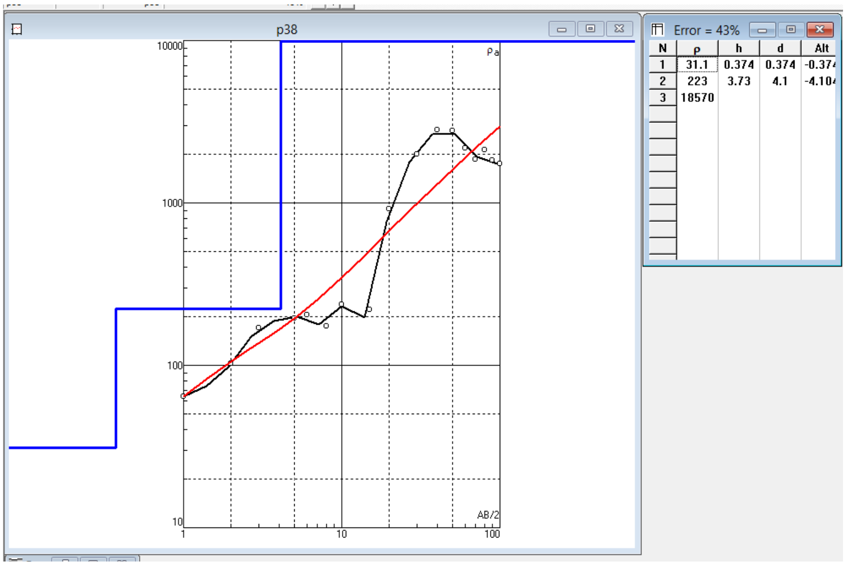


Figure 11. Log-log plot and corresponding data-field of P11-8

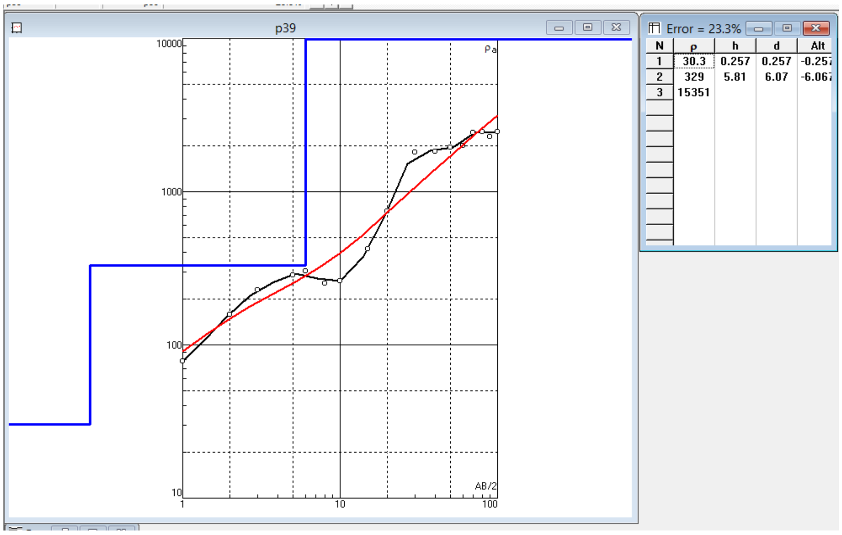


Figure 12. Log-log plot and corresponding data-field of P11-9

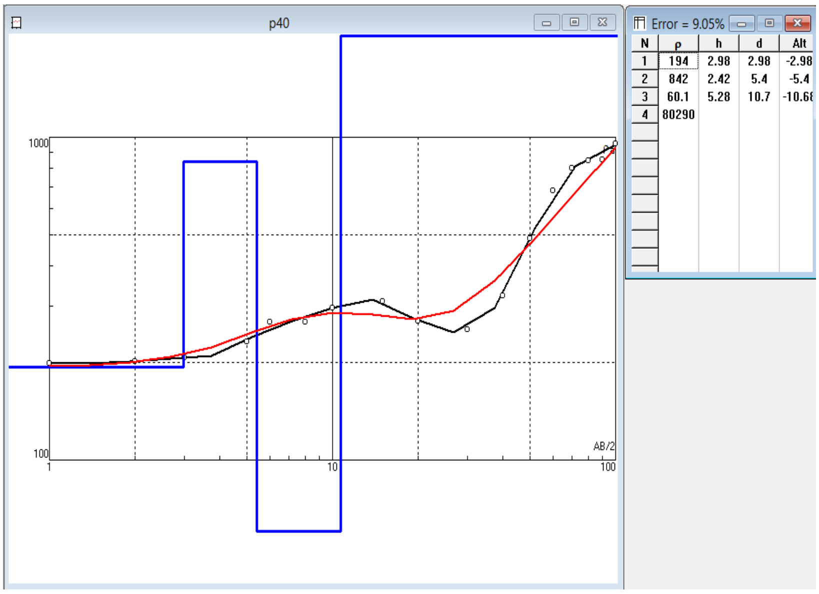


Figure 13. Log-log plot and corresponding data-field of P11-10

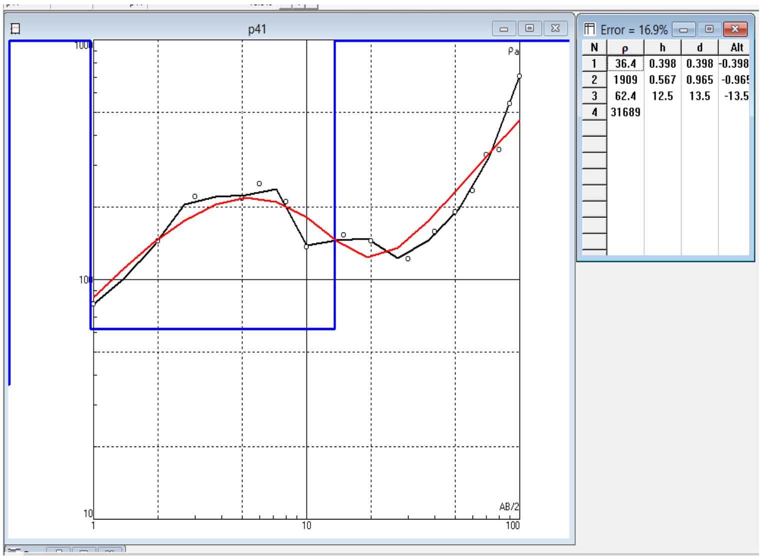


Figure 14. Log-log plot and corresponding data-field of P11-11

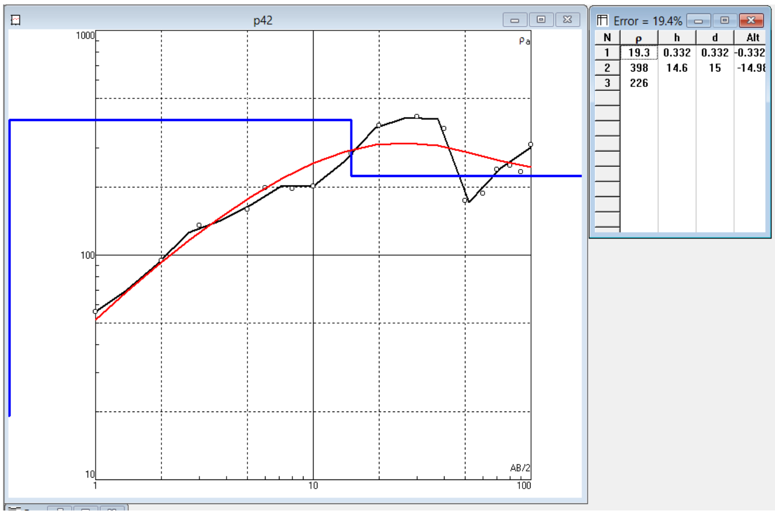


Figure 15. Log-log plot and corresponding data-field of P11-12

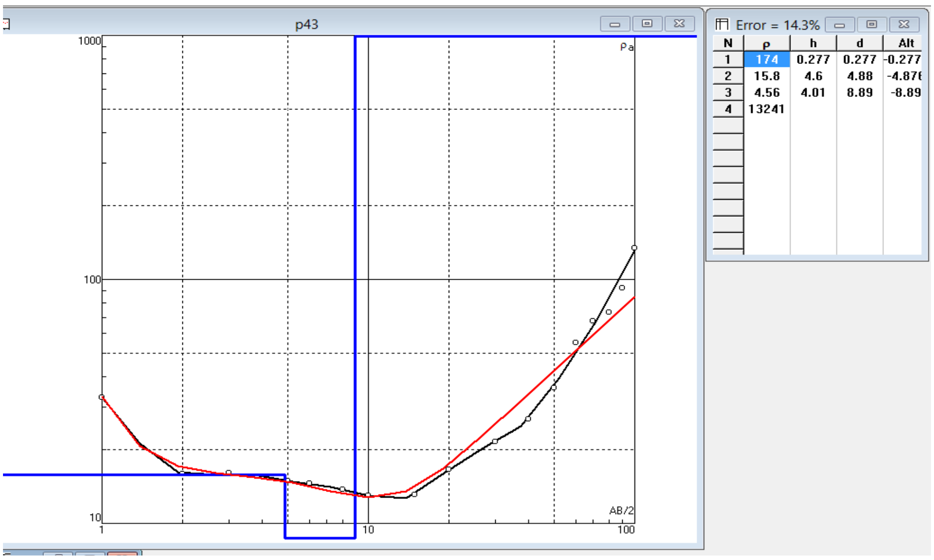


Figure 16. Log-log plot and corresponding data-field of P11-13

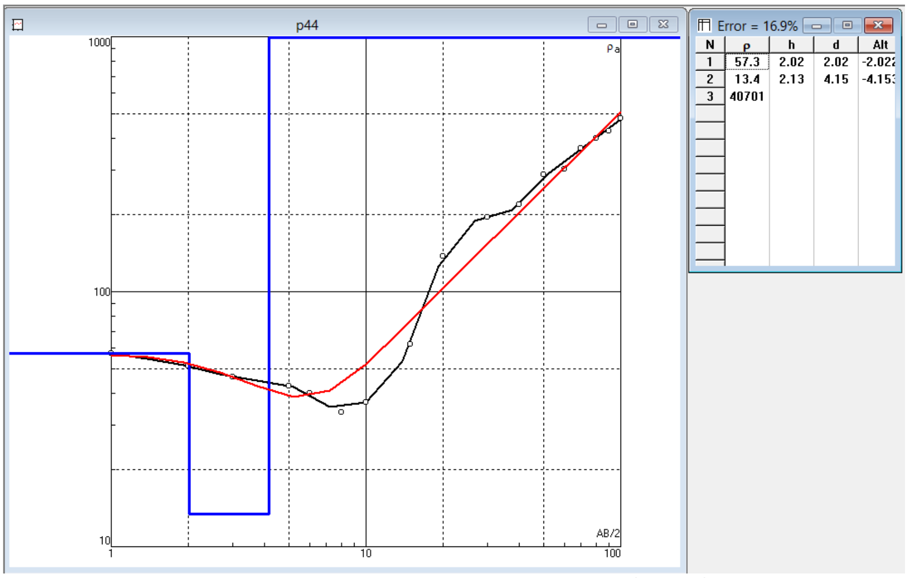


Figure 17. Log-log plot and corresponding data-field of P11-14

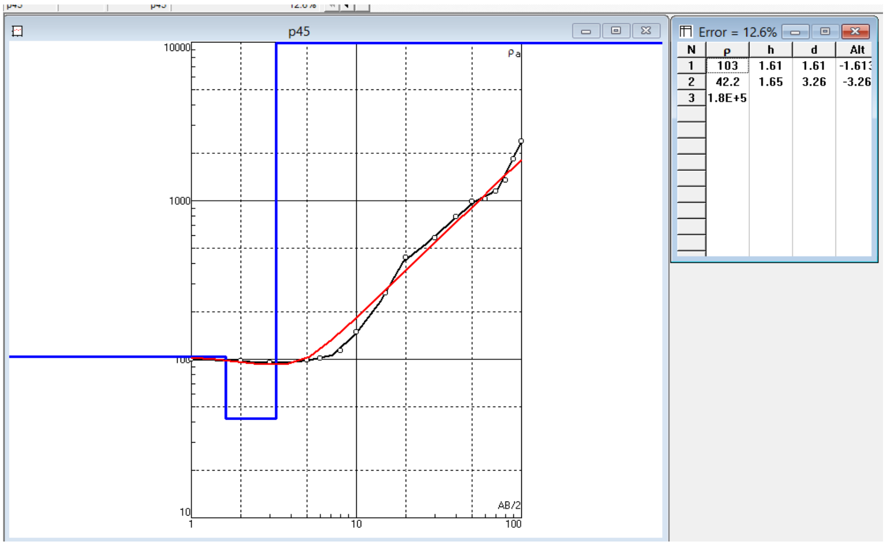


Figure 18. Log-log plot and corresponding data-field of P11-15

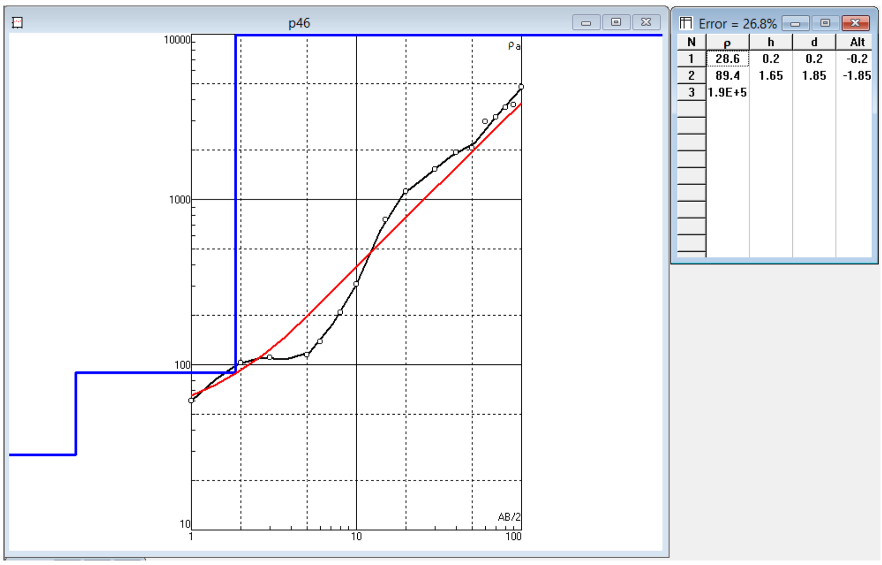


Figure 19. Log-log plot and corresponding data-field of P11-16

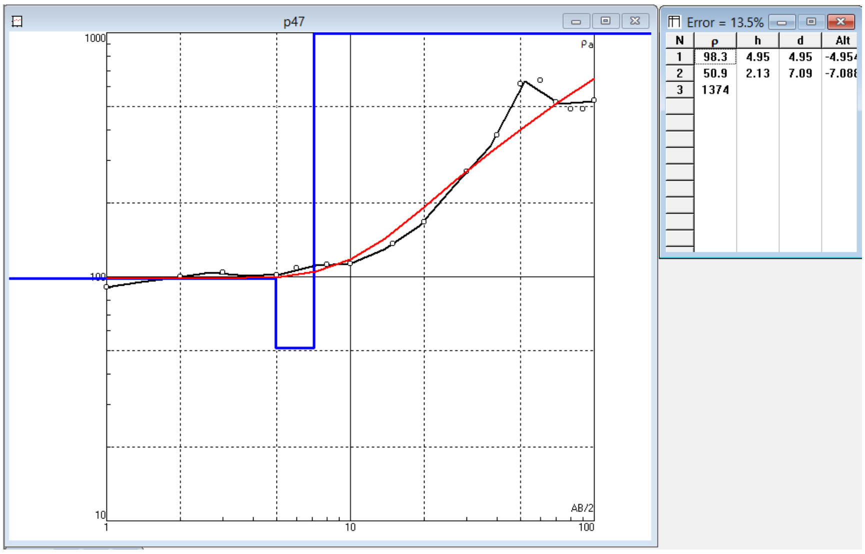


Figure 20. Log-log plot and corresponding data-field of P11-17

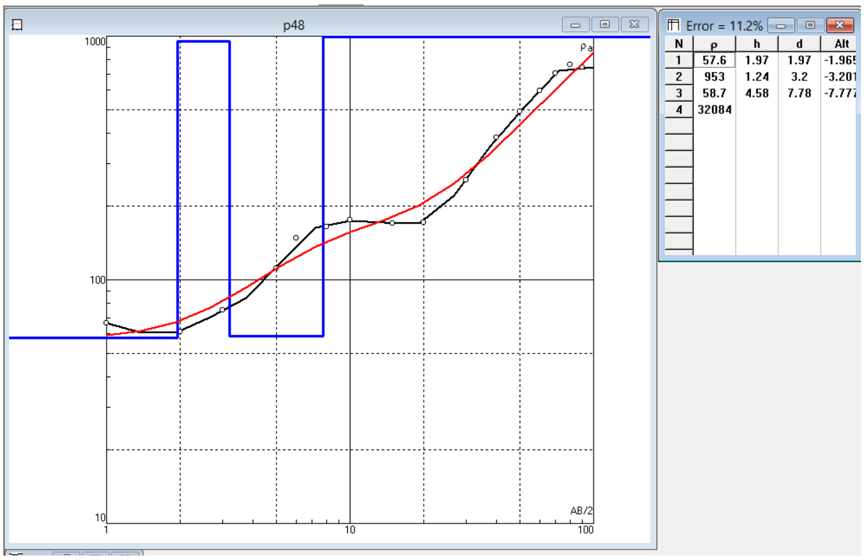


Figure 21. Log-log plot and corresponding data-field of P11-18

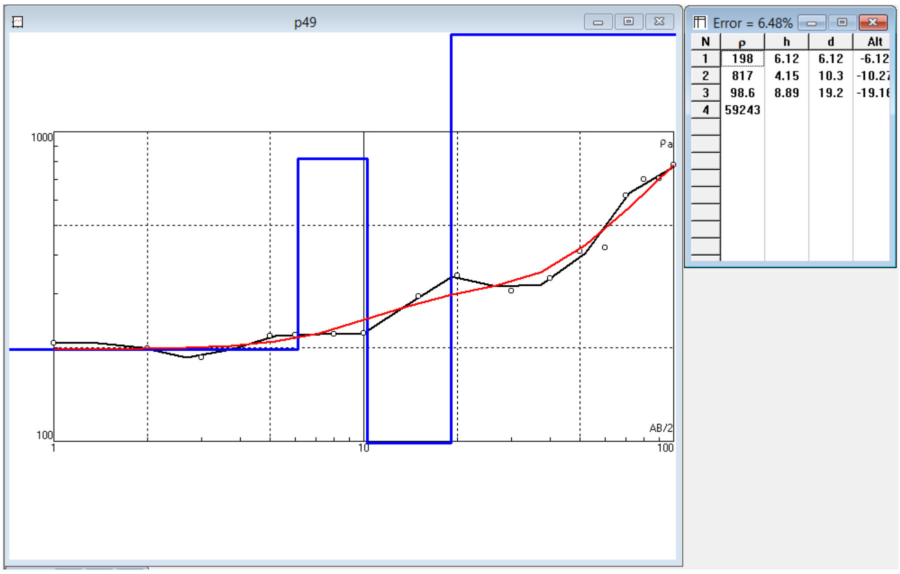


Figure 22. Log-log plot and corresponding data-field of P11-19

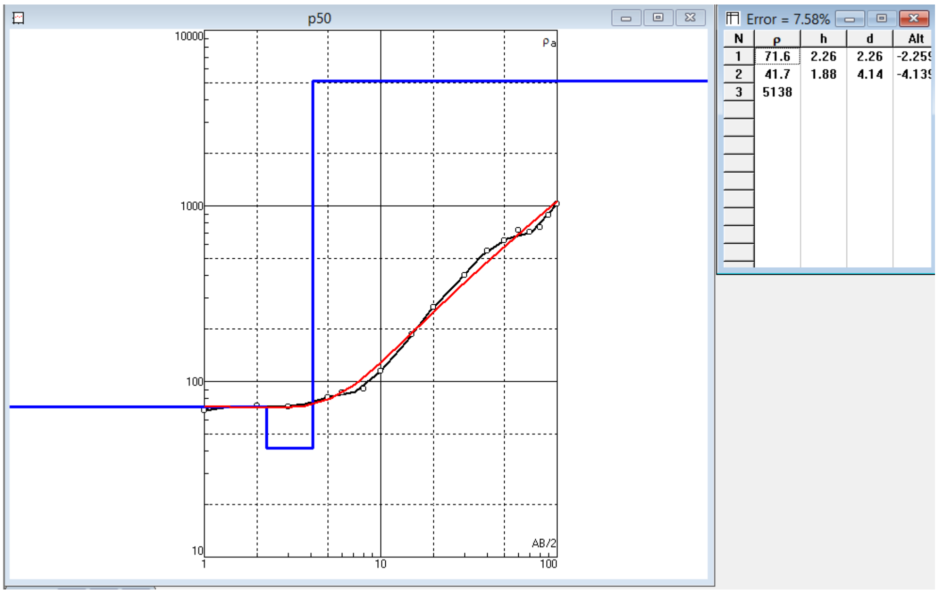
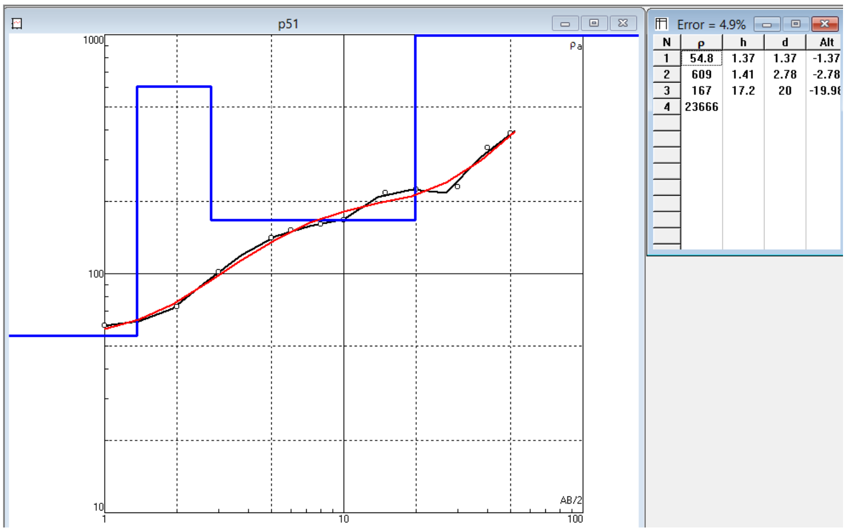


Figure 23. Log-log plot and corresponding data-field of P11-20



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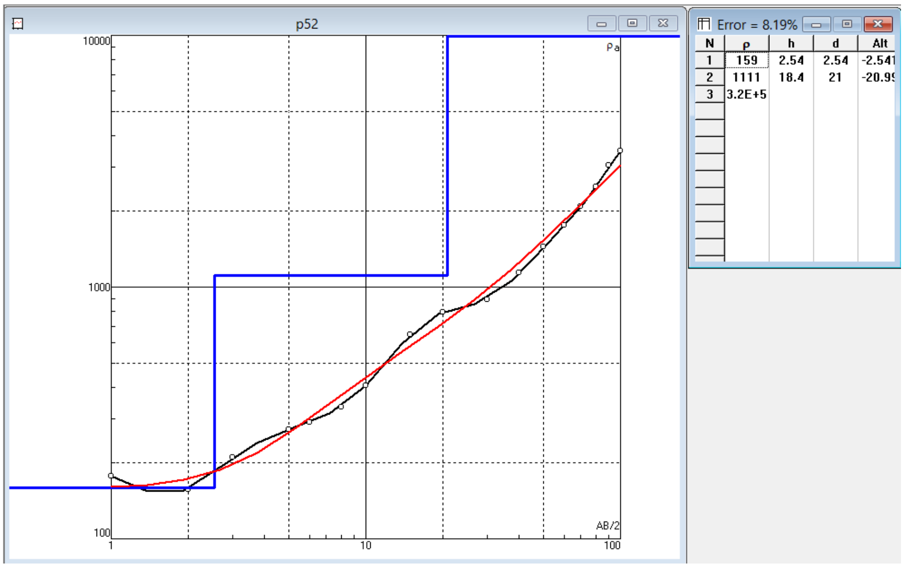


Figure 25. Log-log plot and corresponding data-field of P11-22

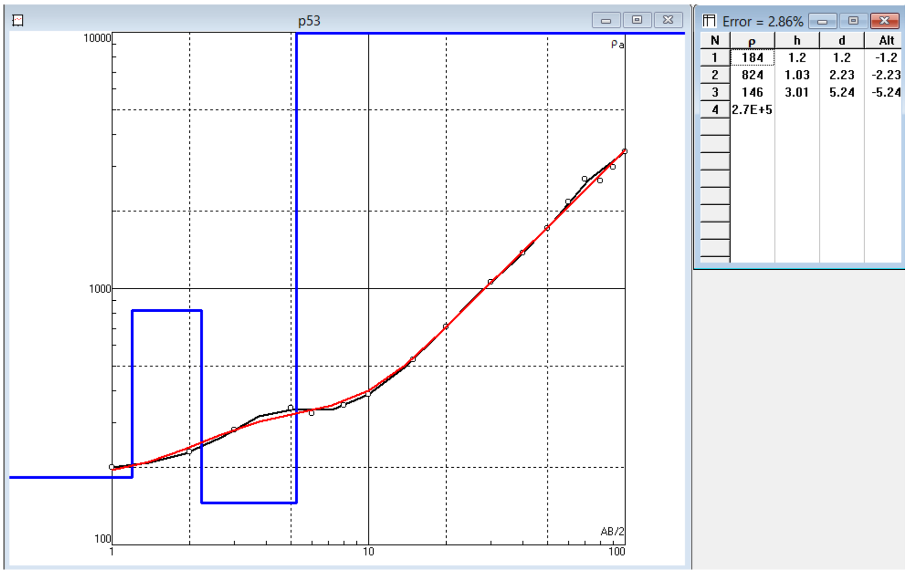
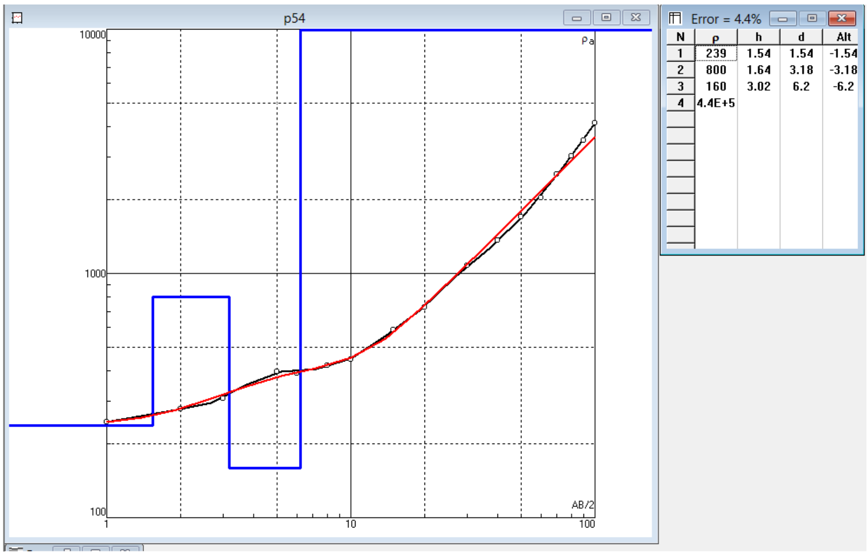


Figure 26. Log-log plot and corresponding data-field of P11-23



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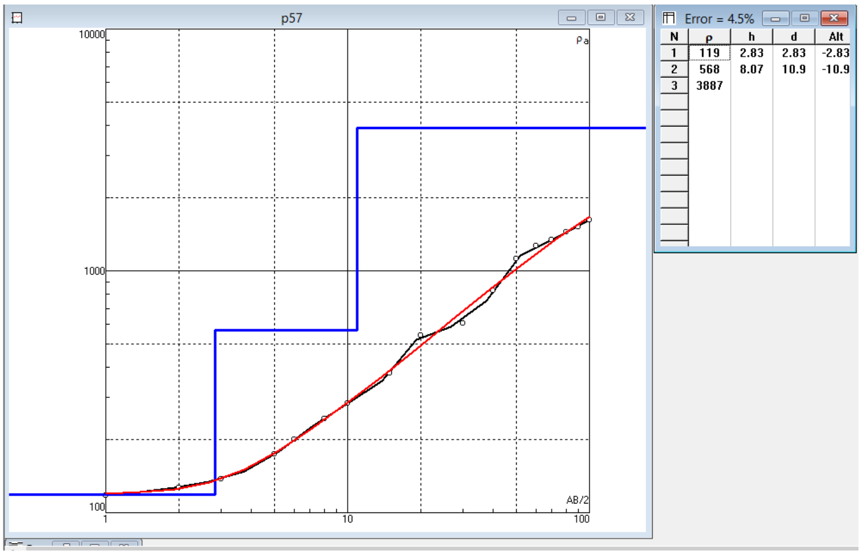

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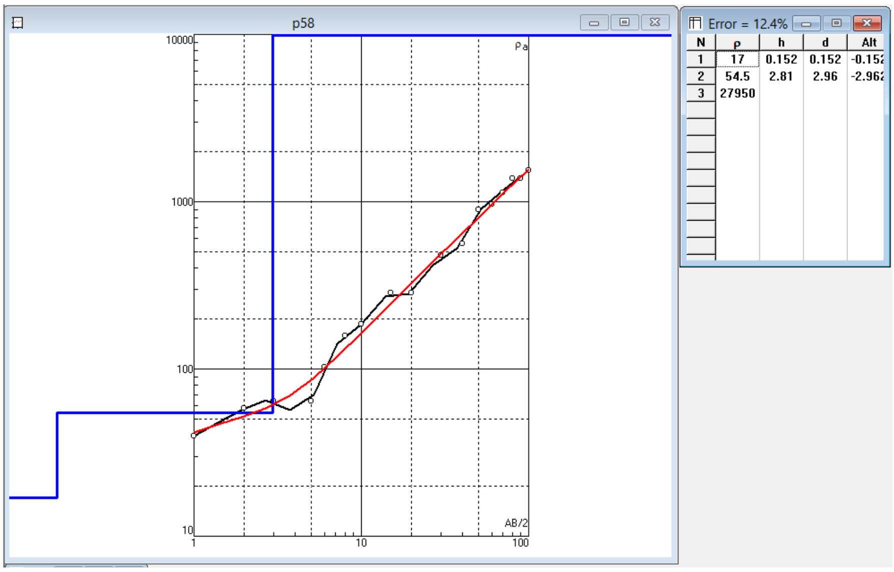


Figure 29. Log-log plot and corresponding data-field of P11-28

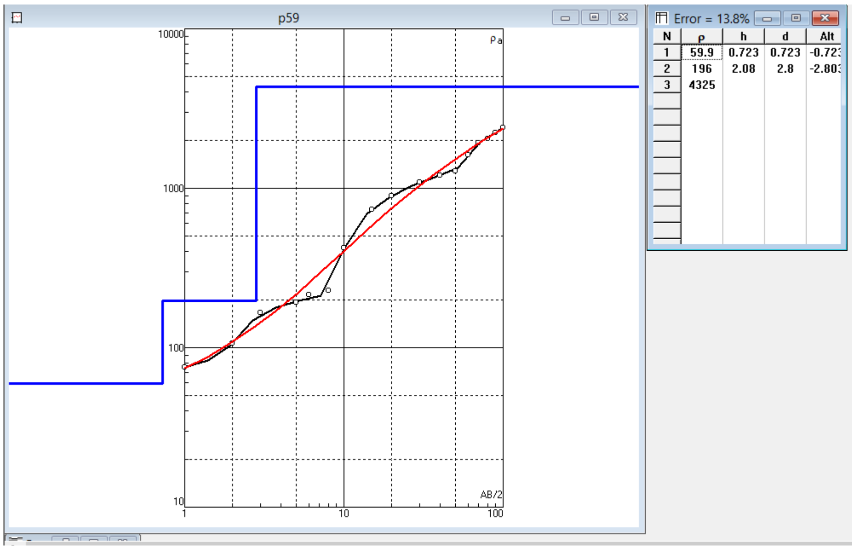


Figure 30. Log-log plot and corresponding data-field of P11-29

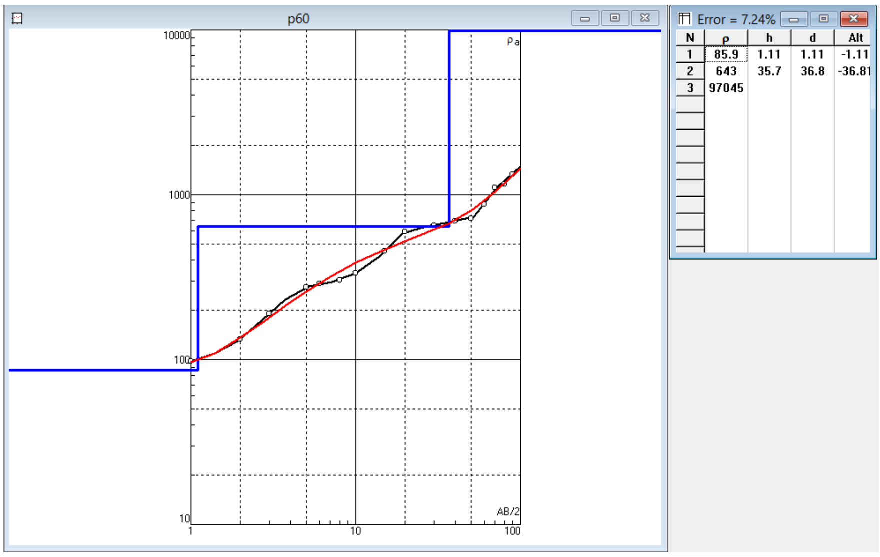


Figure 31. Log-log plot and corresponding data-field of P11-30

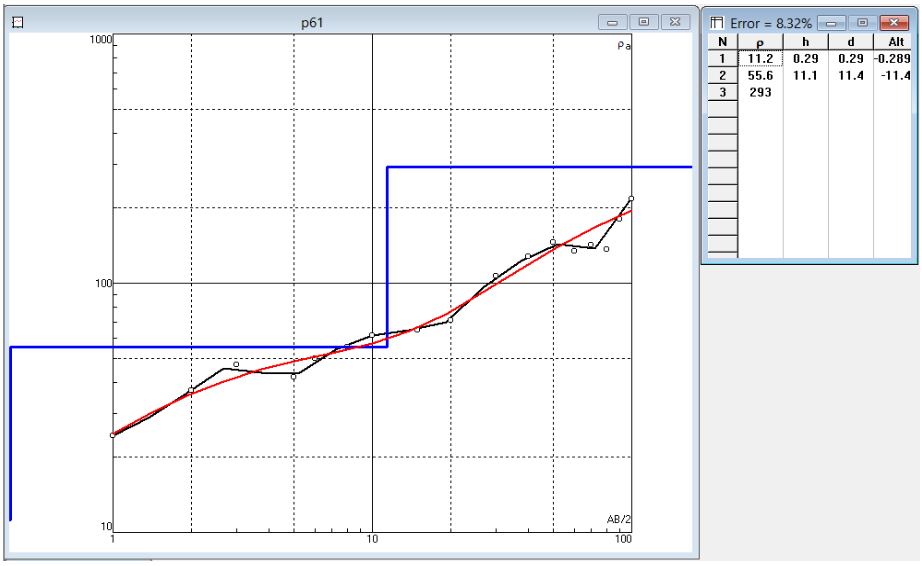


Figure 32. Log-log plot and corresponding data-field of P11-31

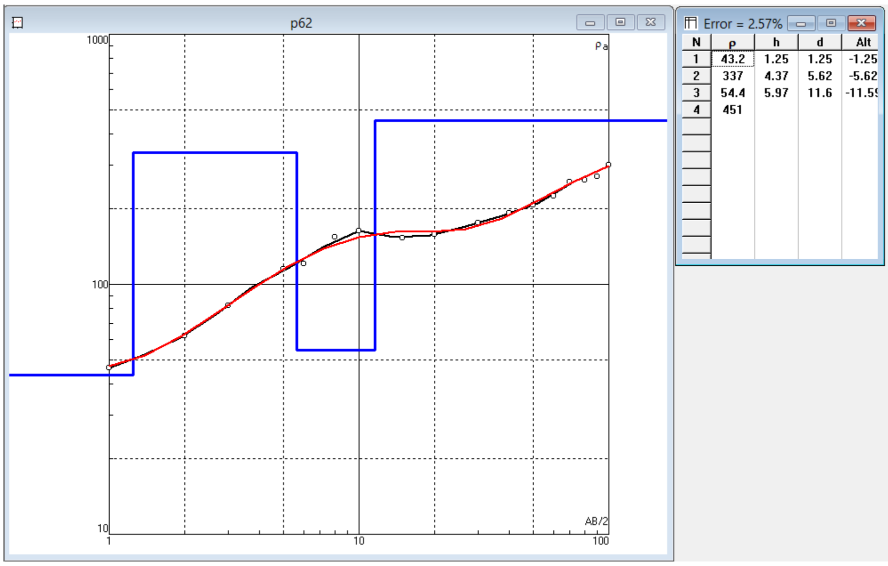


Figure 33. Log-log plot and corresponding data-field of P11-32

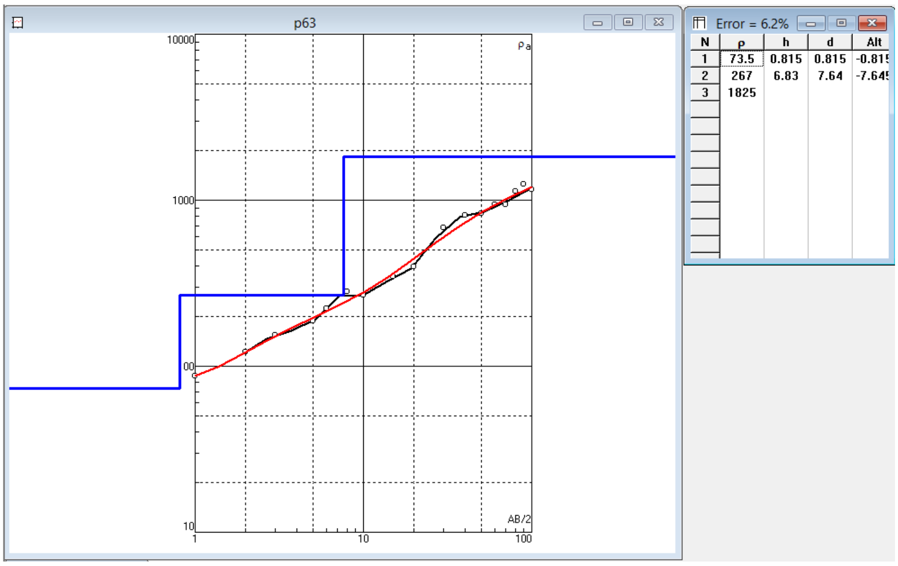


Figure 34. Log-log plot and corresponding data-field of P11-33

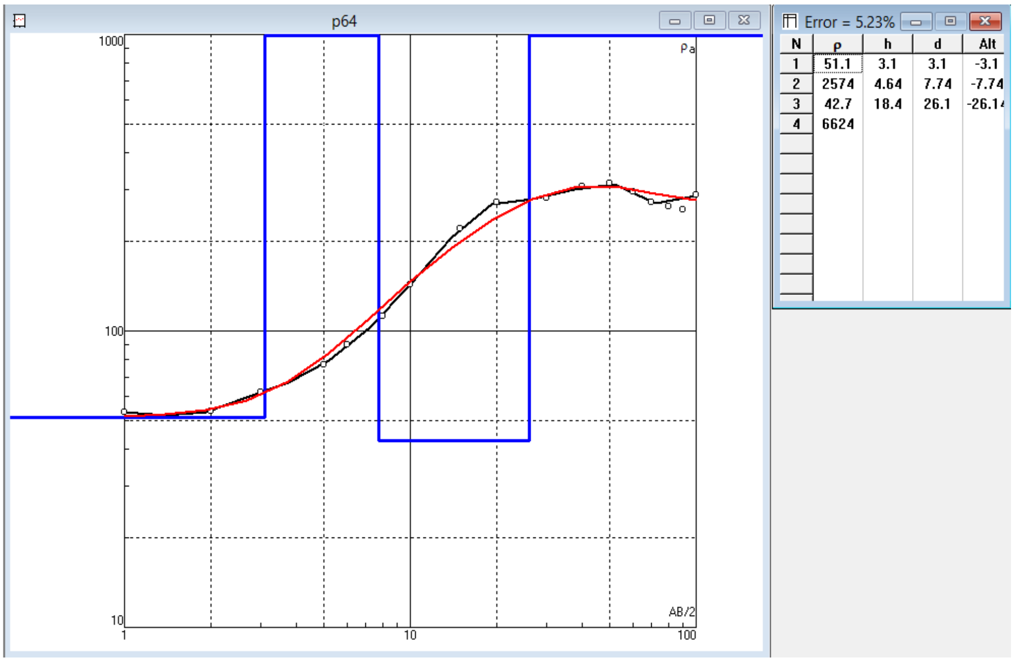


Figure 35. Log-log plot and corresponding data-field of P11-34

Resistivity Values of Rock Types in the Basement Complex of Nigeria

The resistivity values of various rock types in the Nigerian Basement Complex (NBC) are presented in Table 1. (From Shuaibu *et al.*, 2004).

Table 1. Resistivity values of rock types in the Basement Complex of Nigeria

Rock Type	**Resistivity (Ωm)**
Fadama loam30 – 90	
Sandy clay and sandy silt100 – 200	
Sand and gravel laterite150 – 1000	
Weathered laterite150 – 900	
Fresh laterite900 – 3500	
Weathered basement20 – 200	
Fractured basement500 – 1000	
Fresh basement> 1000	

In order to show the profile of the variation of resistivity with its associated actual number of layers at each VES survey station along the central north-south traverse, a geologic cross-section was generated and this is shown as Figure 35a; this cross-section with its corresponding geo-electric information is shown as Figure 35b.

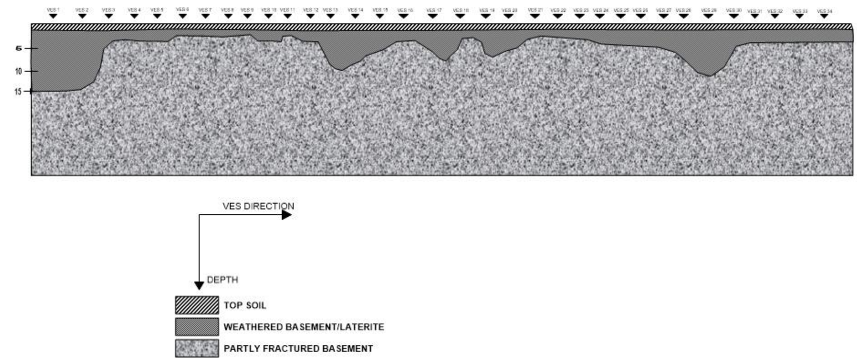
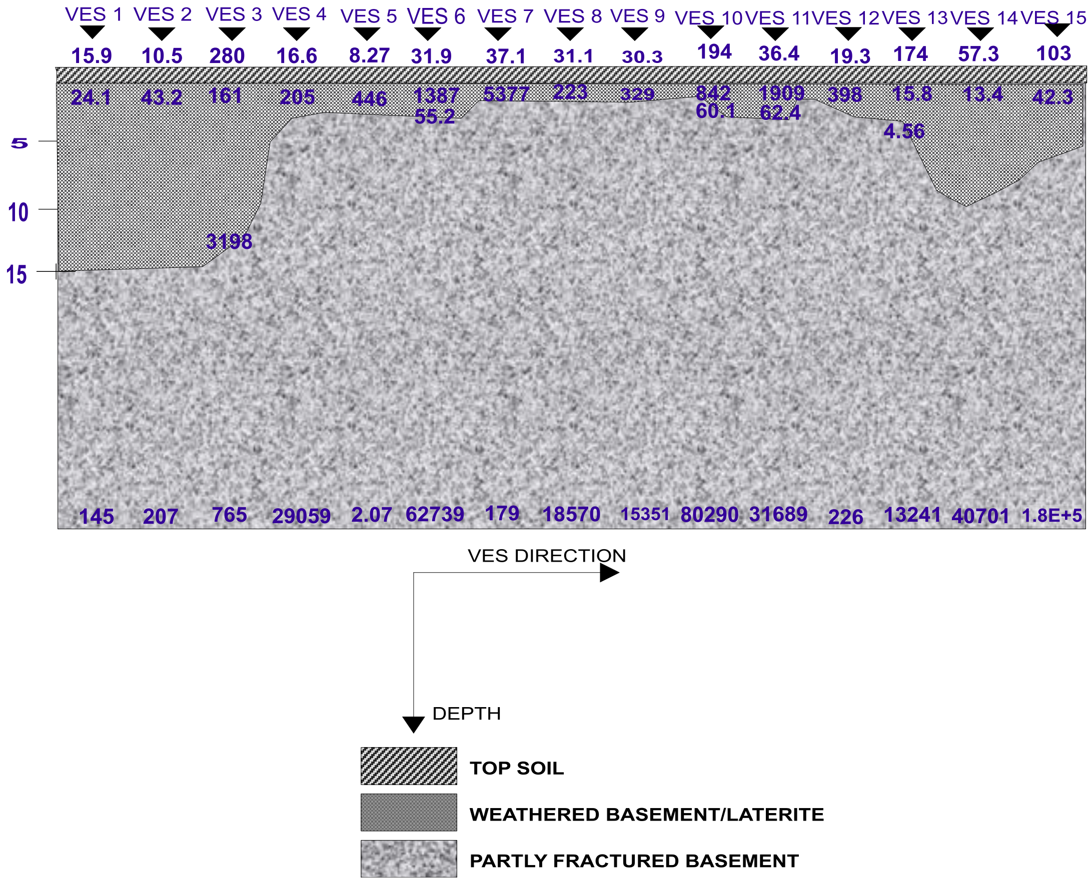


Figure 35a.Geologic cross-section of Profile 11



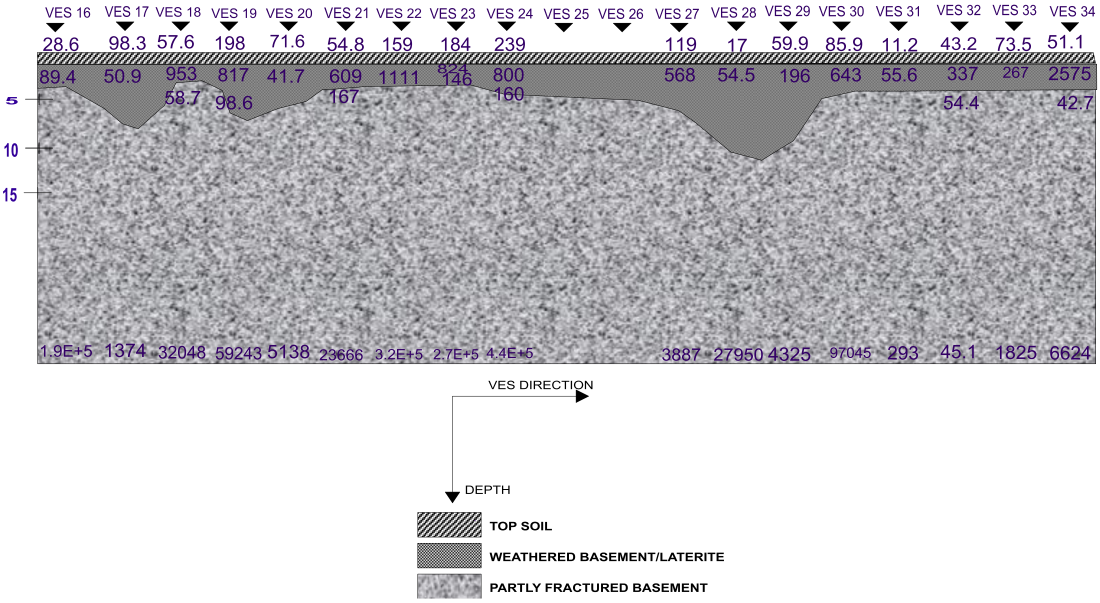


Figure 35b. Geologic cross-section of Profile 11 with its corresponding geoelectric information. (In Figure 35b, the "linear extent" of Figure 35a was "broken up" into two half-segments.)

In order to show the resistivity cross-section along the central north-south traverse, a pseudosection was generated and this is shown as Figure 36.

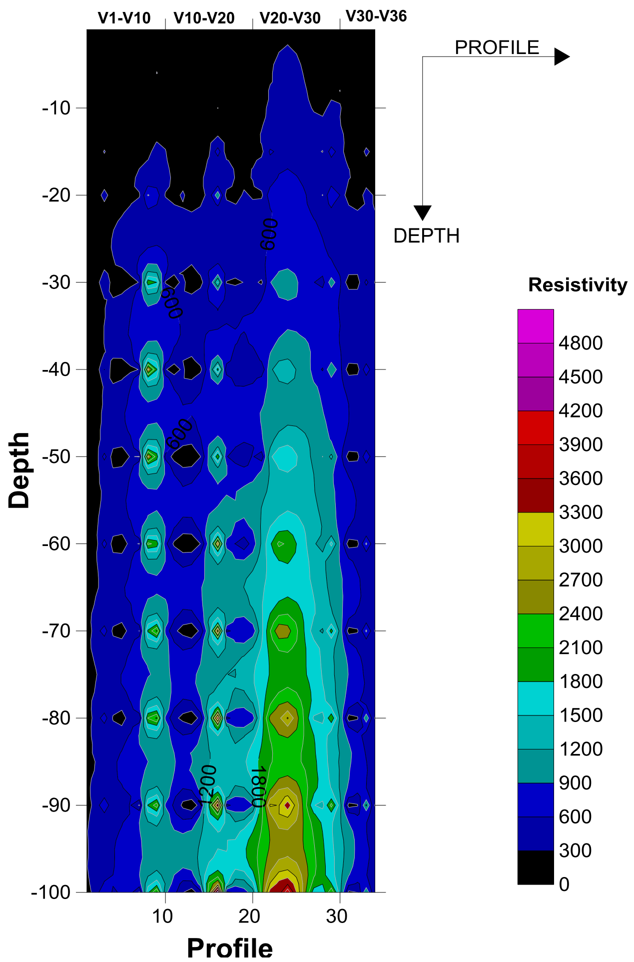


Figure 36. Pseudosection of Profile 11

IV. Discussion

The Log-Log Plots. Essentially, the log-log plots show more three-layer geological formation along the line of study but there are points where a four-layer formation can also be discerned; this three-layer structure is the expected norm at the local basement province of which this line of study is a part (Olasehinde, personal communication). Whereas, too, the norm is to have a comparatively very high resistivity for the third layer for a discerned three-layer geological structure at the general area of survey of which this traverse is but a part, this is not the case for the three-layer P11-1 point and the three-layer P11-2 point; both of these locations show a sequence of comparatively low-resistivity values down to greater depths. However, this expected norm of a comparatively very high resistivity value of the third-layer for a discerned four-layer geologic structure is the situation at P11-3; it is worth pointing out that the resistivity drops sharply at the fourth layer for the geologic structure at P11-3. A three-layer geologic structure at P11-4 follows the expected norm, but for the three-layer geologic structure at P11-5 the resistivity drops ever so sharply at the third layer. Whereas the thicknesses of the discerned second layer of the geologic structure at P11-1, P11-2, and P11-3 are thin it is observed that the second layers at P11-4 and P11-5 are comparatively thick. There is discerned four-layer geologic structure at P11-6, P11-10, P11-11, P11-13, P11-18, P11-19, P11-21, P11-23, P11-24, P11-32, and P11-34 and where these occur, the thicknesses regime of either the combination discerned first and second layers or the discerned second and third layers can conveniently be “smoothed-over” as they are close sometimes very close in values in order to stick to that three-layer convention. The third layer (and last layer) at P11-1, P11-2, P11-5, P11-7, and P11-12 are low-resistive layers; beyond the third layer of P11-12 (the northern ¾ segment of the line of survey), the resistivity of the subsequent third layer at each VES point assumes increasingly very large values. The discerned fourth-layer at P11-3 is a low-resistive material underlying a high resistive material; only at P11-32 is a similar situation observed but at this point the discerned comparatively low-resistive fourth layer actually underlay a very low resistive third layer.

The Geologic Cross-Section. The geologic cross-section shows the conventional and dominant three-layer representation of “top soil,” “weathered basement/laterite,” and “partly-fractured (fresh) basement.” Examination of Figure 35a and Figure 35b shows that the material that is fresh basement which may be partly-fractured at points dominates the geologic structure along the line of survey up to much shallower depths; the combined thicknesses of the top soil and weathered basement/laterite materials are generally not much significant compared to the thickness of this partly-fractured “behemoth” fresh basement along the line of survey. Table 1 aided the equivalent geologic-material associations made in Figure 35a and Figure 35b.

The Pseudosection Plot. The pseudosection plot of Figure 36 shows that, at the lower slope of the line of survey, low-resistivity materials of the sub-300 Ωm range dominate at comparatively shallower depths, but there is observed a “plunge” of this lower resistivity materials to much greater depths at the survey segment that would connect point P11-1 to point P11-2. As the survey-station designation increases in numerals as one proceeds upslope of the line of survey, dominant higher-resistivity material of a uniform kind are noticed at depth-points deeper than the 20 m mark and this is prominent between P11-20 and P11-30; still higher-resistive materials are noticed at the 40 m depth-mark downwards between P11-15 and P11-32 as they are noticed at the 30 m depth-mark downwards at P11-8 and P11-9. The highest-observed resistive material occurs at the approximate locations ofP11-25 and P11-26, although in reality, these dual points are the locations where VES information could not be got because of man-made yam-heap barriers.

“Tricks” for Groundwater Search at the Nigerian Basement Complex. There exists, for the Nigerian Basement Complex, empirical rules by which workers can reliably make deductions with respect to presence of sustainable groundwater at VES survey points along a line or across an area of study. Loke (2011) quoted Ackworth (1981) as stating that, “the weathered layer is thicker in areas with fractures in the bedrock.” Jonah and Jimoh (2016A) examined the validity of an empirical rule for delineating aquifer prospects at the Gidan Kwano Campus Development Phase II, Federal University of Technology, Minna, and this reliable route has been christened “Geoexplore Empirical Standardisation for Minna Area;” the Geoexplore Empirical Standardisation for Minna Area states that resistivity values between 200 Ωm and 300 Ωm at the 20 m depth and less than 200 Ωm at depths greater than 20 m are indicative of possible groundwater prospects.

V. Conclusion

Juxtaposing the examinations of the last-layer low-resistive structure at P11-1, P11-2, P11-5, P11-7, P11-12, P11-31 with the empirical rule of the Geoexplore Empirical Standardisation for Minna Area with the pseudosection of Profile 11 (Figure 36), these VES points could be justifiably flagged as groundwater prospect locations along the line of survey of this study. Further considerations regarding the fact of a low-resistive material, surely not the first layer, of substantial thickness overlying a very resistive material and of depths in the region of 20 m or so, the idea of “the weathered layer is thicker in areas with fractures in the bedrock” from Ackworth 1981 is found at P11-4, P11-5, P11-21, P11-22, P11-30, P11-31, and P11-34.The resistivity values of the third and last layer beyond P11-12 that assumes increasingly very large values can be explained away as a

result of profusion of outcrops of granitic bodies towards the northern ¾ end of the line of survey. A definitive indication of fracture in the basement at depth (“traditionally-determined” by making recourse to Table 1), a favourable condition for the existence of groundwater, is found at P11-3 and P11-32. Now, the VES points along the line of survey flagged for their groundwater prospects are the following:
P11-1 located at latitude $9^0 30'57.80''$ and longitude $006^0 26'11.40''$;
P11-2 located at latitude $09^0 31'01.04''$ and longitude $006^0 26'11.40''$;
P11-3 located atlatitude $09^0 31'04.28''$ and longitude $006^0 26'11.40''$;
P11-4 located at latitude $09^0 31'07.52''$ and longitude $006^0 26'11.40''$;
P11-5 located at latitude $09^0 31'10.76''$ and longitude $006^0 26'11.40''$;
P11-7 located at latitude $09^0 31'17.24''$ and longitude $006^0 26'11.40''$;
P11-12 located at latitude $09^0 31'33.42''$ and longitude $006^0 26'11.40''$;
P11-21 located at latitude $09^0 32'02.58''$ and longitude $006^0 26'11.40''$;
P11-22 located at latitude $09^0 32'05.82''$ and longitude $006^0 26'11.40''$;
P11-30 located at latitude $09^0 32'31.74''$ and longitude $006^0 26'11.40''$;
P11-31 located at latitude $09^0 32'34.98''$ and longitude $006^0 26'11.40''$;
P11-32 located at latitude $09^0 32'38.22''$ and longitude $006^0 26'11.40''$;
P11-34 located at latitude $09^0 32'44.70''$ and longitude $006^0 26'11.40''$.

Overall, there is concentration of more prospect locations at the lower slope of the line of survey (P11-1, P11-2, P11-3, P11-4, P11-5, and P11-7) and at the northern end of the line of survey (P11-30, P11-31, P11-32, and P11-34); these concentrations of prospect locations at the northern segment is of interest here because these could not have been discerned from the limited-areal extent, 2 km x 2 km, of the study of Jonah and Olasehinde (2017A). Also, smack in the middle of the survey line, a couple of prospect locations can be identified (P11-12 and P11-21). Now, as a result of this study, it is possible to make informed deduction about groundwater prospect locations at the northern sector of Jonah and Olasehinde (2017A) and beyond whilst providing insight into the hydro-centric nature of the points very close to the students’ hostel facilities. The “generic” groundwater prospect locations inferred from this study can be specifically classified into “deep-drill prospect” and “shallow-drill prospect.” This being the case, the following schedule is now drawn up:
P11-1: Deep-drill prospect (100-m drill-window);
P11-2: Deep-drill prospect (100-m drill-window);
P11-3: Deep-drill prospect (100-m drill-window);
P11-4: Shallow-drill prospect (29-m drill-window);
P11-5: Deep-drill prospect (100-m drill-window);
P11-7: Deep-drill prospect (100-m drill-window);
P11-12:Deep-drill prospect (100-m drill-window);
P11-21: Shallow-drill prospect (20-m drill-window);
P11-22: Shallow-drill prospect (21-m drill-window);
P11-30: Shallow-drill prospect (39-m drill-window);
P11-31: Deep-drill prospect (100-m drill-window);
P11-32: Deep-drill prospect (100-m drill-window);
P11-34: Shallow-drill prospect (26-m drill-window).
Overall, the points of P11-1, P11-2,P11-3, P11-5, P11-7, and P11-12have complimented the 57 definite groundwater prospect locations inferred from Jonah and Olasehinde (2017A); each of these 57 definite groundwater prospect locations is “deep-drill prospect”-designated.

VI. Recommendation

It is recommended that the groundwater prospect locations at P11-1, P11-2, P11-3, P11-5, P11-7, and P11-12 be integrated into the database of the existing 57 definite groundwater prospect locations inferred from Jonah and Olasehinde (2017A); the database of the definite groundwater prospect locations inferred from Jonah and Olasehinde (2017A) is part of the corpus of information about the local geology of the Gidan Kwano Phase II Development that would surely be needed in the mid- to long-term. As was done for the initially-identified groundwater prospect locations of Jonah and Olasehinde (2017A), the VES points that are flagged as prospects for this study should be subjected to an even stricter control on their hydro-centric nature by making recourse to the concomitantly-acquired induced polarisation (IP) data at coincident points of surveys as those for the VES.

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Appendix

GEOELECTRICAL DATA RECORD SHEET

TYPE OF SURVEY:… Resistivity....**MODE:**…. Vertical Electrical Sounding… **ARRAY:** **…..**Schlumberger…..…

PLACE:…Gidan Kwano Campus…. **WEATHER:**…Fine (Humid).. **EQUIPMENT:**.ABEM Terrameter SAS 4000

LOCATION: (i) **N:**..09^{0}30'57.8''..........(ii) **E:**....006^{0}26'11.4''.......**ELEVATION:**…199m………………….

OPERATOR:…SJ………**RECORDER:**…SJ…… ……**DATE:**.Fri 27th May 2011…. **TIME:**……………

LONGITUDINAL TRAVERSE DESIGNATION:P11-1…… **GPS UNIT:**… Garmin GPSmap76………..

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY (Ωm)
1	.50	2.36	117.70 mΩ	3.25%	10 mA	4	0.277
2	.50	11.8	24.131 mΩ	0.29%	10mA	2	
3	.50	27.8	11.990mΩ	3.08%	10mA	4	
5	.50	77.8	5.2503mΩ	2.87%	10mA	4	
6	.50	112	8.9356mΩ	2.35%	10mA	4	
6	1.00	55	8.8347mΩ	0.000%	10mA	2	
				0.314%	10mA	2	

8	1.00	99	11.384mΩ				
10	1.00	156	9.3395mΩ	1.79%	10mA	4	
10	2.50	58.9	10.955mΩ	0.652%	10mA	2	
15	2.50	137	11.611mΩ	0.615%	10mA	2	
20	2.50	245	7.3959mΩ	3.20%	10mA	4	
30	2.50	562	16.104mΩ	4.53%	10mA	4	
40	2.50	1001	27.387mΩ	6.72%	10mA	4	
40	7.50	323	24.788mΩ	6.27%	10mA	4	
50	7.50	512	18.073mΩ	1.42%	10mA	4	
60	7.50	742	45.208mΩ	0.553%	10mA	2	
70	7.50	1014	51.796mΩ	0.414%	10mA	2	
80	7.50	1329	13.934mΩ	0.512%	10mA	2	
80	15.00	647	17.493mΩ	7.80%	10mA	4	
90	15.00	825	178.64mΩ	0.659%	10mA	2	
100	15.00	1024	6.3357mΩ	76.7%	10mA	4	

GEOELECTRICAL DATA RECORD SHEET

TYPE OF SURVEY:… Resistivity....**MODE:**…. Vertical Electrical Sounding… **ARRAY:** **…..**Schlumberger….…

PLACE:…Gidan Kwano Campus…. **WEATHER:**..Blustery….. **EQUIPMENT:**.ABEM Terrameter SAS 4000

LOCATION: (i) **N:**... 09^{0}31′07.52″........(ii) **E:**.... 006^{0}26′11.4″.........**ELEVATION:**……203m………………….

OPERATOR:…SJ………**RECORDER:**…SJ…… ……**DATE:**… Wed 25th May 2011….**TIME:**………………

LONGITUDINAL TRAVERSE DESIGNATION:…P11-4…… **GPS UNIT:**… Garmin GPSmap76……….

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	79.335mΩ	12.9%	10mA	4	
2	.50	11.8	3.1300mΩ	241%	10mA	4	
3	.50	27.8	-14.312mΩ	91.1%	10mA	4	
5	.50	77.8	-10.652mΩ	165%	10mA	4	
6	.50	112	-10.829mΩ	88.4%	10mA	4	
6	1.00	55	-9.2385mΩ	164%	10mA	4	
8	1.00	99	-14.388mΩ	82.6%	10mA	4	
10	1.00	156	-26.327mΩ	26.2%	10mA	4	
10	2.50	58.9	-29.407mΩ	13.2%	10smA	4	
15	2.50	137	6.6134mΩ	177%	10mA	4	
20	2.50	245	26.630mΩ	87.6%	10mA	4	
30	2.50	562	50.989mΩ	43.3%	10mA	4	
40	2.50	1001	21.178mΩ	97.9%	10mA	4	
			26.151mΩ	92.2%	10mA	4	

40	7.50	323					
50	7.50	512	28.018mΩ	30.7%	10mA	4	
60	7.50	742	-20.345mΩ	109%	10mA	4	
70	7.50	1014	-59.116mΩ	15.4%	10mA	4	
80	7.50	1329	-36.475mΩ	36.5%	10mA	4	
80	15.00	647	-39.882mΩ	48.4%	10mA	4	
90	15.00	825	-47.960mΩ	24.9%	10mA	4	
100	15.00	1024	-54.952mΩ	22.3%	10mA	4	

GEOELECTRICAL DATA RECORD SHEET

TYPE OF SURVEY:… Resistivity....**MODE:**…. Vertical Electrical Sounding… **ARRAY:** **…..**Schlumberger…..…
PLACE:…Gidan Kwano Campus…. **WEATHER:…**Fine…... **EQUIPMENT:**.ABEM Terrameter SAS 4000
LOCATION: (i) **N:**.... 09^{0}31'10.8''..........(ii) **E:**.... 006^{0}26'11.4''........**ELEVATION:**…………201m…………….
OPERATOR:…SJ………**RECORDER:**…SJ…… ……**DATE:**… Wed 25th May 2011….**TIME:**………………
LONGITUDINAL TRAVERSE DESIGNATION:…P11-5…… **GPS UNIT:**… Garmin GPSmap76……….

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	69.567mΩ	0.021%	10mA	2	
2	.50	11.8	55.330mΩ	0.258%	10mA	2	
3	.50	27.8	47.960mΩ	6.94%	10mA	4	
5	.50	77.8	48.540mΩ	0.36%	10mA	2	
6	.50	112	43.921mΩ	0.813%	10mA	2	
6	1.00	55	48.894mΩ	2.74%	10mA	4	
8	1.00	99	78.679mΩ	0.681%	10mA	2	
10	1.00	156	71.485mΩ	304%	10mA	4	
10	2.50	58.9	79.815mΩ	2.59%	10mA	4	
15	2.50	137	73.000mΩ	0.978%	10mA	2	
20	2.50	245	38.115mΩ	3.09%	10mA	4	
30	2.50	562	65.175mΩ	1.82%	10mA	4	
40	2.50	1001	39.100mΩ	0.822%	10mA	2	
40	7.50	323	42.659mΩ	3.31%	10mA	4	
50	7.50	512	5.4270mΩ	16.0%	10mA	4	
60	7.50	742	9.4909mΩ	7.25%	10mA	4	
70	7.50	1014	20.825mΩ	13.4%	10mA	4	
80	7.50	1329	7.3706mΩ	0.969%	10mA	2	
80	15.00	647	11.207mΩ	5.71%	10mA	4	
90	15.00	825	Battery down	Battery down	Battery down	Battery down	
100	15.00	1024	Battery down	Battery down	Battery down	Battery down	