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Overpressure/ Depositional Analysis of Parts of Onshore (X-Field) Niger Delta Basin Nigeria, Based on Well Logs Data

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Abstract
Overpressure in the world's sedimentary basins are known to be allied with permeability barriers, tectonics, shale digenesis, basin structure and undercompaction factors. The Niger Delta basin has many overpressured zones with different depositional enviroments. This study was done using six drilled wells log suits in an x- field (Gama ray log, deep induction log, Density log, and sonic log). The data was acquired from Cheveron Nigeria Ltd in ascii softcopy format, which was analysed using both manual method and computer processed interactive petrophysics (IP) version 3.6 software. The logs were loaded and printed to hardcopies and digitization done at 5m interval to extract the data across the log suits. Characteristic curve patterns along the gamma log were delineated for shape patterns such as bell shape, funnel shape, and blocky to reveal paleoenviroments of the study area. The results indicate twenty one (21) overpressure zones within the wells, three (3) subsurface overpressure zones are correlated across the wells at depth interval between 3000m – 3200m for wells A,B,C,D,E and 2900m – 3000m for wells E and C , and 3600m – 3700m for wells C and F respectively,these overpressured zones occurred within a dominantly fluvial channel with minor detlaic distribution and barrier bar complexes. The areas identified as overpressured zones should be critically examined during drilling to avoid rig blow outs.

1. INTRODUCTION

Over pressure zones are known to be allied with permeability barriers tectonics, shale diagenesis, basin structure and undercompaction (Ogbobe, 1997) Egeh et,al. 2001; Olatubosum, 2014). The Niger Delta is one of the most prolific oil province in the world. Exploration activities is still ongoing with reports of the presence of overpressure zones which has been a source of worry to oil and gas investors. This study is aimed at using available drilled well log suites (resistivity, Gama, sonic and Density)Fig.1 to address the challenges of identifying the subsurface overpressure zones and possible enviroments of deposition within the onshore Niger Delta region. There are reported research work on overpressure zones within the offshore areas (Egeh et, al. 2011, Olatubosun 2014).

However, subsurface literature on the onshore overpressure analysis in scares. This work will enhance safe drilling conditions when areas with overpressure zones in the subsurface are drilled.

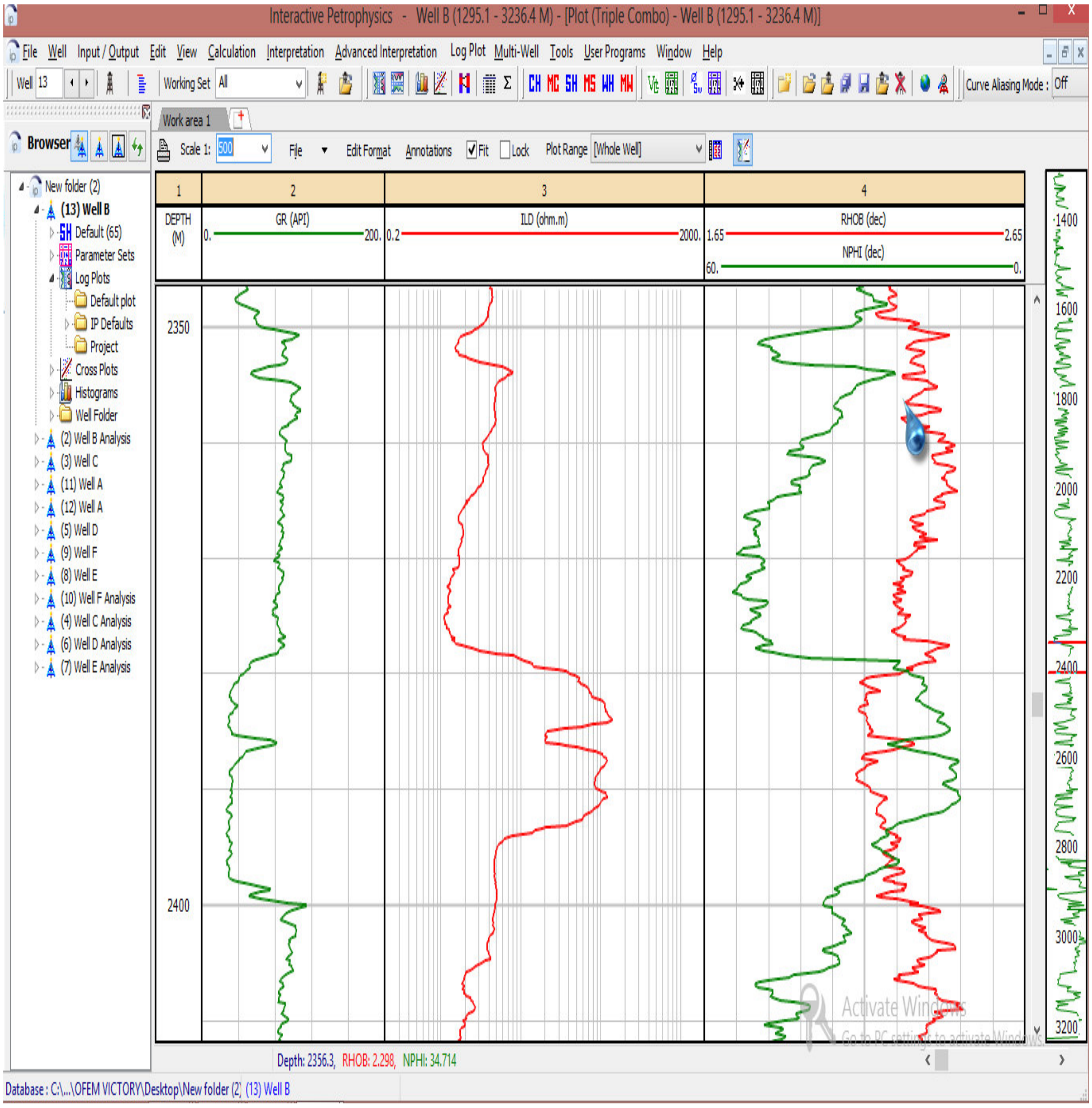

Fig 1.. Printed hard copy of the composite logs

2.GEOLOGY OF THE STUDY AREA

The Niger Delta is an arcuate Delta with sedimentary rocks in excess of 12 km in thickness, it's a prolific hydrocarbon producing basin (Egedewa 1981, evamy et,al.1978). Geological and geophysical evidence supports it's emergence after the formation of the Benue trough and the Anambra basin. Geophysical work from researchers indicate that is the thickest basin in Nigeria with growth Faults and roll-over anticlines as its major structural features (Ako et, al. 2004, Obi et, al. 2008; Okiwelu et, al. 2012; Okiwelu et, al. 2013; corredor, 2005, Hospers 1965).

The tertiary Niger Delta is subdivided into three formations reviewed by many authors (short and staublee 1965, Avbobvo, 1978; Doust and Omatola 1989; whitman, 1982; Reijers, 1996; Evamy, 1978). The Akata formation at the base of the delta is of marine origin and is composed of thick shale sequence (potential source rock), turbidites sand (potential reservoir) in deep water), and minor amount of clays and silt (stracher 1995), this formation is overlain by the Agbada formation (Eocene – Recent) which is the major petroleum bearing unit consisting of alternations of sandstones and shales in alternate amounts of equal proportions at the its base and mostly sandstones at the upper portions with little shale interbeds (Avbovbo 1978, Reijers 1997, Burke 1972). Overlaying the Agbada formation is the benin formation coastal plain sands (Fig 2.0).

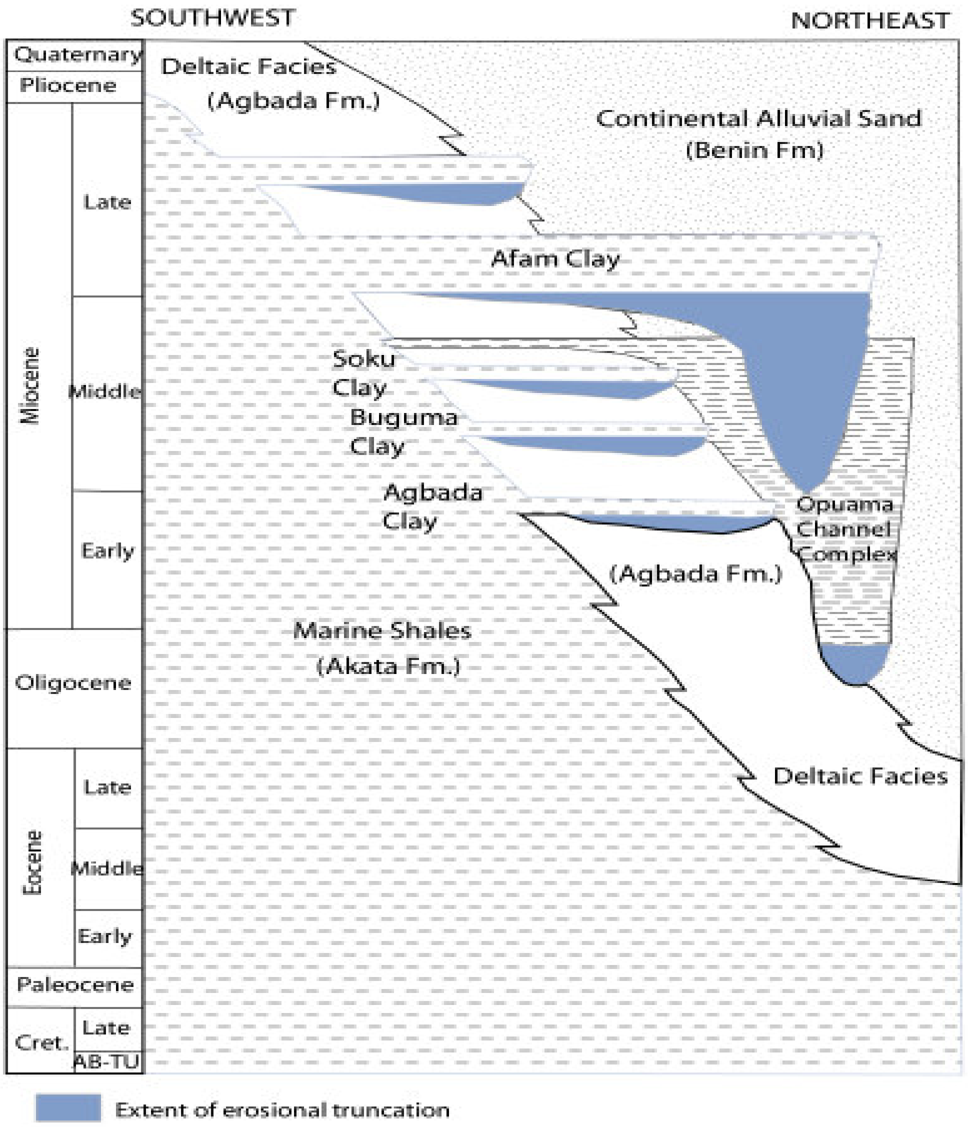

Figure 2: Stratigraphic column of the Niger Delta (modified from Doust and Omatsola, 1989).

3.0 DATA ANALYSIS

Six (6) well log suits which include Gamma ray log, deep induction resistivity log, density log and sonic log were obtained from Agip oil company ltd from an x- field in the onshore Niger Delta. The logs were supplied in soft copies ascii Log format. These log were processed both manually and with computer processed technique of uploading log data. The interactive petrophysics (IP) version 3.6 software was used in loading and printing the hard copies fro which manual analysis was performed. An initial quick look evaluation using the Gama ray long serrating areas with high Gamma Ray (API) as shales and low Gamma ray (API) as sands, then the digitization of all the logs using 5m intervals for the various physical parameters were extracted to depth interval of 3500 m. Overpressure analysis was based on the premise that shale remain the preferred lithology for pore pressure interpretation since they are more responsive to over pressure than other rocks.

There (3) logs which include deep induction resistivity, sonic, and density logs were used for the compaction trend evaluation or geopressure analysis. The extracted data were plotted (Using excel software) as logs paramters of digitized physical parameters against depth at 5 m intervals (Fig 3, 4, 5, 6, 7, 8). The principle behind detecting under compacted zones is that the detection of normal compaction trend or undercompaction is by deviation from the normal of increasing physical parameters with depth , these areas are refered to as over pressured (Egeh et, al. 2001, Opara and Onuoha, 2001, asquith and Gibson 1982). The three (3) logs were analyzed for areas of these deviations tops and bottoms of these deviations were extracted from these logs as areas of over pressured zones (Table1.0).

Also, using a quick look method, the curve shapes or patterns, the various reservoirs were determined from the Gamma ray log and analysis of the different environment of deposition was made from the signature

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shape of the Gama ray logs (bell, funnel, blocky or cylindrical) (Burke, 1972 Asquith Gibson , 1982.) Fig.9. A total of forty (40) reservoirs internals was extracted from the gamma ray logs and log shapes with characteristic patterns was used to deduce depositional enviroments (Table 2.0, 3.0, 4.0, 5.0, 6.0). From the fourty (40) reservoirs and their boundry source rocks, about thirty (30) were fluvial channel sands and ten (10) barrier bars, mouth bars and deltaic distributries environments.

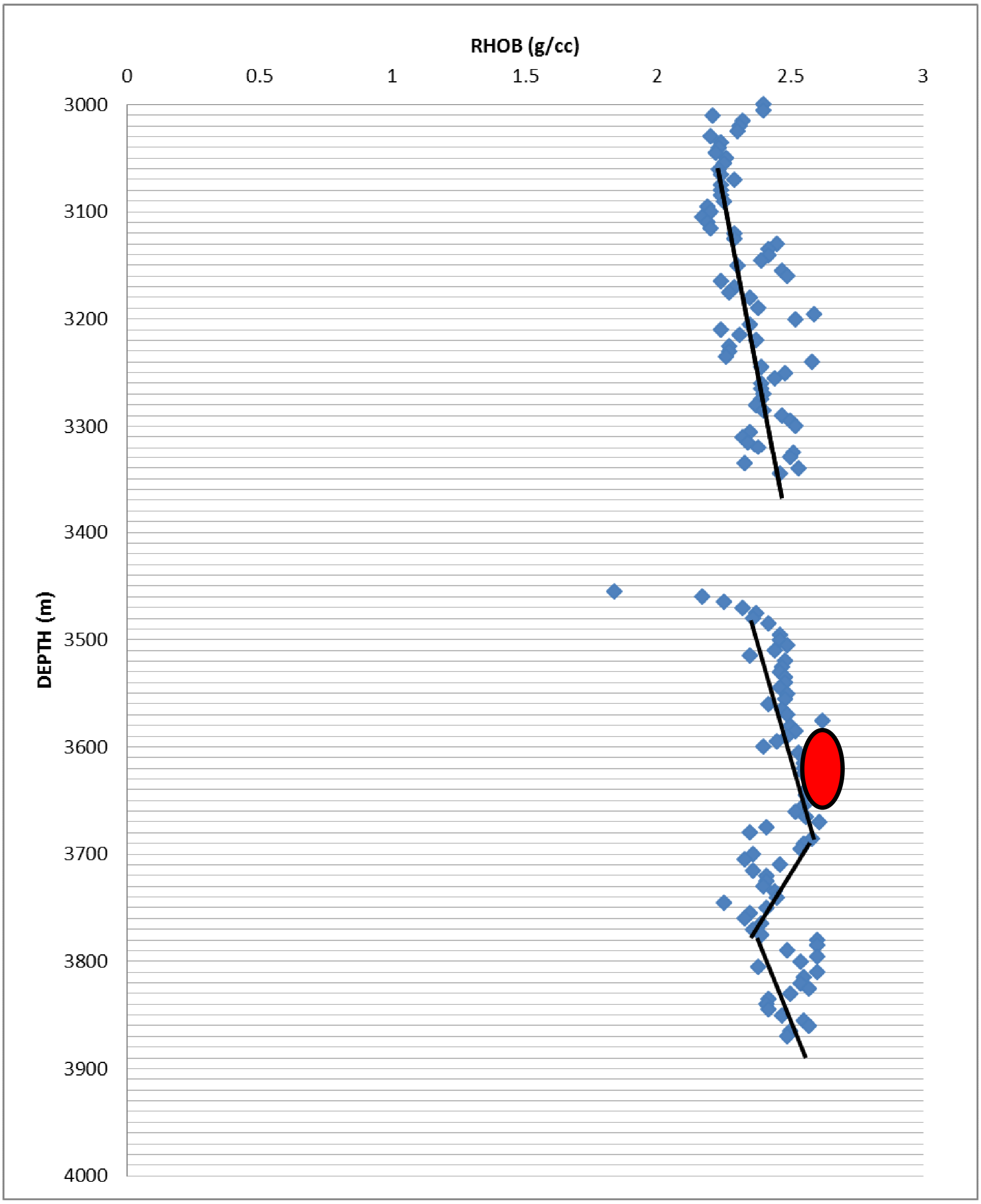

Figure3a. compaction trend for Well F on a plot of bulk density versus depth.

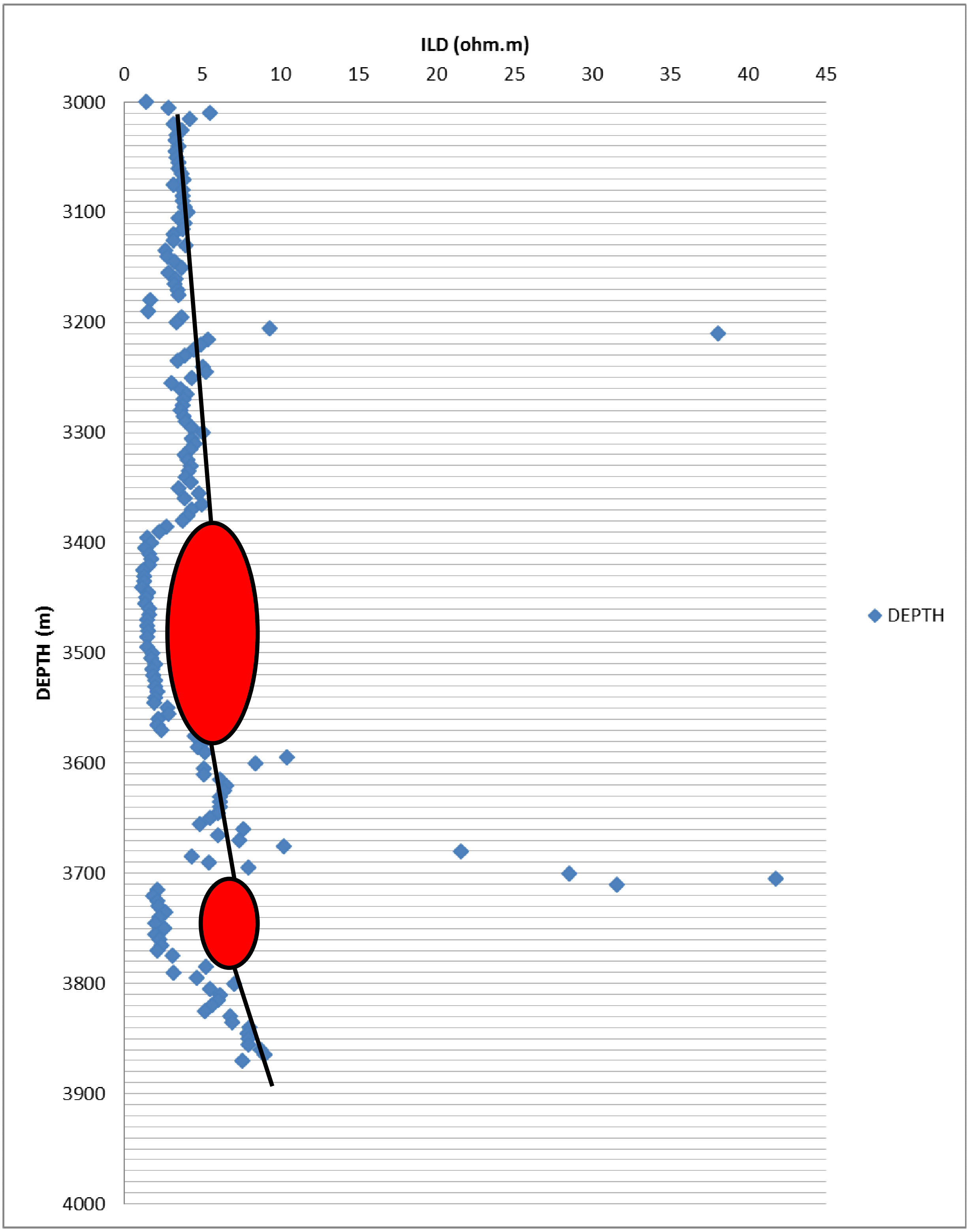

Figure3b.: Compaction trend for Well F on a plot of deep resistivity versus depth.

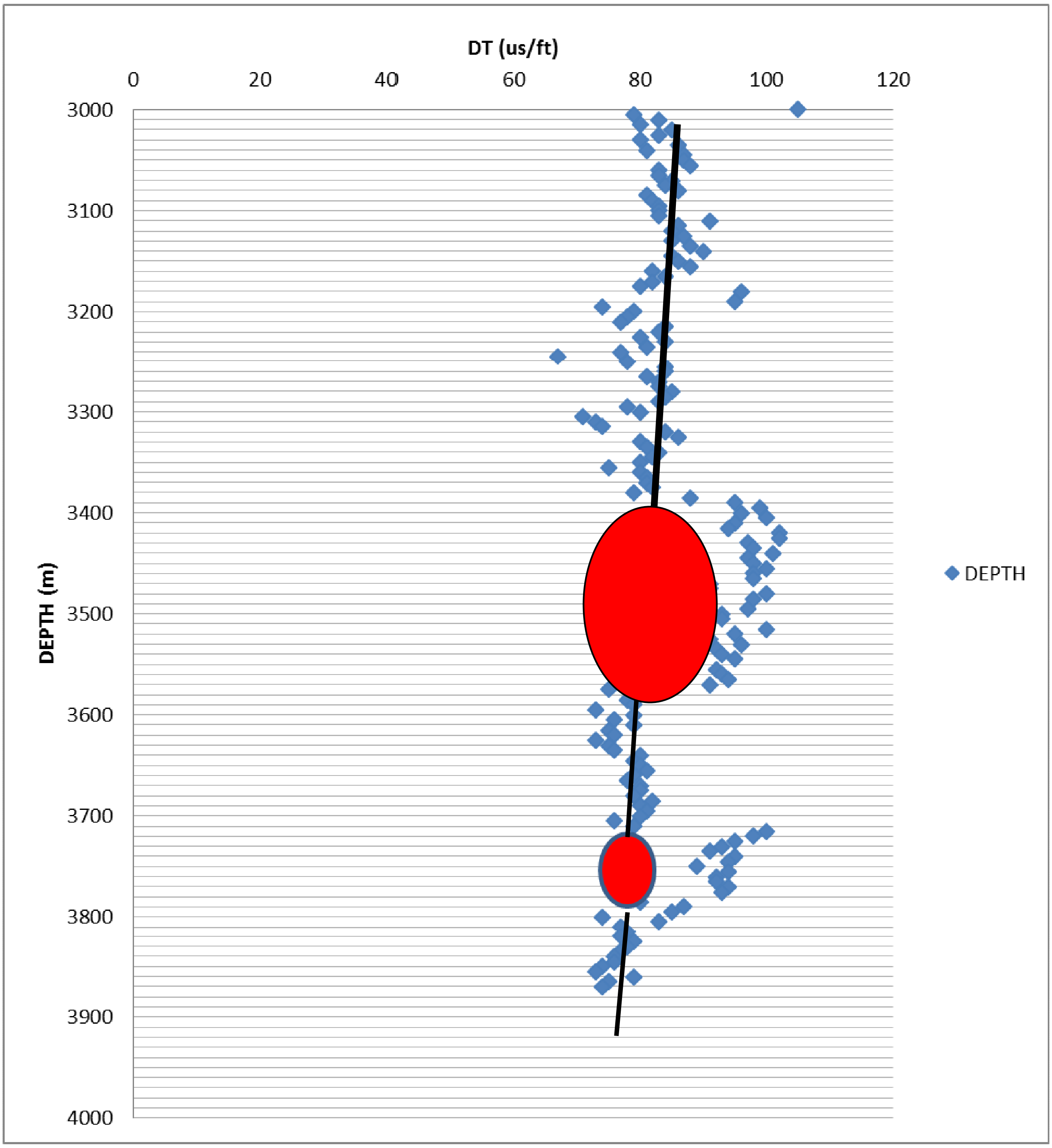

Figure3c: Compaction trend for Well F on a plot of sonic log interval transit time versus depth.

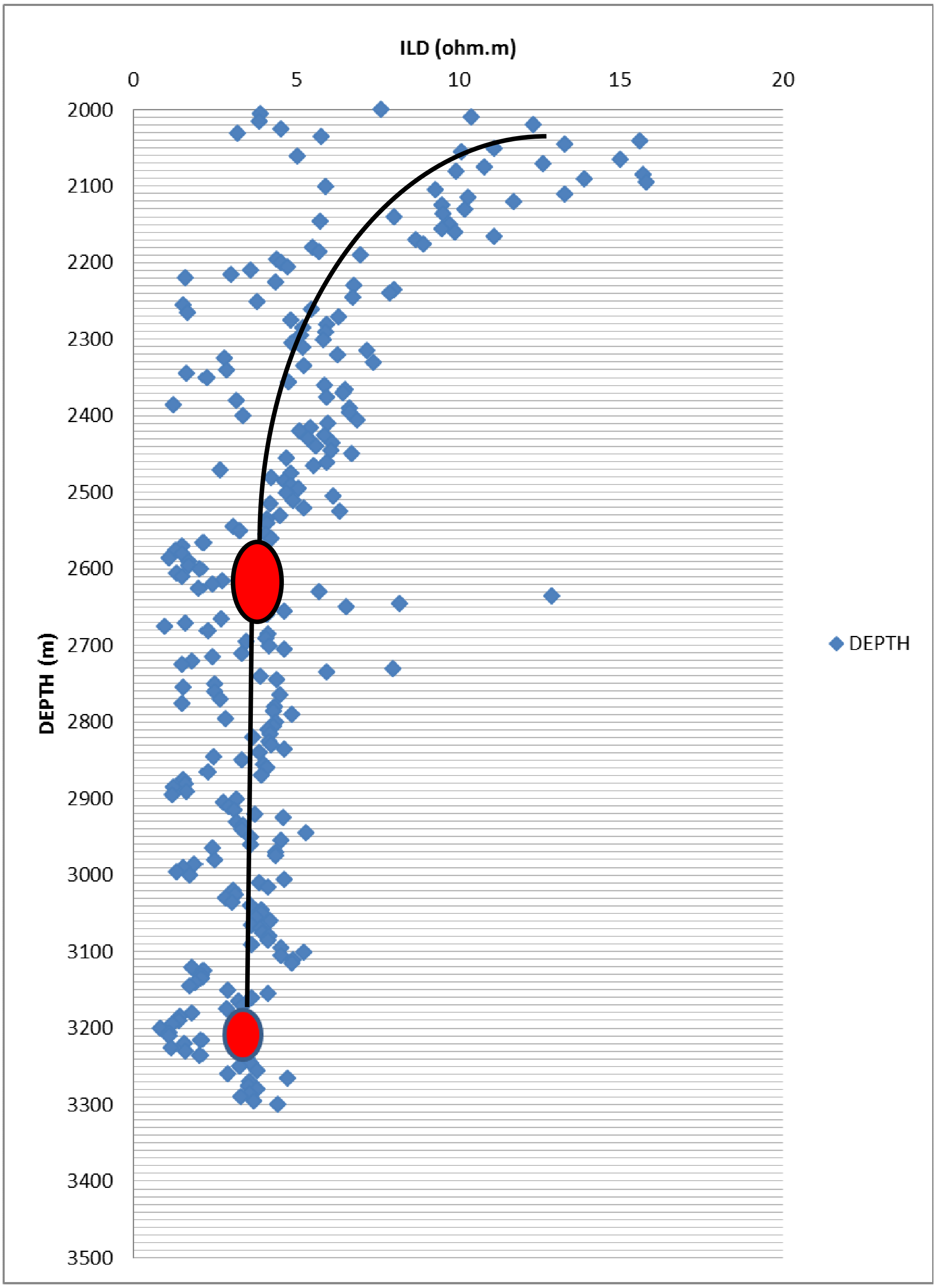

Figure4a: Compaction trend for Well D on a plot of deep resistivity versus depth.

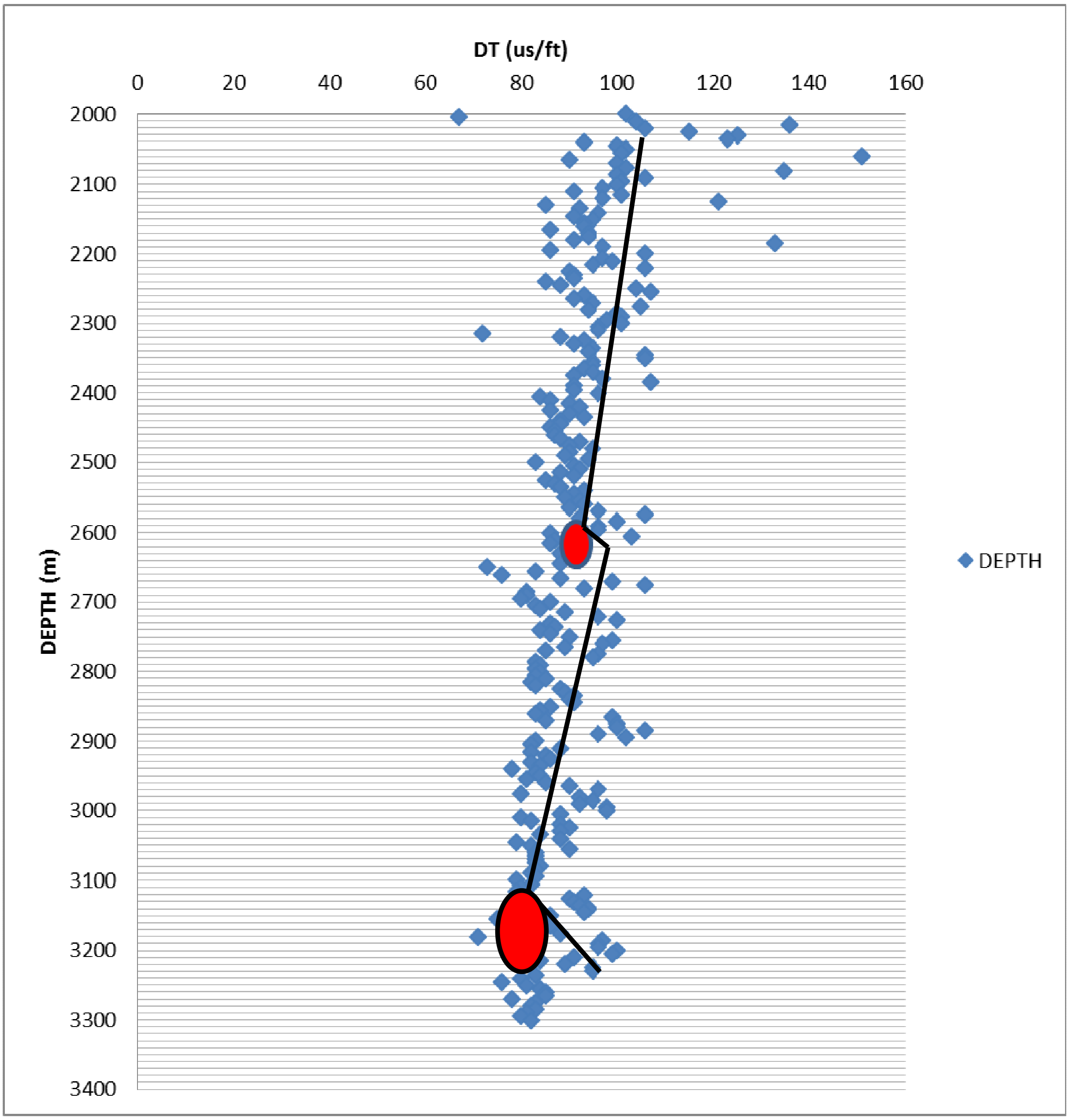

Figure4b: Compaction trend for Well D on a plot of sonic log interval transit time versus depth.

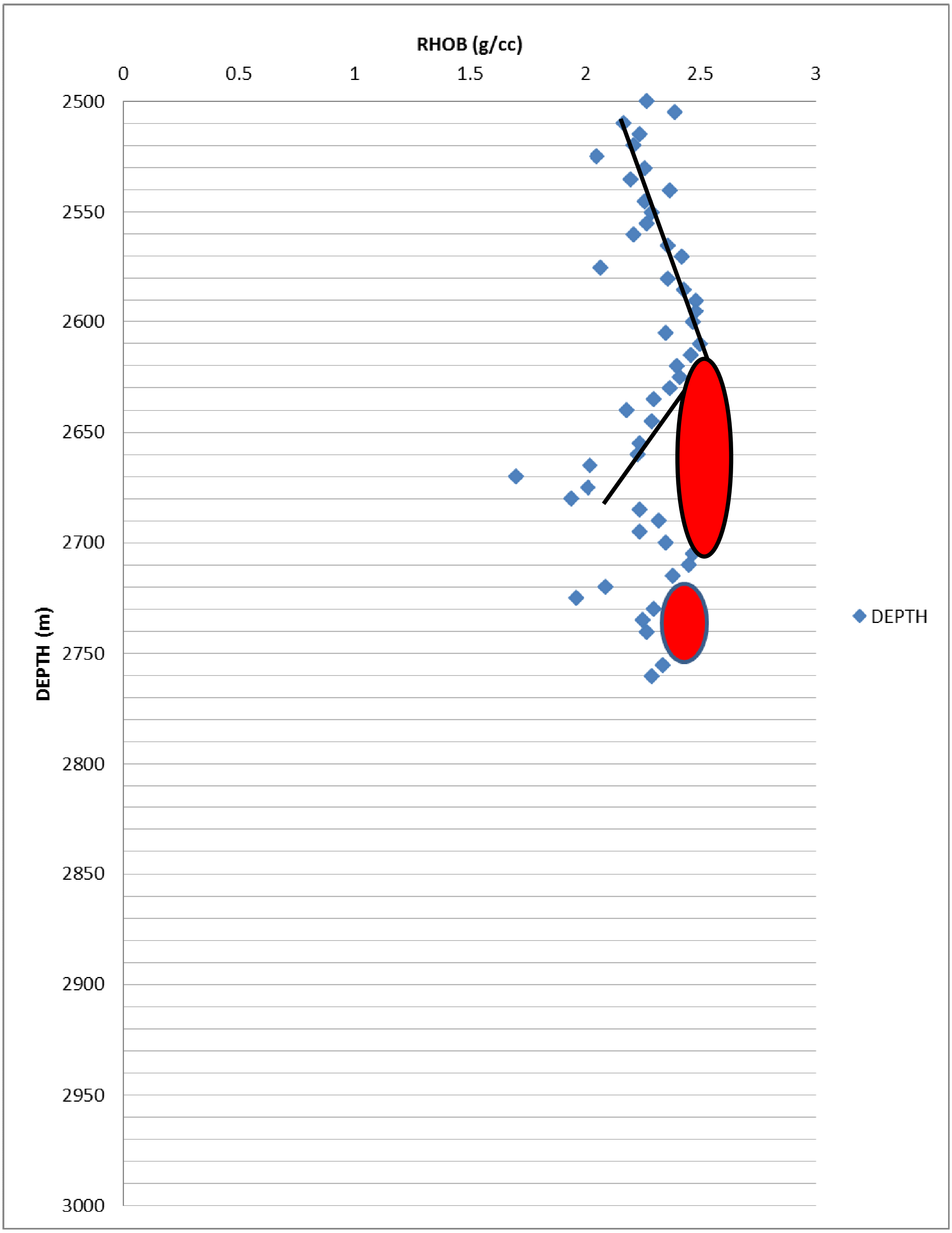

Figure4c: Compaction trend for Well D on a plot of bulk density versus depth.

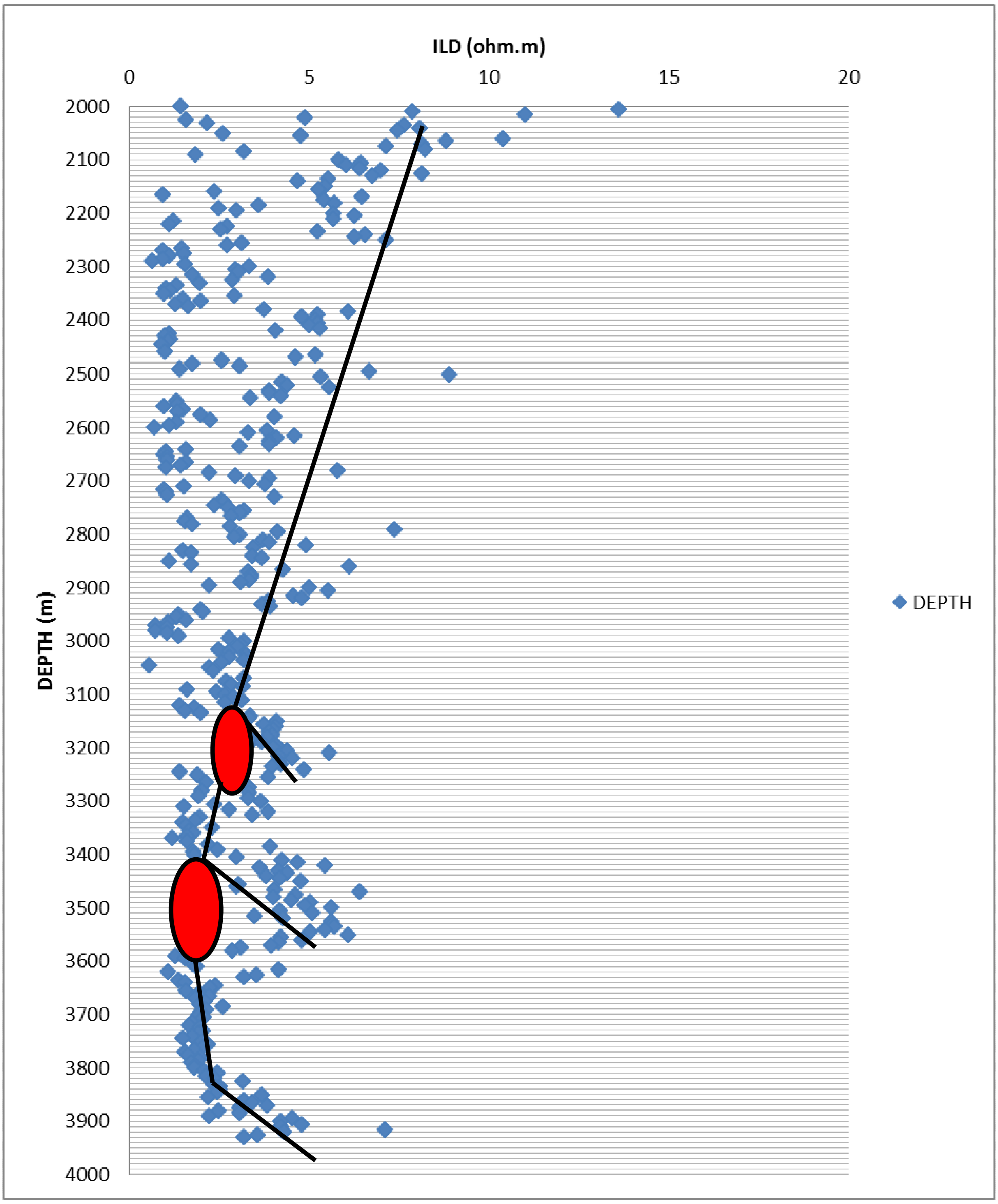

Figure5a: Compaction trend for Well E on a plot of deep resistivity versus depth.

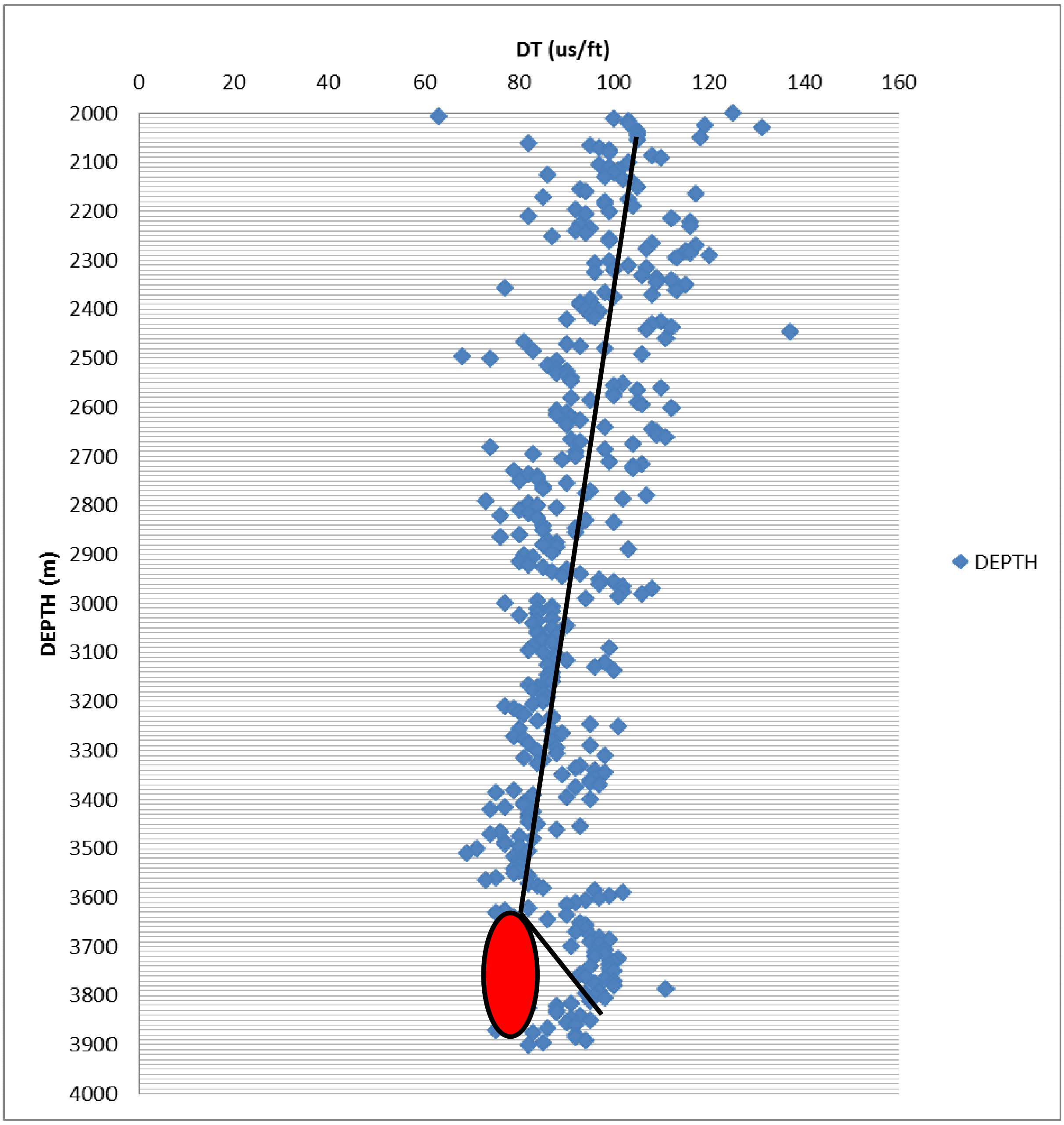

Figure 5b: Compaction trend for Well E on a plot of sonic interval transit time versus depth.

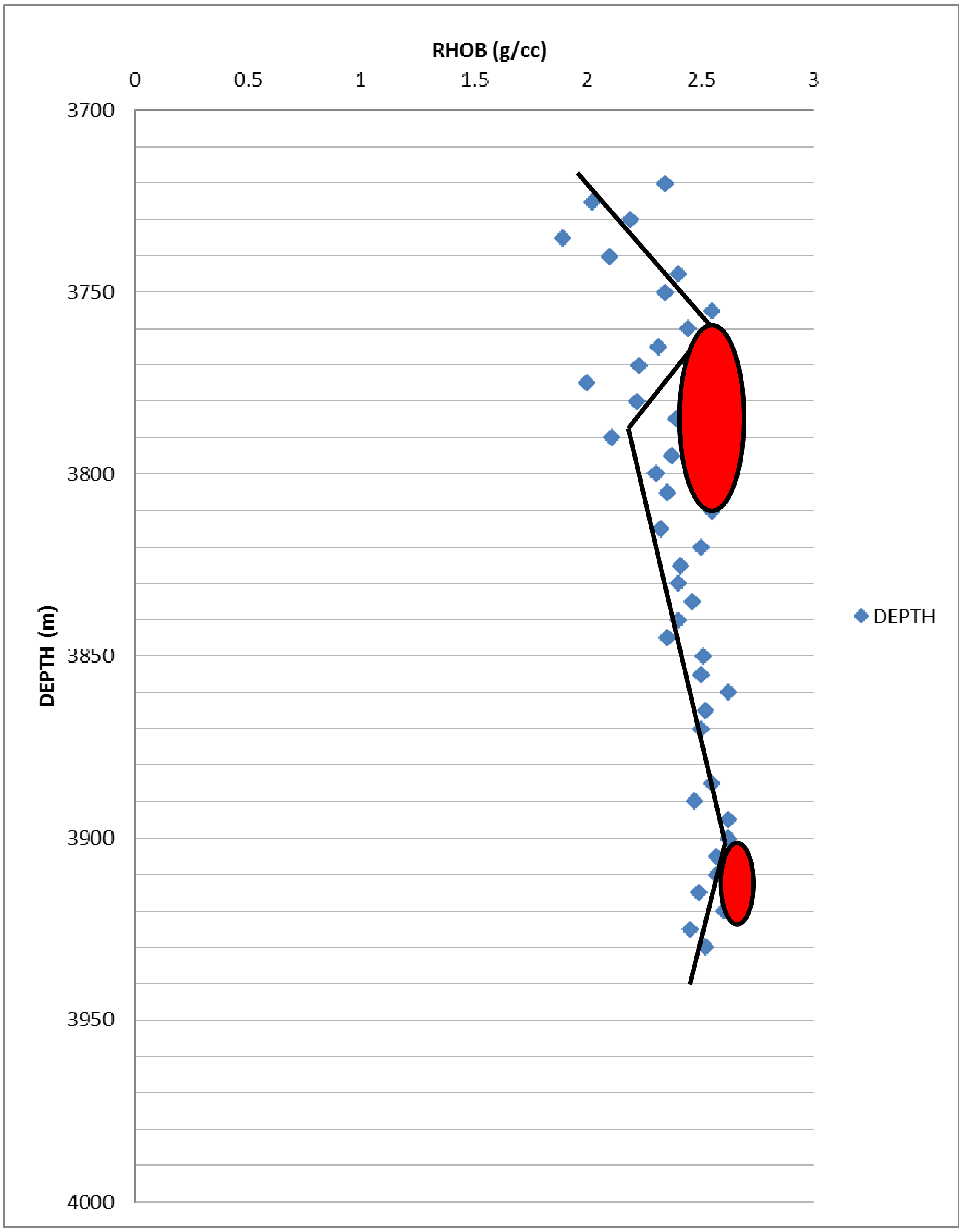

Figure 5c: Compaction trend for Well E on a plot of bulk density versus depth.

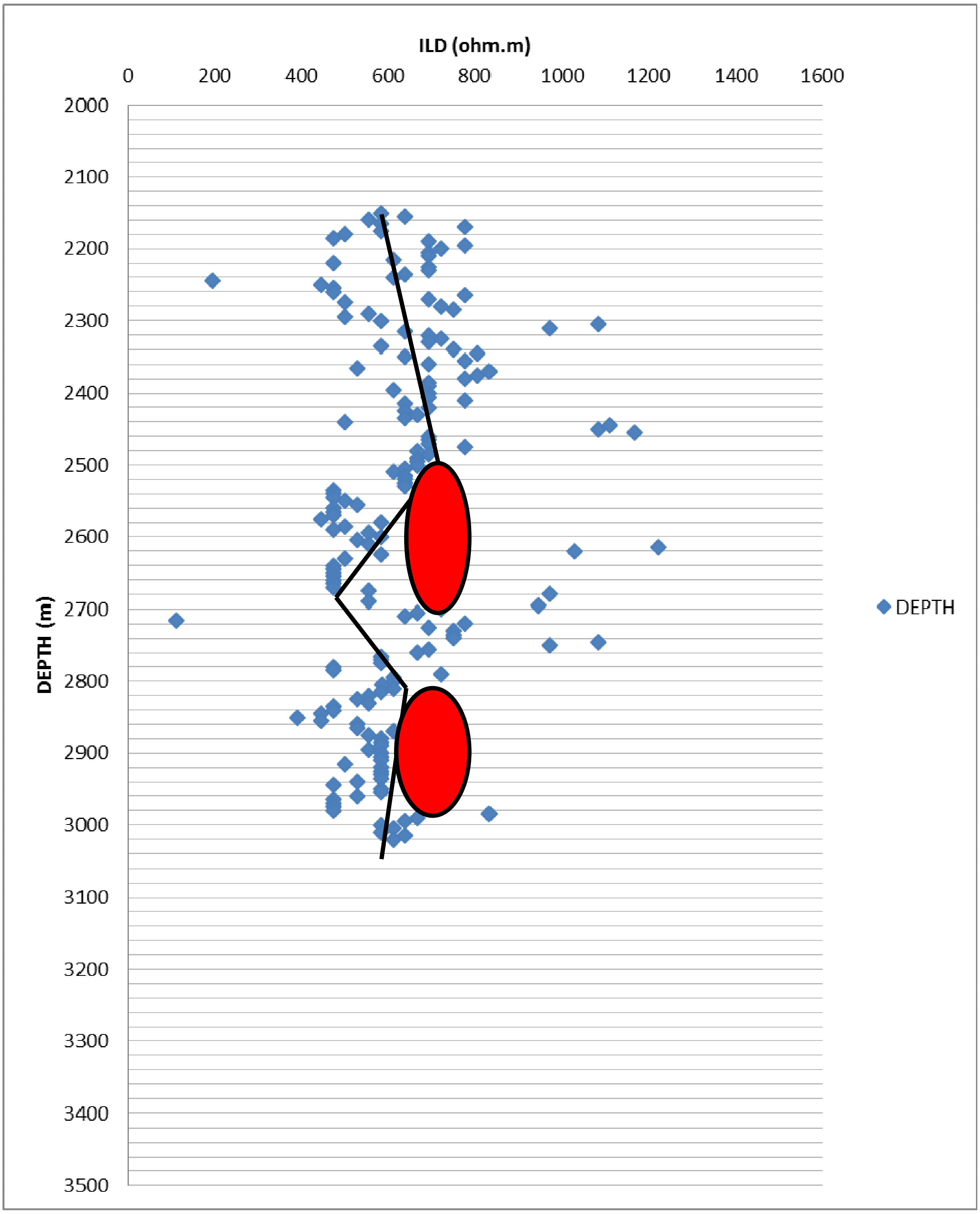

Figure 6a: Compaction trend for Well C on a plot of deep resistivity versus depth.

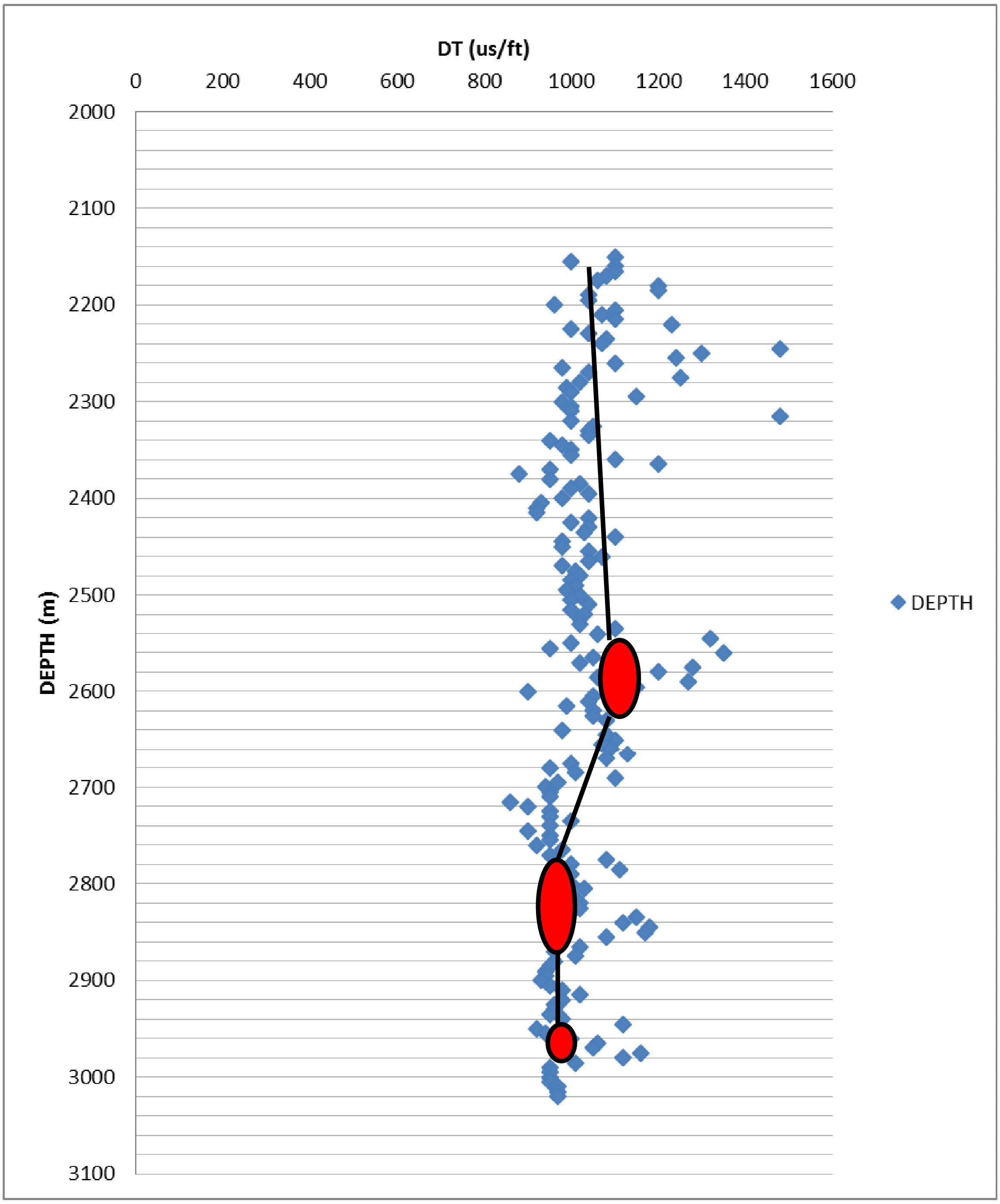

Figure 6b : Compaction trend for Well C on a plot of sonic interval transit time versus depth.

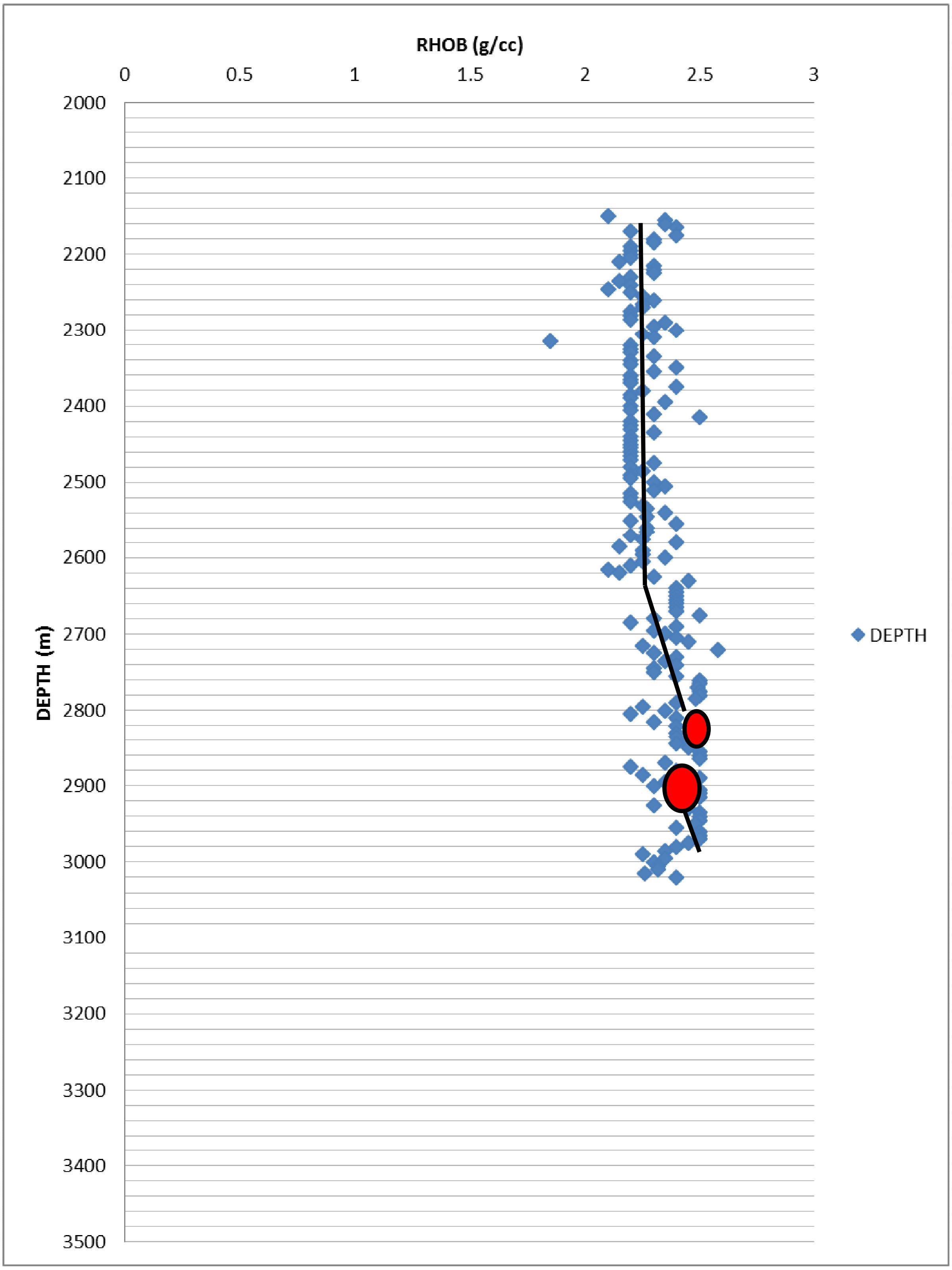

Figure 6c: Compaction trend for Well C on a plot of bulk density versus depth.

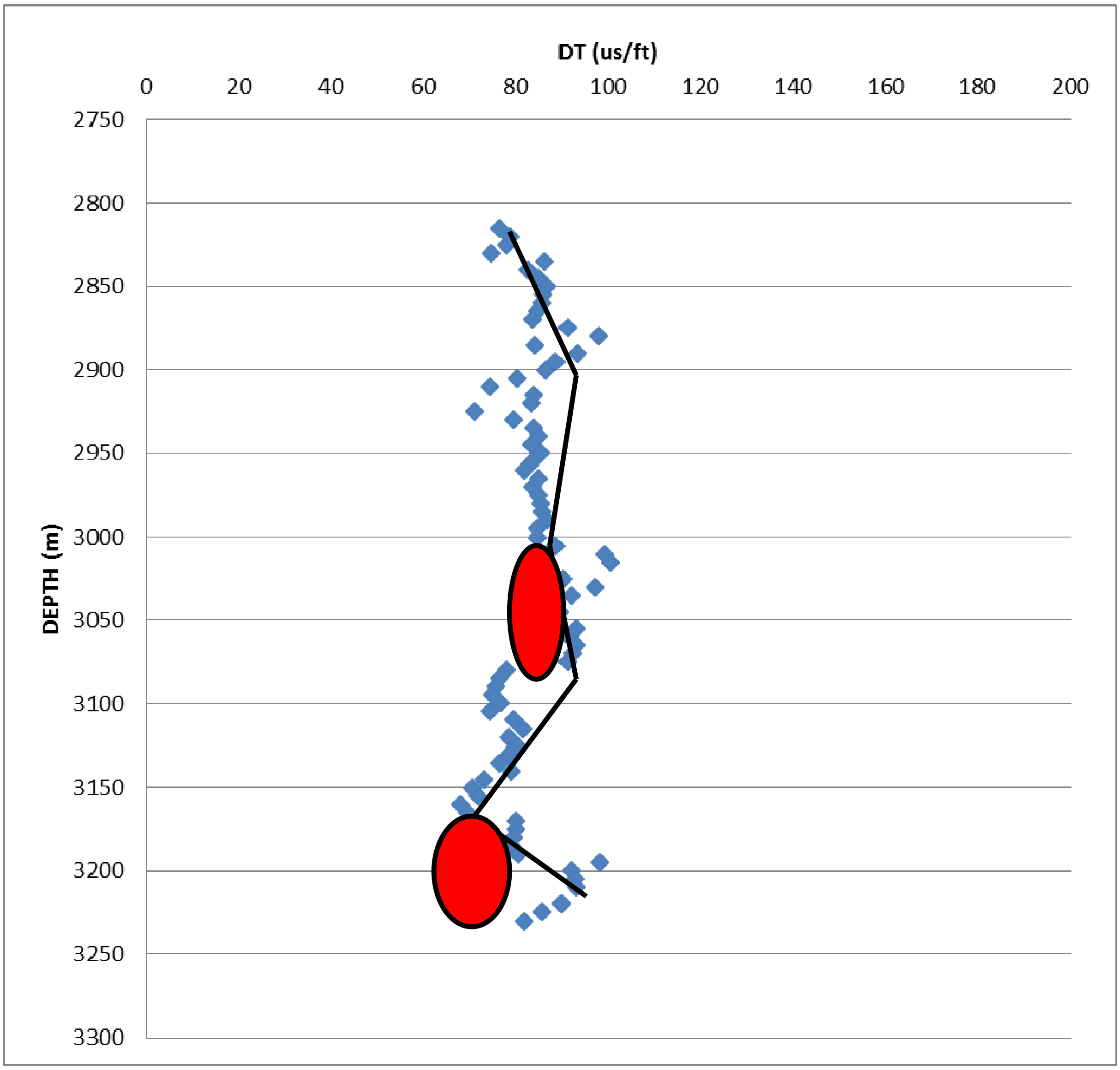

Figure 7a: Compaction trend for well B on a plot of sonic interval transit time versus depth.

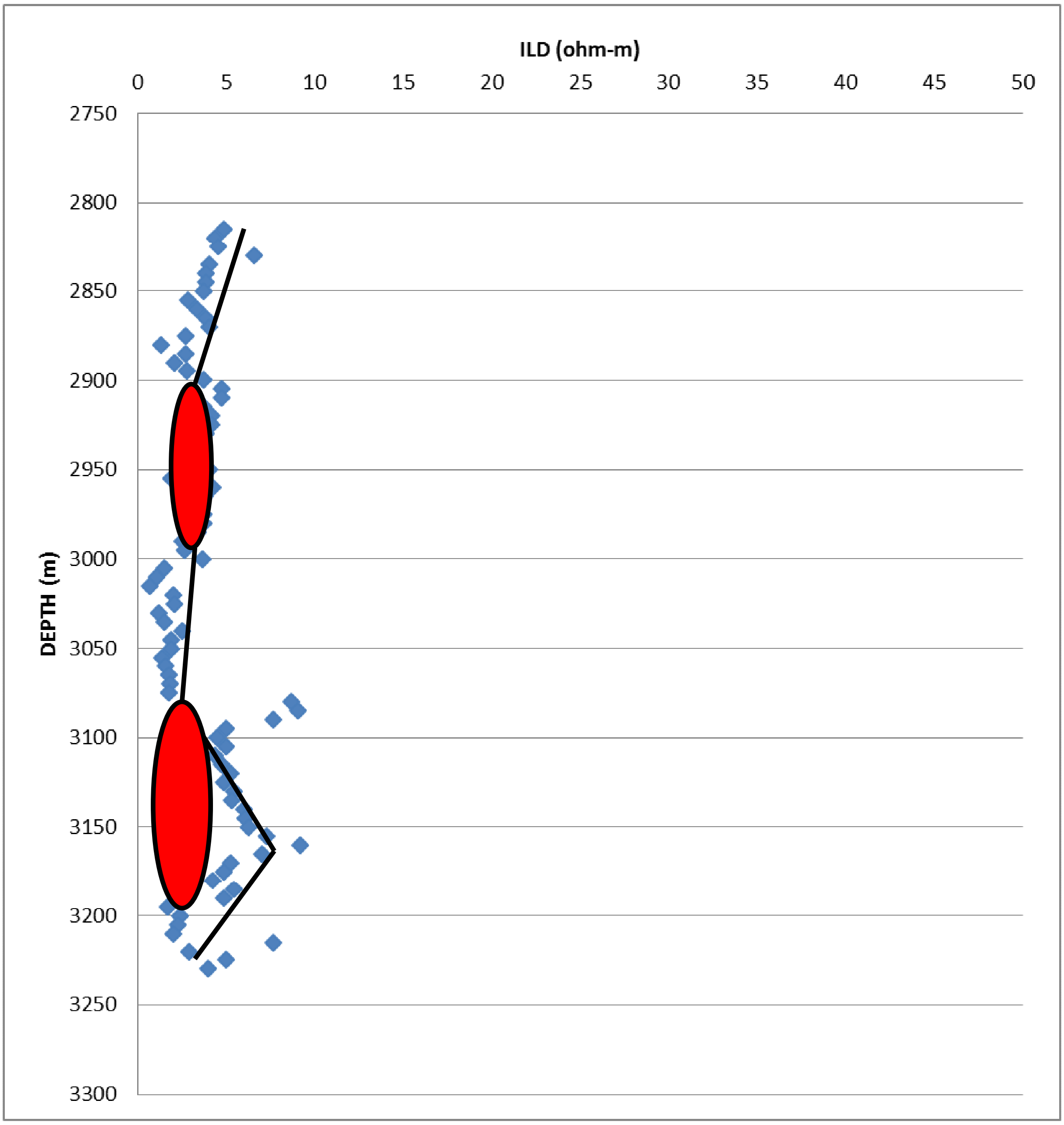

Figure 7b: Compaction trend for well B on a plot of deep resistivity versus depth.

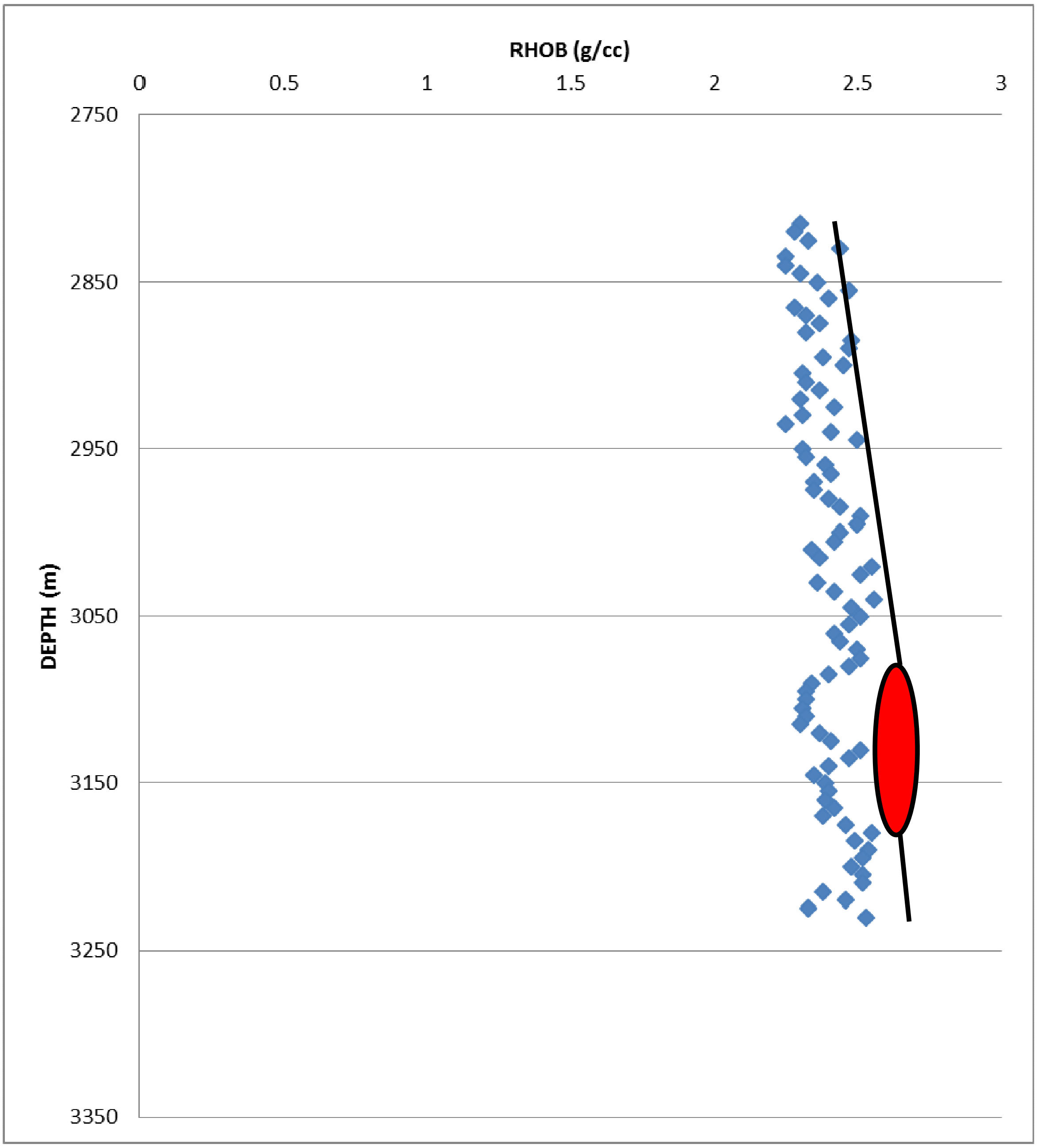

Figure7c: Compaction trend for well B on a plot of bulk density versus depth.

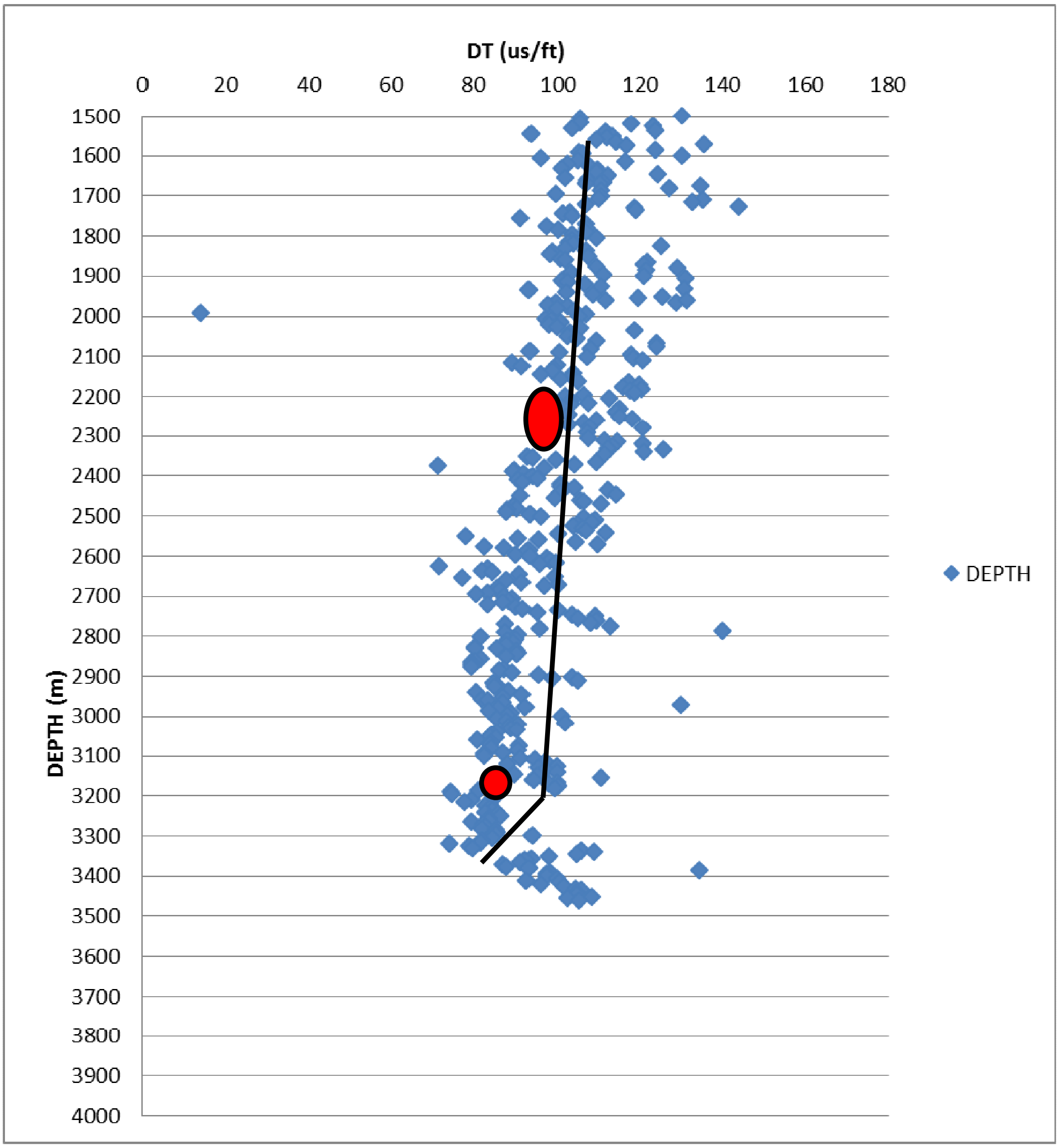

Figure 8a: Compaction trend for well A on a plot of sonic log interval transit time versus depth.

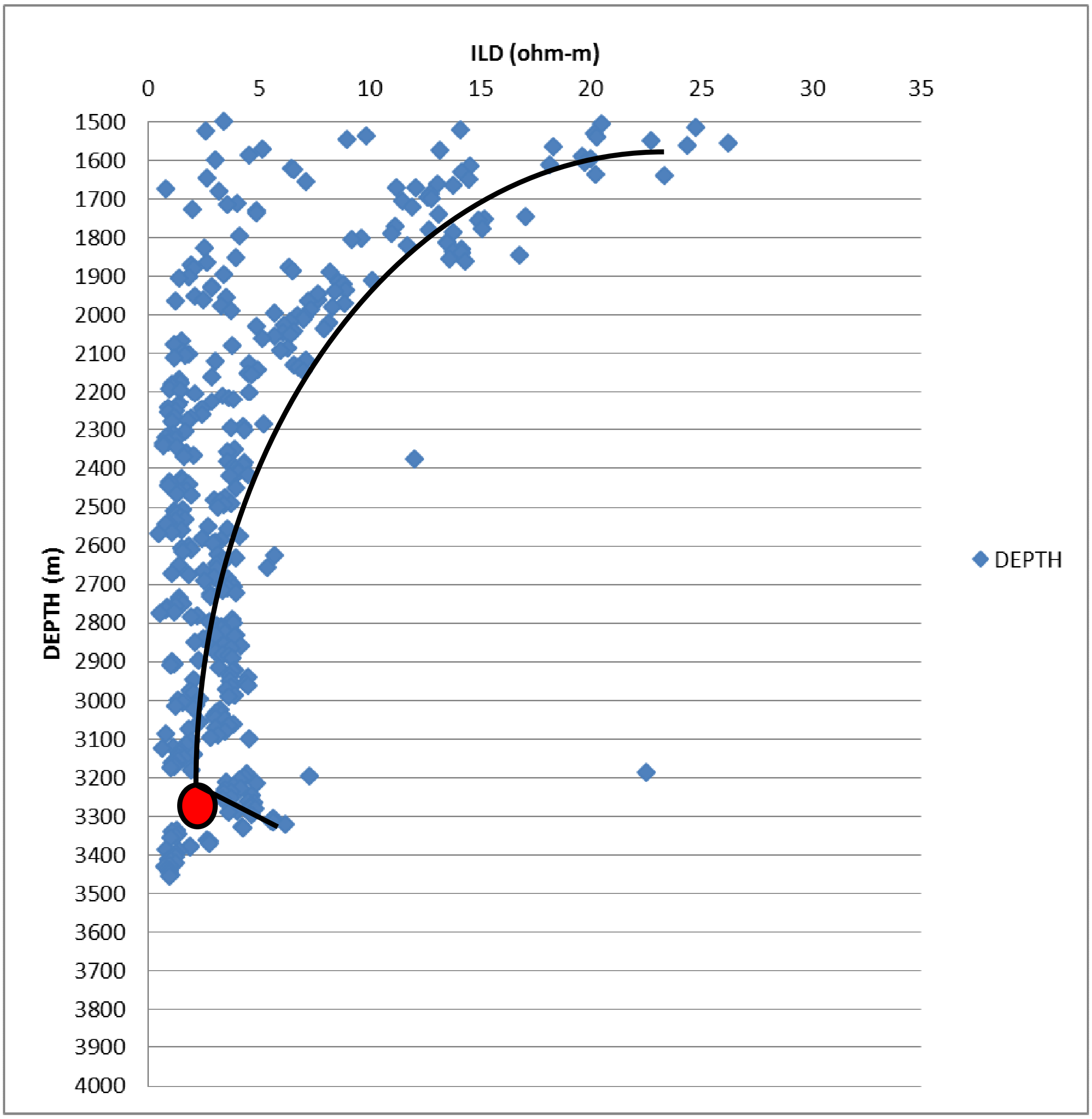

Figure8b: Compaction trend for well A on a plot of true resistivity versus depth.

Table 1.0 overpressured zones within the study area from digitized log of depth and geophysical parameters

Well	Log	Top	Bottom	Thickness
A	Density/ RHOB/g/cc Resistivity/ILD/ohm.m Sonic/ DT us/ft	- 3200 3000	- 3300 3200	- 100 200
B	Density RHOB/(g/u) Resistivity/ILD/ohm.m) Sonic/ DT us/ft	2900 3080 3000	2980 380 3080	80 100 80
C	Density/ RHOB/g/cc Resistivity/ILD/ohm.m Sonic/ DT us/ft	2900 2500 a 2890 b 2790	3000 2620 a 3000 b 2890	100 120 110 100
D	Density/ RHOB/g/cc Resistivity/ILD/ohm.m Sonic/ DT us/ft	2610 3000 3100	2670 3120 3200	60 120 100
E	Density/ RHOB/g/cc Resistivity/ILD/ohm.m Sonic/ DT us/ft	3760 3100 a 3400 b 3650	3790 3200 a 3600 b 3850	30 100 200 200
F	Density/ RHOB/g/cc Resistivity/ILD/ohm.m Sonic/ DT us/ft	3350 3650 a 3390 b 3720 a 3400 b	3450 3750 a 3570 b 3770 a 3570 b	100 100 180 50 170

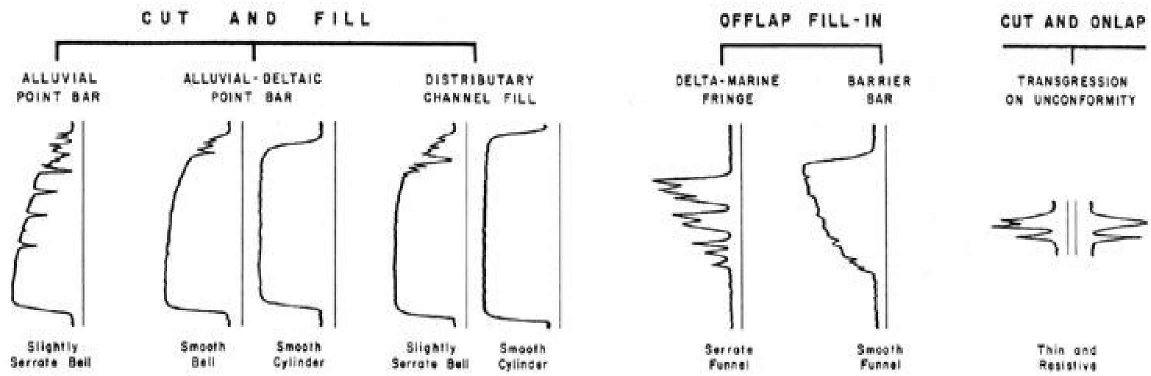

Figure 9: Schematic illustration of gamma-ray logs of sandstone beds or deposits and their environment of deposition.

Table 2: Depositional environments from reservoirs in well F

Sand Units	Reservoir interval	Log shape and characteristics	Depositional environment
1	1915-1964	Cylindrical: smooth	Fluvial channel, tidal sand
2	2085-2100	Bell shaped: smooth	Alluvial fans, point bars
3	2157-2175	Cylindrical: serrated	Deltaic distributaries
4	2288-2322	Cylindrical: serrated	Fluvial channel
5	2370-2395	Cylindrical: serrated	Fluvial channel
6	2525-2570	Funnel/blocky: serrated	Mouth bars, delta marine
7	2604-2625	Bell/funnel: 3fold stacked	Stream mouth bar
8	2700-2713	Cylindrical: smooth	Fluvial channel
9	2810-2876	Cylindrical: serrated, 3fold stacked	Barrier bar complex
10	3003-3117	Cylindrical/funnel: serrated	Deltaic distributaries
11	3205-3250	Cylindrical: Fairly serrated	Fluvial channel
12	3303-3317	Cylindrical: serrated	Fluvial channel
13	3695-3715	Cylindrical: serrated	Fluvial channel
14	3910-3925	Cylindrical: smooth	Fluvial channel

Table 3: Depositional environments from reservoirs in well E

Sand Units	Reservoir interval	Log shape and characteristics	Depositional environment
1	1900-1952	Cylindrical: serrated	Fluvial channel, tidal sand
2	2058-2128	Cylindrical: alternation of shale	Fluvial channel,
3	2500-2543	Cylindrical: highly serrated	Fluvial channel,
4	2785-2820	Cylindrical/bell: stacked/serrated	Fluvial, point bars,
5	2900-2932	Funnel/blocky: serrated	Mouth bars, deep sea fans,
6	3205-3242	Funnel: serrated	Barrier bar,
7	3412-3437	Funnel/blocky: serrated	Mouth bars, delta marine,
8	3495-3523	Cylindrical: serrated	Fluvial, tidal sands,

Table 4: Depositional environments from reservoirs in well C

Sand Units	Reservoir interval	Log shape and characteristics	Depositional environment
1	2183-2214	Cylindrical: serrated	Fluvial, tidal sands, etc
2	2368-2415	Cylindrical: serrated	,,
3	2444-2462	Cylindrical: smooth	,,
4	2613-2625	Cylindrical: smooth	,,
5	2983-3020	Cylindrical: serrated	,,
6	3288-3315	Cylindrical: serrated	,,

Table 5: Depositional environments from reservoirs in well D

Sand Units	Reservoir interval	Log shape and characteristics	Depositional environment
1	2030-2092	Cylindrical: serrated	Fluvial, tidal,
2	2257-2310	Cylindrical: smooth	,,
3	2403-2463	Cylindrical: serrated	,,
4	2798-2823	Cylindrical: smooth	,,
5	3005-3052	Cylindrical: serrated	,,
6	3150-3180	Funnel/blocky: 2fold stacked/serrated	Mouth bars, delta

Table 6: Depositional environments from reservoirs in well B

Sand Units	Reservoir interval	Log shape and characteristics	Depositional environment
1	2048-2065	Cylindrical: smooth	Fluvial, tidal sand, etc
2	2327-2350	Cylindrical: smooth	,,
3	2378-2400	Cylindrical: smooth	,,
4	2520-2550	Cylindrical: serrated	,,
5	2683-2733	Cylindrical: serrated	,,
6	3140-3167	Cylindrical: serrated	,,

4.0 Discussion of Result

The results from the six (6) wells studied reveals the presence of twenty one (21) over pressured zone within the wells. Well E has the largest overpressure depth range of 200m from sonic log. Most other zones has thickness of within 100m. Over pressured zones thickness from resistivity log, indicate that well B =100m, well C= 120m well D = 120m, well F = 180m. These collaborates well with sonic log over pressured depth well B = 80m, well C = 100m, well D= 100m; well E=200m. Results from bulk density log has depth of over pressured zones at well C = 100m and well F=100m (Table 1.0).

Generally, there is an agreed depth range from all the logs for which overpressure occurs between 3000-3200m within wells ABCD and E while wells C and F has overpressure zones at depth between 2900m- 3-00m and 3600m- 3700m respectively. So there are basically three (3) subsurface zones that are experiencing over pressures within the studied field.

The depositional environments deduced from Gamma ray log varied from fluvial channel to barrier bars and mouth bars sands. Wells B, C, D and F are dominantly fluvial channel environments with minor mouth bar and deltaic distributaries sands which signify that the x-field is dominantly a fluvial channel environment.

5.0 Conclusion

Overpressure zones within six (6) wells in an x- field reveals the presence of twenty one (21) subsurface zones within the wells experiencing overpressures. However, the depth ranges of occurrence when considered across the wells indicate only three major over pressured zones between 3000 – 3200 across well A, B, C, D and E and wells F and C at depths at 2900m -3000m and 3600m – 3700m respectively. The thickness of these zones vary between 100 – 200m. Also, the major paleoenvironment within the field is the fluvial channel environment. Since overpressures zones may cause rly blow outs it's important that extreme precaution be taken while drilling in this field.

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