MAJOR PROJECT REPORT

"PETROPHYSICAL ANALYSIS OF WELLS OF CHABUA REGION OF ASSAM BASIN"

Submitted by

Sanskar Srivastava
R490211032

&

Pushkar Raj
R490211025

B. Tech Geo-Science Engineering
University of Petroleum and Energy Studies

Mentored By

Dr. U. Kedareswarudu

Department of Petroleum Engineering and Earth Sciences
University of Petroleum and Energy Studies

UPES
THE NATION BUILDERS UNIVERSITY

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We have been fortunate enough to have completed this work at the Department of Petroleum Engineering and Earth Sciences at the University of Petroleum and Energy Studies, Dehradun.

We would like to thank our mentor Dr. U. Kedareswarudu for his continued support in every possible manner. This project is an example of his enlightening effect on us that has been propagated through their knowledge imparted. It is his guidance and mentorship that has given us the kick required to overcome these ravines of irrationality and senselessness while pushing us towards being a better person and to live a better life. Whatever we have learned throughout this project will be handy in the days to come but what we have experienced will be a memory to cherish.

DECLARATION

We hereby declare that the Major Project entitled, **"**Petrophysical analysis of wells of Chabua region of Assam Basin**"** has been carried out by us under the guidance of Dr. U. Kedareswarudu, Department of Petroleum Engineering & Earth Sciences, University of Petroleum and Energy Studies, Dehradun.

(SANSKAR SRIVASTAVA) (PUSHKAR RAJ)

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ABSTRACT

Formation evaluation is one of the major steps of petrophysical analysis. It is the process to determine the parameters by which we are able to characterize a reservoir. Three main steps of formation evaluation are, first to distinguish between reservoir and non-reservoir rock. Second, for the reservoir intervals only, distinguishing between hydrocarbons and water filling pores, hence calculating water saturation in reservoir rocks and, lastly, third for the hydrocarbon fractions, distinguishing between oil and gas and hence calculating gas oil and gas saturations in the reservoir rocks.

The project aims to estimate porosity, water saturation, hydrocarbon saturation, volume of shale, TOC and various minerals using well logs and various petrophysical techniques. First step in the workflow will be qualitative assessment i.e. assessment of reservoir properties and fluid type from the logs. It will involve 'Quick Look' for the identification of zones of interest followed by plotting 'Cross-plots' for lithology identification. Next step will be quantitative assessment i.e. numerical estimation of reservoir properties of water and hydrocarbons. It will involve calculation of volume of shale, porosity, effective porosity, formation water resistivity, cementation factor, water saturation, hydrocarbon saturation and TOC using various well logs.

The above steps will lead us to identify whether the reservoir zones in the wells are water bearing or hydrocarbon bearing.

1. INTRODUCTION

The Location of the Upper Assam Basin is in between the Eastern Himalayan Foothills and the Assam – Arakan thrust belt. To the north east lies the Mishmi Hills block and the south western region is separated by the Shillong plateau basement uplift. In the subsurface the Assam Basin is bisected by a ridge of Precambrian rocks known as "**Brahmaputra Arch".**

In this project attempt has been made to estimate porosity, water saturation, the volume of shale and identify clay types using well logs. Various petrophysical techniques along with well logs have been used for estimation of these parameters. Also the attempt has been made to estimate the parameters both manually and using petrophysics software and later both the results have been compared.

2. GEOLOGY OF ASSAM BASIN

The **Upper Assam Basin** is a 'foredeep / foreland basin' with respect to Naga Thrust Belt. The Kopilis / Barails deposition represents the **foredeep stage** under the '**Marine influence'** and conditions, the foreland stage by Tipams / Girujans / Namsangs under mainly the '**Continental'** conditions. The various effects were felt during the Foreland Bulge and Foreland Inversion consequently leading to the formation of the Mid Miocene Uconformity and The Late Miocene Unconformity, respectively.

The Upper Barails (oil prone coals) has essentially one principal source rock which have been identified by new data acquisition from rocks. **(ECL Report OIL).** Thus one important petroleum system is being designated in the Upper Assam Basin- '**Naga Petroleum System'.** Source kitchen areas have been delineated in the paleo-foredeep of the advancing Naga Thrust Belt. A migration model has been also developed involving the 'forward migration' (updip) across the foreland (northwards) and back-migration (or re-migration) as a response to Late Miocene inversion and late Himalayan foredeep development.

Refer **Figure 2.1** for location and major structural elements of Upper Assam Basin

2.1 Geotectonic framework

The basement of North East India comprises of the '**Gondwanide fragments'** (which are 'continental fragments' rifted and drifted from Gondwana across Tethys during the Late Paleozoic to late Mesozoic) mainly **Peninsular India** (Indian Craton) and the **West Burma Block**. The ongoing movement of the Indian plate and West Burma Block has led to major differential movement along block boundaries, resulting in basin formation and structuration which continued into the Quaternary.

The **Shillong-Mikir Block**, (consisting of the Shillong Plateau and the Mikir Hills) is a strongly uplifted basement block. On its southern edge it is bounded by the Dauki-Haflong fault system which is usually linked to the east with the Disang Thrust .The Dauki Fault appears to be a normal fault but is strongly inverted in the hanging wall *(e.g. Das Gupta and Biswas2000) although Curiale et al (2002)* depict it as a major southerly-verging-thrust fault.

2.2 Paleozoic and Mesozoic History

Paleomagnetic and faunal data provide the main information for the reconstruction of cratonic Gondwana to the 'north' (**in current orientation**) of India Arabia and Australia in the early Paleozoic. This area included known continental elements, such as the '**North China Craton'** and '**Lhasa Block'**, and also blocks such as' **Tarim', 'Qaidam' and 'West Burma'**.*(Geology Today 2001).* The second phase of rifting began in the Permian, perhaps in response to back-arc rifting due to southerly subduction of Paleotethys *(Şengör 1990),* which led to the rapid northward drift of the **'Cimmerian'** continent *(Metcalfe 1996)*, comprising several Iranian, Afghan and Pamir microcontinental blocks, and also **'Qiantang'** and **'Sibumasu'** in the east.

Ricou and Dercourt (1993) proposed that the Qiantang Block in the east had earlier rift-drift-collision history. The **West Burma Block** and' **Sibumasu Block'** comprised of the **'*Transit Plate*' (Cimmerian Continent)** connected through Lhasa to the rest of the Cimmerian fragments. *Şengör (1990)* proposed two parts to the 'Qiantang Block', one ahead of Cimmeria, one attached. The third phase of rifting shows the drifting of the **West Burma Block** with the **Lhasa Block.** The Cimmerian continent, was a highly disrupted belt of stretched Gondwana metamorphic crustal blocks, which was submerged for the duration of their journey from Gondwana to Eurasia, **(Gaetani 1997).**

The Lhasa Block shares the same stratigraphy as that to the Pamir-Afghan Cimmerian **Blocks** *(Gaetani 1997),* but whether it traversed Tethys in the second phase (colliding in the early Jurassic), or in the third (colliding in the mid Cretaceous) is not known.

The third phase of rifting began in the Late Jurassic according to the (**Metcalf**e **and Şengör)** model. *Mitchell (1993)* assigned an island-arc origin to the basement of the **West Burma Block** and associated ophiolites in the east of Burma. Choosing between the Mitchell and Sengor models is difficult since the evidence and paper literature supporting models is insufficient, but evidence supporting the Mitchell model derives mainly from the numerous papers on the Naga Hills ophiolites *(e.g. Sengupta et al. 1989).* On combination of Mitchell model and evidence of Naga Hills ophiolites, the basalt geochemistry is marginal MORB-arc, with possible back-arc indicators, is known.

Refer **Figure 2.2** for Regional Structural Elements of Assam Arakan Basin

2.3 Stratigraphy

The Precambrian Granitic basement of the Upper Shelf Region is overlain by the Tertiary sediments. These sediments provide valuable hints to the initial phase of basin generation. Fig 2 shows the tectonic map of the Assam- Arakan basin. It is explained as follows:

2.3.1 Naga Metamorphics

The unfossiliferous Pre-Mesozoic sediments are spread in the zone along the Indo Burma border *(Brunnschweiler, 1966).* These sediments are mostly quartzite, sheared granite, crystalline limestone/marble, schist, phyllites weith minor serpentinite *(Brunnschweiler, 1966).* These unfossiliferous Pre-Mesozoic sediments are compared with the Pre-Cambrian Chaung Magyi series or with Lower Paleogene of Burma *(Roa, 1983).*

2.3.2 Ophiolite Suite

Ophiolite Suites have their association mainly with the radiolarian cherts, sediments whose origin is volcanic and metasediments. These suites mainly belong to the Upper Cretaceous age *(Brunnschweiler, 1966, Chattopadhyay et al., 1983).* These are well defined along two belts i.e Mardaly and Naga Hills *(Hutchison, 1975).* There is a sharp tectonic contact of the ophiolite suite of rocks with the epimetamorphosed slates and phyllites along the Moya thrust in Naga Hills *(Ganju et al., 1986).*

2.3.3 Sylhet/ Mikir Trap

The rocks which occurred in the Late Jurassic to Early Cretaceous basic to ultrabasic rocks (Sylhet and Rajamahal traps) represent the rift related igneous suite formed during the continental rifting phase of Gondwanaland separation.

2.3.4 Gondwana and Cretaceous Sediments

There is not even a single trace of outcrop of Gondwana sediments in the Assam shelf. Predominantly arenaceous with locally developed carbonaceous and argillaceous rocks of Cretaceous age are exposed in the Garo, Khasi and Jaintia Hills.The sequence is generally irregular resting either on granite gneiss or on conglomerate of metamorphic and igneous pebbles.

The Cretaceous sediments in these areas are known by *Mahadek and Langpar formations.* In Manipur, impure limestones which occupy large areas near Ukhrul, Lambui and Hundung are of Cretaceous age *(Basu and Rangaraju, 1964; Prithiraj et al., 1992).* The lower Disang shales are also of Cretaceous age.

Some of the Stratigraphic markers in this area are briefly discussed below:

Lakadongs

Kamkhat-1 and Chabua-2 from the Lakadongs indicates deposition within tidal channels and meandering fluvial channels (with floodplain deposits).
The system becomes more distal to the east and southeast.

Kopilis

The setting is that of a low-energy restricted marine basin with many inlets entering the silled basins with stagnant bottom waters.
The system becomes more distal to the south or southeast and progrades slowly into the basin.

Tipams (TIP Biozone)

The Tipams (referred to as '*Tipam Sandstone and Surma Conglomerate in outcrop'*) are a clastic and sand-dominated series of Late Oligocene-Early Miocene age, found throughout the main basin and to the north of the Disang Thrust in the thrust belt. They attain a maximum thickness of 700m (in Sapekhati-1) and with all of the pre-Miocene Unconformity units they thicken (slightly) to the south or southeast. Its base exhibits a local and minor unconformity with the underlying Upper Barails being conformable. *(ECL Report, OIL, 2002).*

Refer **Figure 2.3** for Stratigraphy of Assam Arakan Basin

3. WELL LOGGING

The continuous recording of a geophysical parameter along a borehole produces a geophysical well log. The value of the measurement is plotted continuously against depth in the well. Well logging plays a central role in the successful development of a hydrocarbon reservoir. Examples of the basic physical parameters that can be measured down-hole with logs include (a) the size of the borehole, (b) the orientation of the borehole, (c) temperature, (d) pressure, (e) the natural radioactivity of the rocks, (f) the acoustic properties of the rocks, (g) the attenuation offered by the rocks to radioactivity generated from the tool, (h) the electrical properties of the rocks, (i) the NMR characteristics of the rocks, and so on.

A summary of some of the main standard open-hole tools is given in table below:

Tool	Physical Measurement	Use
LOGGING CONDITION		
Temperature(BHT)	Temperature	Borehole temperature for resistivity calculations.
Pressure(PRESS)	Fluid pressure	Fluid pressure for formation volume factor calculation.
Caliper(CAL)	Borehole diameter	Data quality, Stress tensor, lithology and permeability indicator
LITHOLOGY		
Gamma Ray(GR)	Natural radioactivity of the formation	Shale indicator and depth matching
Spontaneous Potential (SP)	Shale/Sand interface potential	Permeable beds, Resistivity of formation water
POROSITY		
Density(FDC, LDT)	Bulk density of the formation	Total porosity
Neutron (SNP, CNL)	Hydrogen concentration in the formation	Total porosity
Sonic (BHC, LSS)	Velocity of an elastic wave in the formation	Effective porosity

RESISTIVITY		
Simple electrical log (SN,LN,Lat)	Resistivity of flushed shallow and deep zones respectively.	Used in water saturation calculations.
Induction Logs (IES, ISF, DIL, DISF, ILm, ILd)	Conductivity of the formation	Conductivity and resistivity in oil based muds, and hence a calculation of water saturation.
Later logs (LL3, LL7, DLL, LLs, LLd)	Resistivity of the formation	Resistivity in water based muds, and hence calculation of water saturations.
Micro log (ML)	Resistivity of mud cake and flushed zone.	Indicator of permeability and detector o thin beds.
Micro-Later log(MLL)	Resistivity of flushed zone.	To measure R_{xo}.
Proximity Log(PL)	Resistivity of the flushed zone.	To measure R_{xo}.
Micro-spherically focused log (MSFL)	Resistivity of flushed zone.	To measure R_{xo}.
Imaging Logs: There is a range of imaging logs based upon sonic, visual, electrical and NMR measurements.		

Table 1 Common open-hole tools and their uses:

4. FORMATION EVALUATION

Formation evaluation is the process to determine the parameters which characterize the reservoir. These parameters are:

- Volume of Shale (V_{sh})
- Porosity
- Saturation

The traditional role of wireline logging has been limited to participation primarily in two general domains: formation evaluation and completion evaluation. The goals of formation evaluation can be summarized as:

- To identify or infer the presence of hydrocarbons in formations traversed by the wellbore.

- To estimate depth of formations, which contain accumulations of hydrocarbons.

- To quantify the fractional volume available for hydrocarbon in the formation. This quantity, porosity, is of utmost importance. A second aspect is to quantify the hydrocarbon fraction of the fluids within the rock matrix. The third concerns the areal extent of the bed, or geological body, which contains the hydrocarbon.

- To estimate how much producible are hydrocarbons. The most important input is a determination of permeability. Many empirical methods are used to extract this parameter from log measurements with varying degrees of success. Another key factor is oil viscosity, often loosely referred to by its weight, as in heavy or light oil.

- Formation evaluation provides, principally, values of porosity, shaliness and hydrocarbon saturation, as a function of depth, using the knowledge of local geology and fluid properties that is accumulated as a reservoir is developed.

It should be remembered at all times that the main job of the petro physicist is to evaluate the amount of hydrocarbons in place in the reservoir. Hence, the evaluation sequence for a straightforward reservoir will be as follows:

For any given well interval:

- Distinguish between reservoir and non-reservoir rock. (Reservoir rock contains a reasonably high connected porosity.)

- For the reservoir intervals only, distinguish between hydrocarbons and water filling the pores, hence calculate water saturation in reservoir rocks. (Hydrocarbons are electrical insulators, while water conducts.)

- For the hydrocarbon fraction, distinguish between oil and gas, hence calculate gas and oil saturations in reservoir rocks. (Gas has a much lower density than oil)

5. METHODOLOGY

The basic logs, which are required for the adequate formation evaluation, are:
1. Permeable zone logs (SP, GR, and Caliper)
2. Resistivity logs (MFSL, Shallow and Deep resistivity logs)
3. Porosity logs (Density, Neutron and Sonic).

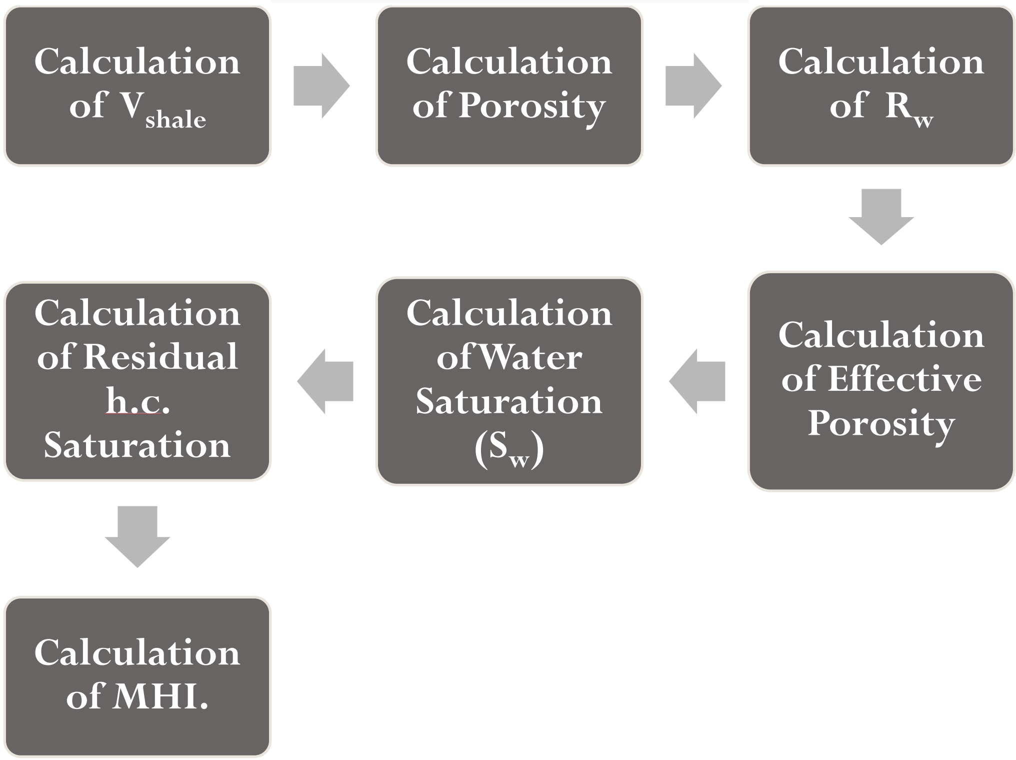
Generally, the permeable zone logs are presented in track one, the resistivity logs are run in track two and porosity logs on track three.

Using such a set of logs, following steps are been followed for selecting zones:

First step: The first step in the log interpretation is to locate the permeable zones. Scanning the log in track one and it has a base line on the right, which is called the shale base line. This base line indicates shale i.e., impermeable zones and swings to the left indicate clean zones- e.g., sand, limestone etc. Later the emphasis is given on these permeable zones.

Second step: To scan the resistivity logs in track 2 to see which of the zones of interest gives high resistivity readings. High resistivities reflect either hydrocarbons in the pores or low porosity.

Third step: Later the porosity logs are scanned on the track 3 to analyze which of the zones have good porosity against the high resistivity zones. The tight formations are discarded and interesting zones are selected for the formation evaluation.



5.1. Calculation of Vshale

The presence of shale (i.e. clay minerals) in a reservoir can cause erroneous results for water saturation and porosity derived from logs. These erroneous results are not limited to sandstones, but also occur in limestone and dolomites.

Whenever shale is present in the formation, porosity tools like, (sonic and neutron) will record too high porosity. The only exception to this is the density log. It will not record too high a porosity if density of shale is equal to or greater than the reservoir's matrix density. In addition, the presence of shale in a formation will cause resistivity logs to record lower resistivity. The first step in the shaly-sand analysis is the calculation of volume of shale from a gamma ray log. Volume of shale from gamma ray log is determined by the chart or by the following formulas:

$$\mathbf{V_{Sh} = \frac{(GR_{log}-GR_{min})}{(GR_{max}-GR_{min})}}$$

Where:
V_{Sh} = Shale Volume
GR_{log} = actual borehole-corrected GR response in zone of interest
GR_{min} = minimum borehole-corrected GR response against clean zones
GR_{max} = maximum borehole-corrected GR response against shale zones

5.2. Porosity Measurement:

Density porosity Formation bulk density (ñb) is the function of matrix density, porosity, and density of the fluid in the pores (salt mud, fresh mud, or hydrocarbons). To determine density porosity, either by chart or by calculation the matrix density and the type of fluid in the borehole must be known.
The formula for calculating the density porosity is:

$$\mathbf{\Phi= [(\rho_{ma}-\rho_b)/ (\rho_{ma}-\rho_f)]}$$

Where;
ρ_{ma} = matrix density of formation.
ρ_b = bulk density of the formation.
ρ_f = pore fluid density in the borehole.

5.3. Determining Formation Water Resistivity (Rw):

Traditional method for determining the value for formation water resistivity (Rw) from logs may not always provide reliable because traditional method is applicable only for clean sand area. As the area of project has shaly sand, therefore following formula will be used for calculation of Rw:

$$\mathbf{R_{wa} = R_t * (\Phi \wedge 2)}$$

Where:
R_t = resistivity of the uninvaded zone
Φ = porosity

5.4. Determining Effective Porosity (Φe):

The second step of shaly sand analysis is to determine the effective porosity of the formation i.e. determining porosity of the formation if it did not contain clay minerals.
Effective Porosity from Neutron-Density Combinations:

$$\mathbf{\Phi_d\text{-corrected} = \Phi_d - (V_{cl} \times \Phi_{dsh})} \quad \textbf{For Density}$$

These values of neutron and density porosity corrected for the presence of clays are then used in the equations below to determine the effective porosity (Φ_e) of the formation of interest.

$$\Phi_{effective} = \frac{(\Phi n - corrected + \Phi d - corrected)}{2} \qquad \textbf{for Oil}$$

$$\Phi_{effective} = \sqrt{\frac{(\Phi n - corrected)^2 + (\Phi d - corrected)2}{2}} \qquad \textbf{for Gas}$$

5.5. S_w Calculations:

Water saturation may now be calculated for those zones that appear to be hydrocarbon bearing.
The water saturation equation for clean formations is as follows:

Archie's Equation

$$S_w = \sqrt[n]{\frac{a}{\Phi^m} \times \frac{R_w}{R_t}}$$

Where:
S_w = water saturation
n = saturation exponent
a = tortuosity factor.
Φ = porosity.
m = cementation exponent
R_t = formation resistivity
R_w = formation water resistivity

Here, as the area considered for the project has shaly sand and the above equation is applicable only for clean sand.

There are many different equations by which water saturation (Sw) of a clay-bearing formation may be calculated. However, the most suitable equation is the **Indonesian Equation**, which is as follow

$$S_w = \sqrt{R_t}\ \frac{1}{\left[\frac{V_{cl}^{(1-(Vcl/2))}}{\sqrt{R_{cl}}} + \frac{\sqrt{\Phi_e^{m/2}}}{\sqrt{a*R_w}}\right]}$$

Where:
R_t = resistivity of uninvaded zone
V_{cl} = volume of clay
Φ_e = effective porosity
R_{cl} = resistivity of clay
R_w = resistivity of formation water

5.6. Movable Hydrocarbon Index (MHI)

The movable hydrocarbon index (MHI) was derived using:

MHI = Sw / Sxo

Where:
MHI > 1 implies that hydrocarbon was not moved during invasion and MHI < 0.7 implies that hydrocarbon was moved during invasion. The parameters Sw and Sxo are water saturation of the uninvaded zone and the flushed zone respectively.

6. RESULTS AND DISCUSSIONS

Steps mentioned above for formation evaluation were followed and following results were obtained in the mentioned steps:

6.1. Crossplots

6.1.1. Neutron-Density Plot:

This crossplot is mainly used for lithology determination which can further also be used for determination of change in sorting. The formations were further divided into small zones on the basis of variations shown by various logs.

Refer **Figure 6.1 to Figure 6.26** for the results which were obtained when neutron-density plot was plotted in the divided zones.

6.2. Calculation of V_{shale}

As the area of study contained Glauconite along with Shale, therefore V_{shale} was calculated from Gamma Ray Log as well as Neutron Density Log. The minimum value of V_{shale} obtained from both the calculations is considered for further calculation. As many negative values are obtained, results are further normalized for eliminating negative values.

Average V_{shale} value calculated for the zones are:

For Chabua 1

Zone Name	Formation Name	Depth Range	Vshale
Zone 1	Sh 2B	3443.0-3447.6	0.05-0.63
Zone 2	Sh 3B	3460.1-3463.0	0.03-0.68
Zone 3	Sh 3B	3469.2-3471.9	0.09-0.54
Zone 4	Sh 4T	3482.9-3484.9	0.02-0.62
Zone 5	Sh 5B	3520.6-3524.9	0.01-0.30
Zone 6	Langpar	3547.2-3549.6	0.02-0.55
Zone 7	Langpar	3565.5-3567.5	0.02-0.20

For Chabua 2

Zone Name	Formation Name	Depth Range	Vshale
Zone 1	Sh 3B	3459.7-3462.9	0.05-0.60
Zone 2	Sh 3B	3463.3-3467.8	0.02-0.41
Zone 3	Sh 4T	3469.0-3470.2	0.15-0.25
Zone 4	Sh 5B	3519.7-3523.1	0.03-0.40
Zone 5	Sh 5B	3525.0-3527.2	0.02-0.57
Zone 7	Langpar	3565.0-3568.0	0.05-0.73

Refer **Figure 6.27 to Figure 6.33** for complete results of V_{shale} calculation obtained in zones mentioned above.

6.3. <u>Porosity Measurement:</u>

Average porosity value calculated for the zones are:

For Chabua 1

Zone Name	Formation Name	Depth Range	Vshale	Porosity
Zone 1	Sh 2B	3443.0-3447.6	0.05-0.63	0.13-0.26
Zone 2	Sh 3B	3460.1-3463.0	0.03-0.68	0.16-0.25
Zone 3	Sh 3B	3469.2-3471.9	0.09-0.54	0.21-0.31
Zone 4	Sh 4T	3482.9-3484.9	0.02-0.62	0.12-0.25
Zone 5	Sh 5B	3520.6-3524.9	0.01-0.30	0.15-0.24
Zone 6	Langpar	3547.2-3549.6	0.02-0.55	0.02-0.19
Zone 7	Langpar	3565.5-3567.5	0.02-0.20	0.09-0.12

For Chabua 2

Zone Name	Formation Name	Depth Range	Vshale	Porosity
Zone 1	Sh 3B	3459.7-3462.9	0.05-0.60	0.25-0.30
Zone 2	Sh 3B	3463.3-3467.8	0.02-0.41	0.15-0.30
Zone 3	Sh 4T	3469.0-3470.2	0.15-0.25	0.21-0.27
Zone 4	Sh 5B	3519.7-3523.1	0.03-0.40	0.15-0.18
Zone 5	Sh 5B	3525.0-3527.2	0.02-0.57	0.11-0.20
Zone 6	Langpar	3565.0-3568.0	0.05-0.73	0.09-0.15

Refer **Figure 6.34 to Figure 6.40** for complete results of porosity measurement obtained in zones mentioned above.

6.4. Formation Water Resistivity Determination (R_w):

For Chabua 1

Zone Name	Formation Name	Depth Range	Rw
Zone 1	Sh 2B	3443.0-3447.6	0.01-0.03
Zone 2	Sh 3B	3460.1-3463.0	0.01-0.07
Zone 3	Sh 3B	3469.2-3471.9	0.03-0.40
Zone 4	Sh 4T	3482.9-3484.9	0.01-0.02
Zone 5	Sh 5B	3520.6-3524.9	0.01-0.08
Zone 6	Langpar	3547.2-3549.6	0.01
Zone 7	Langpar	3565.5-3567.5	0.01

For Chabua 2

Zone Name	Formation Name	Depth Range	Rw
Zone 1	Sh 3B	3459.7-3462.9	0.03-0.14
Zone 2	Sh 3B	3463.3-3467.8	0.01-0.07
Zone 3	Sh 4T	3469.0-3470.2	0.02-0.04
Zone 4	Sh 5B	3519.7-3523.1	0.01
Zone 5	Sh 5B	3525.0-3527.2	0.01
Zone 6	Langpar	3565.0-3568.0	0.01

6.5. Determination of Effective Porosity:

Effective porosity is estimated by correcting density and porosity for shale.
Average effective porosity calculated for the decided zones are:

For Chabua 1

Zone Name	Formation Name	Depth Range	Vshale	Porosity	Eff Porosity
Zone 1	Sh 2B	3443.0-3447.6	0.05-0.63	0.13-0.26	0.10-0.25
Zone 2	Sh 3B	3460.1-3463.0	0.03-0.68	0.16-0.25	0.14-0.23
Zone 3	Sh 3B	3469.2-3471.9	0.09-0.54	0.21-0.31	0.18-0.29
Zone 4	Sh 4T	3482.9-3484.9	0.02-0.62	0.12-0.25	0.09-0.23
Zone 5	Sh 5B	3520.6-3524.9	0.01-0.30	0.15-0.24	0.11-0.21
Zone 6	Langpar	3547.2-3549.6	0.02-0.55	0.02-0.19	0.01-0.15
Zone 7	Langpar	3565.5-3567.5	0.02-0.20	0.09-0.12	0.06-0.10

For Chabua 2

Zone Name	Formation Name	Depth Range	Vshale	Porosity	Eff Porosity
Zone 1	Sh 3B	3459.7-3462.9	0.05-0.60	0.25-0.30	0.21-0.28
Zone 2	Sh 3B	3463.3-3467.8	0.02-0.41	0.15-0.30	0.11-0.28
Zone 3	Sh 4T	3469.0-3470.2	0.15-0.25	0.21-0.27	0.20-0.25
Zone 4	Sh 5B	3519.7-3523.1	0.03-0.40	0.15-0.18	0.12-0.15
Zone 5	Sh 5B	3525.0-3527.2	0.02-0.57	0.11-0.20	0.10-0.18
Zone 6	Langpar	3565.0-3568.0	0.05-0.73	0.09-0.15	0.07-0.13

6.6. S_w Calculation:

After calculation of V_{shale}, porosity, R_w and effective porosity, S_w was calculated using Indonesian equation.

Average values of S_w calculated for the decided zones are:

For Chabua 1

Zone Name	Formation Name	Depth Range	Vshale	Porosity	Eff Porosity	Sw
Zone 1	Sh 2B	3443.0-3447.6	0.05-0.63	0.13-0.26	0.10-0.25	0.36-0.86
Zone 2	Sh 3B	3460.1-3463.0	0.03-0.68	0.16-0.25	0.14-0.23	0.50-0.83
Zone 3	Sh 3B	3469.2-3471.9	0.09-0.54	0.21-0.31	0.18-0.29	0.35-0.81
Zone 4	Sh 4T	3482.9-3484.9	0.02-0.62	0.12-0.25	0.09-0.23	0.54-0.94
Zone 5	Sh 5B	3520.6-3524.9	0.01-0.30	0.15-0.24	0.11-0.21	0.60-0.93
Zone 6	Langpar	3547.2-3549.6	0.02-0.55	0.02-0.19	0.01-0.15	0.22-0.89
Zone 7	Langpar	3565.5-3567.5	0.02-0.20	0.09-0.12	0.06-0.10	0.70-0.99

For Chabua 2

Zone Name	Formation Name	Depth Range	Vshale	Porosity	Eff Porosity	Sw
Zone 1	Sh 3B	3459.7-3462.9	0.05-0.60	0.25-0.30	0.21-0.28	0.48-0.81
Zone 2	Sh 3B	3463.3-3467.8	0.02-0.41	0.15-0.30	0.11-0.28	0.53-0.84
Zone 3	Sh 4T	3469.0-3470.2	0.15-0.25	0.21-0.27	0.20-0.25	0.54-0.80
Zone 4	Sh 5B	3519.7-3523.1	0.03-0.40	0.15-0.18	0.12-0.15	0.54-0.82
Zone 5	Sh 5B	3525.0-3527.2	0.02-0.57	0.11-0.20	0.10-0.18	0.61-0.90
Zone 6	Langpar	3565.0-3568.0	0.05-0.73	0.09-0.15	0.07-0.13	0.70-0.99

Refer **Figure 6.41 to Figure 6.47** for complete results of S_{hc} measurement obtained in zones mentioned above.

6.7. Movable Hydrocarbon Index (MHI)

Average values of MHI calculated for decided zones are:

For Chabua 1

Zone Name	Formation Name	Depth Range	Sw	Sxo	MHI
Zone 1	Sh 2B	3443.0-3447.6	0.36-0.86	0.33-0.84	1.02-1.06
Zone 2	Sh 3B	3460.1-3463.0	0.50-0.83	0.49-0.81	1.01-1.05
Zone 3	Sh 3B	3469.2-3471.9	0.35-0.81	0.40-0.85	0.59-0.99
Zone 4	Sh 4T	3482.9-3484.9	0.54-0.94	0.56-0.95	0.71-0.99
Zone 5	Sh 5B	3520.6-3524.9	0.60-0.93	0.62-0.95	0.80-0.95
Zone 6	Langpar	3547.2-3549.6	0.22-0.89	0.26-0.92	0.72-0.91
Zone 7	Langpar	3565.5-3567.5	0.70-0.99	0.72-0.99	0.89-0.99

For Chabua 2

Zone Name	Formation Name	Depth Range	Sw	Sxo	MHI
Zone 1	Sh 3B	3459.7-3462.9	0.48-0.81	0.46-0.78	1.02-1.06
Zone 2	Sh 3B	3463.3-3467.8	0.53-0.84	0.51-0.83	1.01-1.05
Zone 3	Sh 4T	3469.0-3470.2	0.54-0.80	0.56-0.82	0.82-0.94
Zone 4	Sh 5B	3519.7-3523.1	0.54-0.82	0.57-0.83	0.84-0.97
Zone 5	Sh 5B	3525.0-3527.2	0.61-0.90	0.63-0.93	0.84-0.96
Zone 6	Langpar	3565.0-3568.0	0.70-0.99	0.72-0.99	0.89-0.99

7. CONCLUSIONS

- Based on quick look interpretation, in Langpar reservoir it was found that MSFL is reading higher to LLD and GR log depicts the values ranging between 20-50 API, which is an indication of water bearing zone.
- Based on the Porosity-Density Crossplot and quick look interpretation, seven reservoir zones in Chabua 1 and six reservoir zones in Chabua 2 were selected.
- Based on calculation of Water Saturation (Sw), it was found that zone1 to zone 6 in Chabua 1 and zone 1 to zone 5 in Chabua 2 are hydrocarbon bearing.
- Based on calculation of Water Saturation (Sw), it was found that zone 7 of Chabua 1 and zone 6 of Chabua 2 are water bearing.
- Based on the calculation of Movable Hydrocarbon Index, it was found that zone 1 and 2 of Chabua 1 and Chabua 2, have values greater than 1. Hence, testing is not recommended here.
- Based on the calculation of Movable Hydrocarbon Index, it was found that zones 3 to 7 of Chabua 1 and zones 3 to 6 of Chabua 2, have values less than 1. Hence, testing is recommended here.

8. REFERENCES

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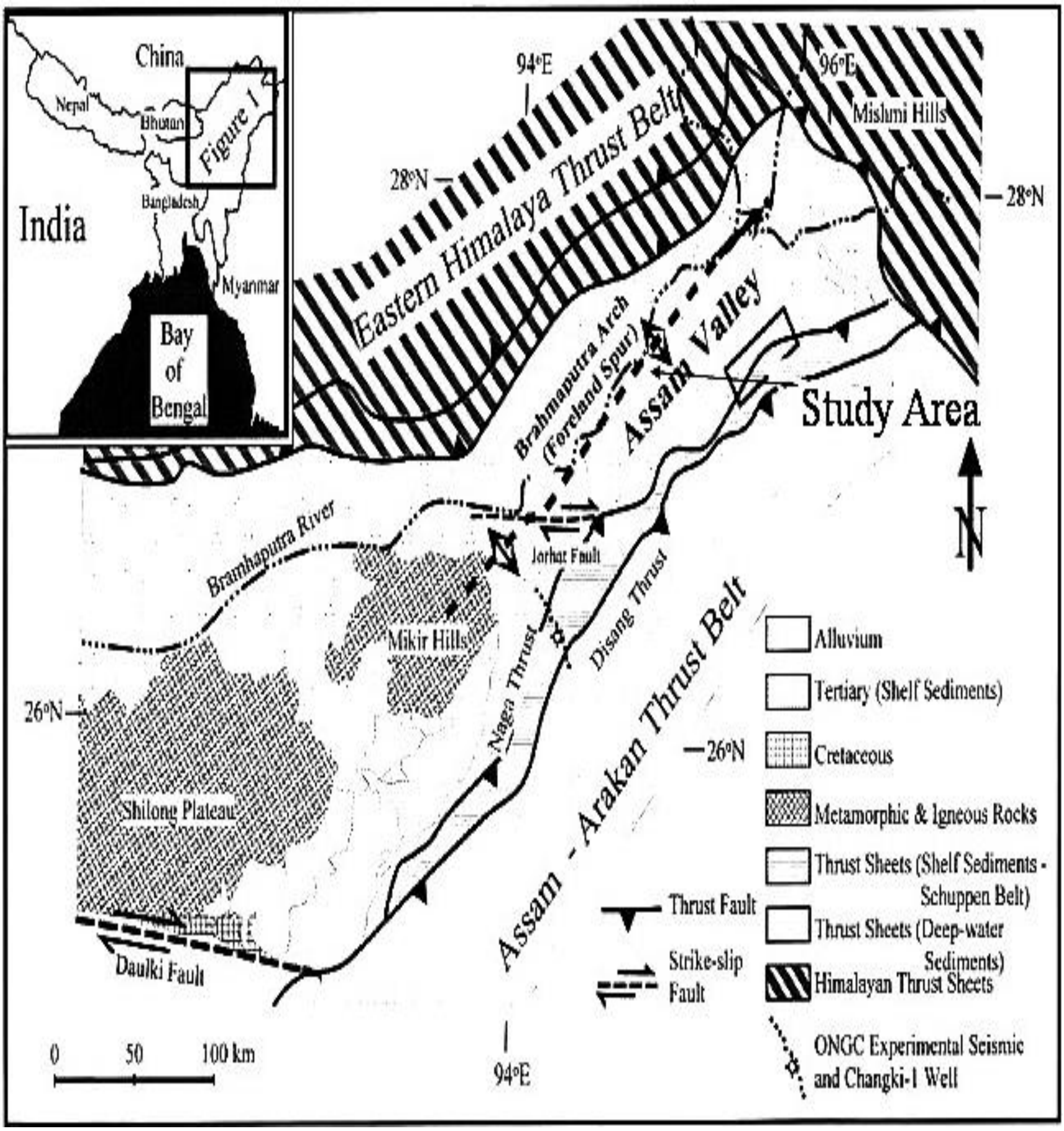

Figure 2.1. Locations and structural elements of Upper Assam Basin.

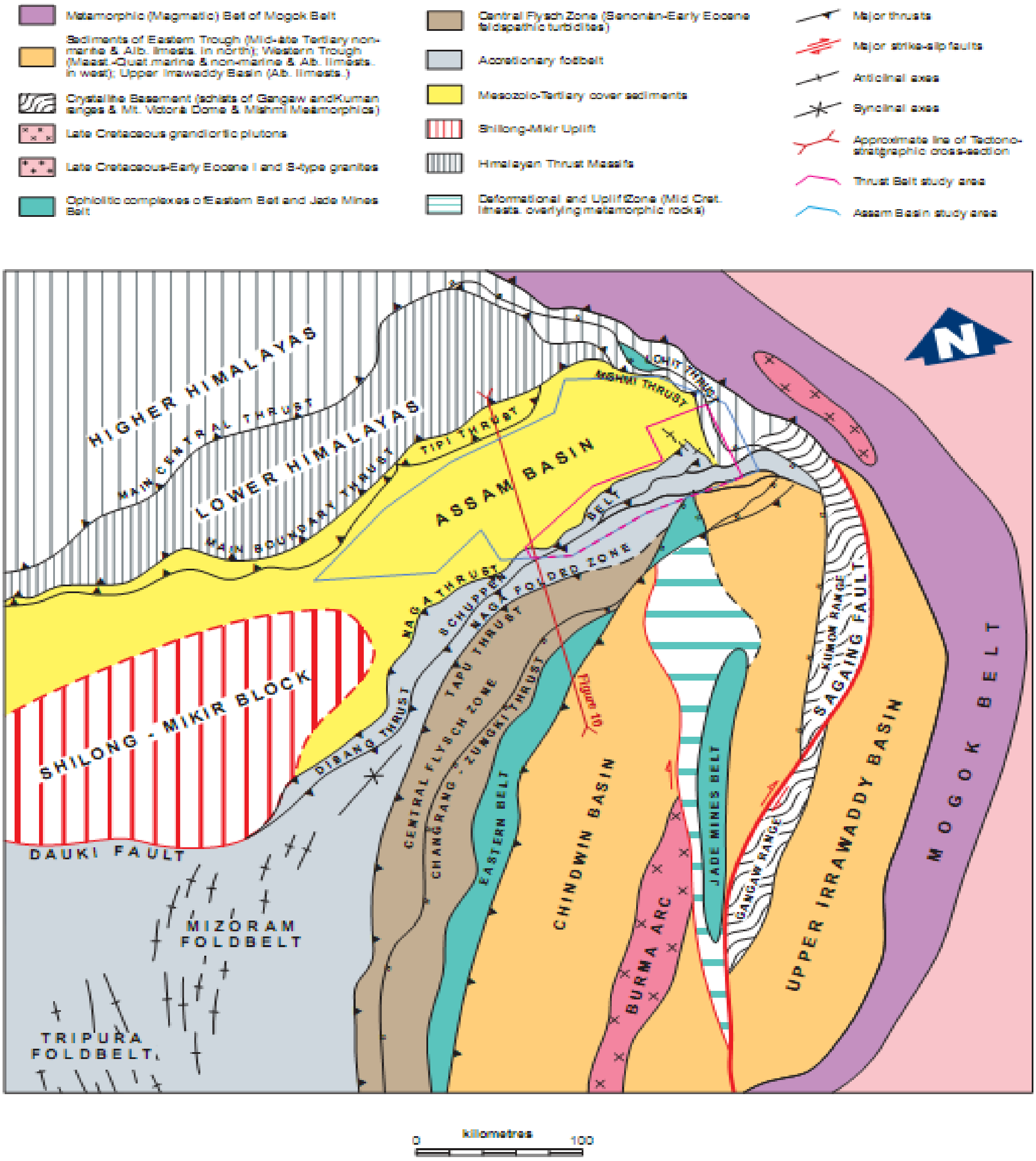

Figure 2.2. Regional structural elements of Assam-Arakan Basin.

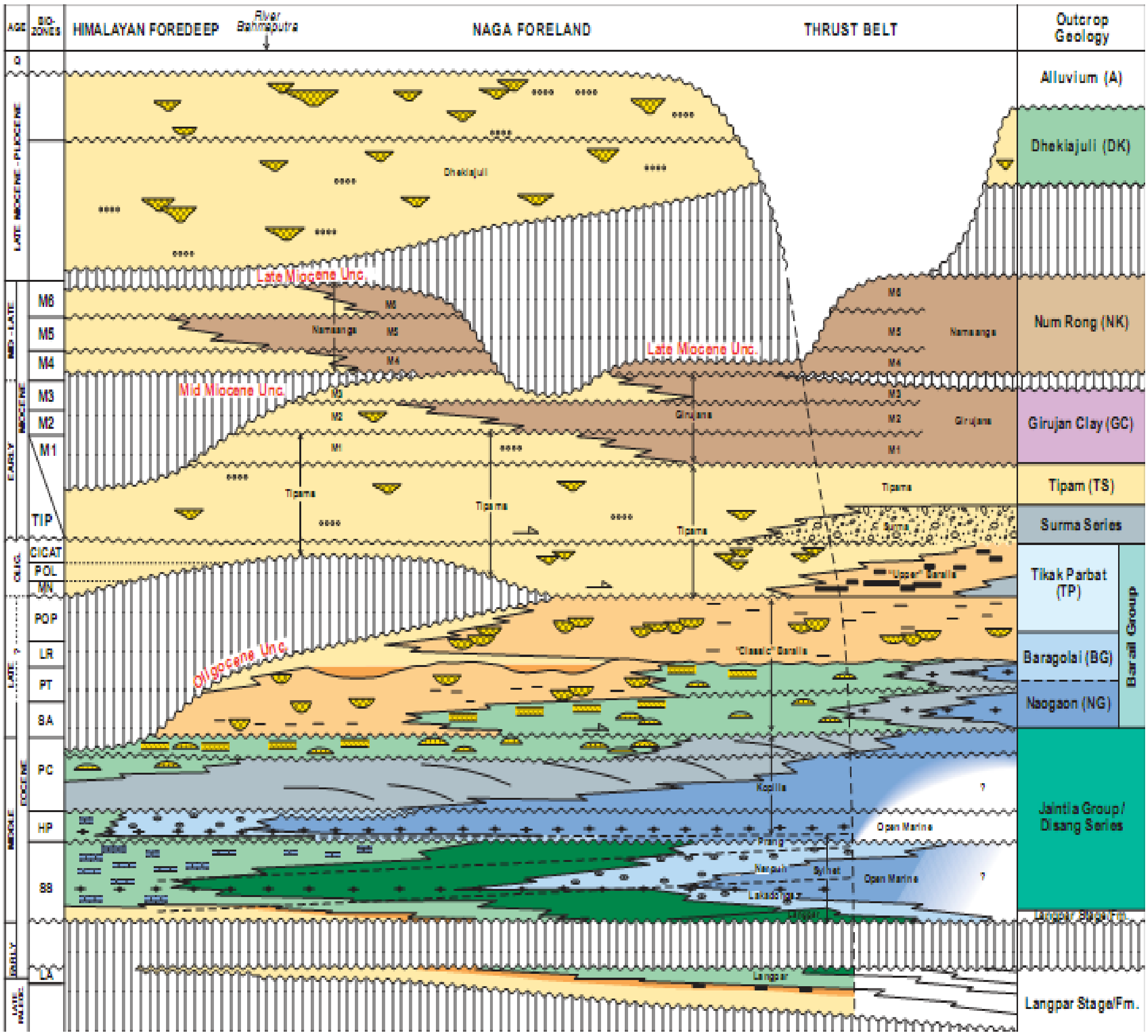

Figure 2.3 Stratigraphy of Assam Arakan Basin

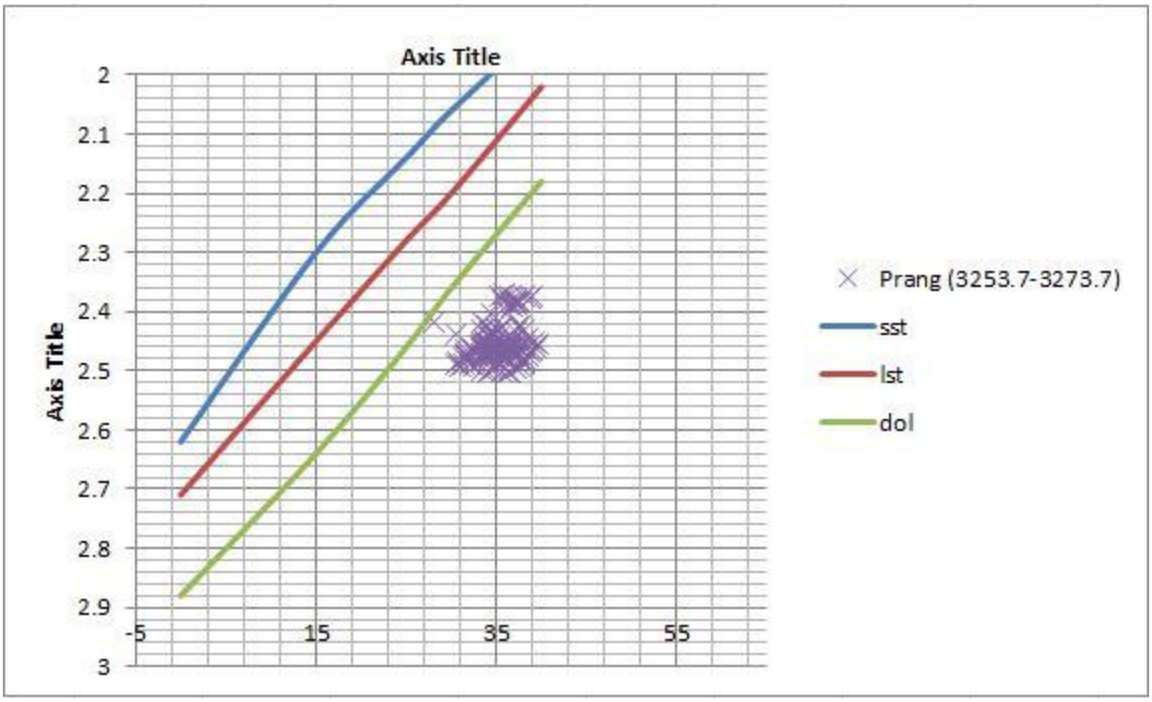

Figure 6.1. Neutron-Density Crossplot (Depth Range: 3253.7-3273.7)

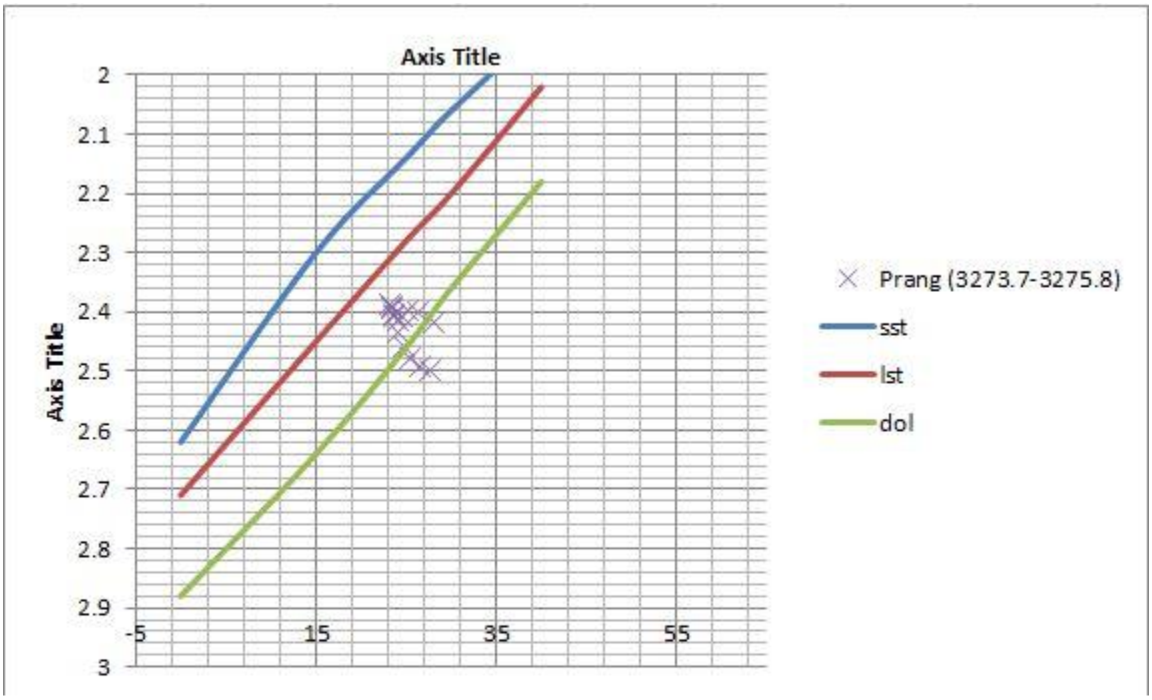

Figure 6.2. Neutron-Density Crossplot (Depth Range: 3273.7-3275.8)

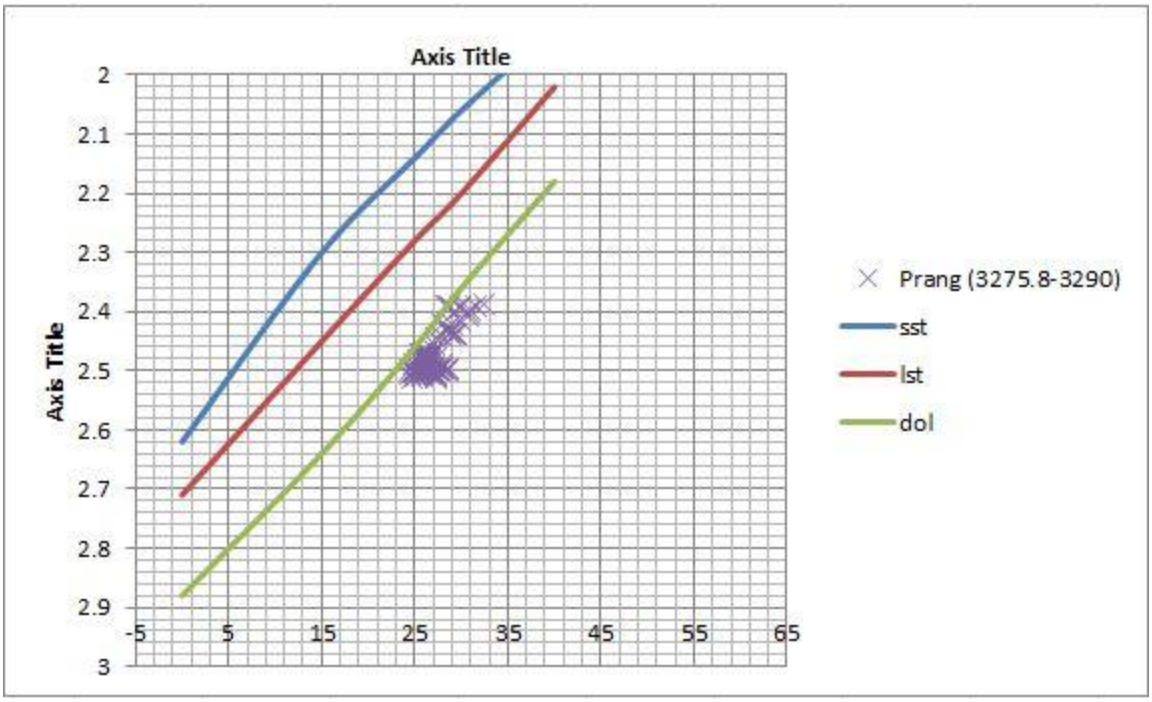

Figure 6.3. Neutron-Density Crossplot (Depth Range: 3275.8-3290)

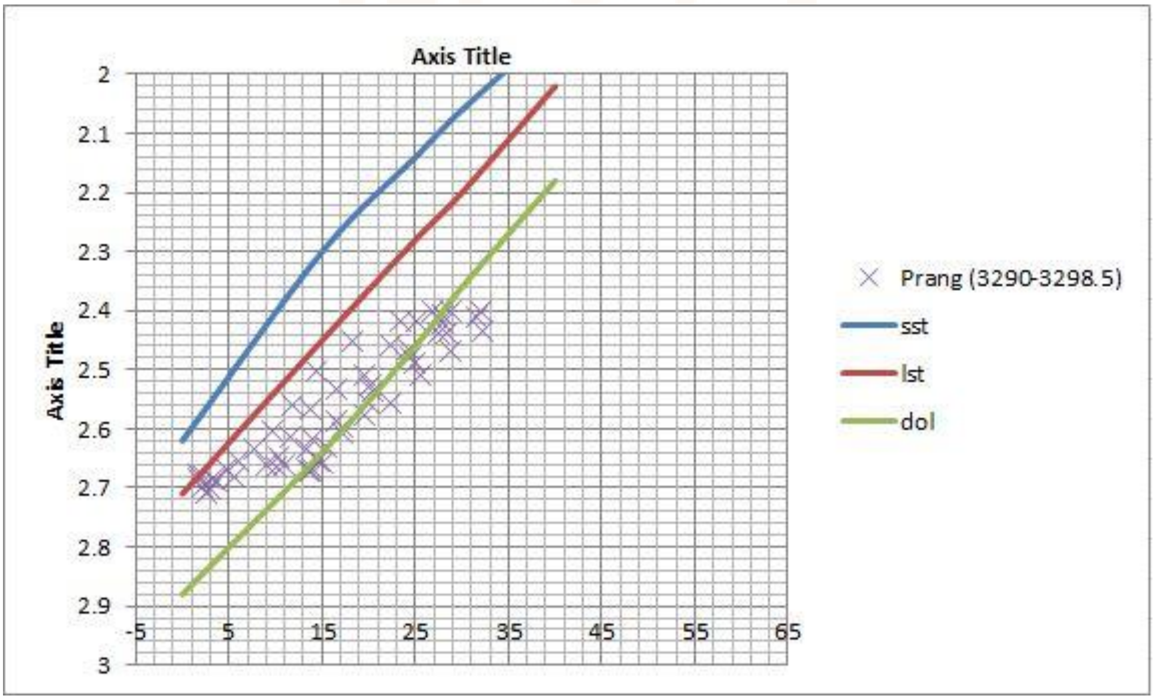

Figure 6.4. Neutron-Density Crossplot (Depth Range: 3290-3298.5)

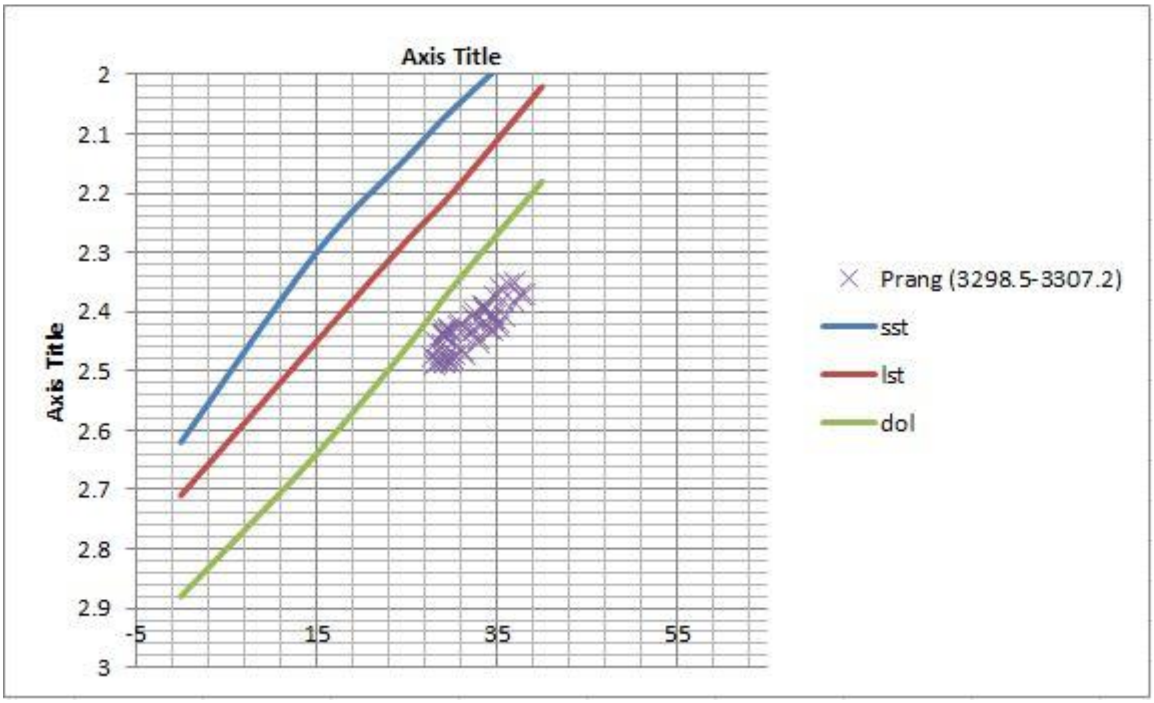

Figure 6.5. Neutron-Density Crossplot (Depth Range: 3298.5-3307.2)

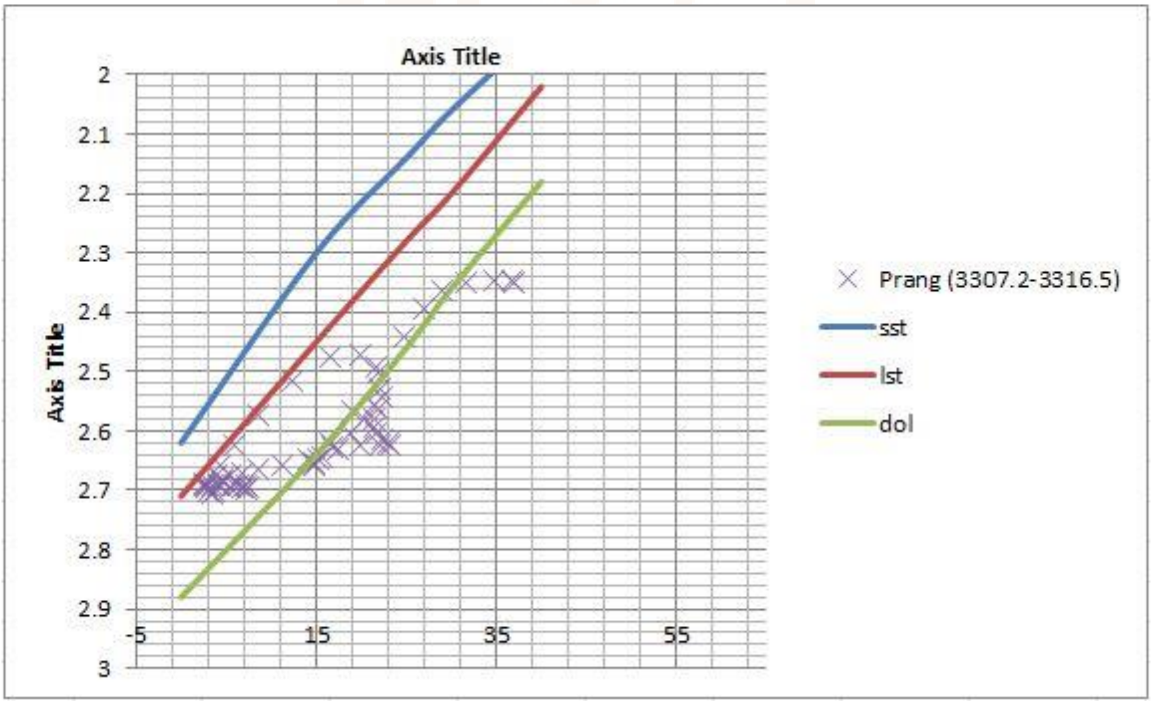

Figure 6.6. Neutron-Density Crossplot (Depth Range: 3307.2-3316.5)

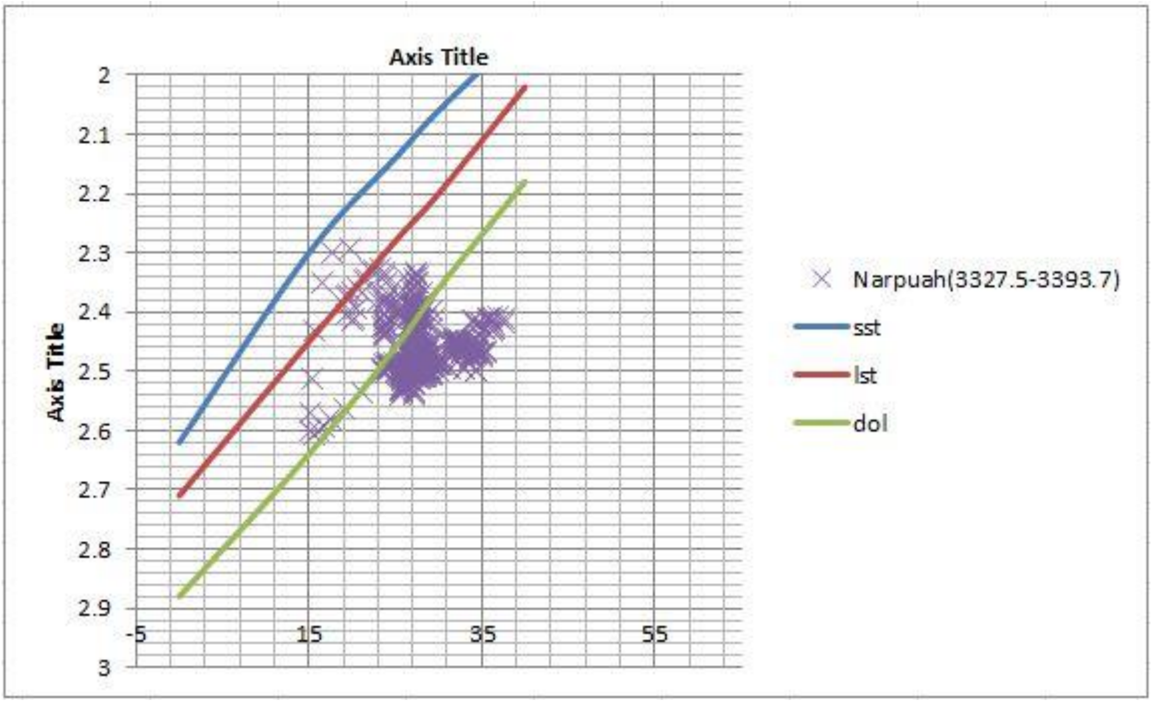

Figure 6.7.. Neutron-Density Crossplot (Depth Range: 3327.5-3393.7)

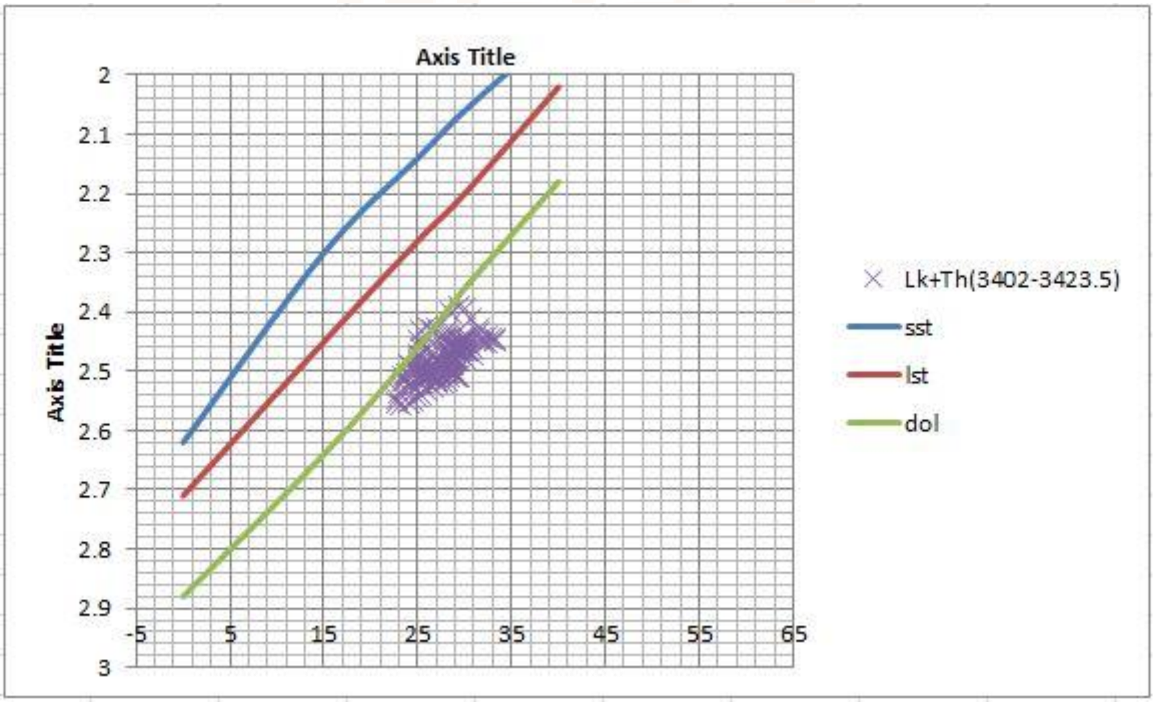

Figure 6.8.. Neutron-Density Crossplot (Depth Range: 3402-3423.5)

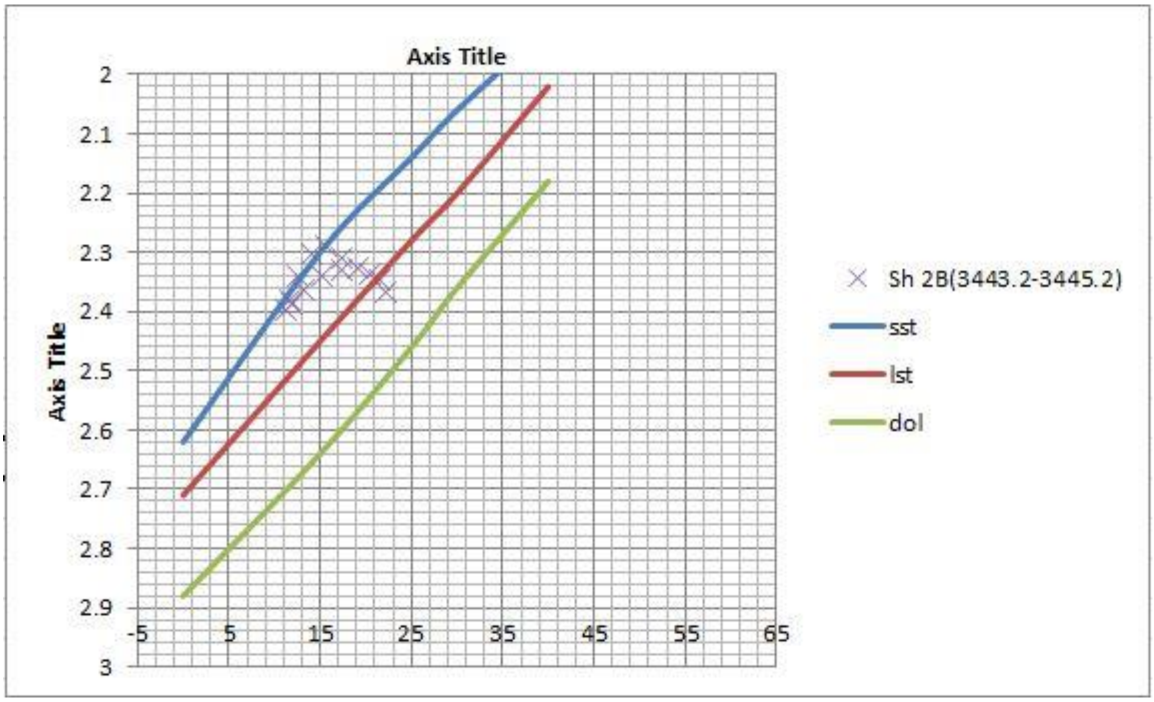

Figure 6.9.. Neutron-Density Crossplot (Depth Range: 3443.2-3445.2)

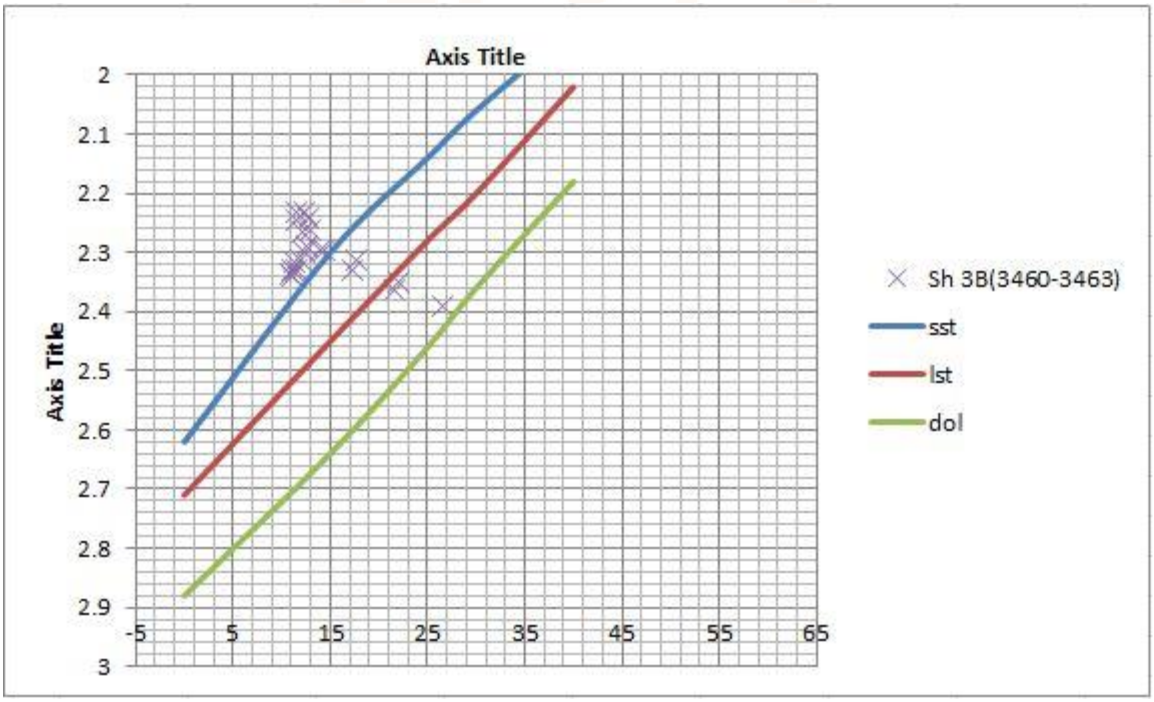

Figure 6.10.. Neutron-Density Crossplot (Depth Range: 3460-3463)

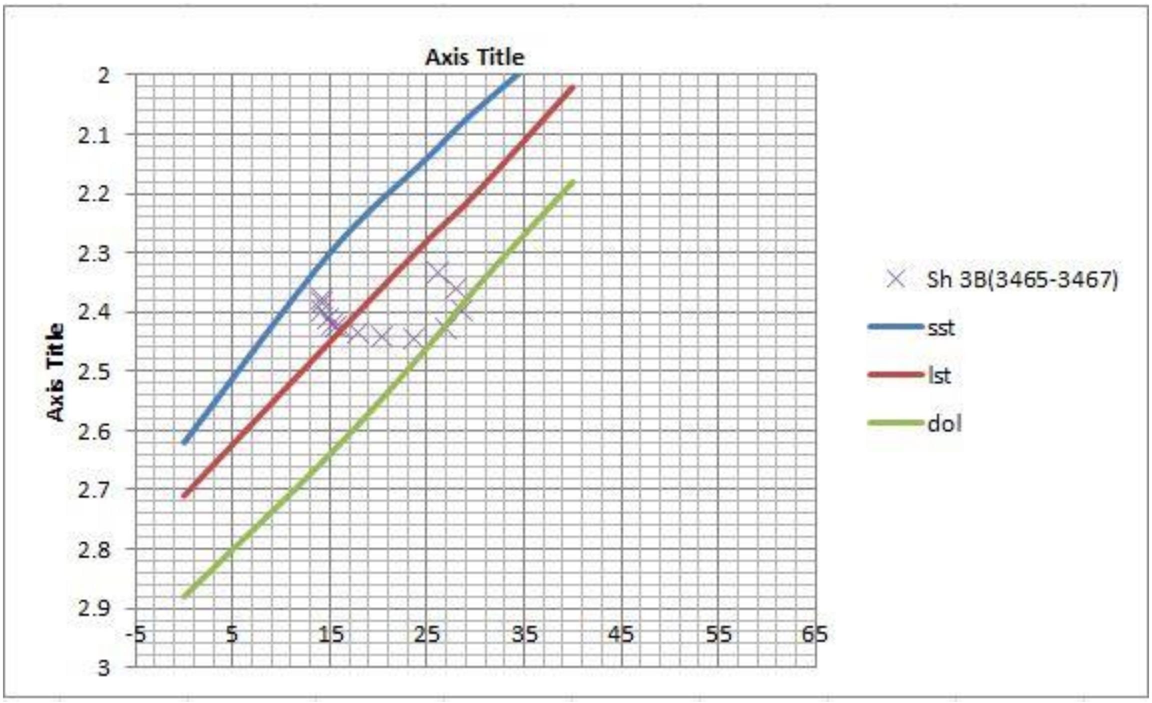

Figure 6.11.. Neutron-Density Crossplot (Depth Range: 3465-3467)

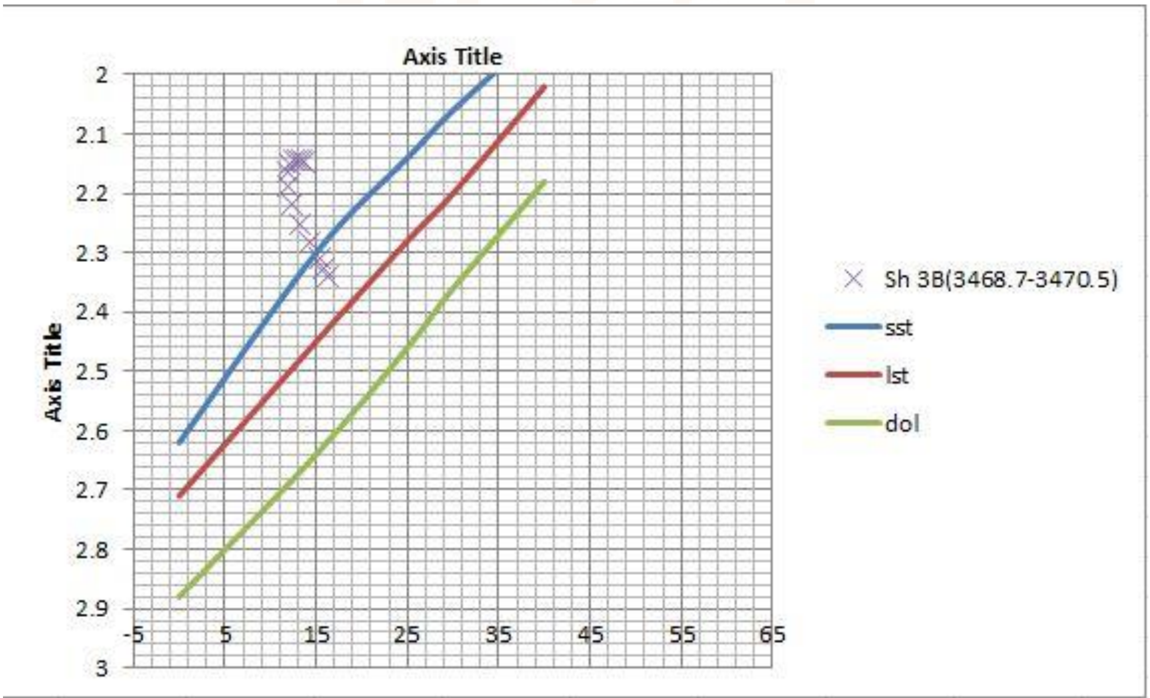

Figure 6.12.. Neutron-Density Crossplot (Depth Range: 3468.7-3470.5)

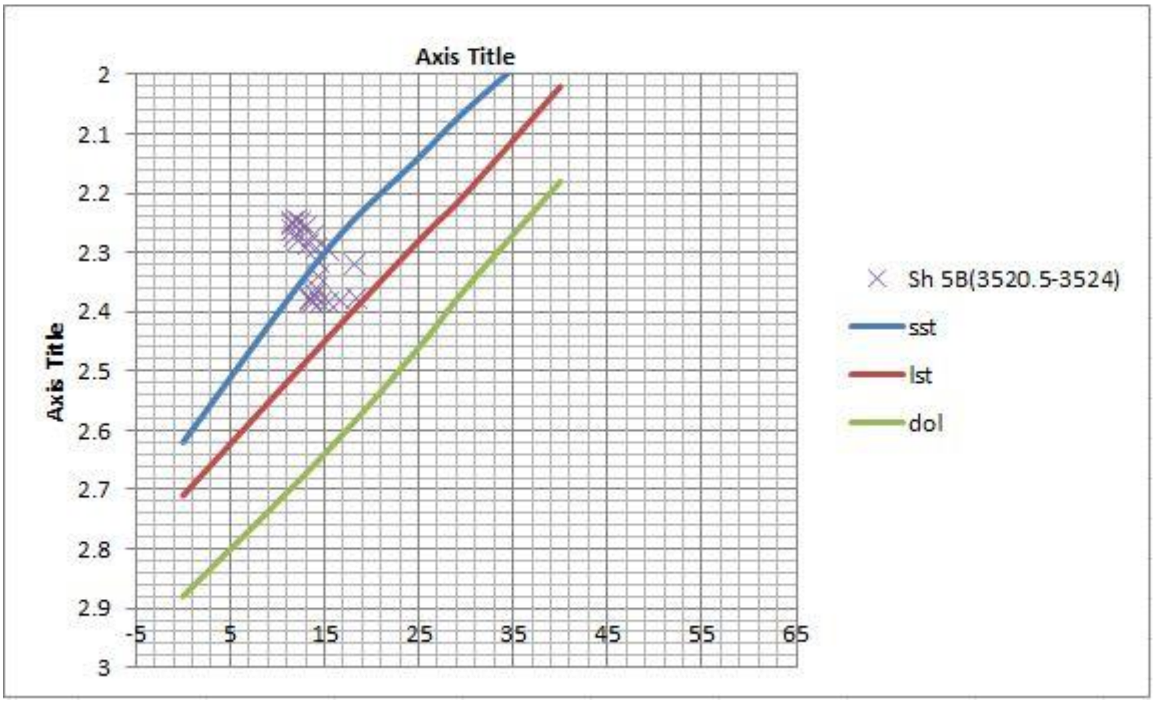

Figure 6.13.. Neutron-Density Crossplot (Depth Range: 3520.5-3524)

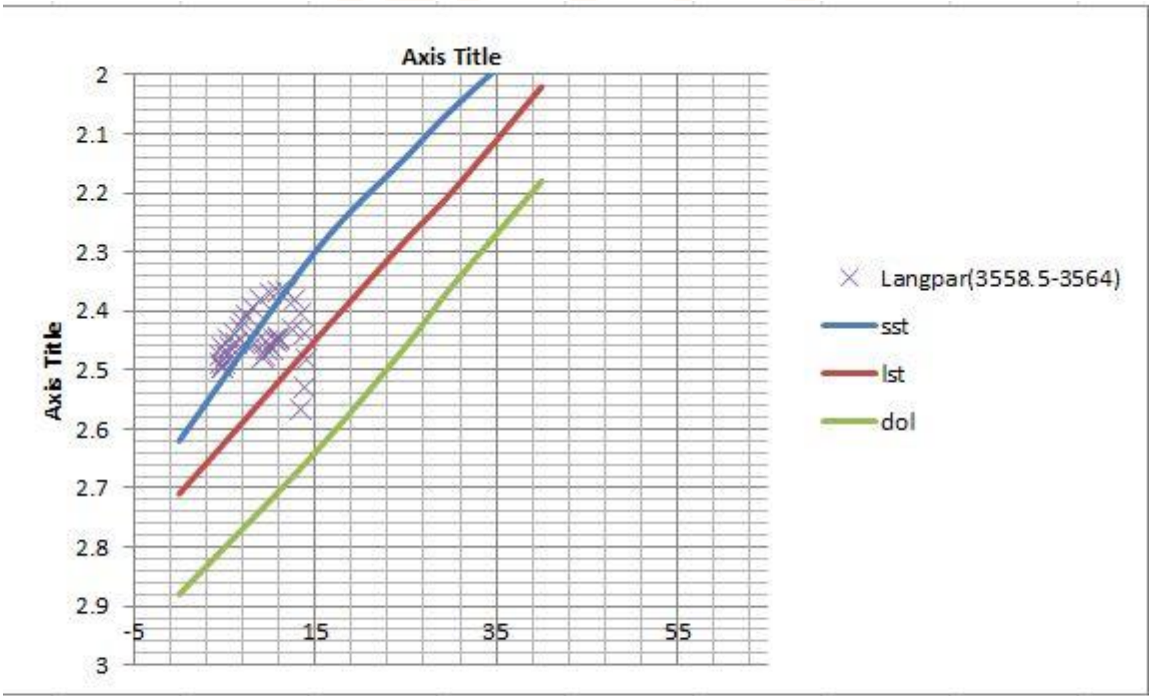

Figure 6.14.. Neutron-Density Crossplot (Depth Range: 3558.5-3564)

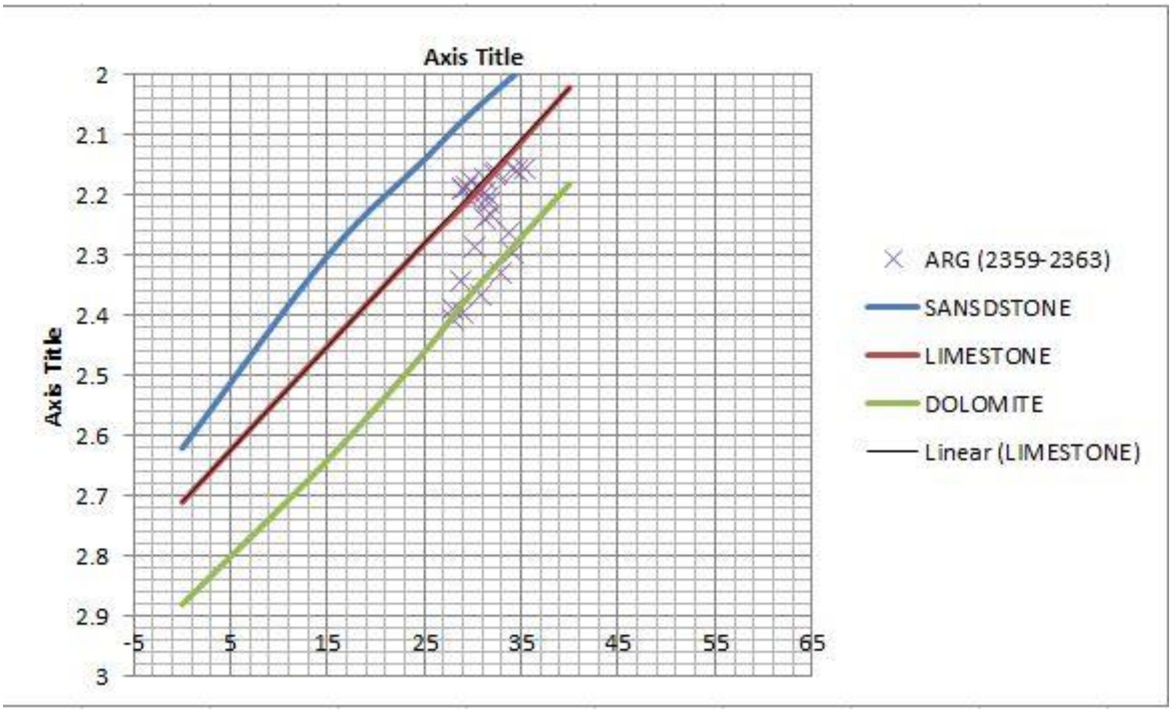

Figure 6.15.. Neutron-Density Crossplot (Depth Range: 2359-2363)

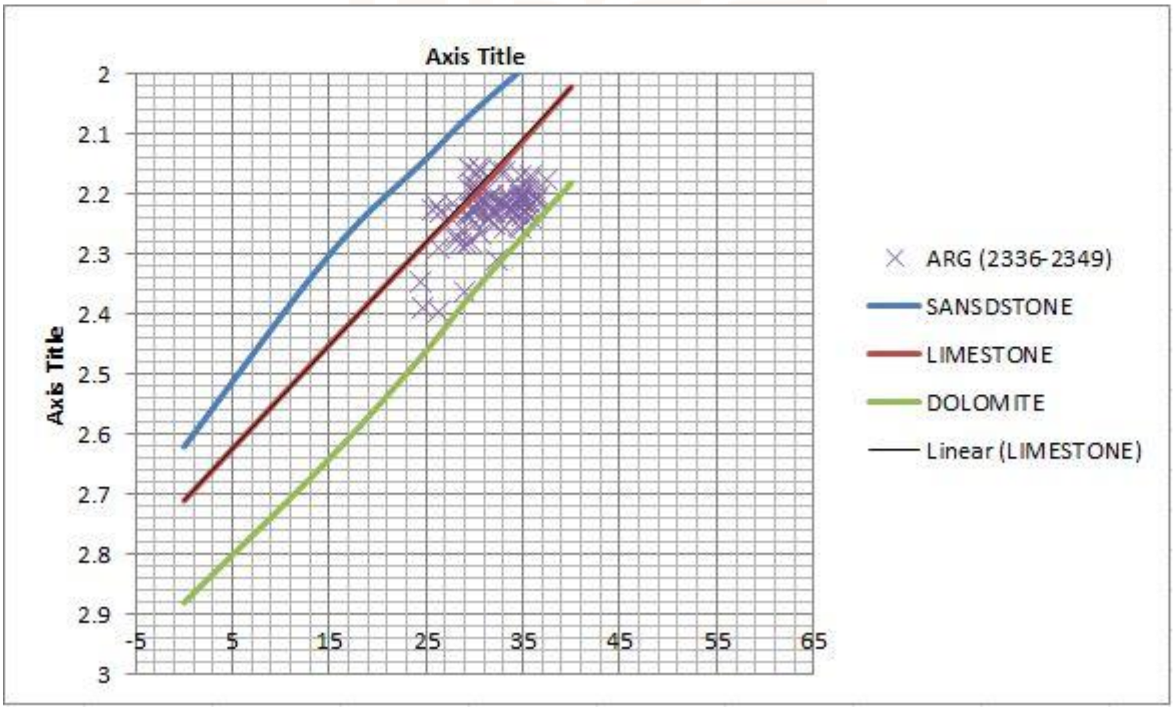

Figure 6.16.. Neutron-Density Crossplot (Depth Range: 2359-2363)

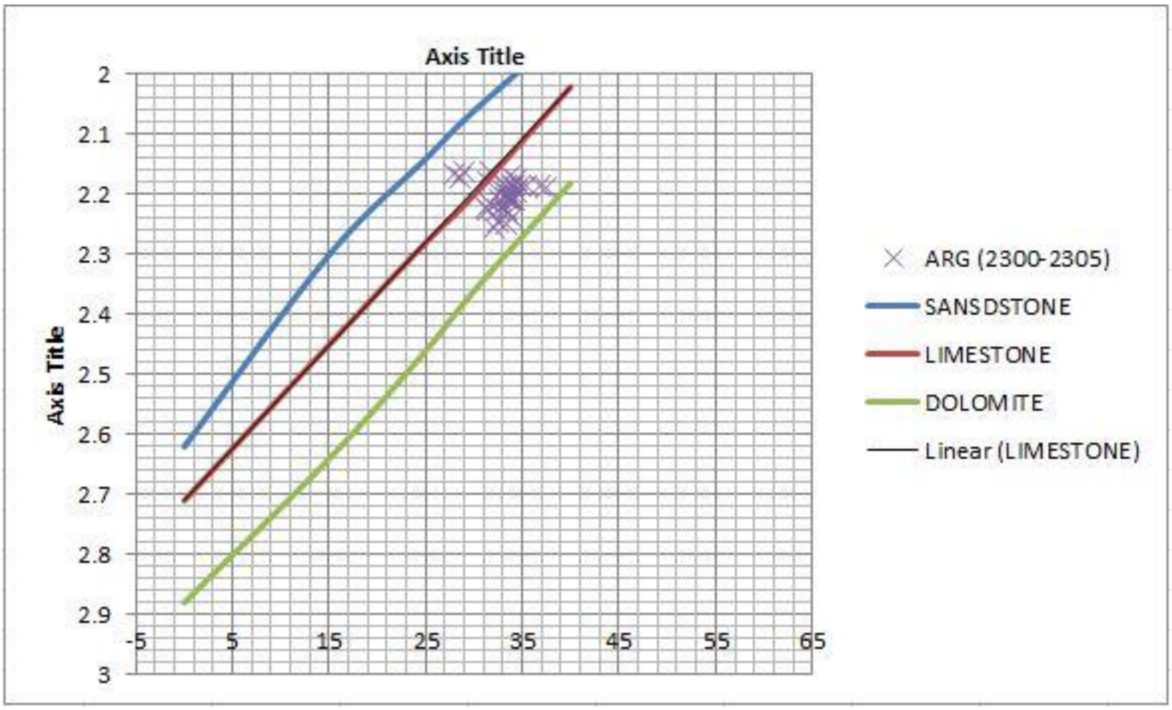

Figure 6.17.. Neutron-Density Crossplot (Depth Range: 2300-2305)

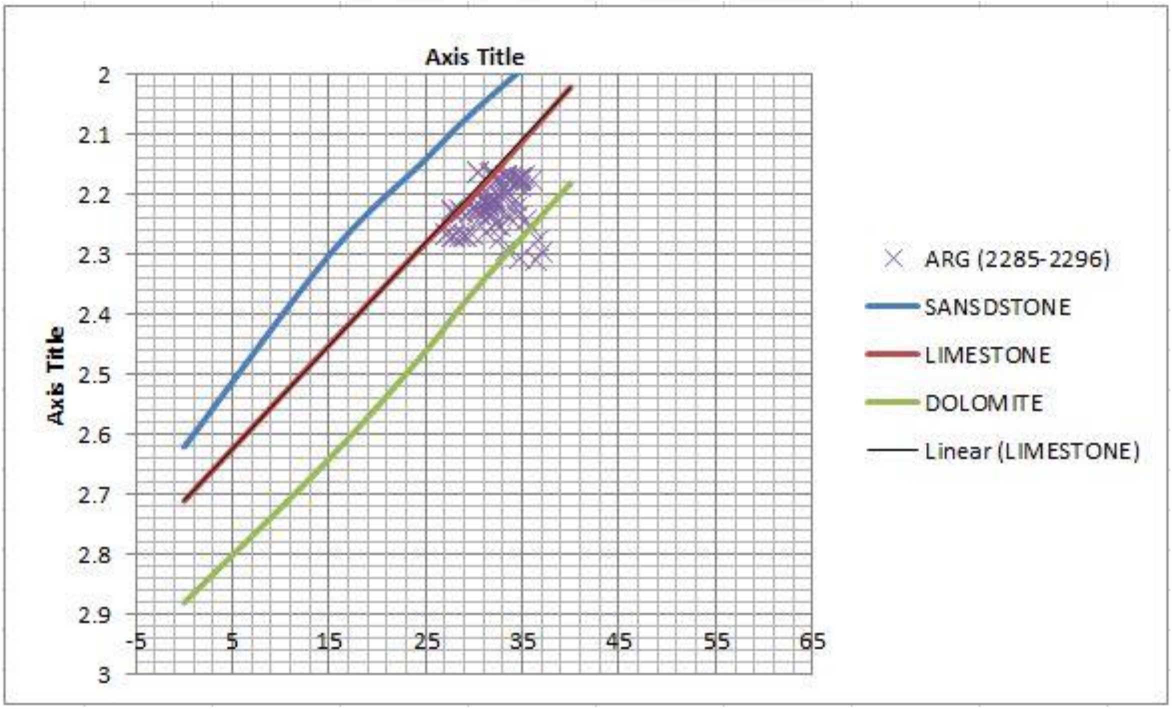

Figure 6.18.. Neutron-Density Crossplot (Depth Range: 2285-2296)

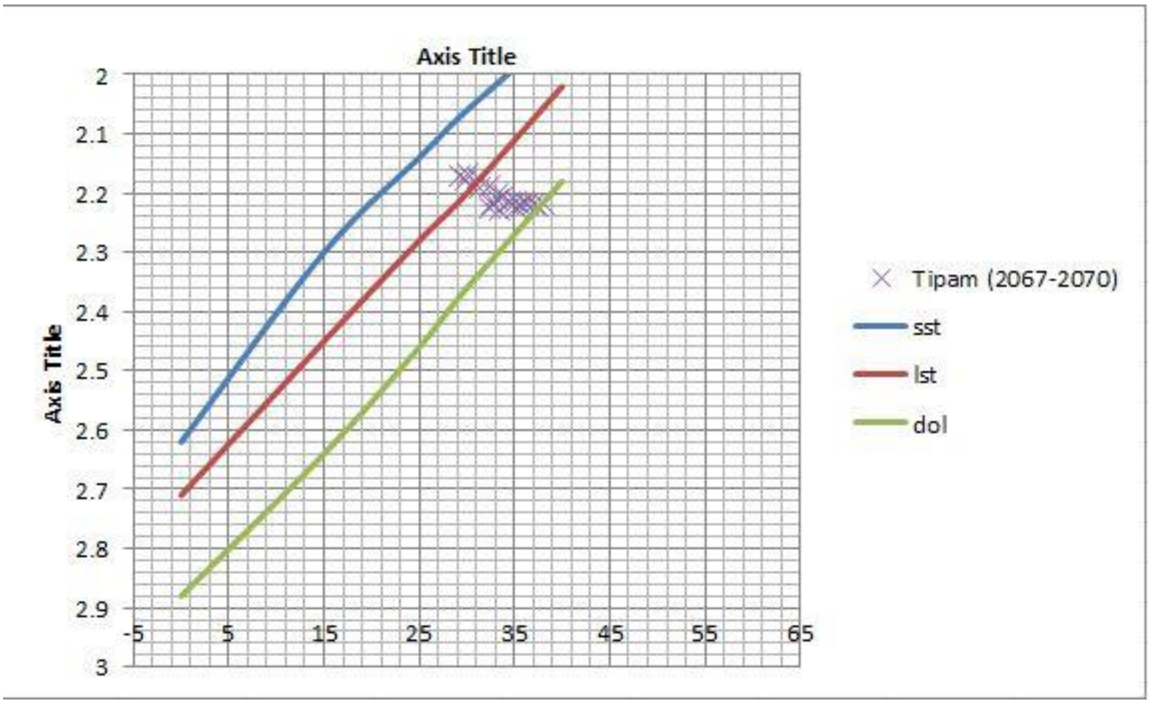

Figure 6.19.. Neutron-Density Crossplot (Depth Range: 2067-2070)

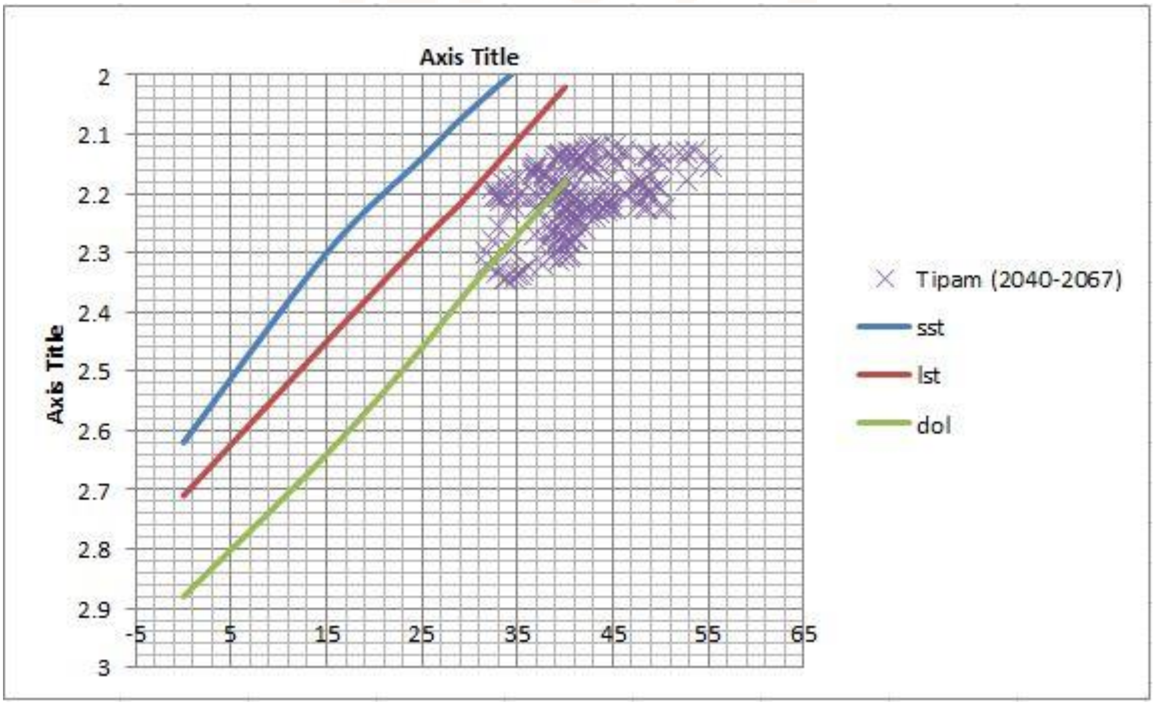

Figure 6.20.. Neutron-Density Crossplot (Depth Range: 2040-2067)

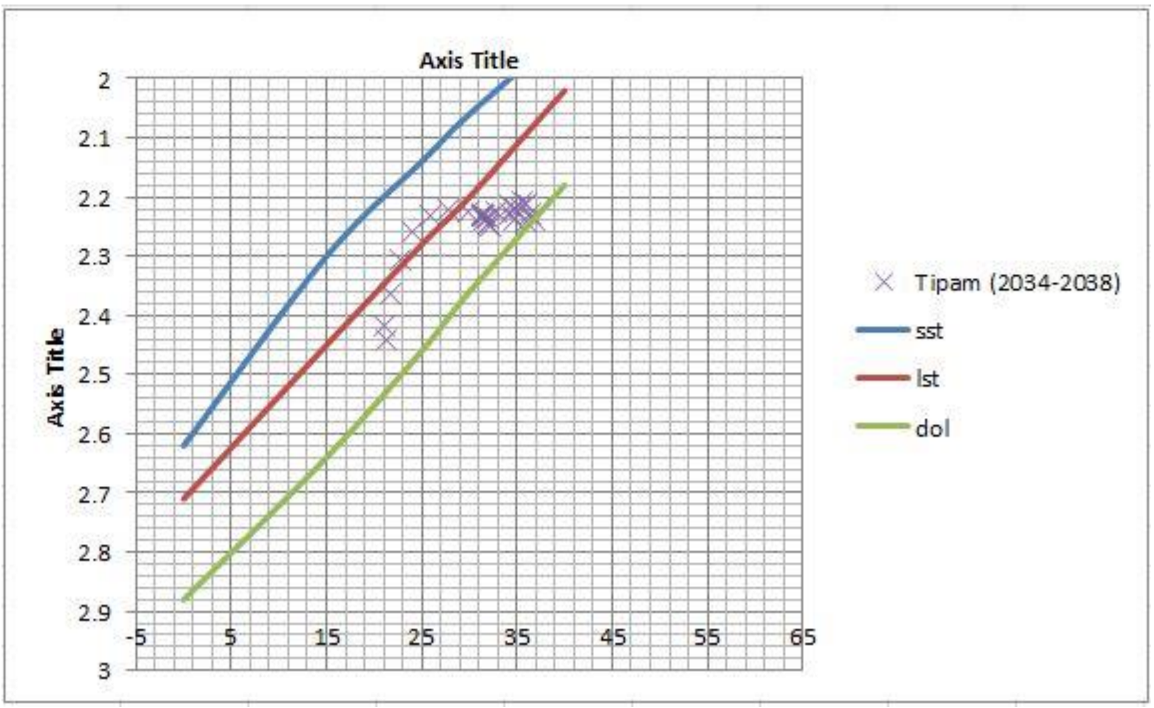

Figure 6.21.. Neutron-Density Crossplot (Depth Range: 2034-2038)

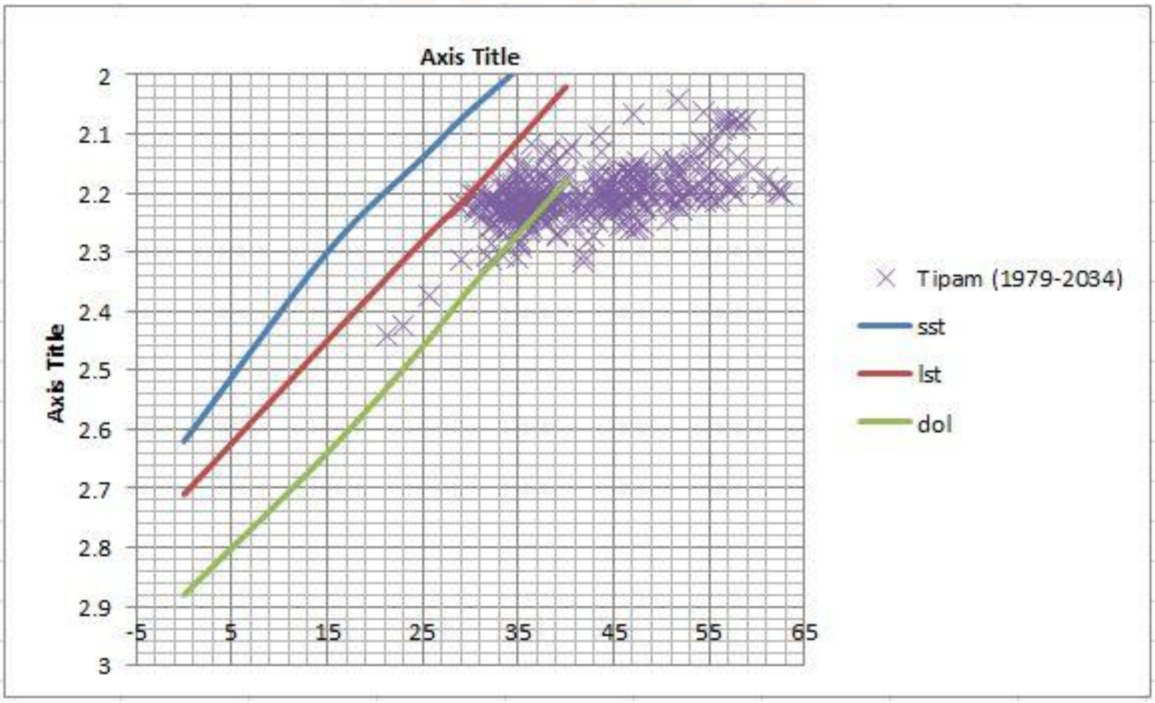

Figure 6.22.. Neutron-Density Crossplot (Depth Range: 1979-2034)

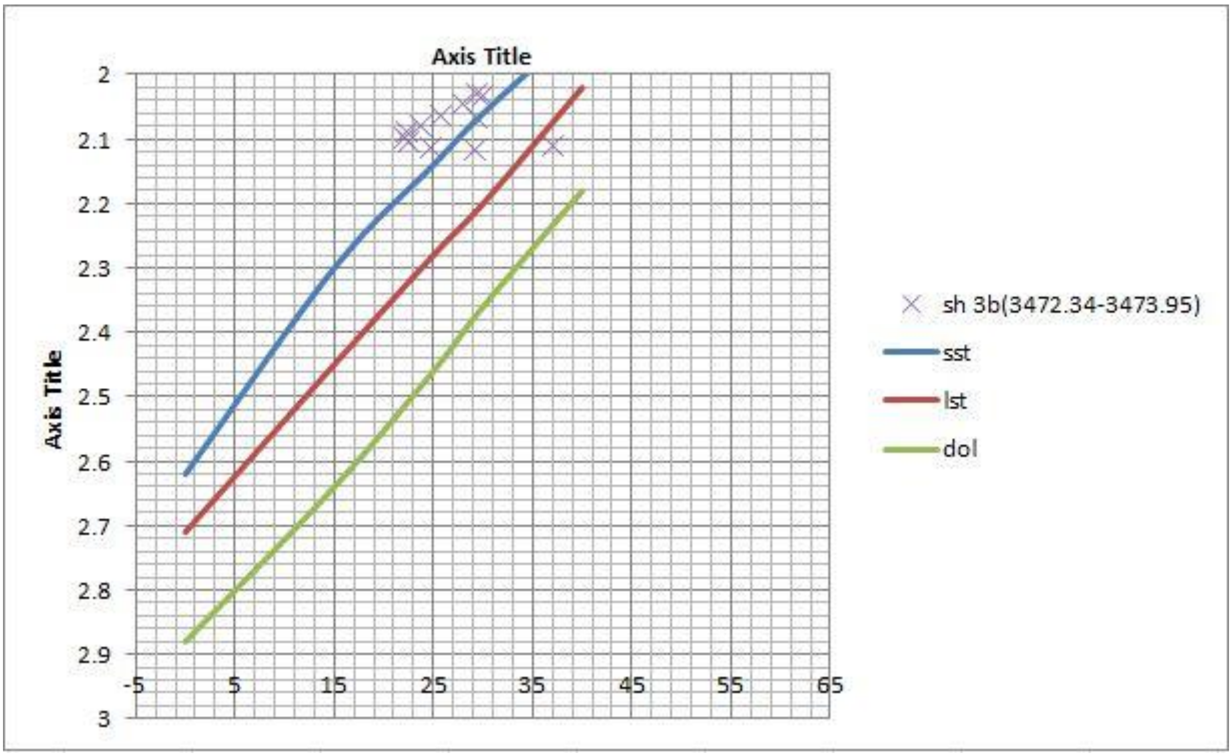

Figure 6.23.. Neutron-Density Crossplot (Depth Range: 3472.34-3473.95)

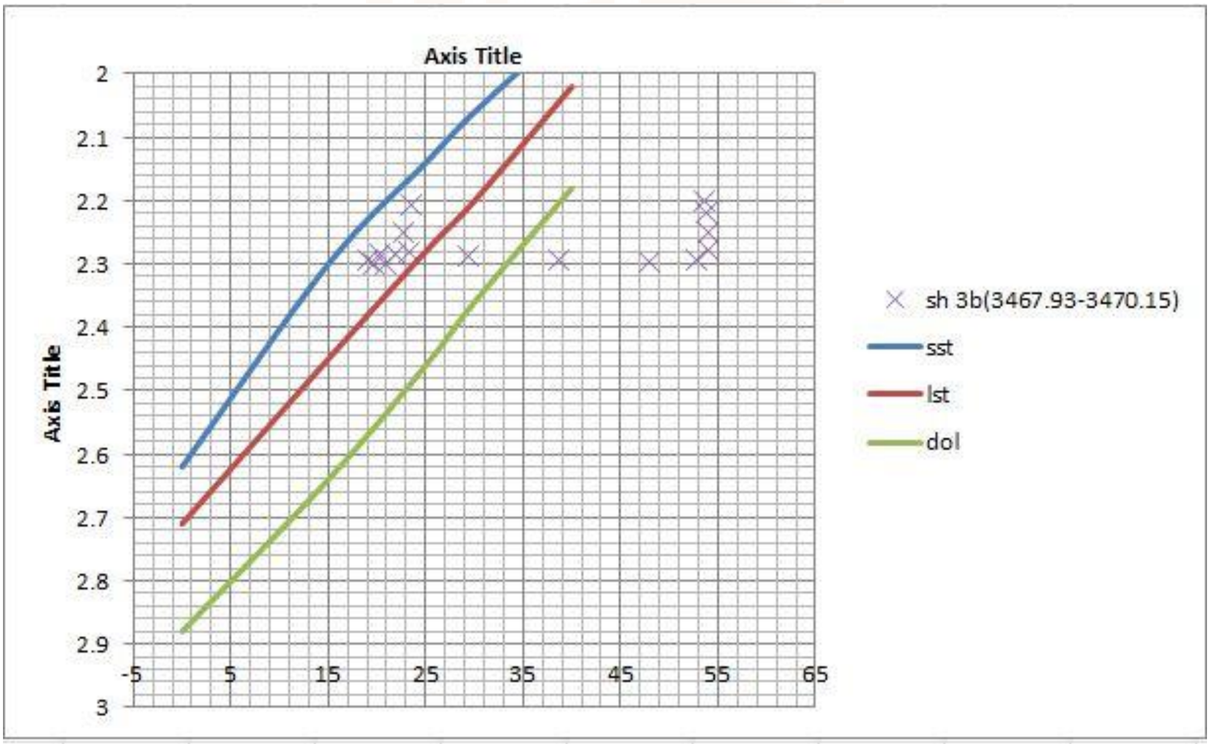

Figure 6.24.. Neutron-Density Crossplot (Depth Range: 3467.93-3470.15)

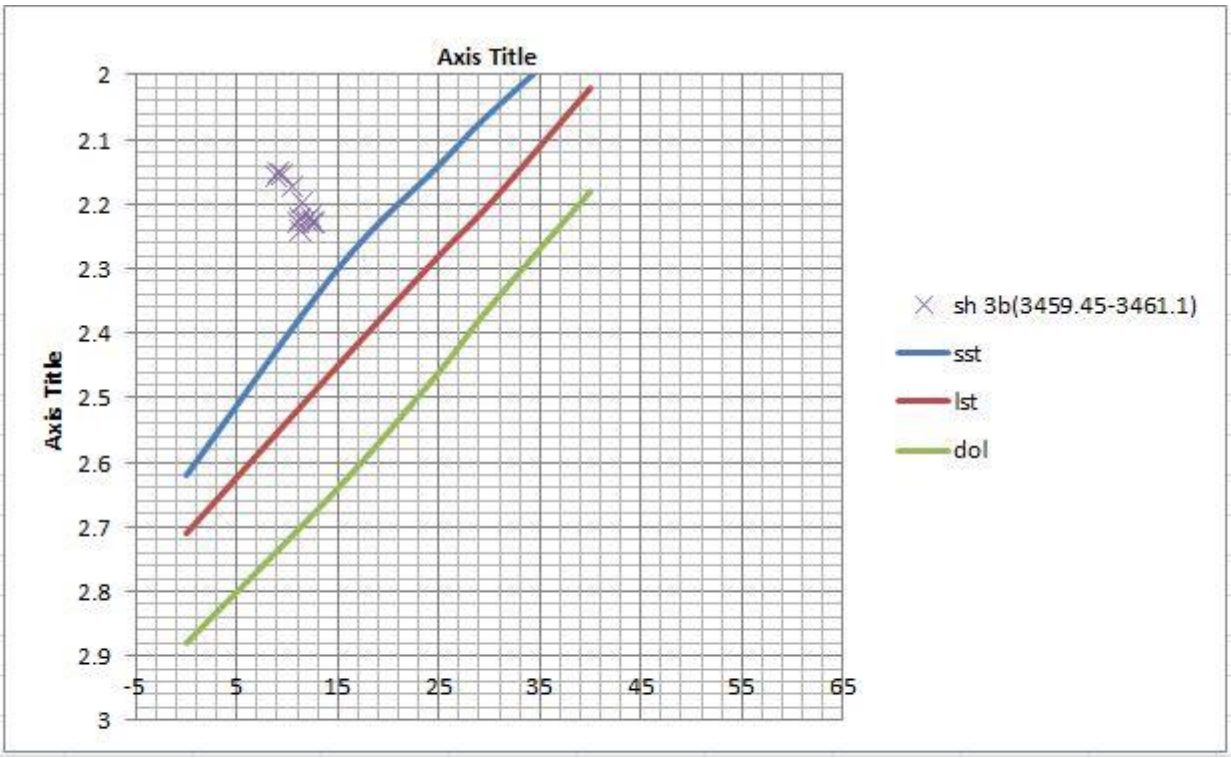

Figure 6.25.. Neutron-Density Crossplot (Depth Range: 3459.45-3461.1)

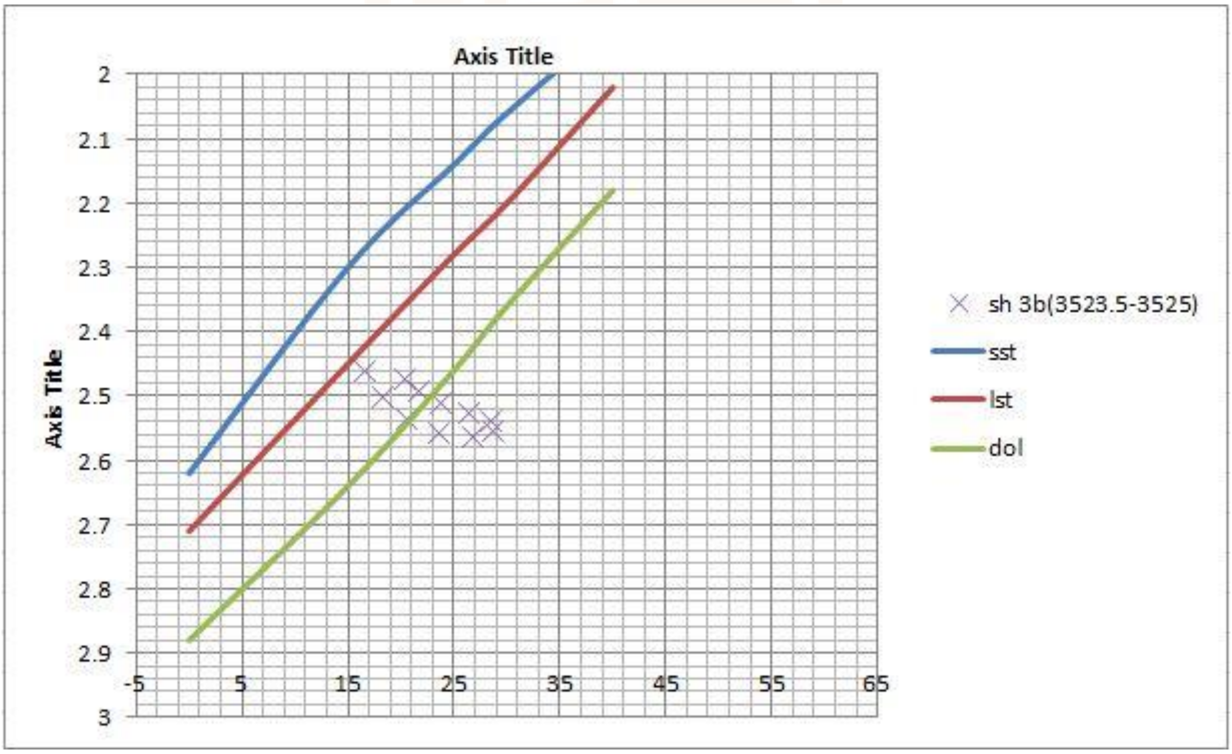

Figure 6.26.. Neutron-Density Crossplot (Depth Range: 3523.5-3525)

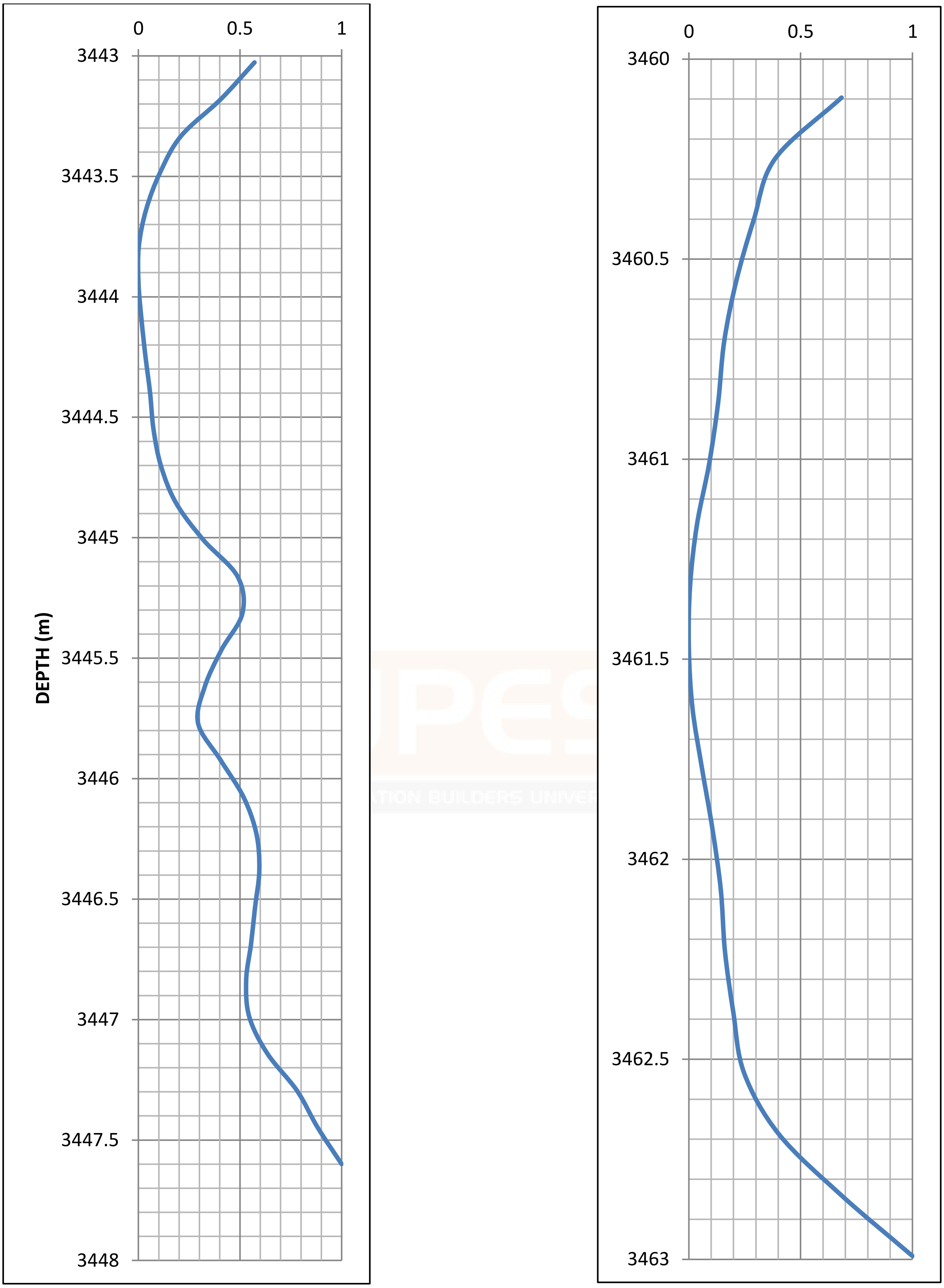

Figure 6.27. V_{shale} of Zone 1 and Zone 2 of Chabua 1

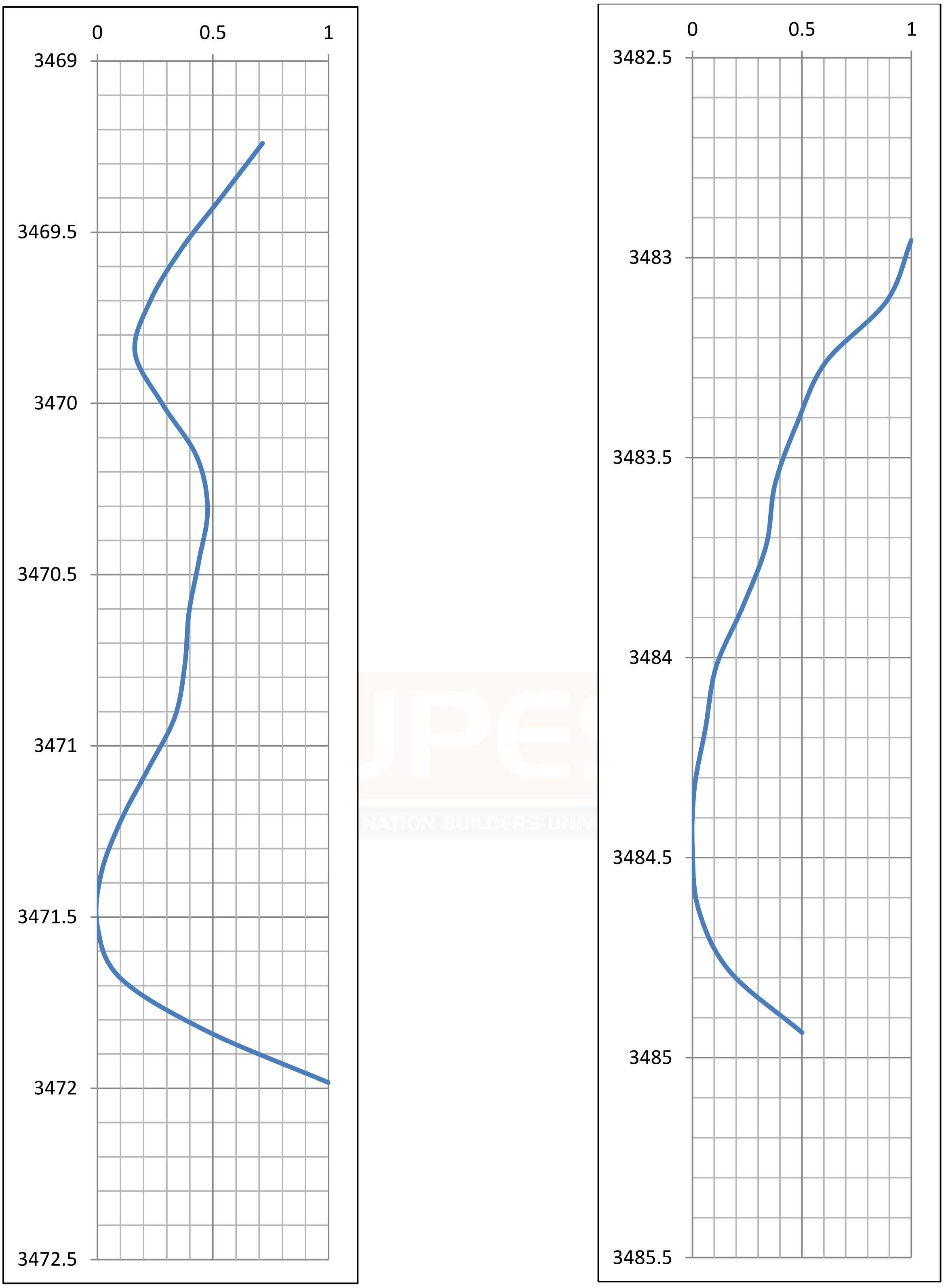

Figure 6.28. V_{shale} of Zone 3 and Zone 4 of Chabua 1

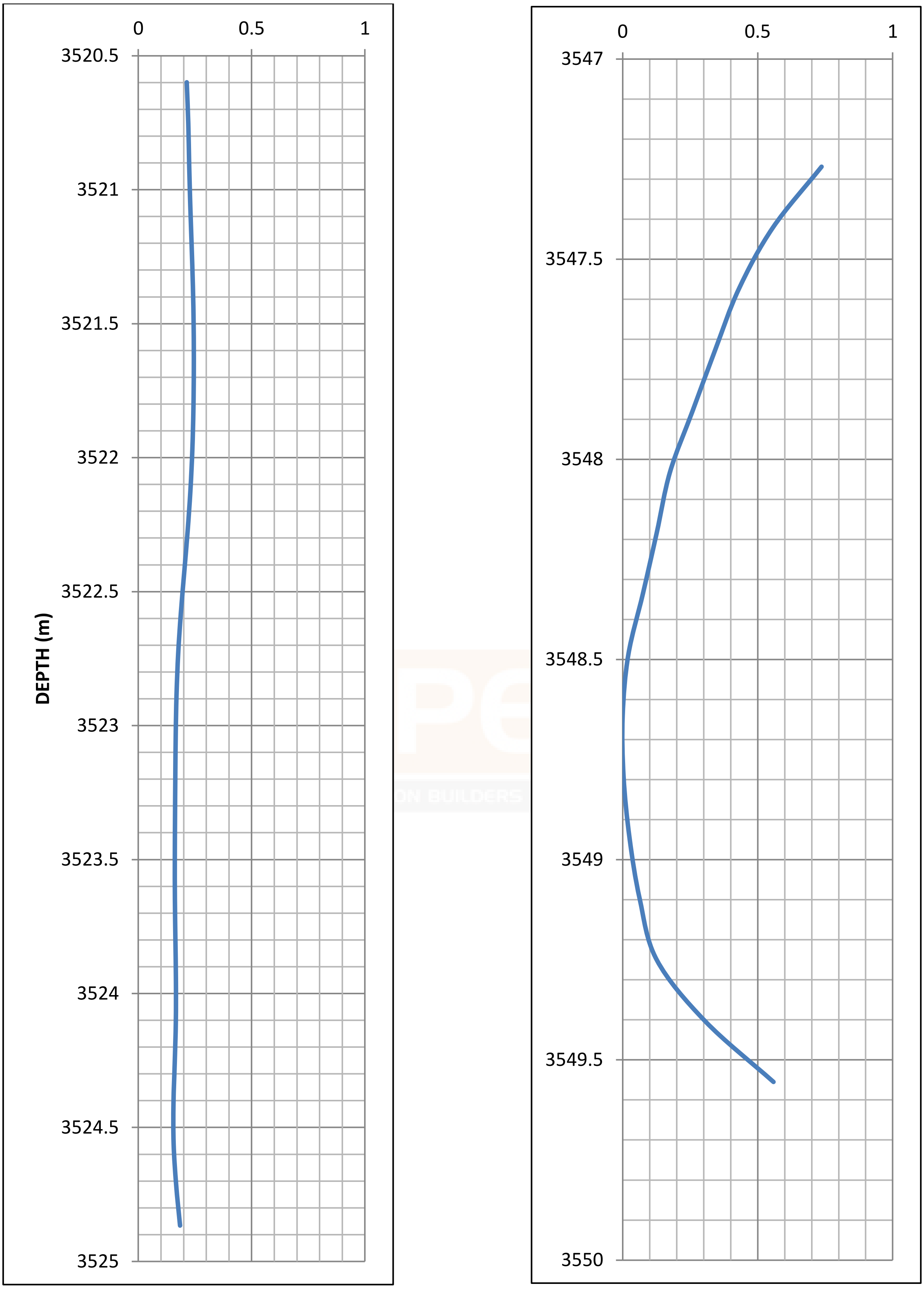

Figure 6.29. V_{shale} of Zone 5 and Zone 6 of Chabua 1

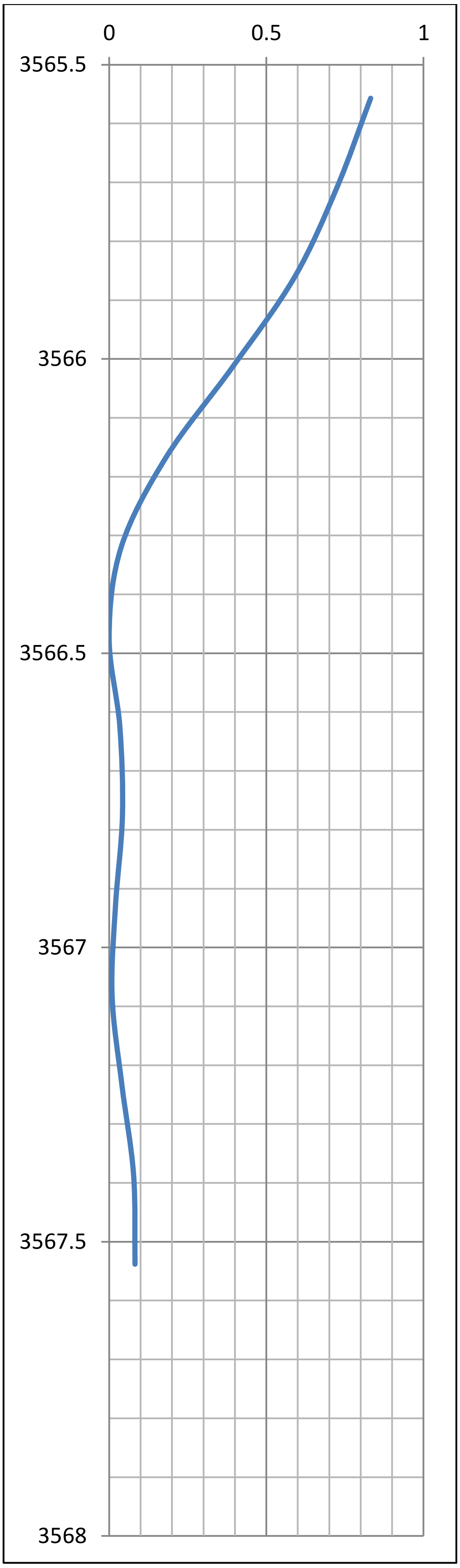

Figure 6.30. V_{shale} of Zone 7 of Chabua 1

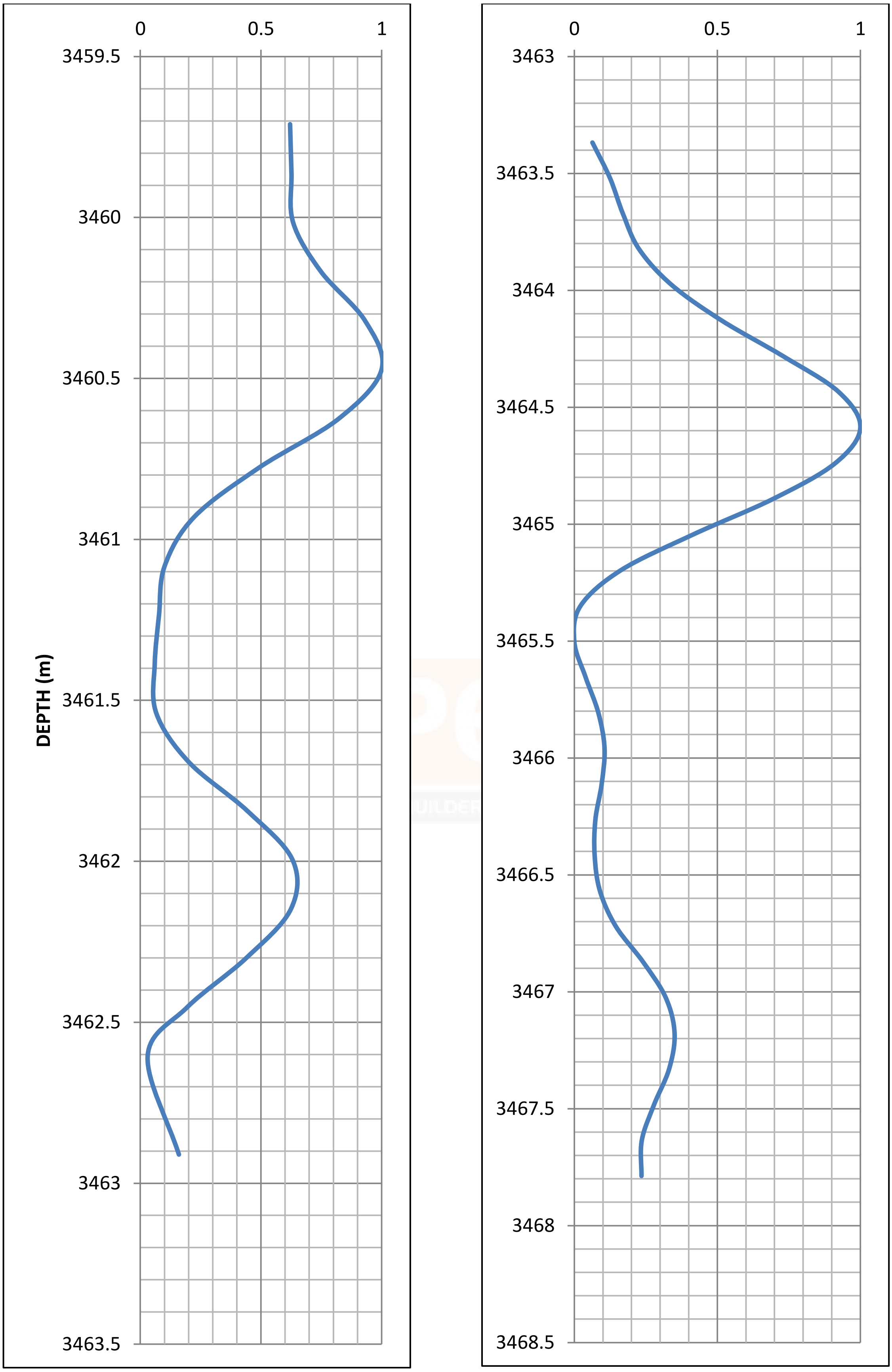

Figure 6.31. V_{shale} of Zone 1 and Zone 2 of Chabua 2

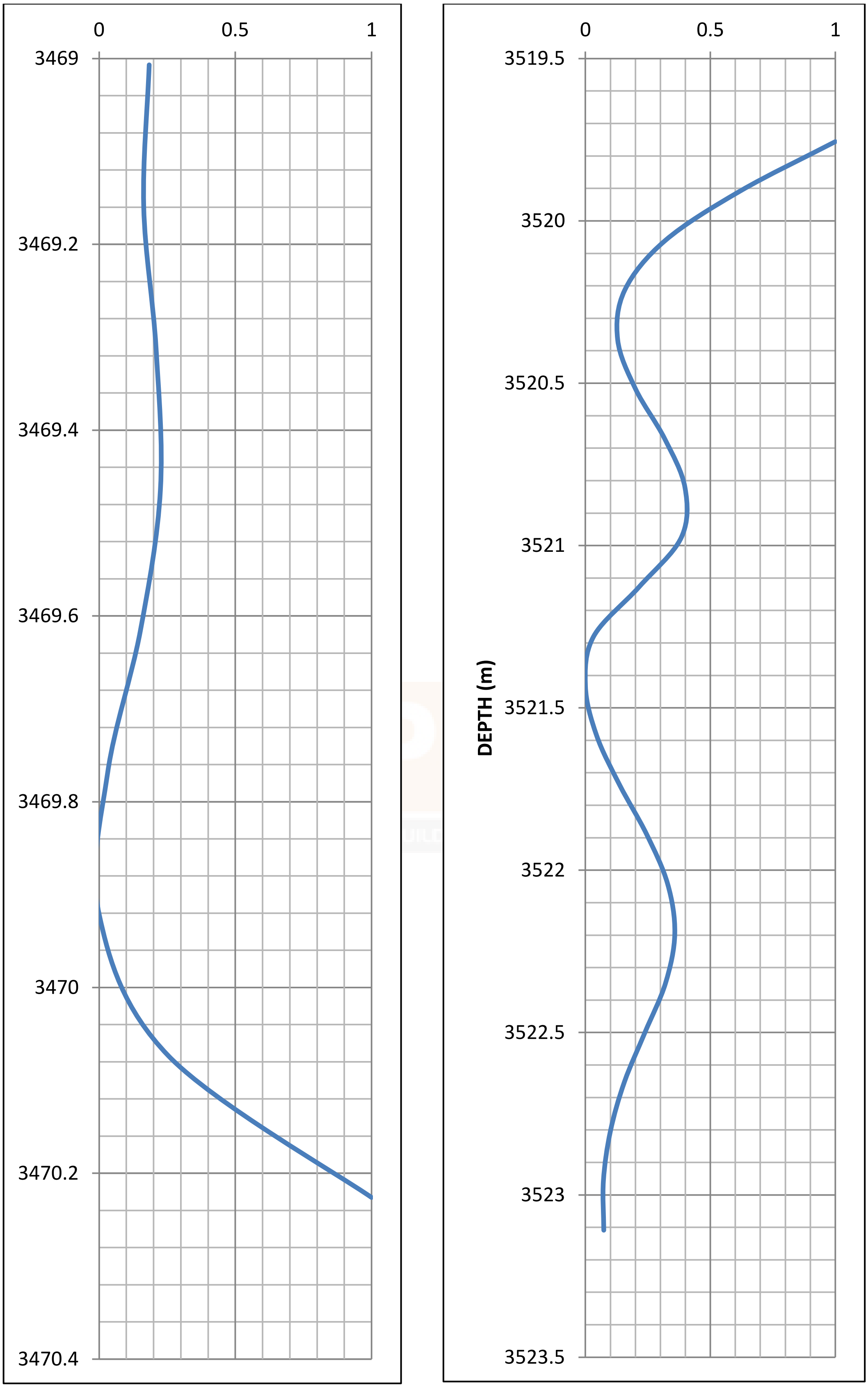

Figure 6.32. V_{shale} of Zone 3 and Zone 4 of Chabua 2

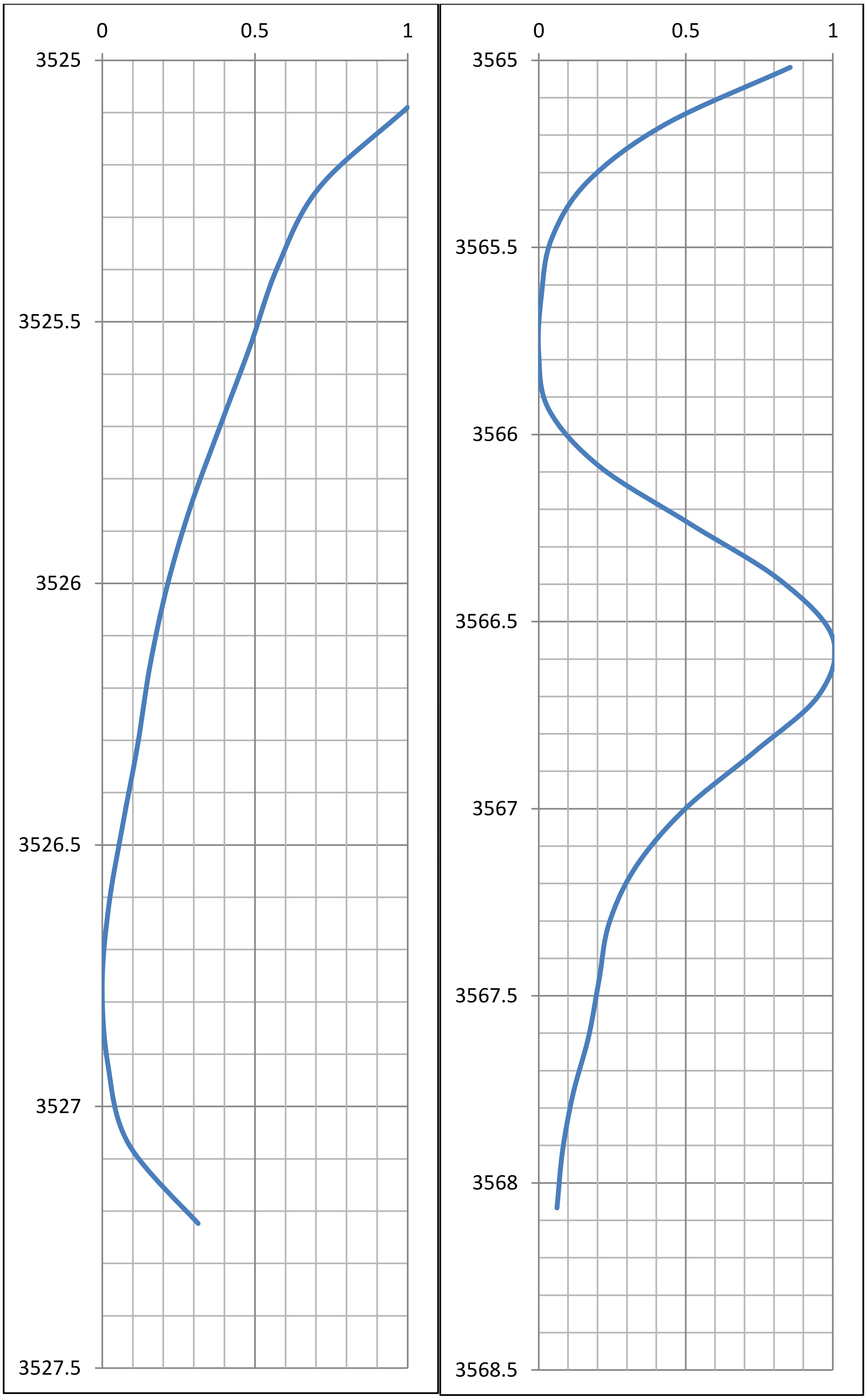

Figure 6.33. V_{shale} of Zone 5 and Zone 6 of Chabua 2

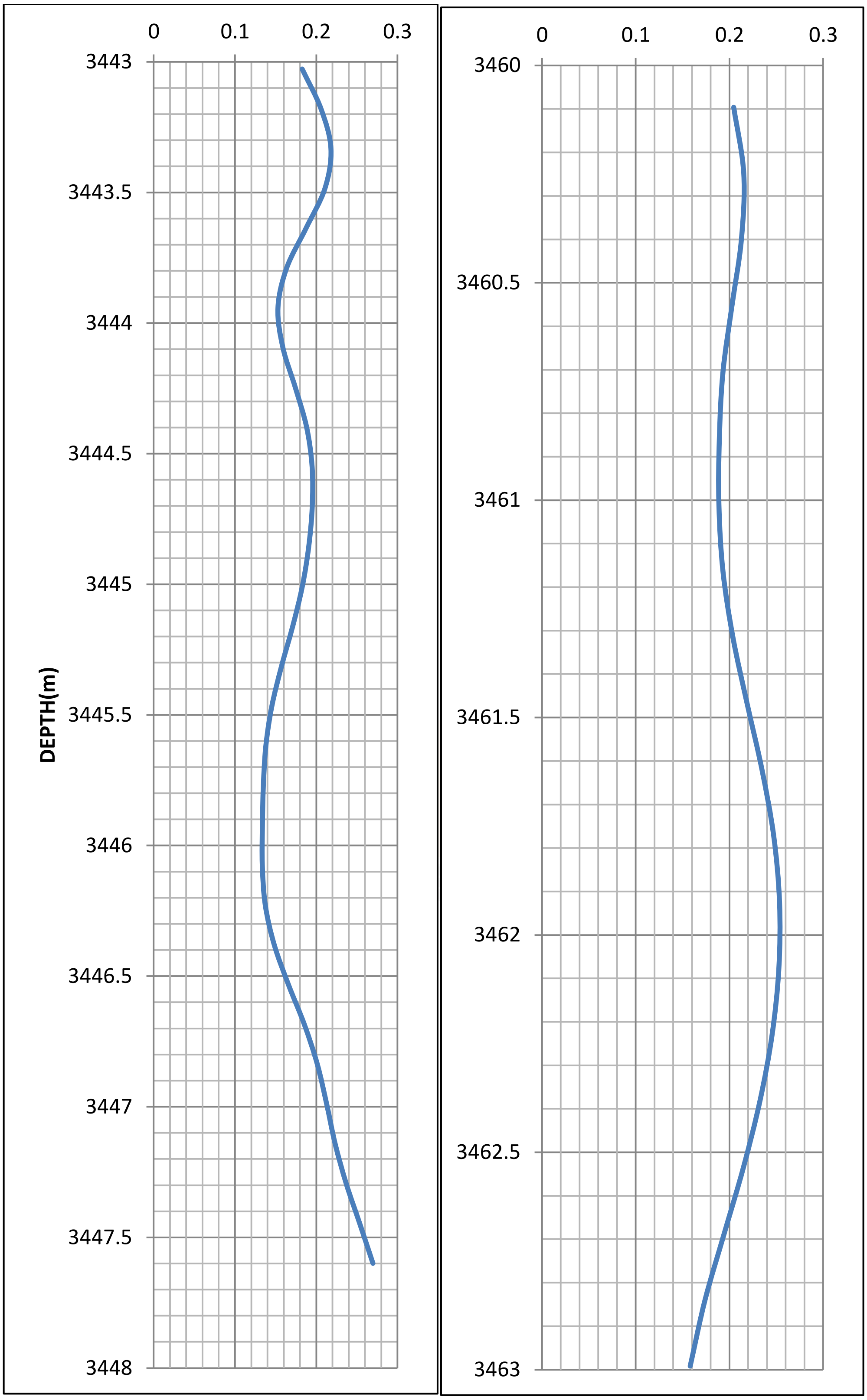

Figure 6.34. Porosity of Zone 1 and Zone 2 of Chabua 1

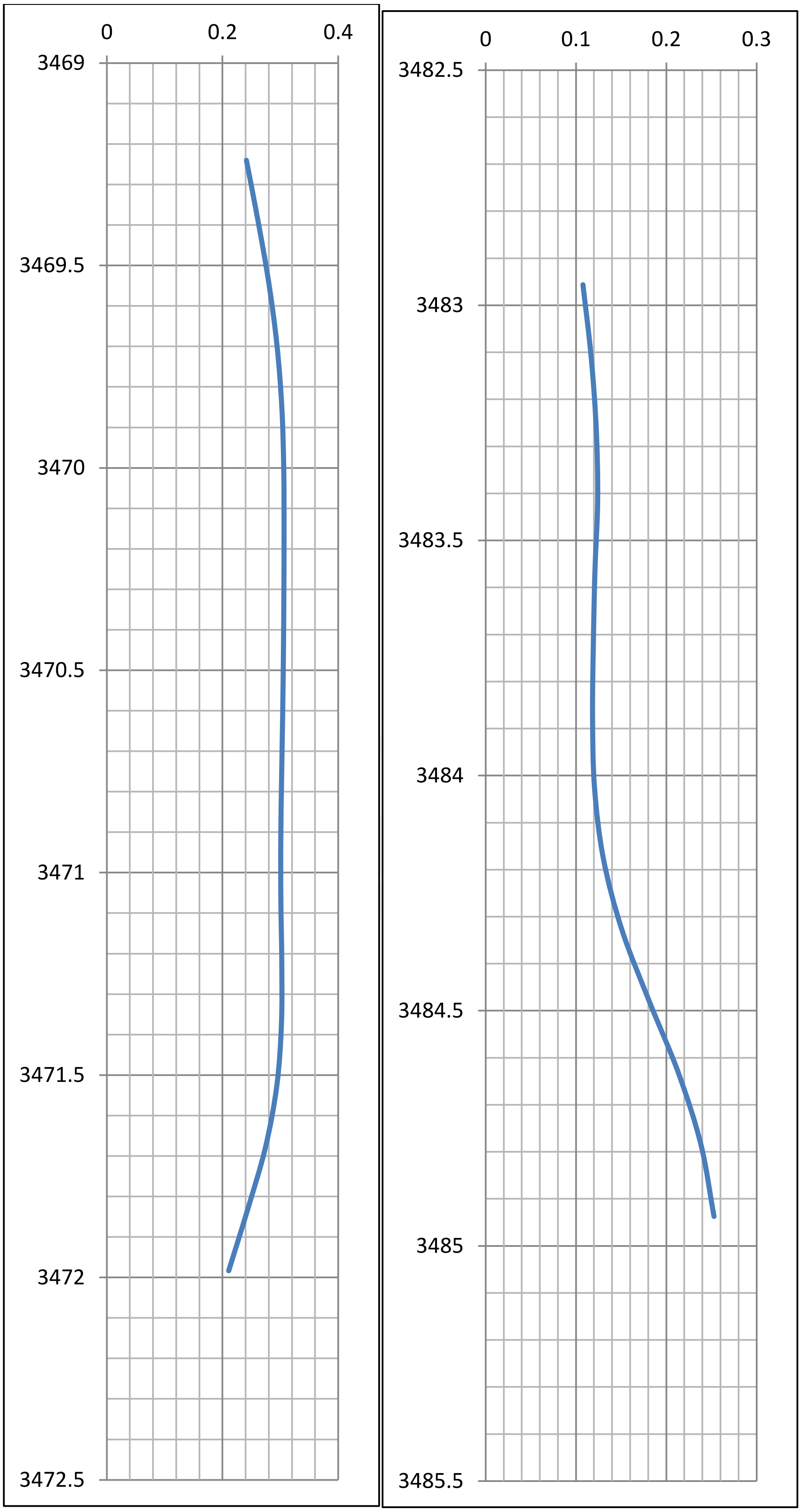

Figure 6.35. Porosity of Zone 3 and Zone 4 of Chabua 1

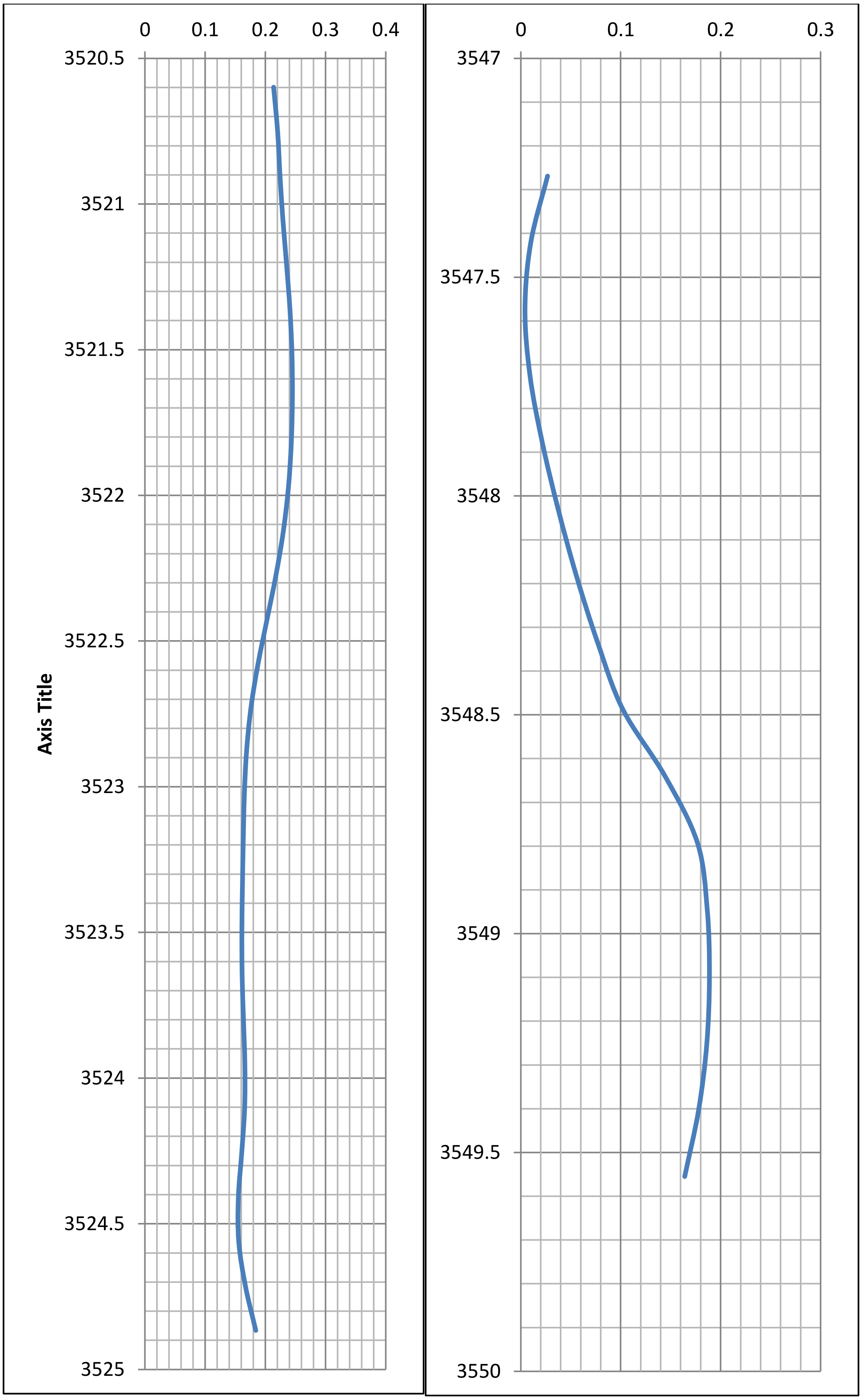

Figure 6.36. Porosity of Zone 5 and Zone 6 of Chabua 1

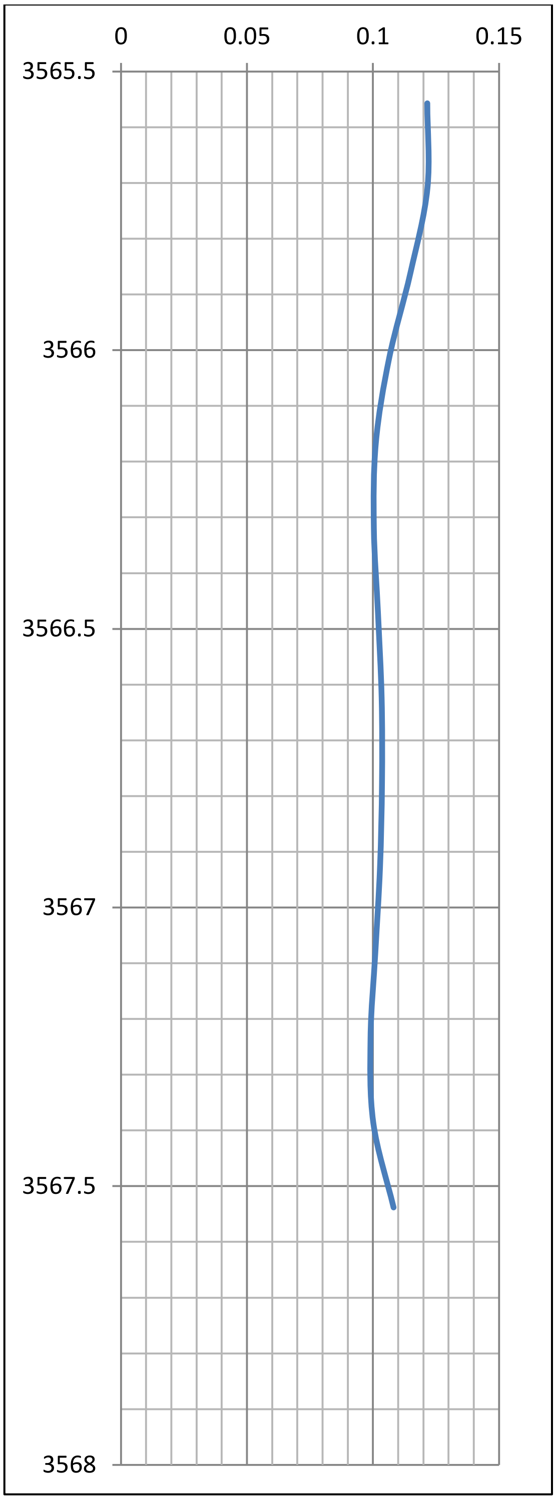

Figure 6.37. Porosity of Zone 7 of Chabua 1

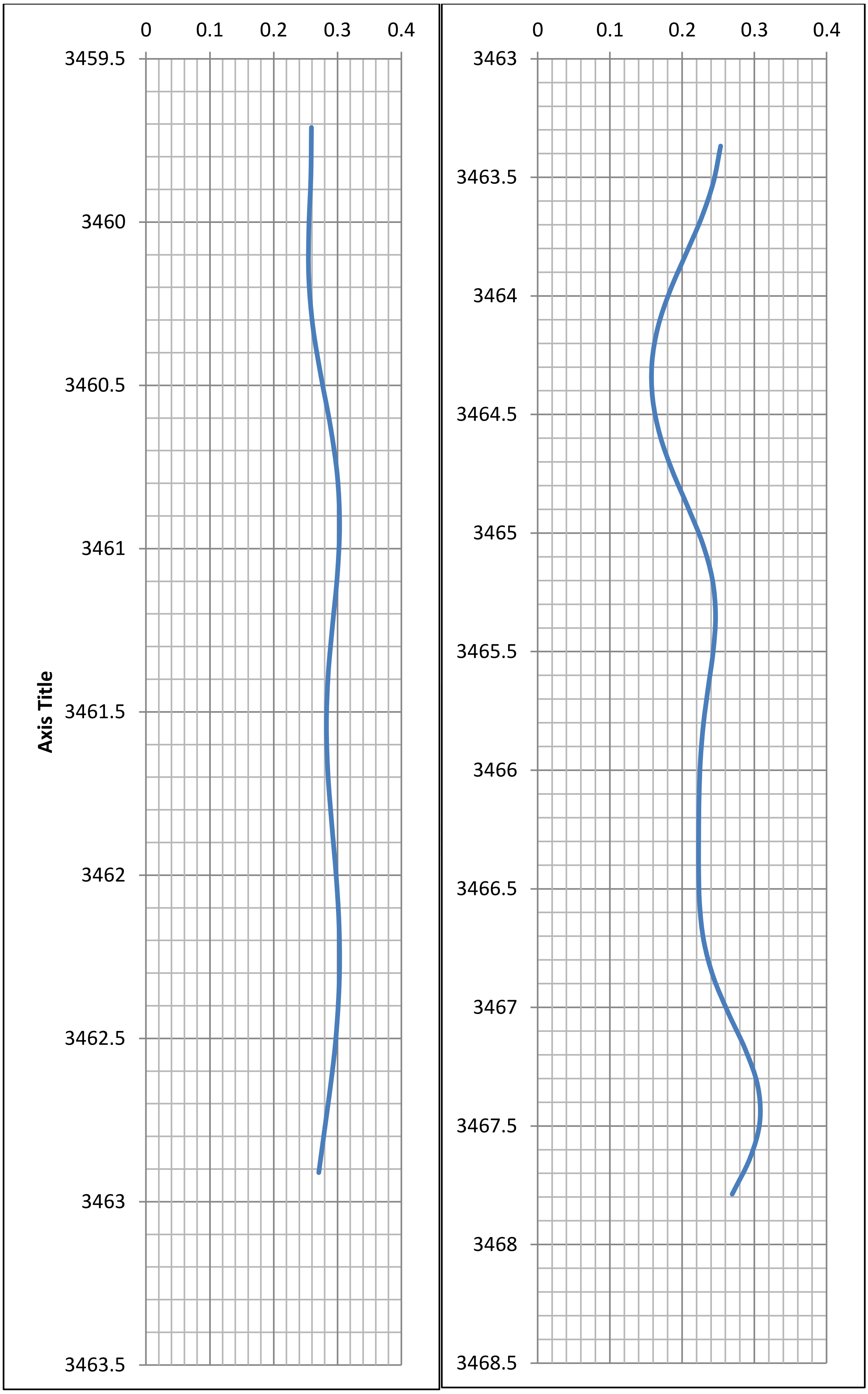

Figure 6.38. Porosity of Zone 1 and Zone 2 of Chabua 2

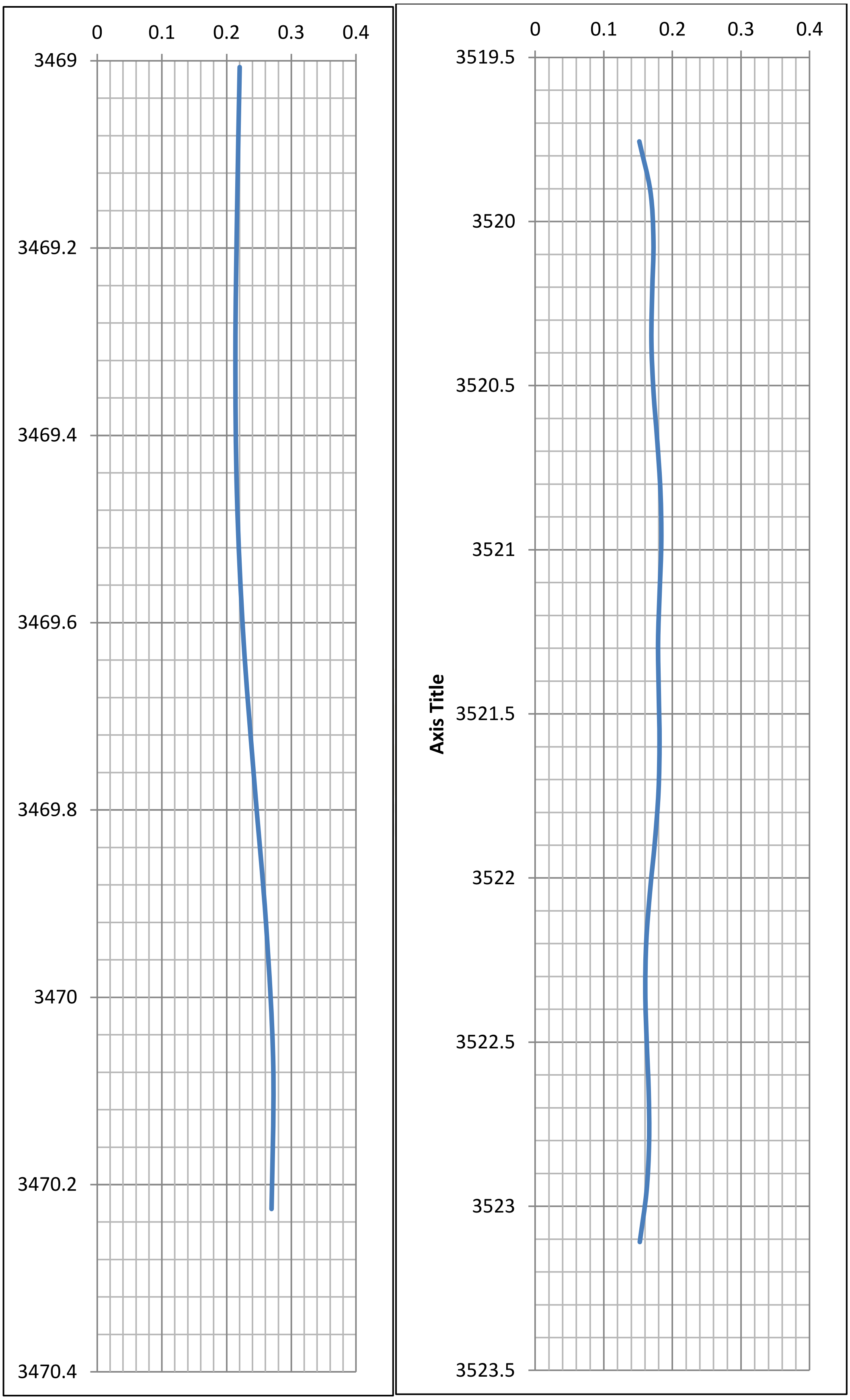

Figure 6.39. Porosity of Zone 3 and Zone 4 of Chabua 2

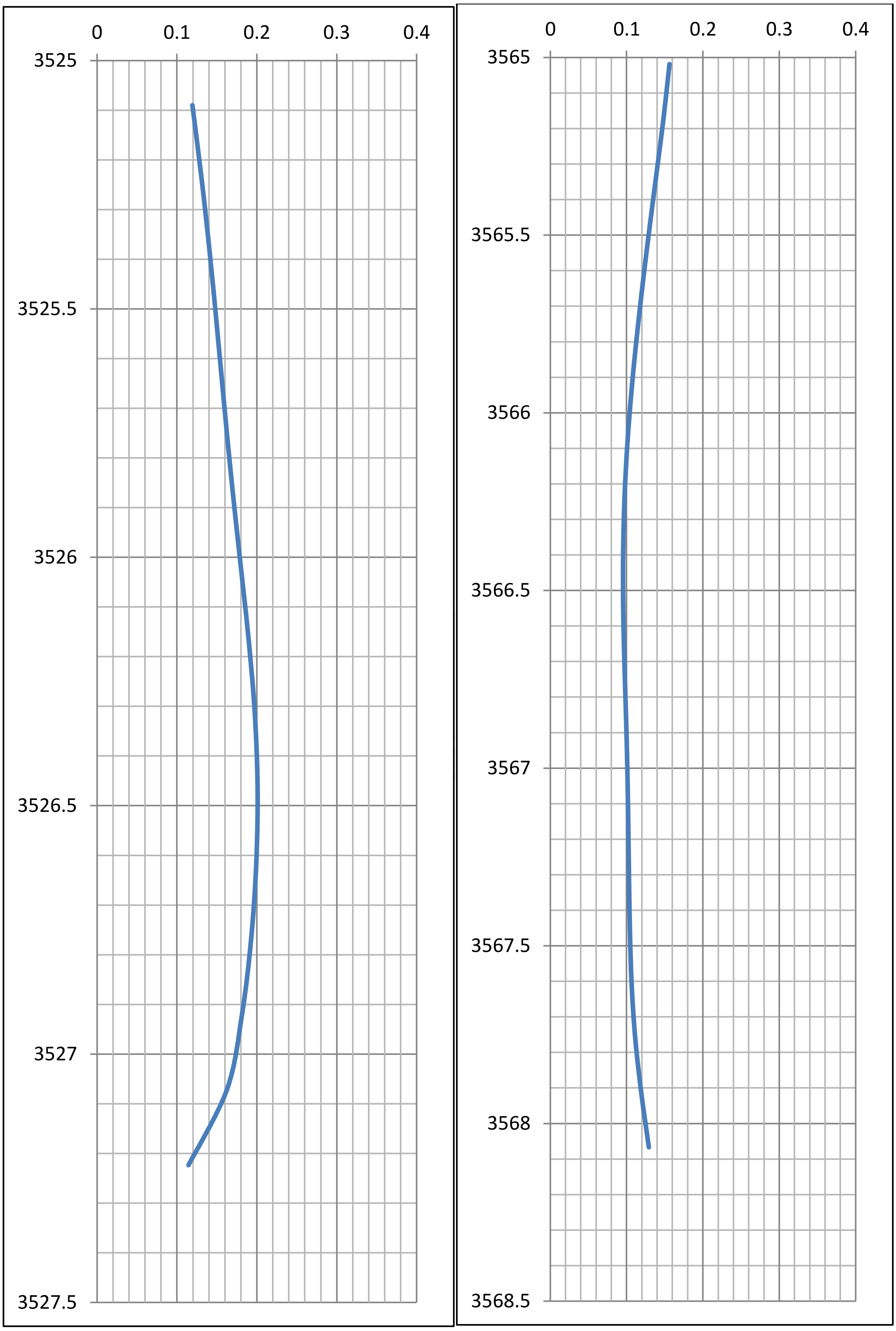

Figure 6.40. Porosity of Zone 5 and Zone 6 of Chabua 2

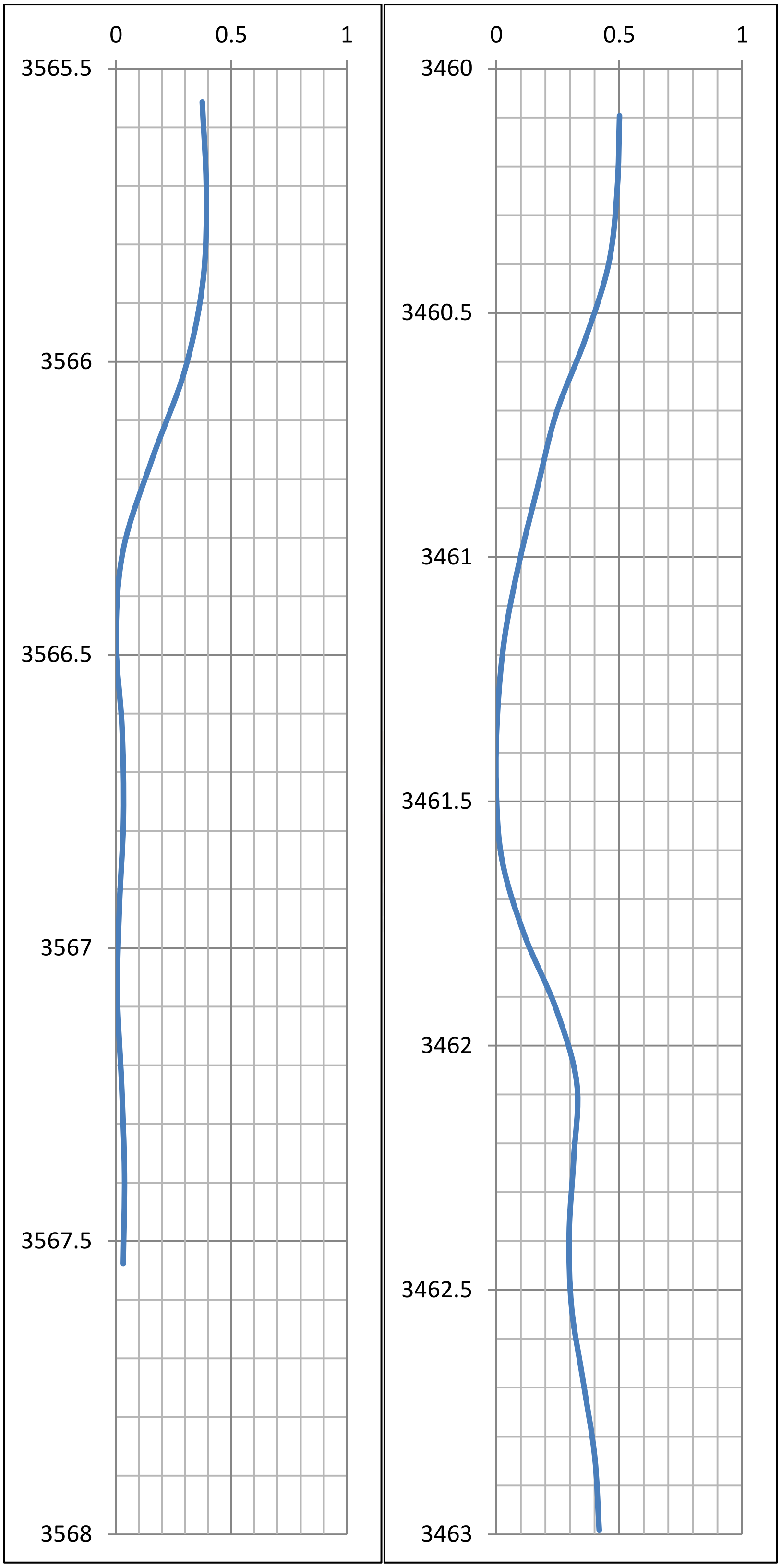

Figure 6.41. Shc of Zone 1 and Zone 2 of Chabua 1

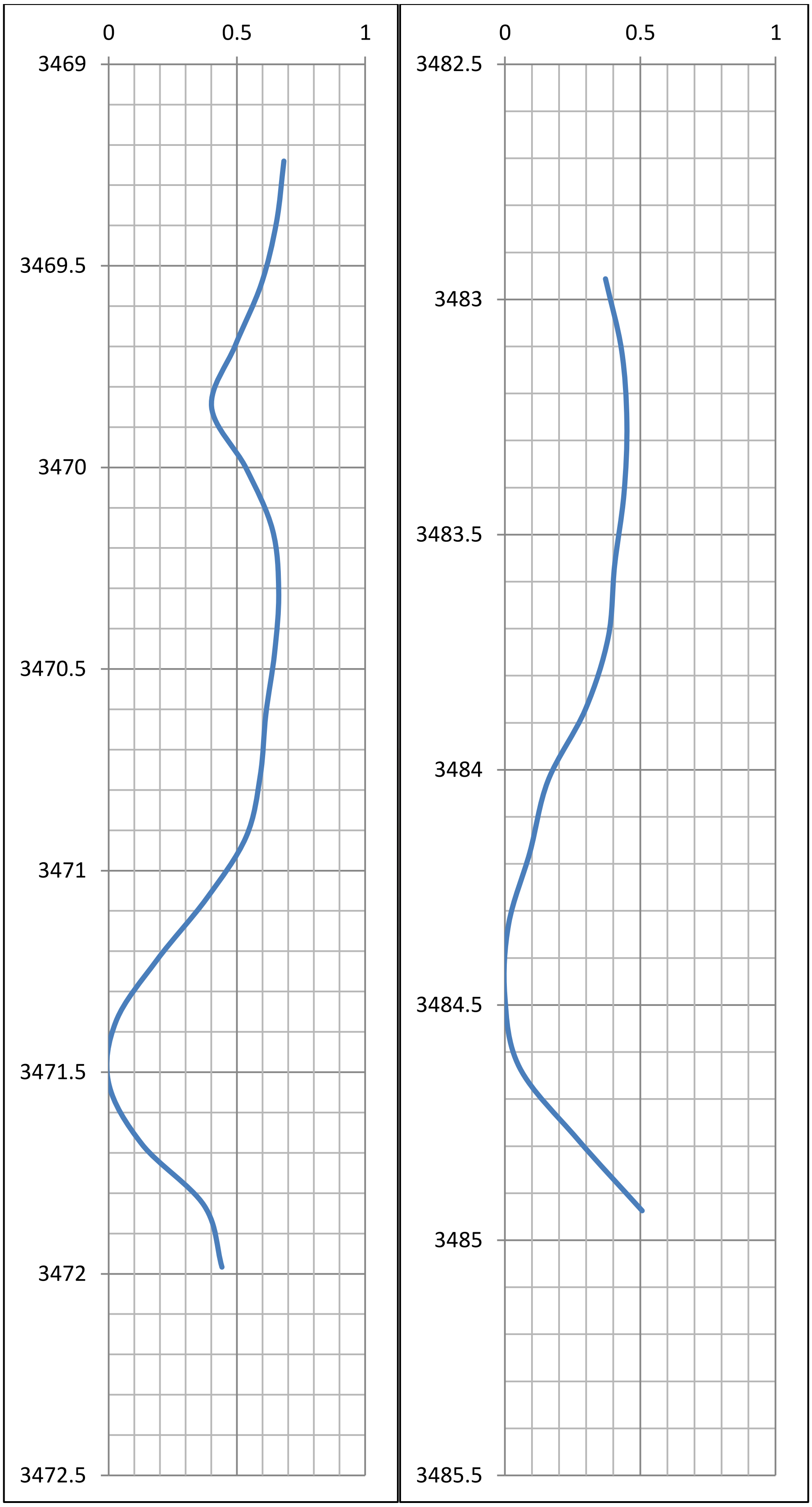

Figure 6.42. Shc of Zone 3 and Zone 4 of Chabua 1

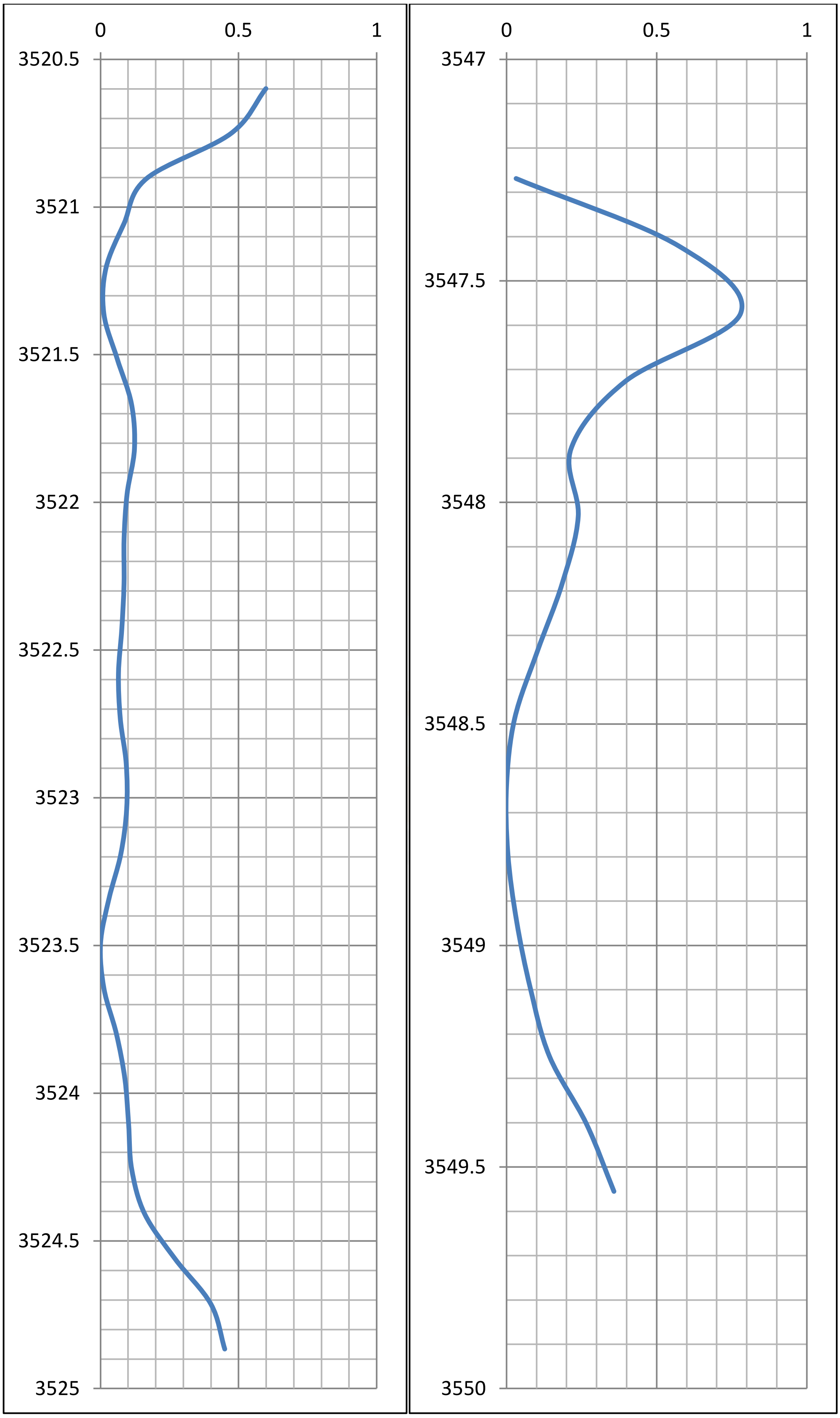

Figure 6.43. Shc of Zone 5 and Zone 6 of Chabua 1

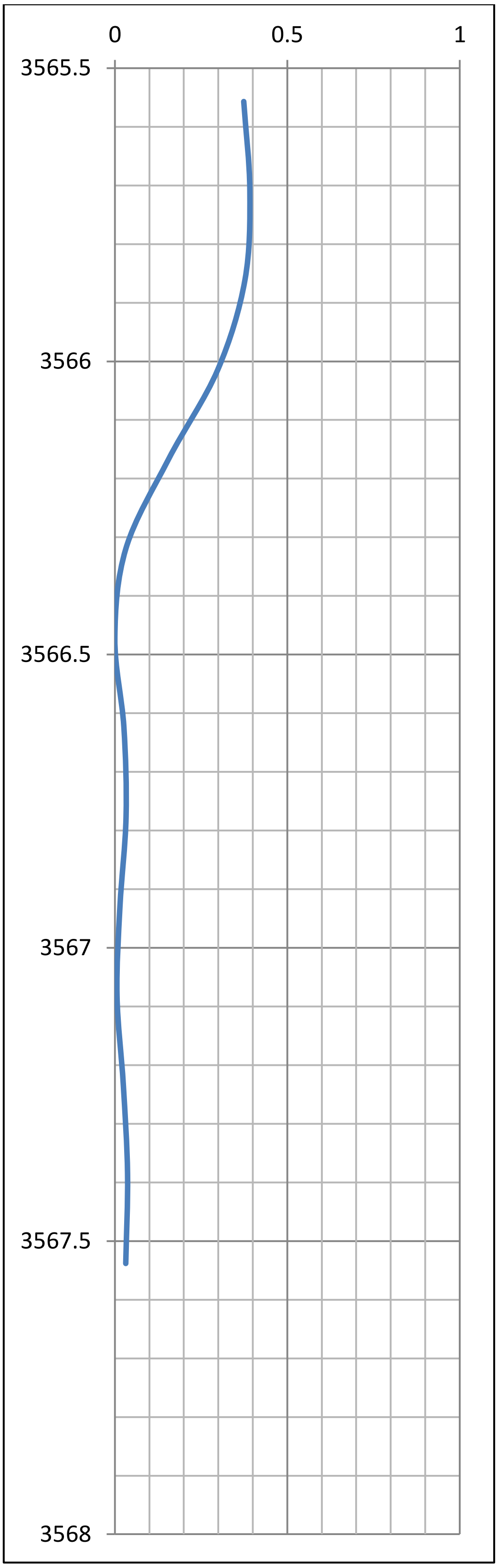

Figure 6.44. Shc of Zone 7 of Chabua 1

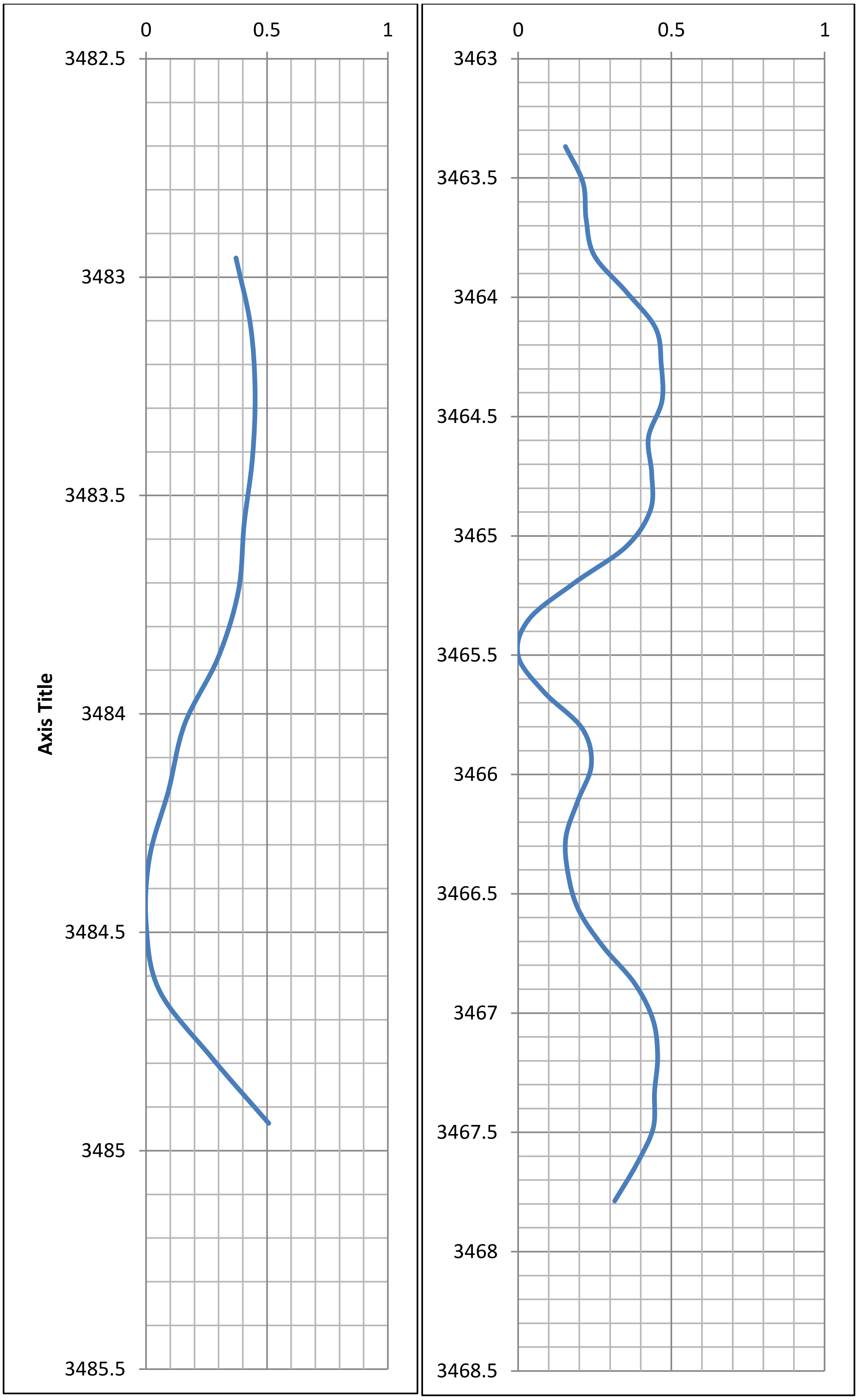

Figure 6.45. Shc of Zone 1 and Zone 2 of Chabua 2

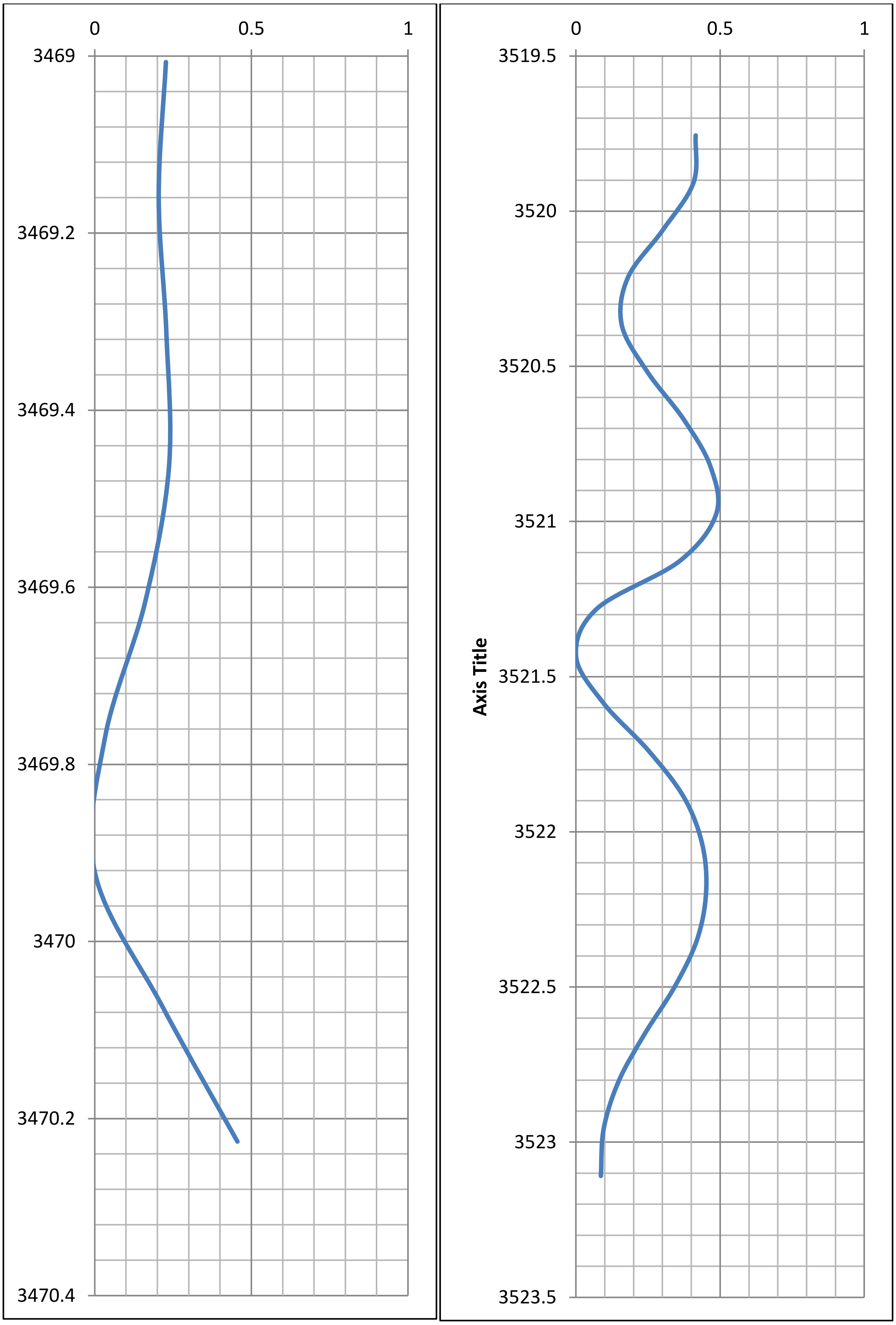

Figure 6.46. Shc of Zone 3 and Zone 4 of Chabua 2

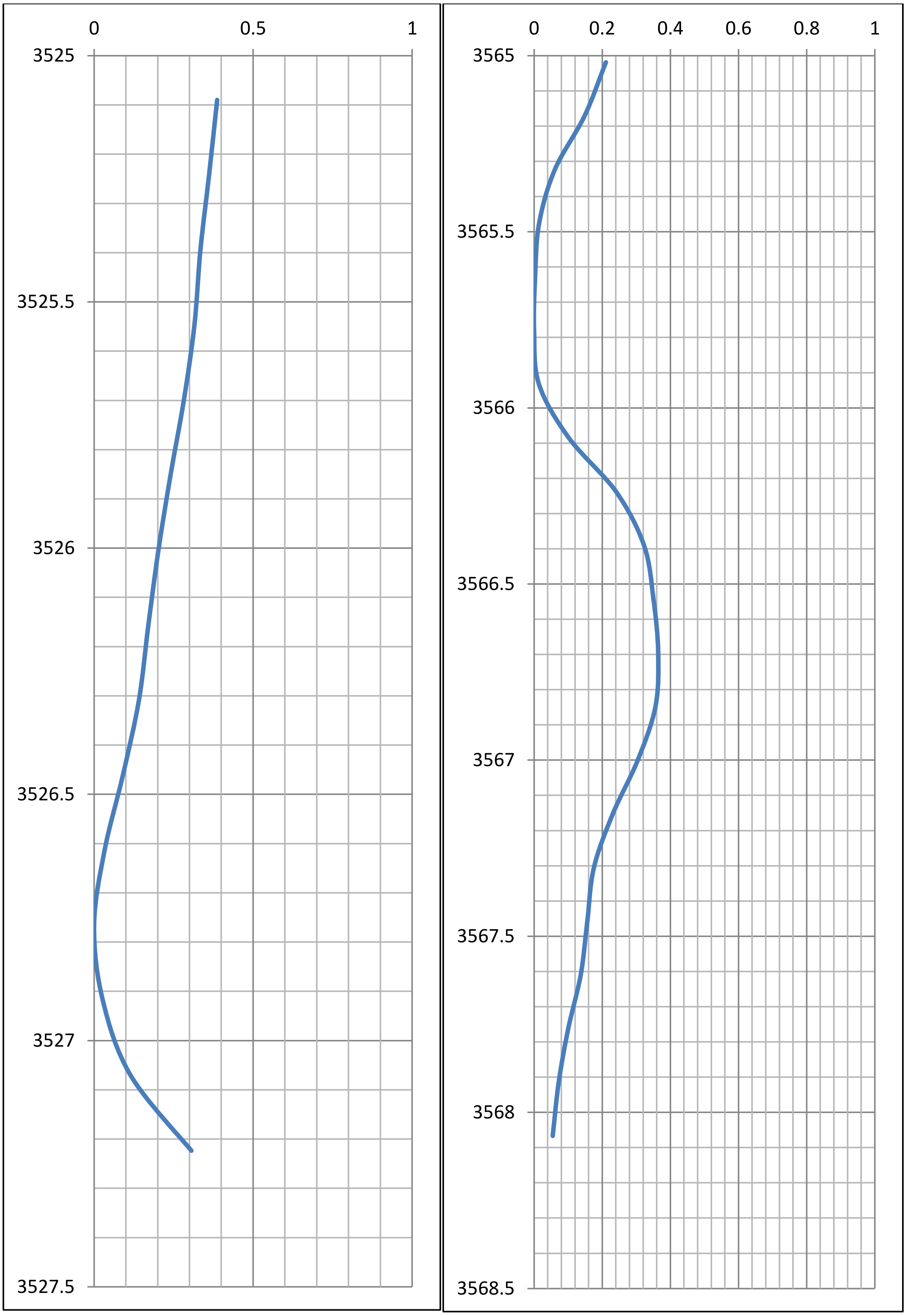

Figure 6.46. Shc of Zone 5 and Zone 6 of Chabua 2