CASE STUDY: RELATIONSHIP BETWEEN CORRELATION RADIUS AND PERMEABILITY, VOLVE FIELD, NORTH SEA

By:
Conrad Suen

A thesis submitted to the Department of Earth and Atmospheric Science,
University of Houston
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in Geophysics

Chair of Committee: Evgeny Chesnokov

Committee Member: Thomas Lapen

Committee Member: Yasser Metwally

University of Houston
May 2020

ACKNOLEDGEMENTS

I would like to thank Dr. Evgeny Chesnokov for his patience, guidance, and expertise in the realm of geophysics and petrophysics. Without his assistance this project would not have been possible. Further, thank you to my advisory committee Dr. Thomas Lapen, and Dr. Yasser Metwally for their advice and support as well as subject matter expertise. Finally, thank you to my family and friends for their never-ending support through my educational and personal endeavors; I would not be here without all of you.

ABSTRACT

A productive layer is a stratigraphic interval that is prone to contain hydrocarbons with physical parameters favorable for production or extraction. Using the pair correlation function (PCF), a method of Effective Medium Theory (EMT), nine sets of amplitude and correlation radii were determined. These values were then analyzed with permeability (mD) at a given depth in measured depth (ft) to determine relationships between correlation radius and permeability over the productive layer. Previous work completed determined low correlation radius relates to a high amplitude in which a productive interval can be predicted. As permeability is essential for a successful reservoir, high permeability values are expected in such productive intervals. By understanding the relationship between permeability and correlation radius over a productive interval, the determination of defining a productive reservoir interval is increased with knowledge from well log data. Results of this study support the hypothesis that relative high permeability values are synonymous with relative low correlation radii and allow for another analog in which the productive interval can be determined. The goal of this study is connected to the potential to show the link between measured characteristics (amplitudes and radii of various correlation functions) and unmeasured characteristics (permeability).

CONTENTS

List of Tables

List of Figures

Background

Motivation

This study aims to analyze well log data to determine productive intervals while also defining further relationships that can help to identify a hydrocarbon bearing layers. Specifically, this study seeks to investigate the hypothesis that high permeability values can be expected at areas with low correlation radii. By determining a relationship between correlation radius and permeability, the confidence in determining a productive interval is increased, providing another analog to aid in finding optimal areas to extract hydrocarbons while being highly cost effective. Given the physical properties of a productive interval, permeability values are expected to be high for the flow of hydrocarbons to occur. Understanding of the relationship between an unmeasured field characteristic, permeability, and measured characteristics, correlation radius and amplitude, coupled with knowledge of reservoir geology and stratigraphy can prove the robust nature of this relationship. On a second order basis, familiarity and experience with well log and petrophysical analysis would be gained in addition to understanding how physical parameters vary under various geologic circumstances.

Introduction

The Volve field was discovered in 1993 and is 200 kilometers west of Stavanger in the North Sea. The field was decommissioned in September 2016 after operating for 8.5 years under Equinor (formerly Statoil). This field yielded a 54% recovery rate and delivered over 60 million barrels of oil throughout its life span. (Volve Dataset, 2018)

The Volve field is located in the Sleipner Øst area which is in the southeastern portion of the Viking Graben. (**Fig. 1**). Within this area, there were 9 wells that were drilled (**Fig. 2**), however not all of these wells were used for this study. Based upon the well proximity, characteristics can potentially be inferred between wells In the data section, well selection is further discussed.

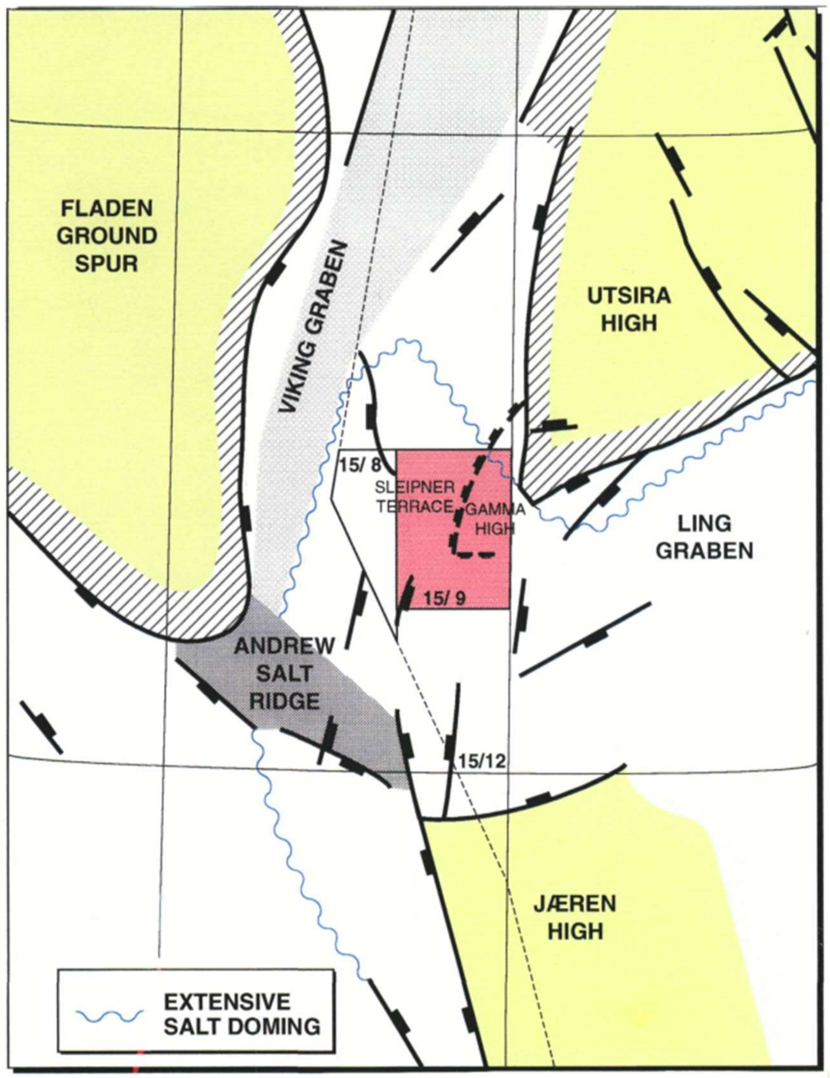


Figure 1 Volve Field Outlined in Red, Viking Graben (Volve Dataset, 2018)

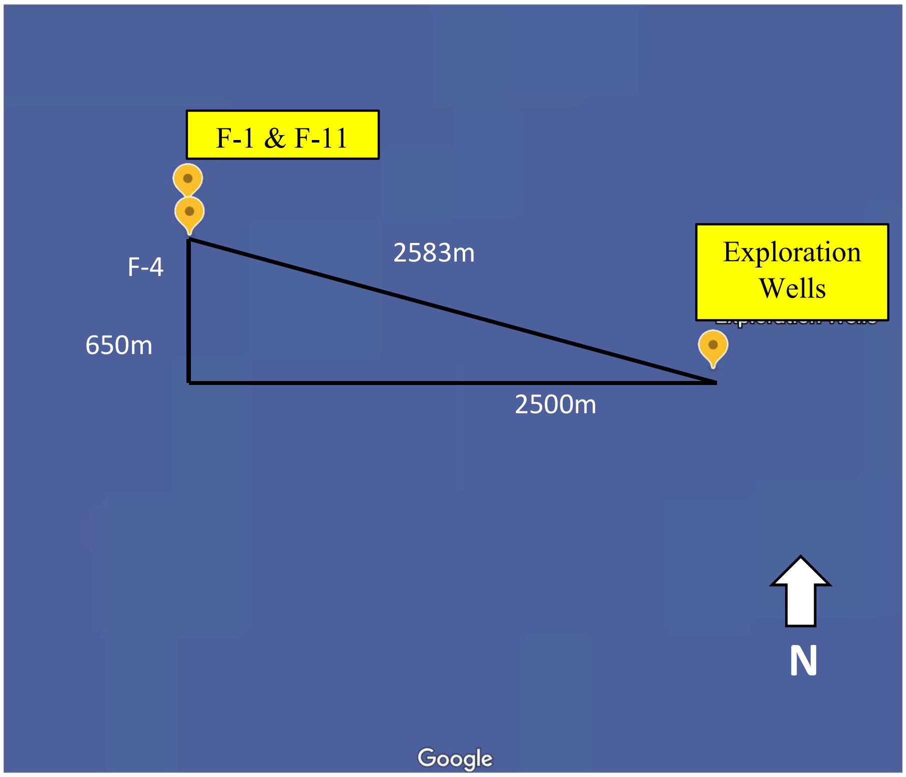


Figure 2. Well clusters within the Volve Field (Modified from Zerr 2019)

Geology

The Hugin Formation was up the producing reservoir for this region. The Hugin Formation is a Jurassic sandstone likely deposited in a mouth bar setting (high energy marine environment). Given the depositional environment, it is unsurprising that the Hugin formation is composed of fine to coarse grained subarkosic arenite sandstones with claystone stringers. (Volve Field Dataset, 2019)

The Hugin formation was charged with hydrocarbons from 2 major areas, the South Viking Graben and Local basins within the Sleipner Vest Field and Gamma High structure. The Hugin formation in Theta Vest structure was filled with type 4 oil as well as unclassified gas. Within the Loke (structure), the Triassic and Jurassic reservoirs were filled with type 1 condensate and type 1 gas. Within the Sleipner Øst region, the Hugin formation was filled with type 2 condensate as well as type 1 gas. The gasses in the Sleipner Øst and Loke regions both share the same source rock however the condensates in each region had their own respective source rock.

Regionally, hydrocarbon migration occurred most commonly via fault zones and thus the reservoirs were filled. Structural (i.e. structural domes) and stratigraphic traps were the main mechanism that kept the hydrocarbons within the reservoirs. Structural seals in the form of faults and lineaments further sealed the reservoirs from leaking.

Notable Formation Lithology

There are several notable and reoccurring formations within the productive intervals that will be further detailed. The Draupne, Heather, Hugin, Sleipner, and Skagerrak formations are of significance and are seen consistently throughout the wells being studied.

Asgard Formation: Interbedded limestone and marl with some minor layers of claystone and siltstone

Draupne Formation: very organic rich claystone, micaceous, carbonaceous, and traces of pyrite

Heather Formation: Claystone with limestone stringers and interbedded claystone, kaolin, sandstone, and limestone in the lower part of the formation

Hugin Formation: Sandstone, very fine to very coarse grained, moderately to well sorted. Rare claystone stringers. Specific characteristics of the Hugin formation are later discussed

Sleipner Formation: Sandstone, very fine to medium grained, moderately to well sorted, grey claystone and layers of coal

Skagerrak Formation: Fine grained sandstones with some interbedded silty sections

Theory and Methods

Three main methods are utilized within this study; Pair Correlation Function (PCF), Fluctuations, and the Dynamic Averaging Window.

Pair Correlation Function (PCF) is a method under Effective Medium Theory (EMT) that can approximate physical properties of media.

$B_{ijkl}^{pqmn}(r) = \langle C'_{ijkl}(x) C'_{pqmn}(x+r) \rangle$ (Chesnokov 1995)

is the PCF where $C'_{ijkl}(x)$ denotes fluctuations of the stiffness tensor. Further, PCF can also be written as

${}^{cc}B_{ijkl}^{PQMN}(r) = A_{ijkl}^{pqmn} \varphi(r)$ (Chesnokov 1995)

${}^{cc}B_{ijkl}^{PQMN}(r)$ is PCF, $A_{ijkl}^{pqmn}\ \varphi(r)$ characterizes the Amplitude of the PCF. (Chesnokov 1995).

Another important characteristic of random processes is correlation radius. The correlation radius means that the values are independent from one another at distances greater than correlation radius r_{corr}. By definition, the correlation radius is determined as follows (Riley, et al. 2002):

$$r_{cor} \equiv \frac{1}{|R(0)|} \int_0^{\infty} |R(x)| dx$$

When averaging with a moving window, reliable values can only be obtained if the correlation radius is smaller than the window size

Amplitude and radius values refer to the inhomogeneity of a given medium (**Fig. 3**). This means that the increased heterogeneity in the reservoir corresponds to large amplitude and low radius (Chesnokov et al., 2002). When the difference between the properties of the matrix and inclusion materials increase, the amplitude value increase and the correlation radius decrease. For a homogeneous medium, the correlation function amplitude is zero and the relative correlation radius is infinitely large.

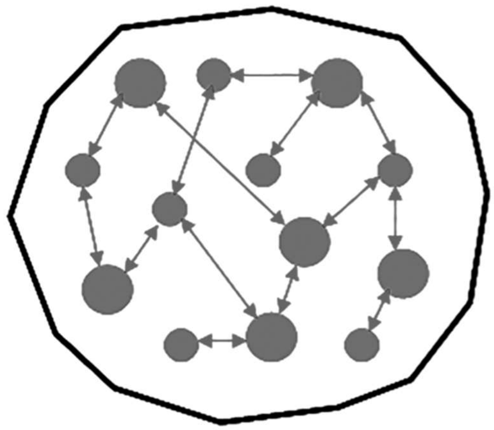


Figure 3. Representation of random heterogeneous media. The white background is the matrix rock, and the gray solid circles are the inclusions in the matrix. The double- ended arrows specify the interaction between two arbitrary points in the space (Tiwary et al., 2009, Gassiyev 2014)

Amplitude values are determined as a function of the average and fluctuations of the data. Fluctuations are the deviation from the average value of a function defined as follows: $C'_{ii}(r) = C_{ii}(r) - \langle C_{ii}(r) \rangle$ for elasticity tensors at a point r of heterogenous media (Tiwary et al., 2009, Gassiyev et al., 2014). In order to determine the average, the Dynamic Averaging window is utilized.

The Dynamic Averaging window (**Fig. 4**) is method that calculates the arithmetic mean over a given window. This is done in order to determine the average value of layers for properties of inhomogeneous media.

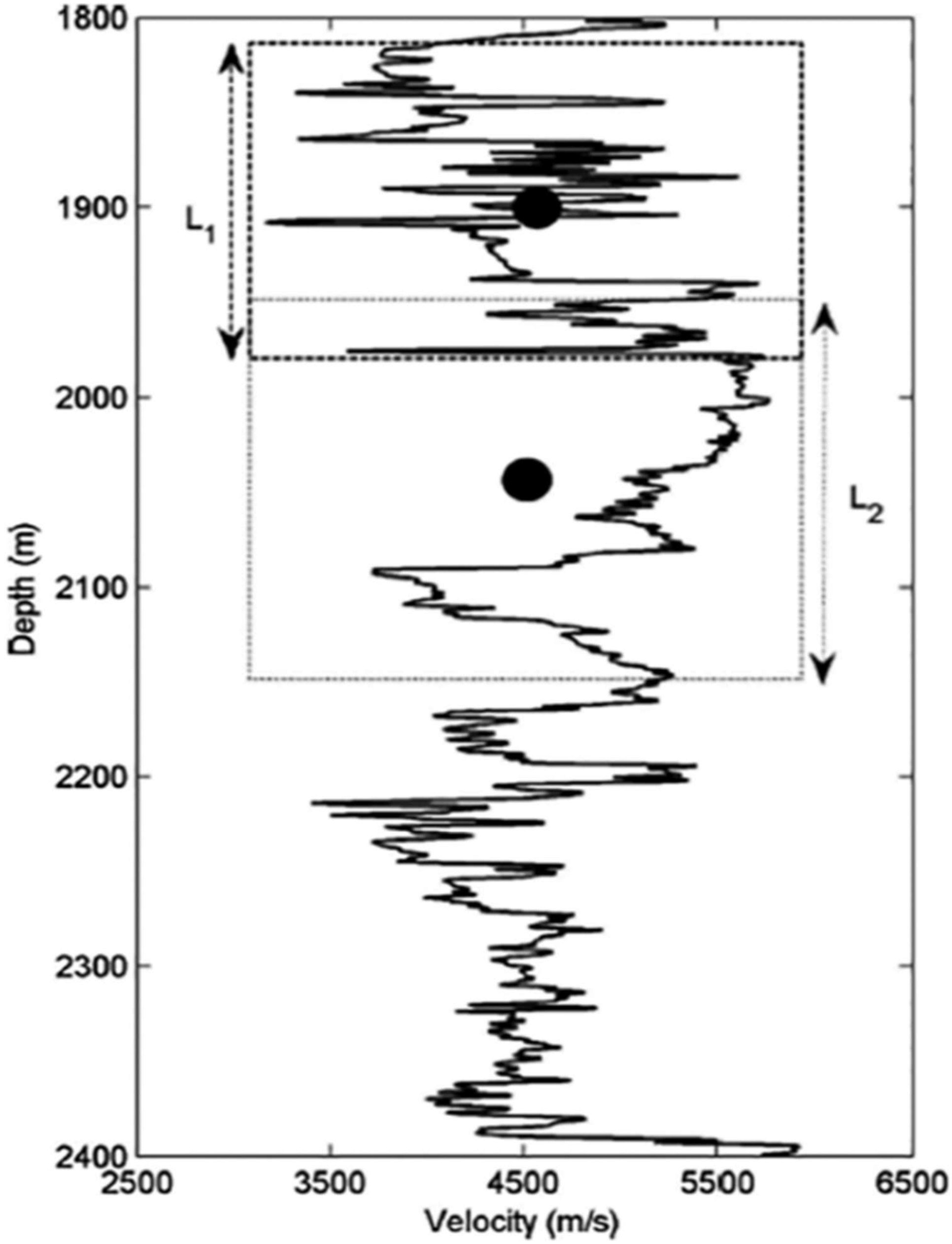


Figure 4. Schematic of the running-window concept. The center of the dashed window with length L1 is shown by a dark solid circle, and the window size is L1 (Tiwary et al., 2009, Gassiyev 2014)

Pair Correlation Approximation and Function

The effective stiffness tensor and density using the pair correlation function method can be determined from the pair correlation approximation function as follows:

$$\begin{cases} C^{*}_{ijkl}(\omega, k) = \langle C_{ijkl} \rangle + \int B^{ijmn}_{pqkl} G^{0}_{mp,nq}(\omega, r) e^{-ikr} dr \\ \\ \rho^{*}(\omega, k) = \langle \rho(r) \rangle + \omega^{2} \int cos(k, r) G^{0}_{ii}(\omega, r)^{\rho\rho} B(r)\, dr \\ \end{cases} \qquad \text{(Chesnokov 2001)}$$

Where ω is the cyclic frequency, k is the wave vector, B is the correlation function, C_{ijkl} is the 4th rank effective elasticity tensor, and G^0 is the dynamic Green's function which depends on medium properties and frequency (Chesnokov 2001). This study uses the pair correlation function term within the pair correlation approximation equation:

$$B^{pqmn}_{ijkl}(r) = \langle C'_{ijkl}(x) C'_{pqmn}(x + r) \rangle \qquad \text{(Chesnokov 1995)}$$

$B^{pqmn}_{ijkl}(r)$ is the PCF

$C'_{ijkl}(x)$ denotes fluctuations of the stiffness tensor

$^{\rho}B(r) = \langle \rho'(x) \rho'(x + r) \rangle$

The pair correlation function (PCF) utilized within this study is a method under effective medium theory (EMT) was initially introduced by Lifshitz and Rozensweig (1947). The PCF is utilized in order to efficiently calculate and determine dynamic frequency dependent physical parameters of porous anisotropic media. This further modified version of PCF is an averaging and upscaling technique that is implemented in order to better identify productive intervals. (Chesnokov 1995). In this modification of PCF, the amplitude and radii of the correlation function versus depth are computed by an algorithm using log data as the input values. Physically, large amplitude values with small radius values denote increased inhomogeneous interactions at a given depth which indicate greater interactions between the matrix and inclusions. The components of the amplitude of PCF are as follows:

$${}^{cc}B_{ijkl}^{PQMN}(r) = A_{ijkl}^{pqmn}\varphi(r) \qquad \text{(Chesnokov 1995)}$$

$${}^{cc}B_{ijkl}^{PQMN}(r) = PCF$$

$$A_{ijkl}^{pqmn}\varphi(r) = \text{Amplitude}$$

The definition of a correlation radius was given earlier (see page 8).

An example of correlation radii behavior versus depth for different correlation functions for a 300-foot window is shown in the **Figure 5**. All correlation radius values show in the figure below are smaller than the window size at all depths.

The minimum of correlation radius corresponds to the location of the productive layer which will be detailed later.

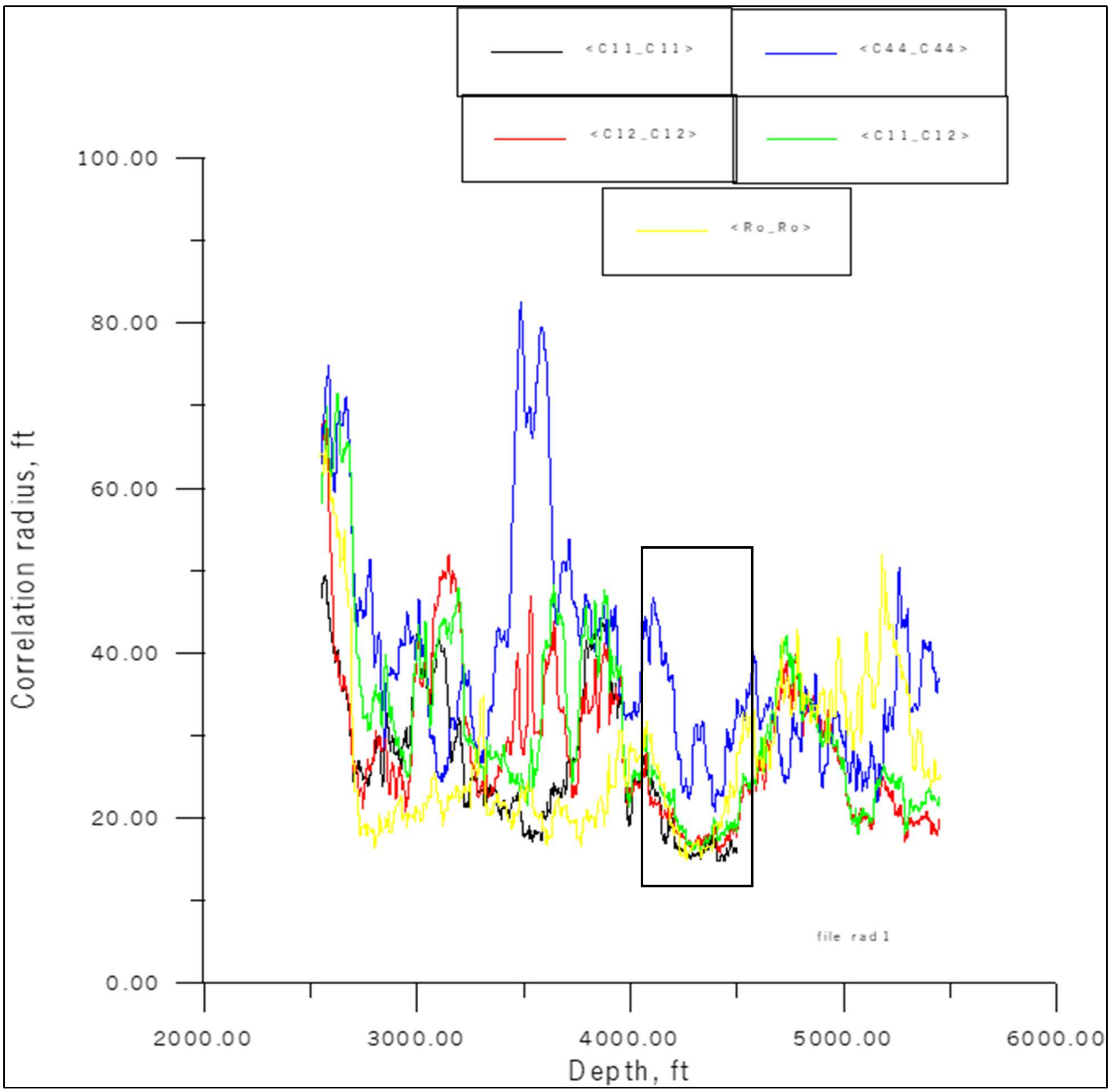


Figure 5. Correlation radius versus depth for different correlation functions (Chesnokov et al. 1995)

Fluctuations

A fluctuation is deviation from the average value of a function defined as follows:

$C'_{ij}(r) = C_{ij}(r) - \langle C_{ij}(r) \rangle$ (Tiwary et al., 2009, Gassiyev et al., 2014)

for elasticity tensors at a point r of heterogenous media (Tiwary et al., 2009, Gassiyev et al., 2014).

$C'_{ij}(r)$ is the fluctuation stiffness tensor at point r

$C_{ij}(r)$ is the relative specific stiffness tensor

$\langle C_{ij}(r) \rangle$ is the average value determined by a dynamic averaging window.

We calculate and analyze the parameter of the PCF: amplitude & radius. Commonly, the amplitude & radius of correlation function reflects the inhomogeneity level of the medium. This means that the increased heterogeneity in the reservoir corresponds to large amplitude and low radius (Chesnokov et al., 2002). When the difference between the properties of the matrix and inclusion (fractures or cracks) materials increase, the amplitude value increase and the correlation radius decrease. For a homogeneous medium, the correlation function amplitude is zero and the relative correlation radius is infinitely large. Therefore, the correlation function high amplitude and low radius will indicate the reservoir.

Dynamic Averaging Window

The averaging technique (**Fig. 3**) used in this study in order to determine fluctuations was known as the "Dynamic Averaging Window". In short, it is a version of a moving average. In order to determine the properties of inhomogeneous media, average values of the layers must be taken. Thus, based on a window size, the arithmetic average value of a physical property can be determined. The window is a wavelength determined based on the velocity and frequency. The window then shifts down to the next depth and the process is repeated (Eid 2017). Smoothness of the curves are generally a result of window size; larger windows smooth the curve more than that of a smaller window. In ideal situations, small windows are utilized as they are most representative of petrophysical data. Thus, we can determine the following given the use of the Dynamic Averaging Window:

$$\langle C_{33} \rangle = \frac{1}{L_w} \sum_{r=1}^{L_w} C_{33}(r) \qquad \text{(Tiwary et al., 2009)}$$

$$C_{33}(r) = V_p^2(r)\rho(r) \qquad \text{(Tiwary et al., 2009)}$$

Where C_{33} is the stiffness tensor, L_w is the window length, V_p is the P-Wave velocity, and ρ is the bulk density.

Data & Previous Work

Previous Work

Based on a previous study by Jackson Zerr (2019), the productive interval within a well was predicted with 81% accuracy given a low correlation radius and high amplitude. The dynamic averaging window was dependent on well depth and is noted in **Table 1**. Accuracy in the case of the Volve Field dataset is defined as a productive interval in which there is low correlation radius and high permeability. It is important to note that the fluctuations of three parameters, density, C33, and impedance, predicted the productive interval with 100% accuracy. Based on these predictions the following productive intervals (Table 1) were defined and will be further investigated for this study:

	Well Name	**Productive Interval (ft)**	**Dynamic Averaging Window (ft)**
Exploration Wells	15_9-19 A	12,700 – 12,850	180
	15_9-19 B&BT	13,450 – 13,700	180
	15_9-19 S&ST	14,160 – 14,250	180
Production Wells	15_9-F-1	10,650 – 11,000	180
	15_9-F-1 A	11,100 - 11520	125
	15_9-F-1 B	10,600 – 10730	40
Productio n Wells	15_9-F-11 A	11,500 – 11,950	180
	15_9-F-11 T2	14,400 – 14,525	180

Table 1. Overview of wells with the top of the productive interval in feet labeled (Modified from Zerr 2019).

Data

Permeability values for this study were obtained from petrophysical analyses completed by Statoil (Equinor) under the Creative Commons License (Volve Dataset, 2018). Petrophysical in LAS format in which permeability values were gathered.

Permeability values in the petrophysical logs were calculated from the following equation as per Statoil's Petrophysical Report:

KLOGH = $10^{(-0.7+17.3.PHIF\ -5.VSH)}$ (Volve Dataset 2018)

In which PHIF is the final porosity and VSH is the shale content. Final porosity (PHIF) is a value determined as follows:

$$\phi_F = \phi_D + \alpha \cdot (NPHI - \phi_D) + \beta$$ (Volve Dataset 2018)

ϕ_F is the final porosity (fraction), ϕ_D is the density porosity (fraction), α & β are regression constants, and NPHI is the neutron porosity (fraction) (Volve Dataset 2018).

From the LAS files (**Fig. 6**), all permeability and depth values were taken and edited in Microsoft Excel. Values of -999.25 were denoted as null values as per the file header. Depth was then converted from meters to feet to stay consistent with previous results obtained from earlier studies.

Based on the presence of the reservoir interval as well as the availability of logs and well depth, 8 wells were deemed relevant for this study. In addition to the exploration well, 15/9-19SR, appraisal wells 15/9-19A**,** and 15/9-19B, as well as production wells 15/9-F-1, 15/9-F-1A, 15/9-F-1B, 15/9-F-11A, and 15/9-F-11T2 were all deep enough, penetrating the productive layer (reservoir interval), while also having a thorough log suite for the calculation of amplitude and correlation radius values.

```
~Version Information Block
VERS .                 2.00:  CWLS LOG ASCII STANDARD - VERSION 2.00
WRAP .                  NO:  One line per depth step
~Well Information Block
#MNEM.UNIT        Data Type   Information
#---------- ---------------  -----------
STRT .M           3549.7008:  START DEPTH
STOP .M           4618.3296:  STOP DEPTH
STEP .M              0.0000:  STEP
NULL .              -999.25:  NULL VALUE
COMP .                     :  COMPANY
WELL .        NO_15/9-19_SR:  WELL
FLD  .                     :  FIELD
LOC  .                     :  LOCATION
CTRY .                     :  COUNTRY
STAT .                     :  STATE
CNTY .                     :  COUNTY
SRVC .                     :  SERVICE COMPANY
DATE .                     :  DATE
API  .                     :  API NUMBER
UWI  .                     :  UNIQUE WELL ID
~Curve Information Block
#MNEM.UNIT         API CODE   Curve Description
#---------- ---------------  -----------------
DEPTH.M                    :
BWV  .                     :  0
DT   .                     :
KLOGH.MD                   :  KLOGH
KLOGV.MD                   :  Vertical PERMEABILITY calculated from logs
PHIF .V/V                  :  0
SAND_FLAG.UNITLESS                 :  SAND_FLAG
SW   .V/V                  :  SW
VSH  .V/V                  :  VSHGR
~Parameter Information Block
#MNEM.UNIT            Value   Description
#---------- ---------------  -----------
PROJECT.     SLEIPNER_OST@st-vlinapp01:
SET  .             STAT_CPI:
~Other Information Block
#
~A       DEPTH          BWV          DT        KLOGH        KLOGV          PHIF    SAND_FLAG           SW          VSH
     3549.7008     0.081830   -999.2500    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3549.8532     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3550.0056     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3550.1580     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3550.3104     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3550.4628     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3550.6152     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3550.7676     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3550.9200     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3551.0724     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3551.2248     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3551.3772     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3551.5296     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3551.6820     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3551.8344     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3551.9868     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3552.1392     0.081830     54.5940    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
     3552.2916     0.081836     54.5920    -999.2500    -999.2500   -999.250000    -999.2500    -999.2500    -999.2500
```

Figure 6. Partial view of raw LAS file from petrophysical reports (Volve Dataset 2018)

Results

The following table (**Table 2**) indicates whether or not a parameter accurately relates high permeability values within the productive interval at high amplitude and low correlation radius values.

Well Name	Productive Interval (ft)	Rho	Vp	C33	Res	Porosity	Impedance	Phi, Rho	Rho, Vp	Vp, Phi
15_9-19A	12,700 – 12,850	✓	✓	✓	✓	×	✓	✓	✓	✓
15_9-19 B&BT2*	13,450 – 13,700	✓	✓	✓	×	✓	✓	✓	✓	✓
15_9-19 S&SR*	14,160 – 14,250	✓	✓	✓	✓	✓	✓	✓	✓	✓
15_9-F-1	10,650 – 11,000	✓	✓	✓	✓	✓	✓	✓	✓	✓
15_9-F-1 A	11,100 - 11520	×	✓	✓	×	×	✓	×	✓	✓
15_9-F-1 B	10,600 – 10730	✓	×	×	✓	×	×	✓	✓	×
15_9-F-11 A	11,500 – 11,950	✓	×	✓	✓	×	✓	✓	×	×
15_9-F-11 T2	14,400 – 14,525	✓	✓	✓	×	✓	✓	✓	✓	✓

Key:

✓ Indicates a parameter correctly predicting low correlation radius and high amplitude at productive interval bounds with high permeability

× Indicates a parameter failing to predict low correlation radius and high amplitude at productive interval bounds with high permeability

* Indicates a well with both vertical and horizontal permeabilities

Table 2. Accuracy of low correlation radius and high amplitude predicting high permeability

Conclusions

Based upon the available permeability data from the Volve Field well logs and the PCF data, relationships between correlation radius, amplitude, and permeability were studied. Several logs were more successful in supporting the hypothesis that low correlation radius and high permeability values were found in areas of high permeability. Bulk Density, Modul C33, Impedance, PhiRho, and RhoVp were the most accurate logs, each supporting the hypothesis in 7 of the 8 wells. **Figure 7** is an example of bulk density demonstrating low correlation radius values and high amplitude values in areas of high permeability. **Figure 8** demonstrates an example of a well where low correlation radius and high amplitude are not synonymous with high permeability.

Across all wells where amplitude, radius, and permeability values were available, the productive interval corresponds with high amplitude, low correlation radius, and high permeability with 78% accuracy. If the parameters in which the productive interval was predicted with 100% accuracy (Density, C33, and Impedance) from the previous study by Jackson Zerr are focused on, the accuracy increases to 87.5%.

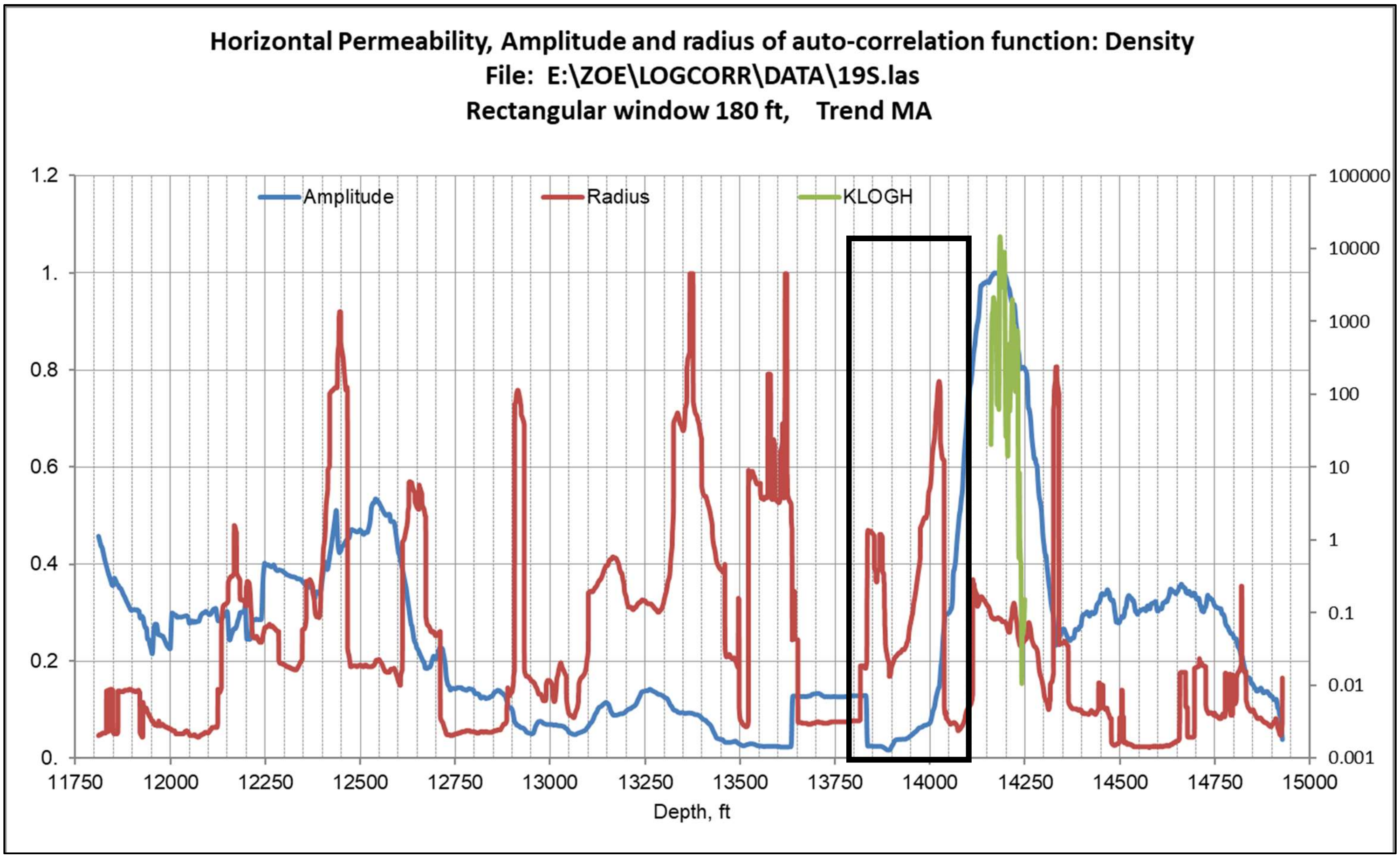


Figure 7. Well 15/9-19S, productive interval indicated by black box with high horizontal permeability, high amplitude and low correlation radius

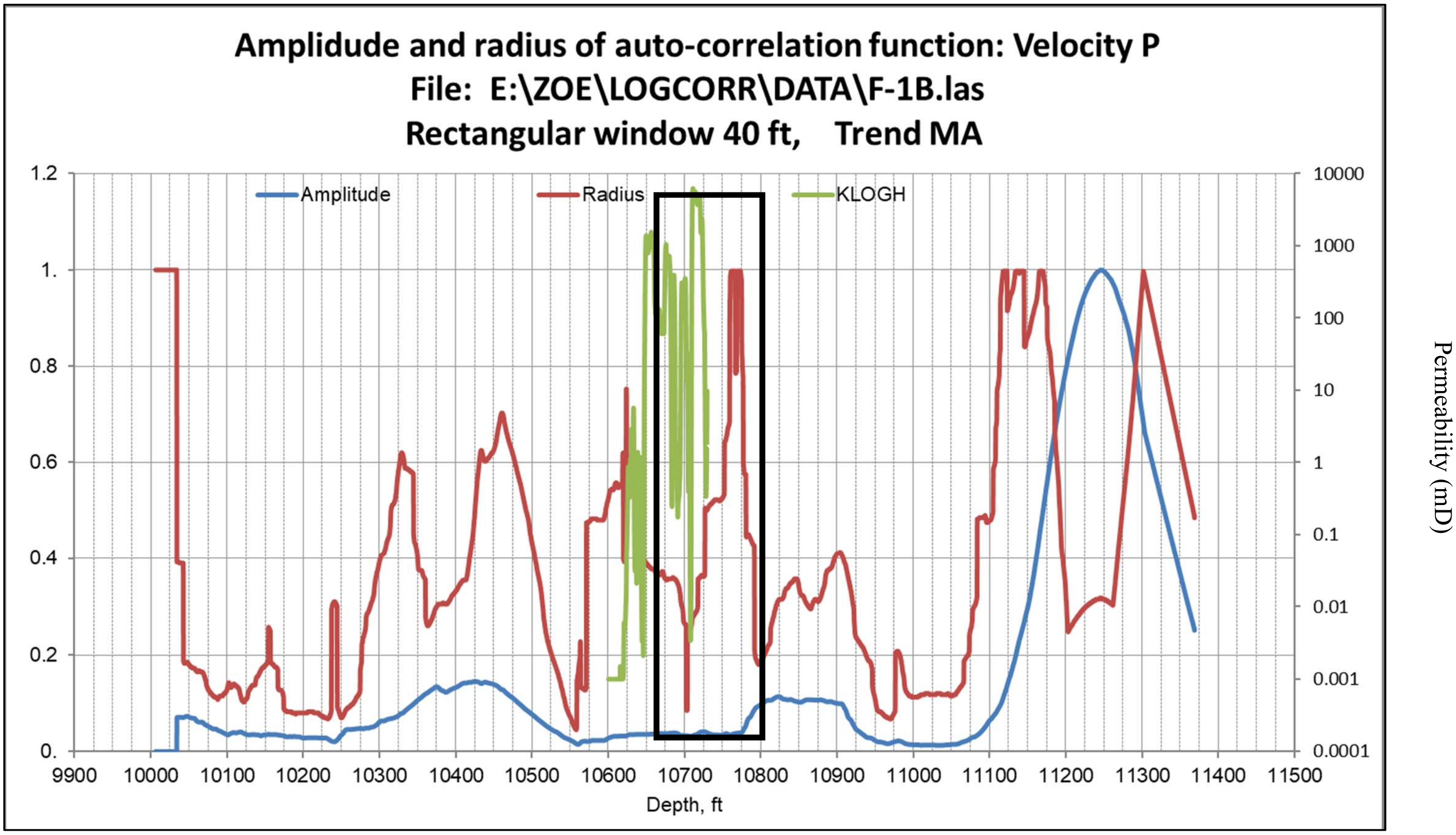


Figure 8 Relationship between amplitude, correlation radius, and permeability over the productive layer for Well 15/9-F-1B

Discussion

The hypothesis that high permeabilities are expected in areas of low amplitude and high correlation radius is supported by this study. Strictly looking at Well 15/9-19S, the amplitude and radius values alone suggest high permeability is to be expected within the productive interval. **Figure 7** shows a clear relationship of the productive interval with the relationship of high amplitude and low correlation radius. Seeing this behavior, we would expect high permeabilities in the productive interval denoted in **Figure** 9; these permeabilities are show in **Figure 10** and **Figure 11**. Within the productive interval this relationship was found the be 100% accurate in well 15/9-19S. The productive interval had low correlation radius with both high amplitude and permeabilities (**Fig. 12**).

After detailed investigation, the hypothesis that high permeabilities are related to low correlation radius and high amplitudes is supported. Thus, it is plausible to predict permeabilities in areas that have the characteristic of low correlation radius and high permeability. Please see the appendices for further plots of this relationship.

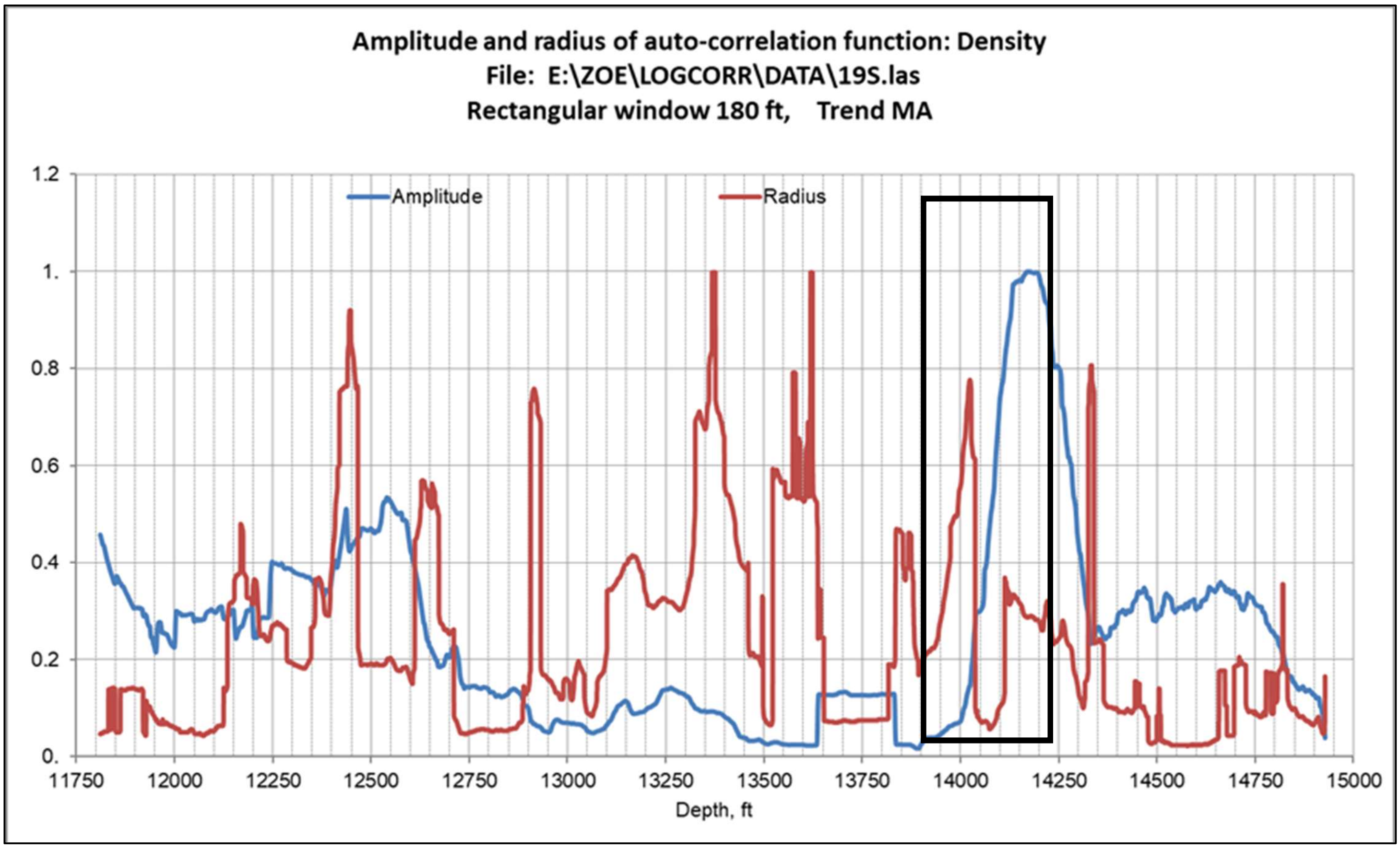


Figure 9. Well 15/9-19S, productive interval indicated by black box with high amplitude and low correlation radius

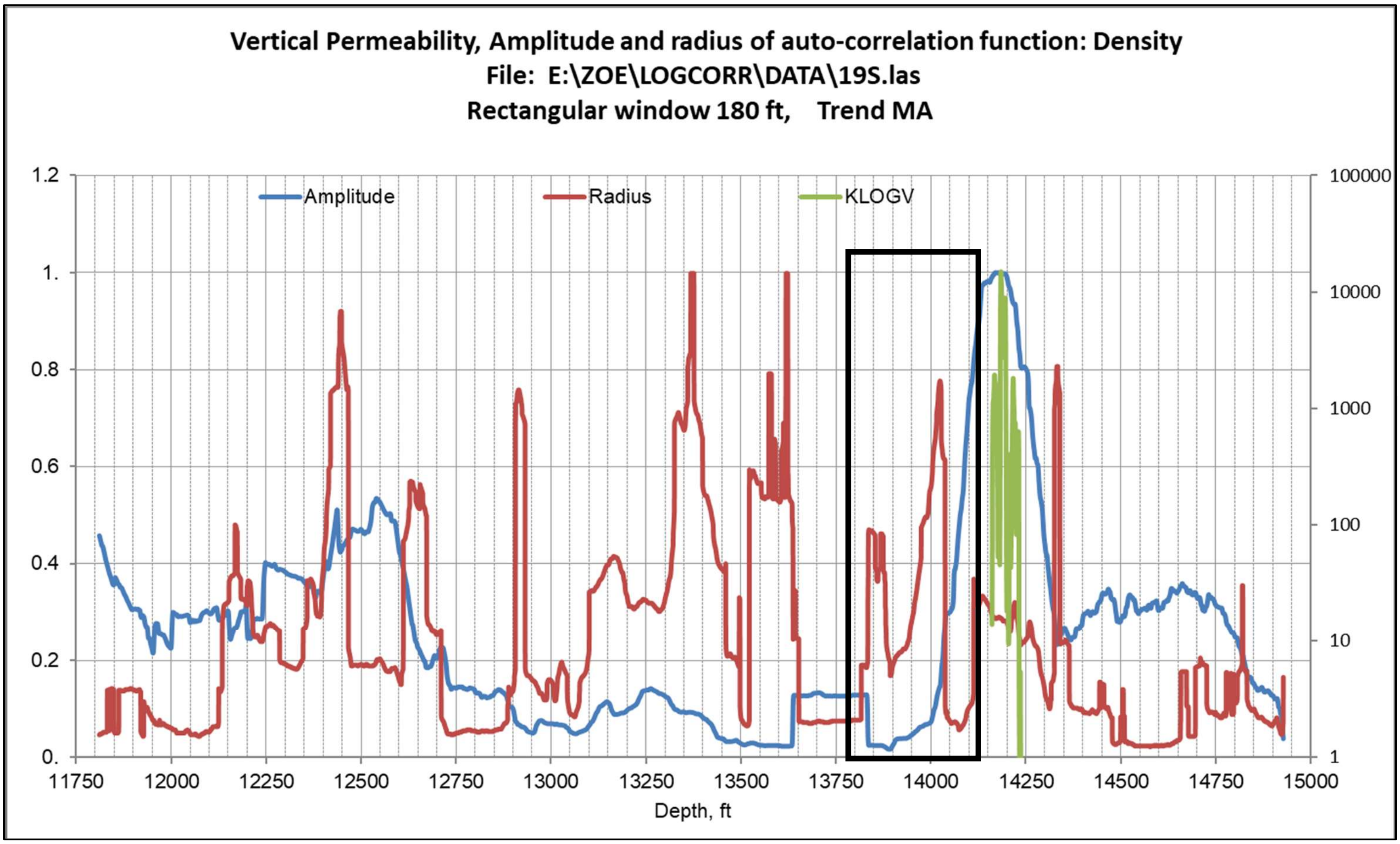


Figure 10. Well 15/9-19S, productive interval indicated by black box with high vertical permeability, high amplitude and low correlation radius

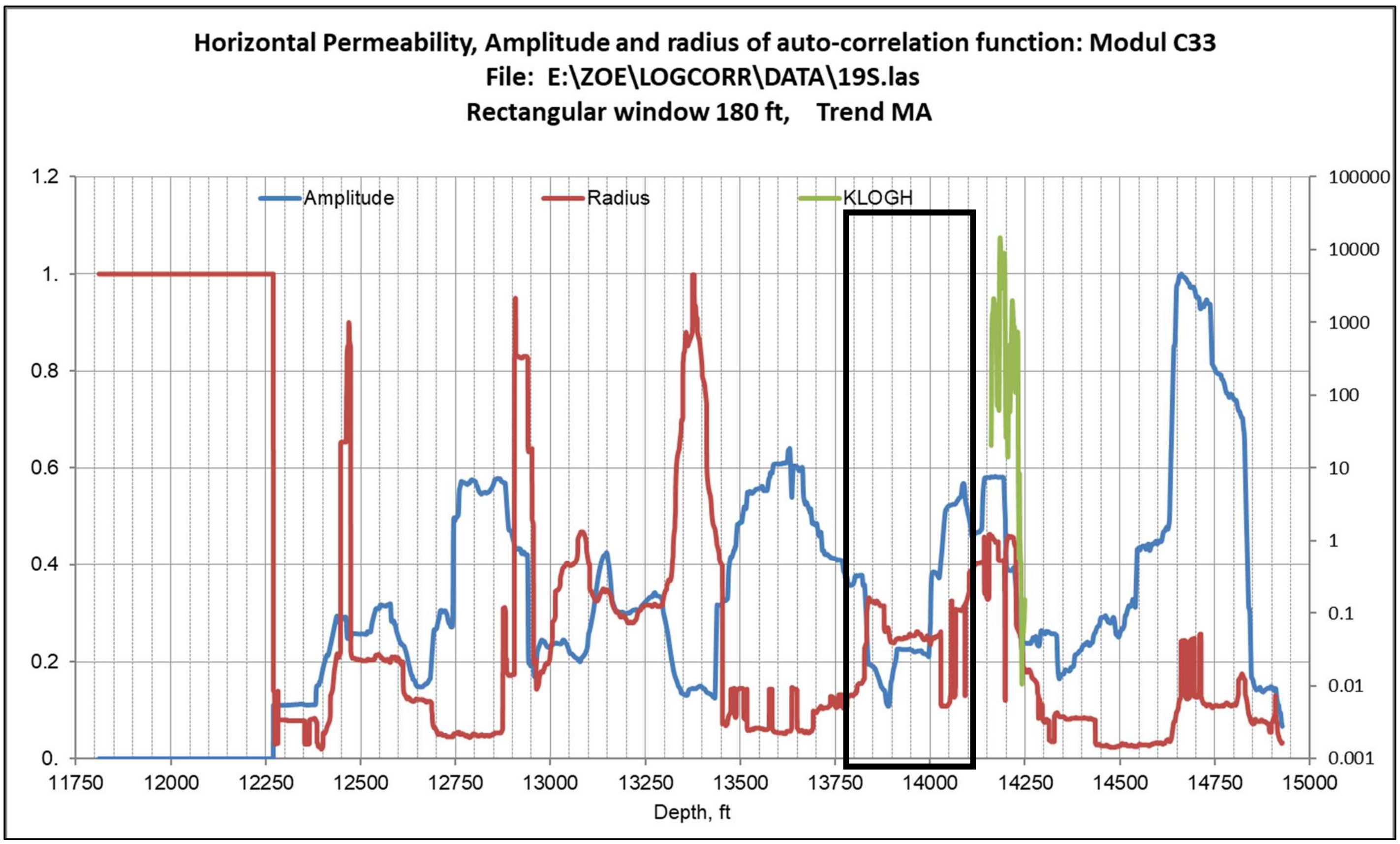


Figure 11. Well 15/9-19S, productive interval indicated by black box with high vertical permeability, high amplitude and low correlation radius

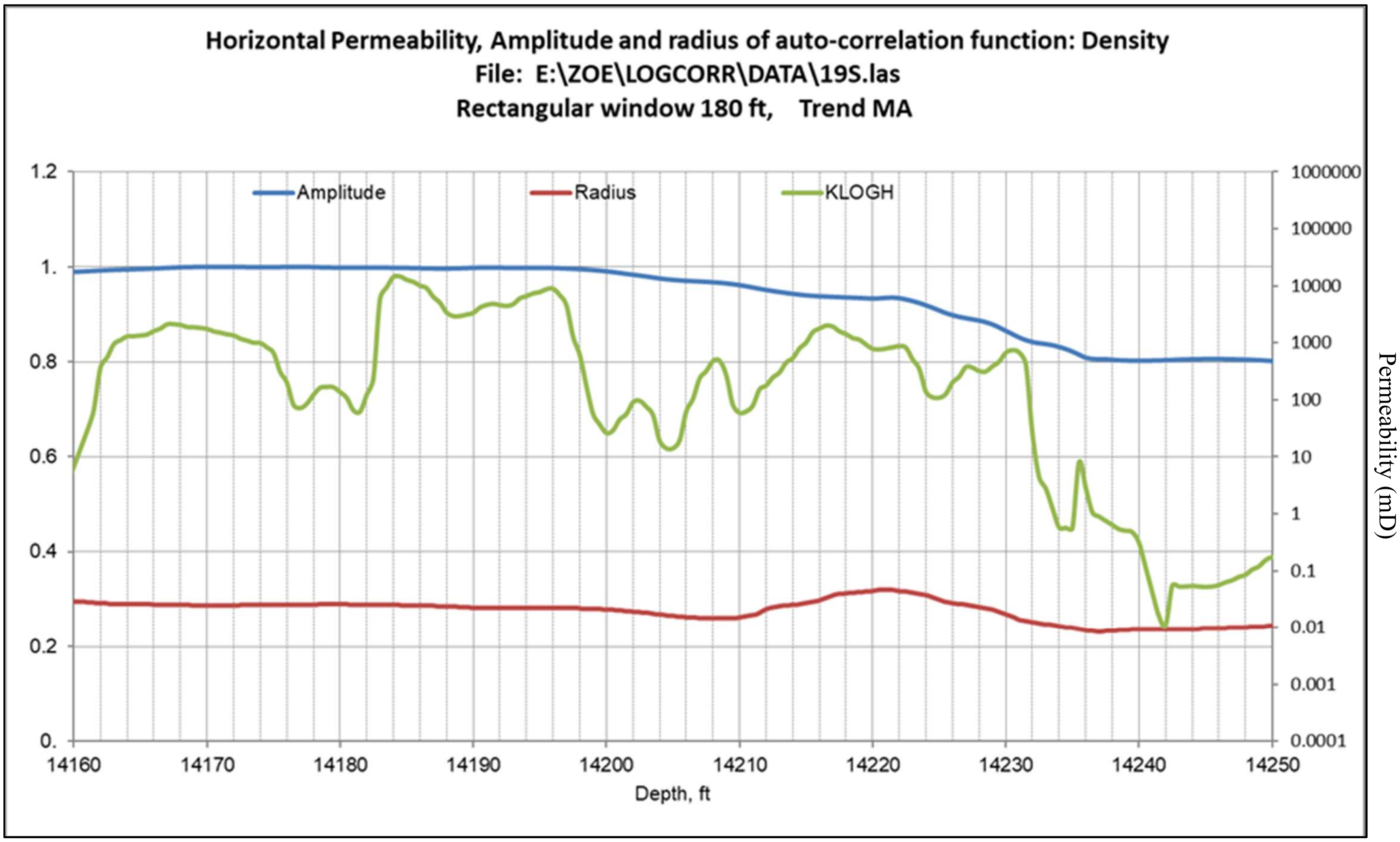


Figure 12. Well 15/9-19S, productive interval, area of high permeability, high amplitude and low correlation radius

The effectiveness of this method can be further supported if the reservoir geology is considered. The Hugin formation is mainly comprised of sandstone with thin interbeds of claystone. Furthermore, the sandstones within the Hugin formation are poorly sorted and friable with a large grain size distribution; very fine to medium grains **(Volve Dataset 2018).**

Given the nature of the Hugin formation it is expected for permeabilities to be higher as well. Despite permeabilities reaching tens of thousands of millidarcies, Abdon Atangana (Atangana 2018) determined that "sandstones may vary in permeability from less than one to over 50,000 millidarcies (md)". Knowing the lithology of the Hugin formation is predominately sandstone, these permeability values can be utilized within geologic reason.

Furthermore, given the anisotropic nature of sandstones, permeability values would be expected to be similar in both the horizontal and vertical directions. Such anisotropic behavior is seen in the measurements of both wells (19B and 19S) that vertical and horizontal permeability measurements are available (**Fig. 13 and 14**).

There are concerns regarding the reliability of the permeability values. Based upon the petrophysical reports, there are no indications of a method used to determine vertical permeability. A suspicious assumption would be that horizontal and vertical permeabilities were thus calculated using the same formula previously mentioned: $KLOGH = 10^{(-0.7+17.3.PHIF -5.VSH)}$ (Volve Dataset 2018). A small dataset of lab measured horizontal permeabilities for well 15/9-19B&BT2 are seen below (**Fig 15**).

Sample orientation of these lab measurements is unknown; thus, we cannot be confident if horizontal and vertical permeability values are truly representative of the reservoir. Furthermore, measured permeabilities within the productive interval were not available. **Figure 16** shows the cross plot of calculated and lab measured permeabilities. Despite the potential discrepancies within the permeability data, given the lithology it is plausible that permeabilities from the measured data translate to similar values for the productive interval. Comparing the **Figure 15** and **Figure 16**, a similar character of these plots is exhibited.

Although the lab measured permeability data was significantly more limited than that of the permeability values from the petrophysical analysis files, when comparing the ranges of the data, lab measured permeabilities range from 0.032 to 7360 m, whereas permeabilities from the petrophysical reports reach a maximum value of 13705 mD.

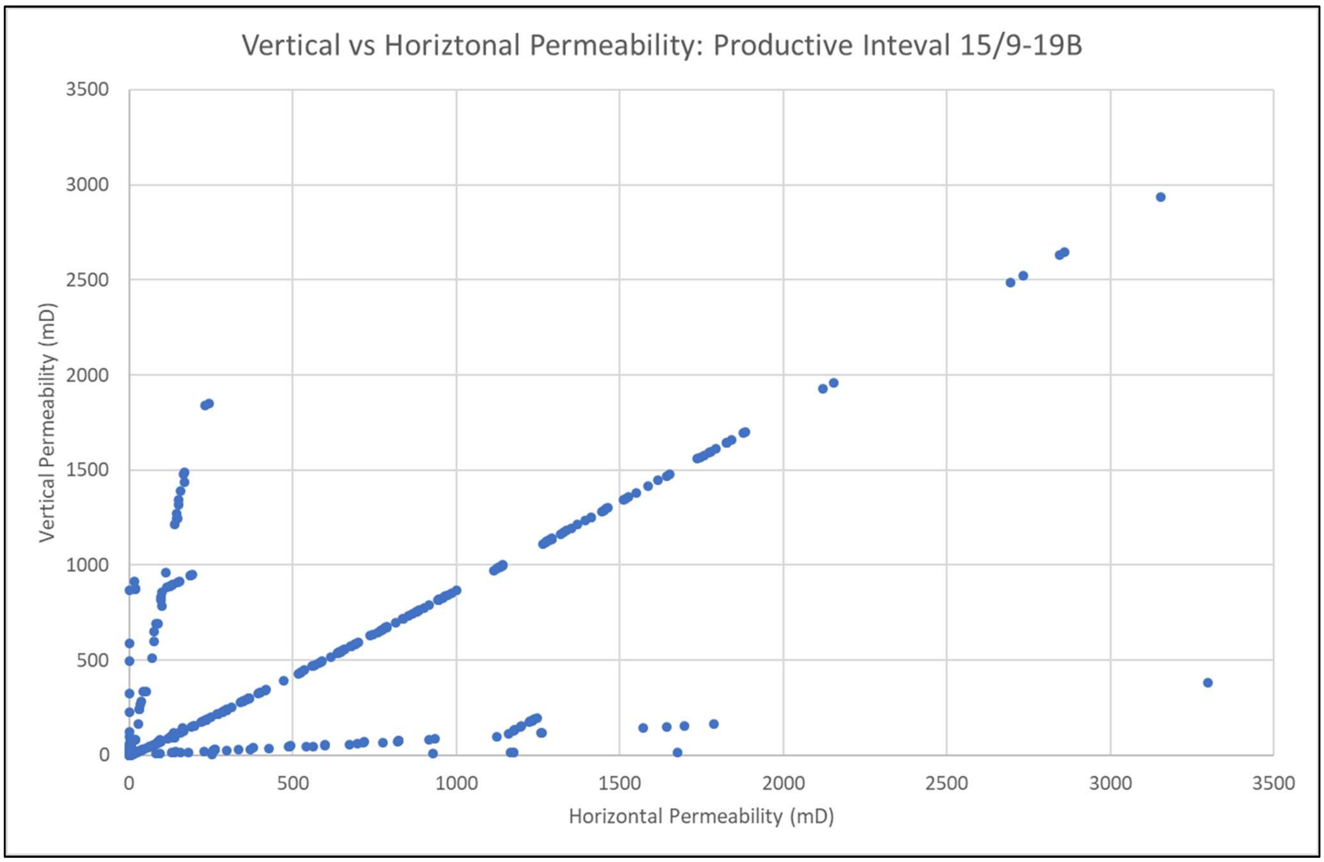


Figure 13. Behavior of Vertical and Horizontal permeabilities over the productive interval in well 15/9-19B

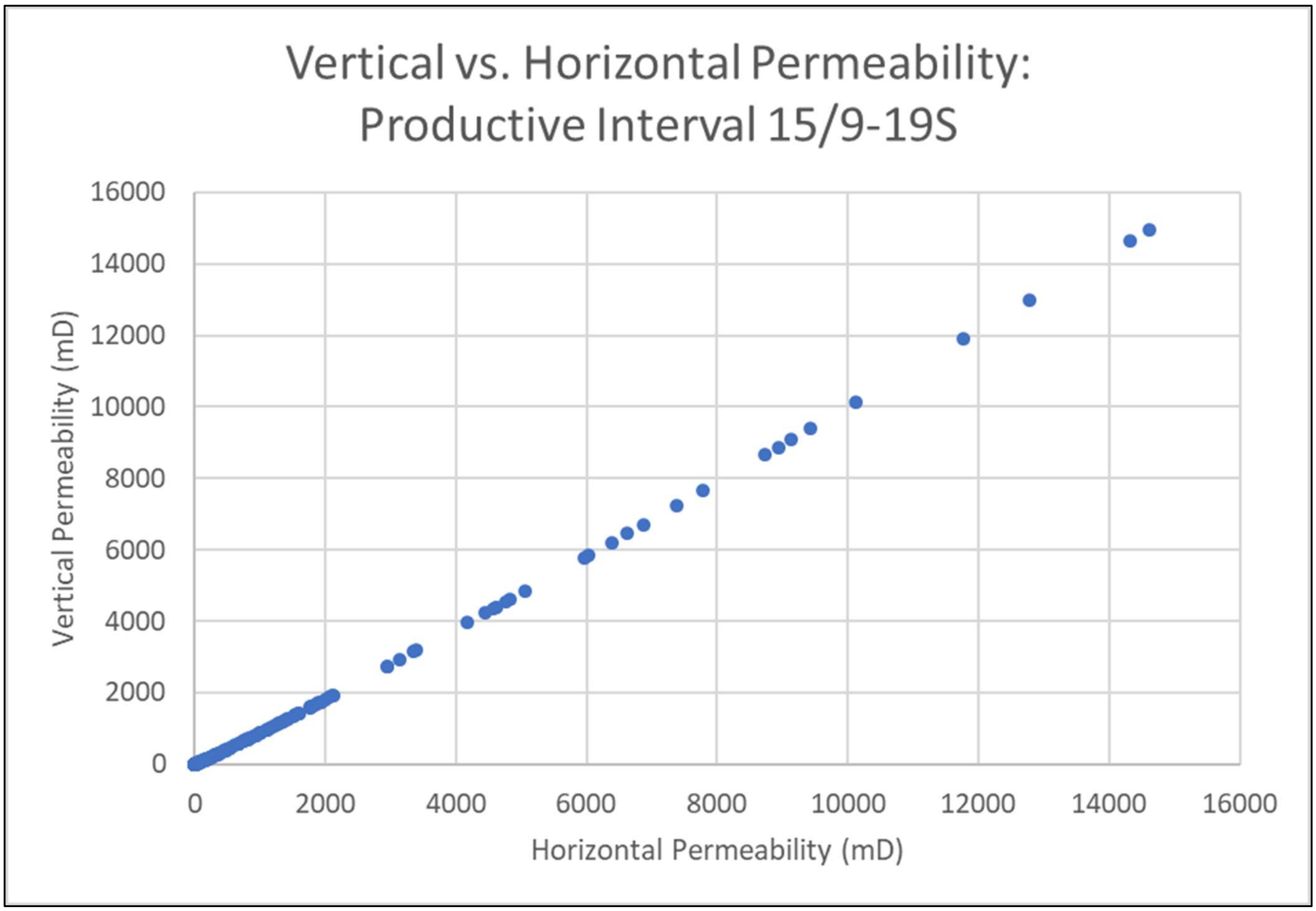


Figure 14. Behavior of Vertical and Horizontal permeabilities over the productive interval in well 15/9-19S

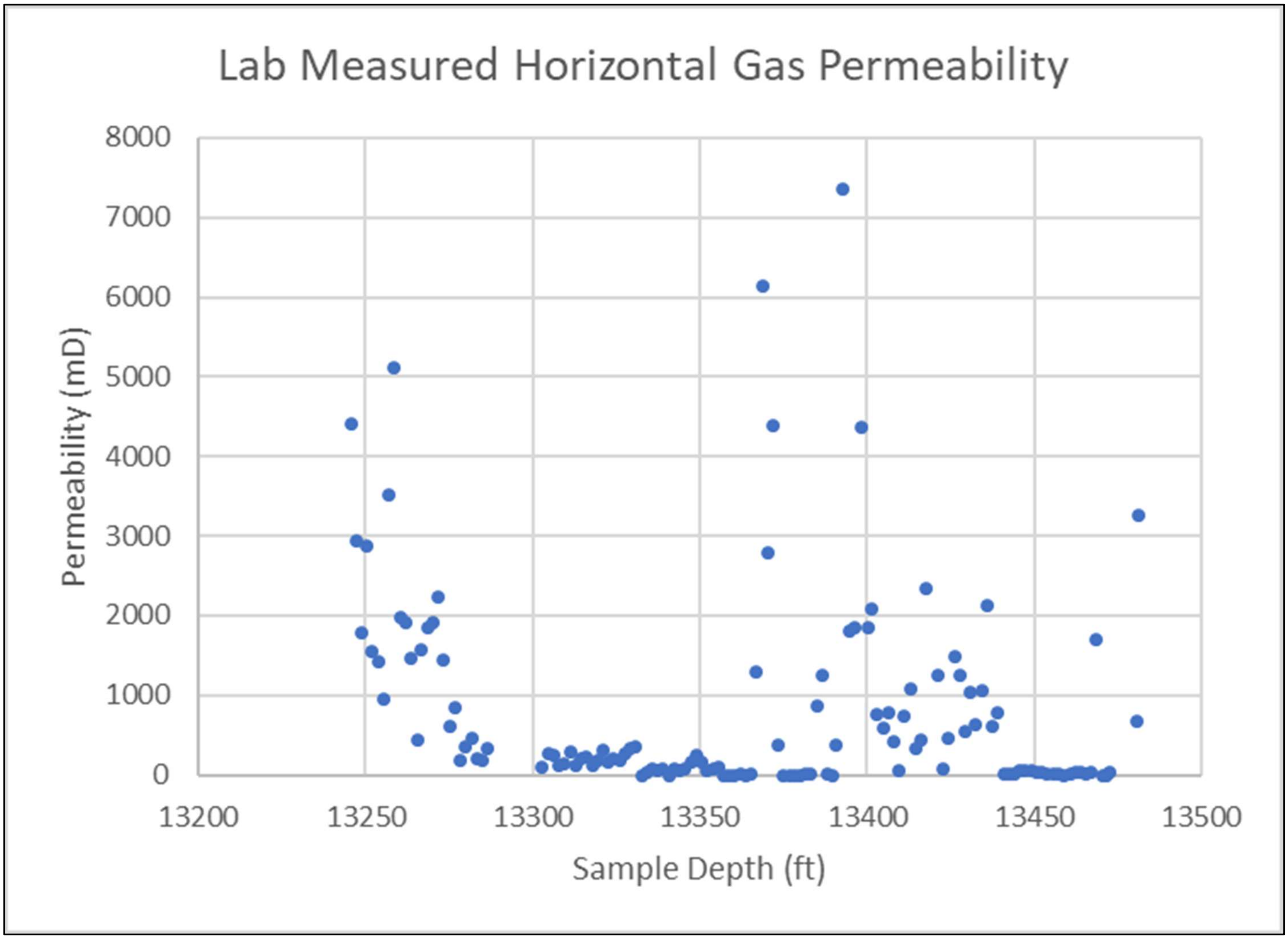


Figure 15. Lab Measured Horizontal Gas Permeability, Well 15/9-19B

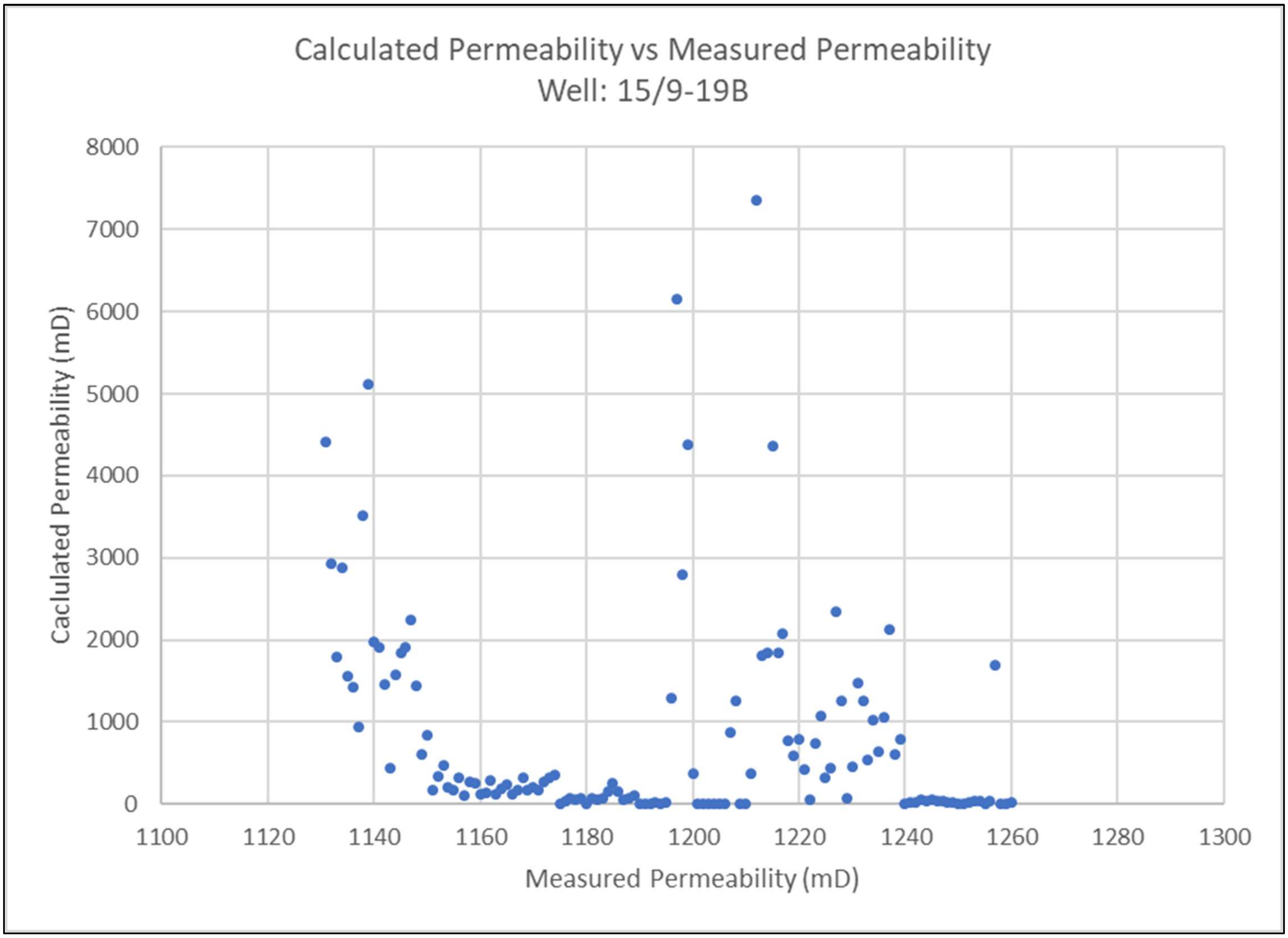


Figure 16. Calculated vs. Measured Permeability, Well 15/9-19B

Future Study

This study was somewhat limited by both the available data and the consistent reservoir formation lithology. Without more detailed information or data regarding permeabilities, it is suspected that the permeability values may not be fully consistent with the reservoir properties. By obtaining a field with detailed data containing sample orientation, permeabilities. A field with both measured and calculated permeability values for the reservoir interval would be imperative in order to further support this study's findings. Further study of other fields with both, similar and differing reservoir geologies can further corroborate the hypothesis that hydrocarbon bearing intervals or reservoirs can be denoted and predicted by first locating the areas demarcated by low correlation radius and high amplitudes which then high permeabilities are to be expected. Given this field was a sandstone reservoir, anisotropy was expected and exhibited. Studying a field with a shale reservoir or a field with isotropic media may yield different results. In addition to analyzing other fields with sufficient data availability, defining quantitative criteria such as defining a ratio of correlation radius to amplitudes can further increase the accuracy of this method.

Appendix Notes

Section **A1** outlines results from a previous study. These plots denote the productive interval with a thick black box. The most telling signs of a productive layer are a dramatic increase to decrease in correlation radius with a large increase in amplitude.

Sections **A2** and **A3** are plots that show the same relationships as section **A1**, however these have the permeabilities included. We can see that there are high permeabilities within the productive interval. This area has low correlation radius and high amplitude; this is what is expected within the productive interval.

Sections **A4** through **A7** show the relationship between permeability (horizontal or vertical) and correlation radius or permeability (horizontal or vertical) and amplitude. Similarly, we would expect to see correlation radius LOW when permeabilities are HIGH. Conversely, amplitudes and permeabilities should both be HIGH.

Sections **A8** and **A9** are "zoomed in" plots that focus on strictly the productive interval to show the relationship between all three parameters: permeability (either vertical or horizontal, correlation radius, and amplitude).

Sections **A10** through **A13** show the relationships of permeability (horizontal or vertical) and correlation radius or permeability (horizontal or vertical) and amplitude for just the productive layer. Again, correlation radius should be low when permeabilities are high and amplitudes should be high when permeabilities are high.

Section **A17** through **A18** depict a several behaviors of permeability within the productive interval. **A17** shows the behavior of permeability throughout the productive interval. One plot shows both permeabilities on the same plot, the other plots have the horizontal or vertical permeability plotted separately. **A18** shows the coefficient of anisotropy throughout the productive interval. The formula used to determine the coefficient of anisotropy is as follows: $\left|\frac{K_{vertical}-K_{horizontal}}{K_{vertical}}\right| * 100$. Section **A19** shows the relationship of vertical versus horizontal permeabilities which represent characteristics of an anisotropic medium. Given the reservoir is of sandstone lithology, this is expected. Please refer to the **Discussion** for further information regarding permeability values.

APPENDICES

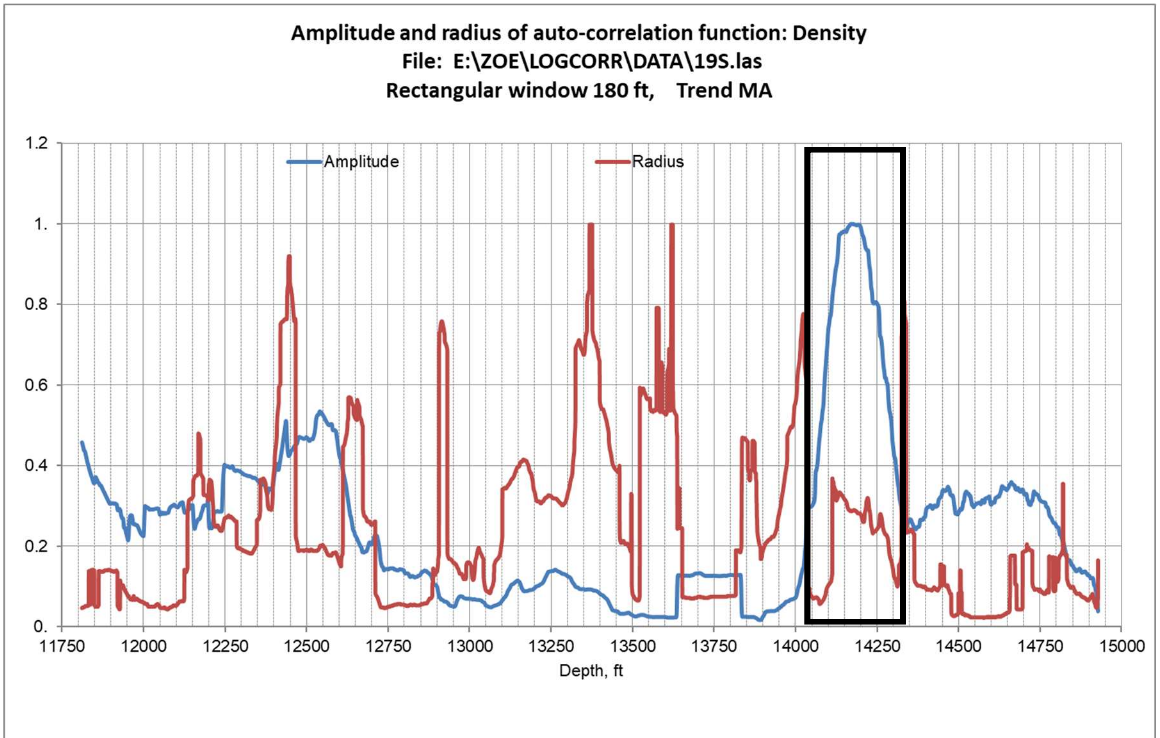
TABLE OF CONTENTS

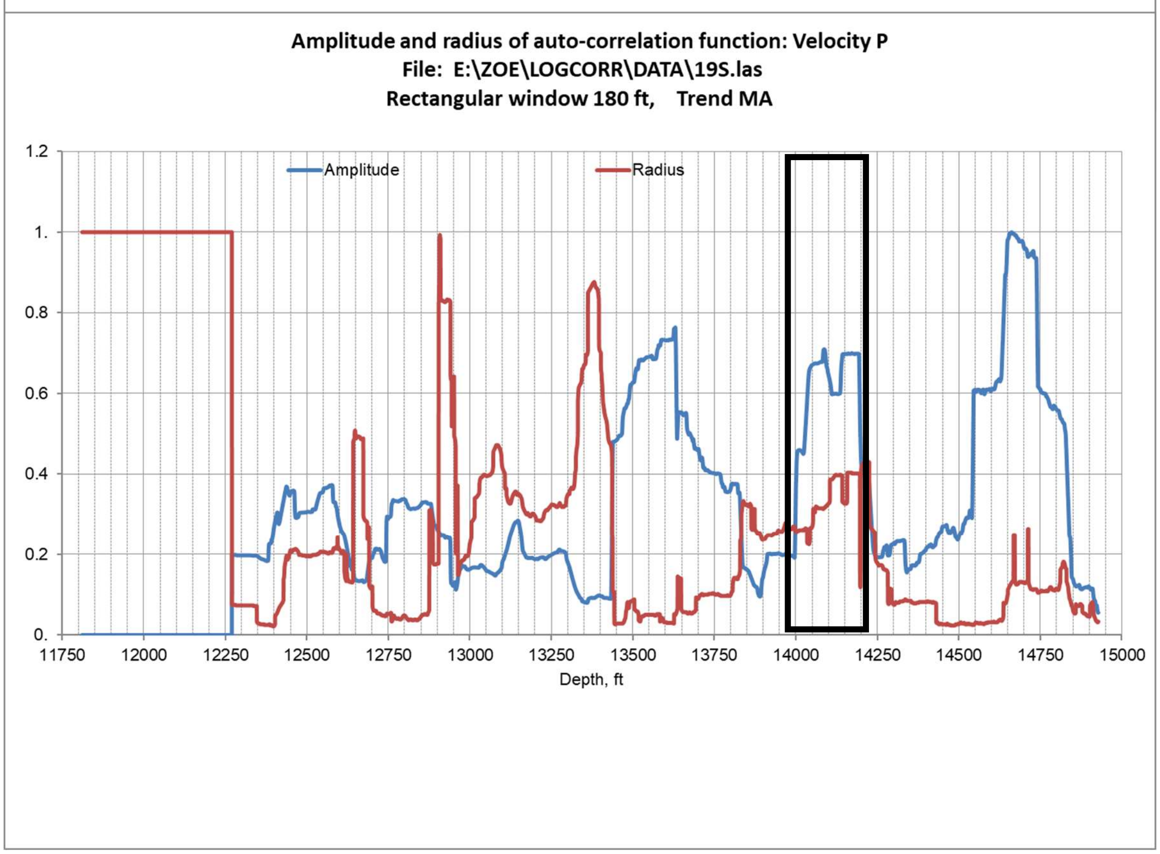
This page was intentionally left blank

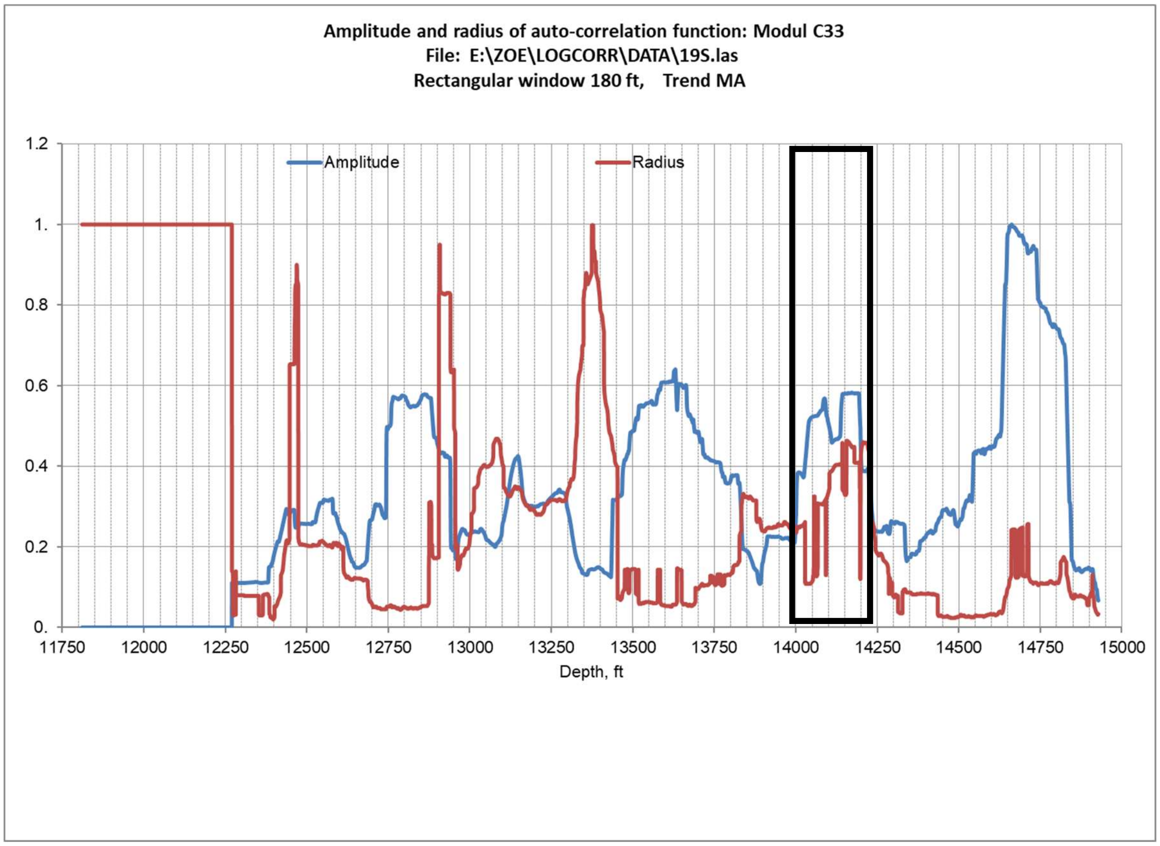
A1: Amplitude, Radius vs. Depth

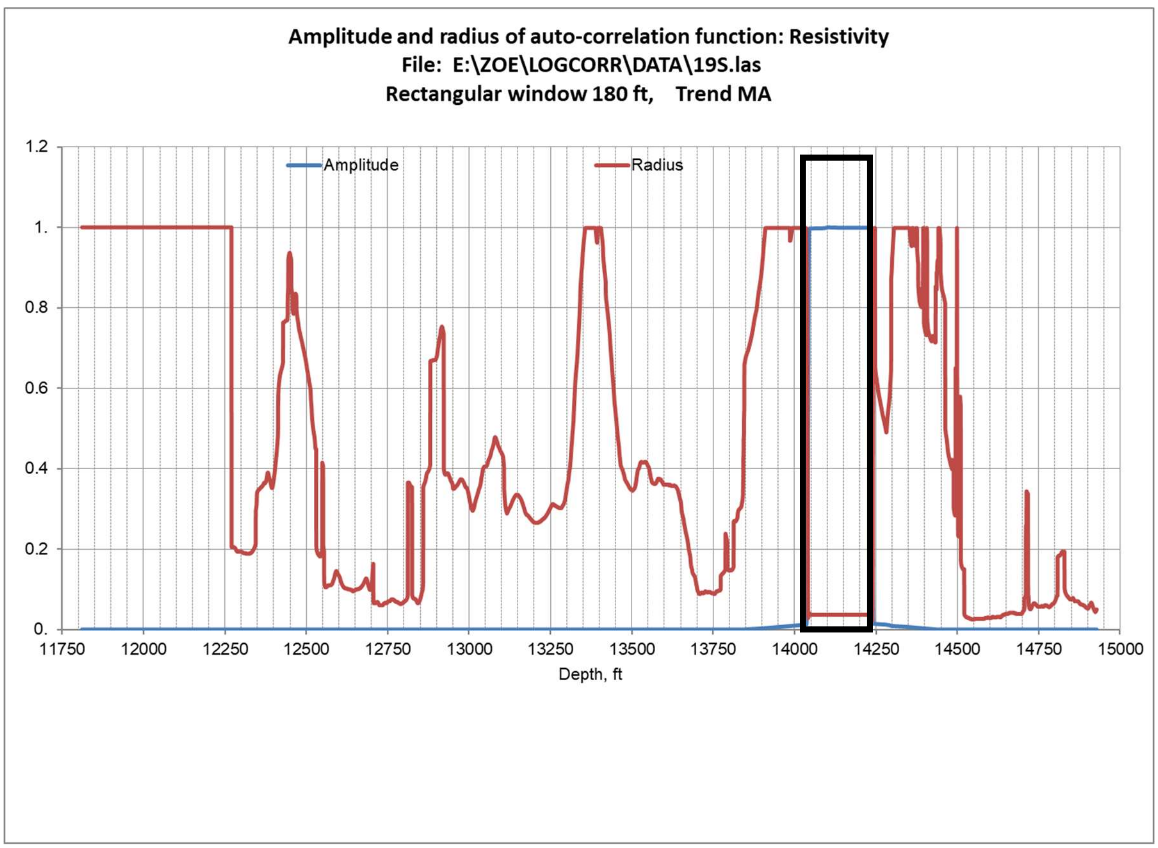
A1: Amplitude, Radius vs. Depth

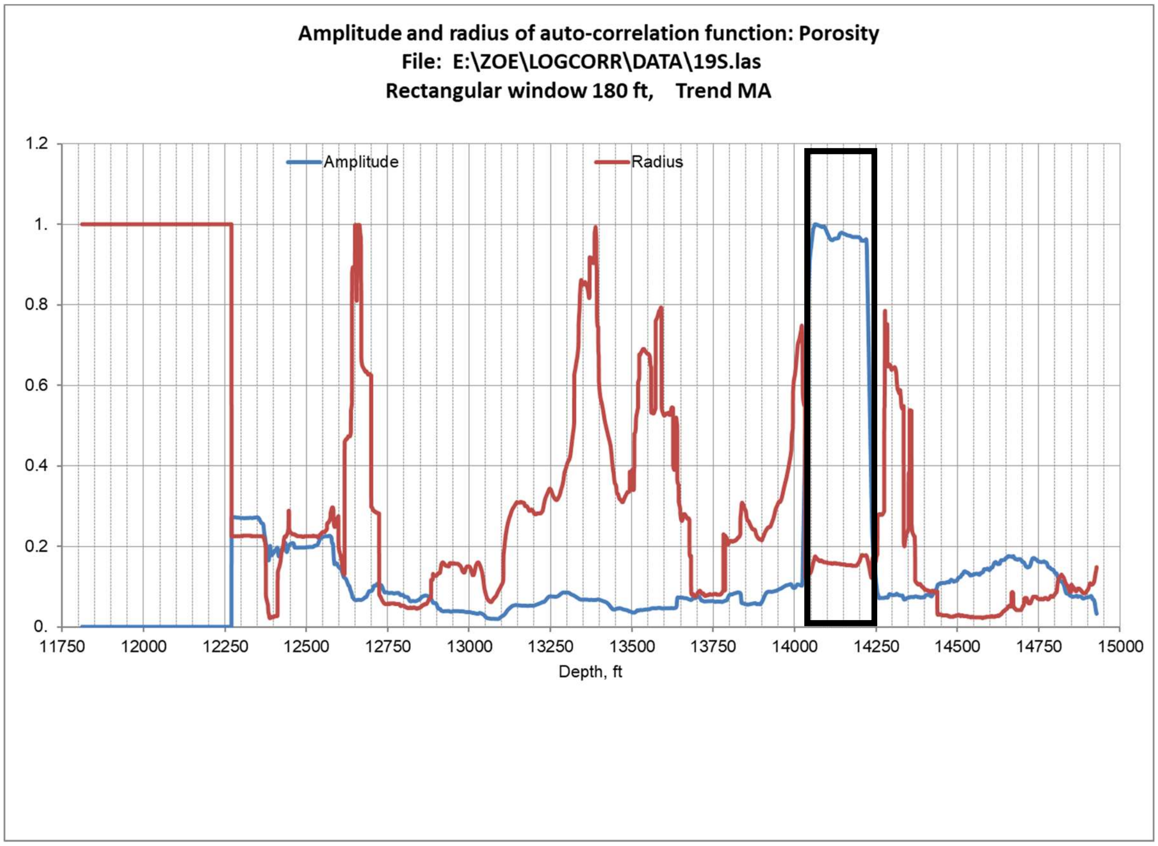
This section outlines the previous results modified with the productive layer outlined in black. As a whole, the productive layer/interval is bound by a sharp increase and decrease in correlation radius. Between these "layers", the amplitude increases. Within the productive layer, high permeability is expected in conjunction with the high amplitudes. Further, high permeability is essential for hydrocarbon extraction within reservoir intervals. Understanding this gives the foundation for the following sections where high permeabilities are seen in the productive interval.

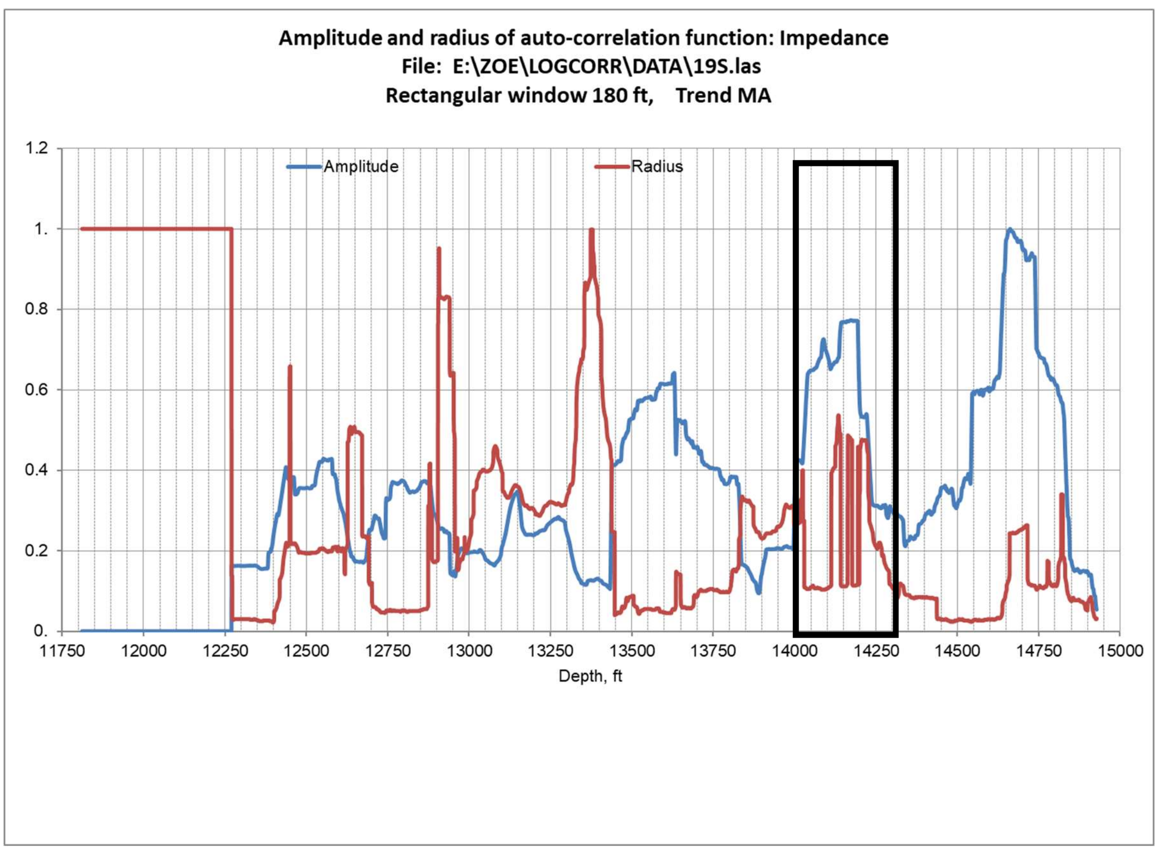

Amplitude and radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft

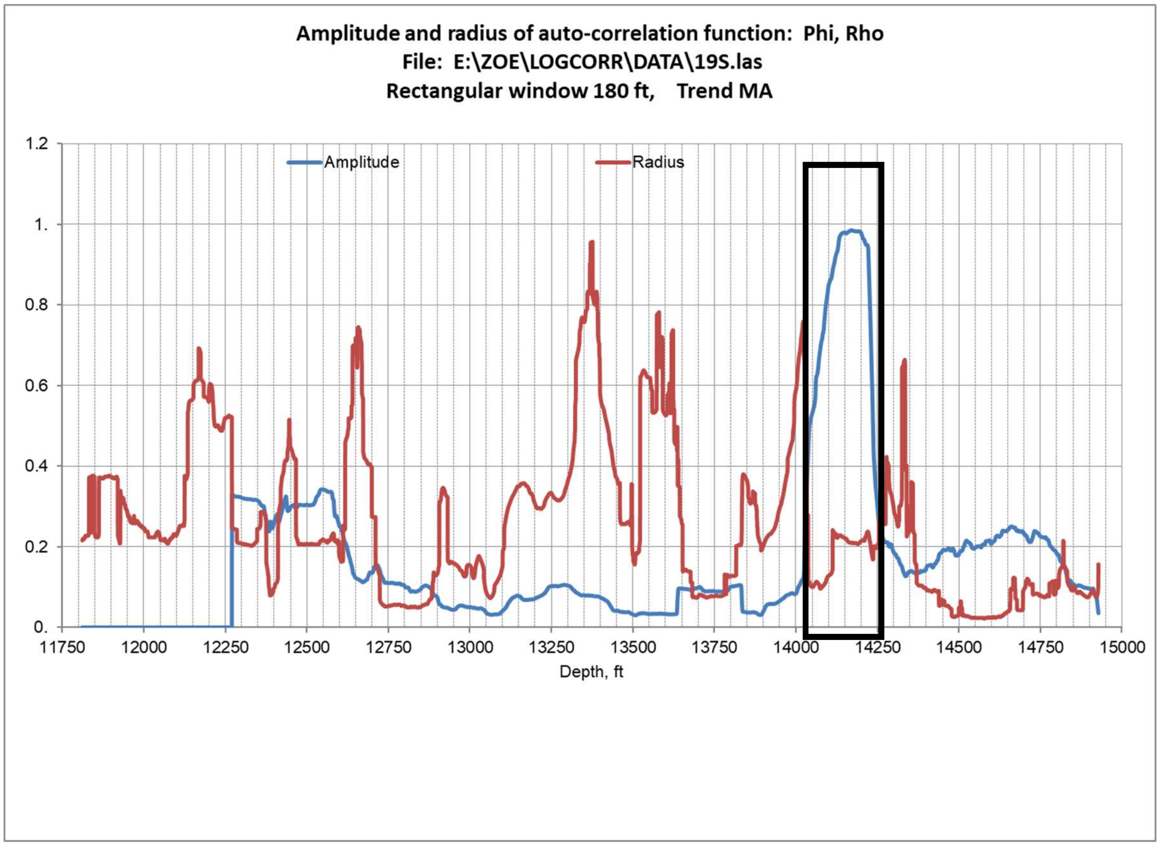

Amplitude and radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft

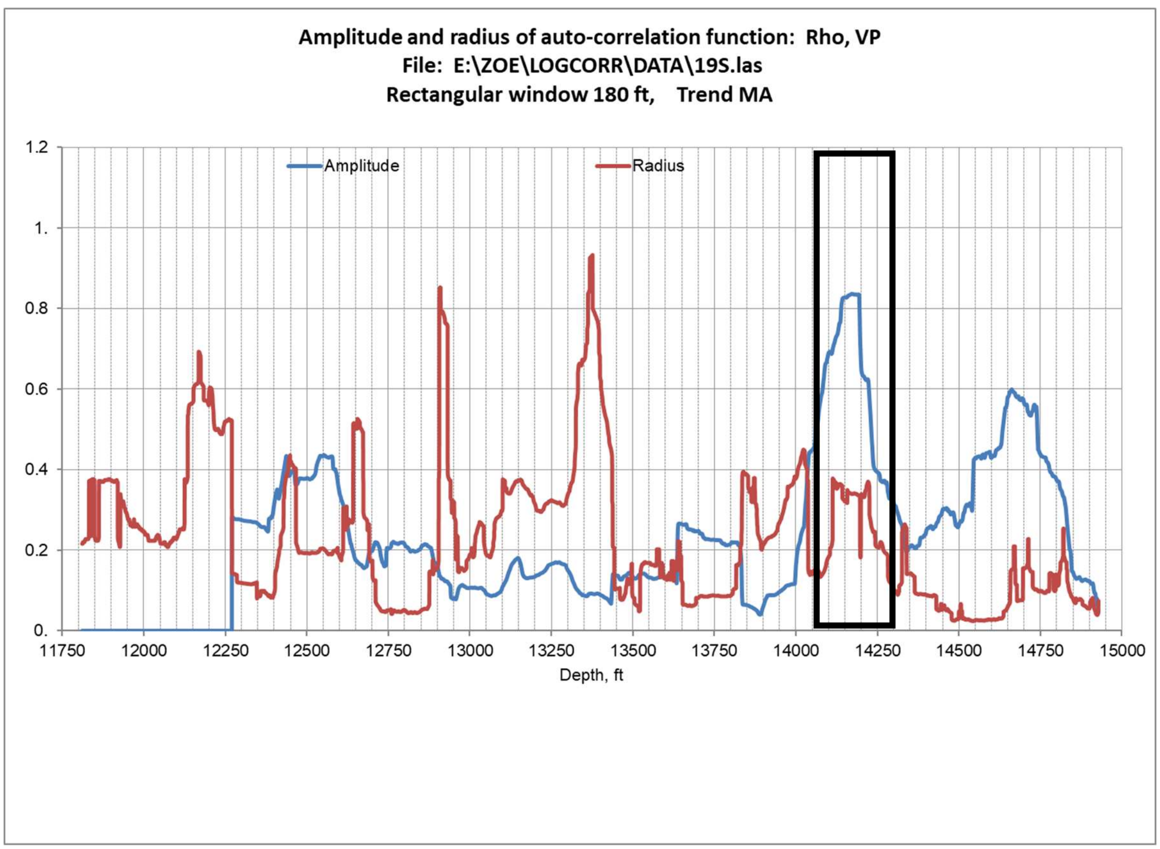

Amplitude and radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft

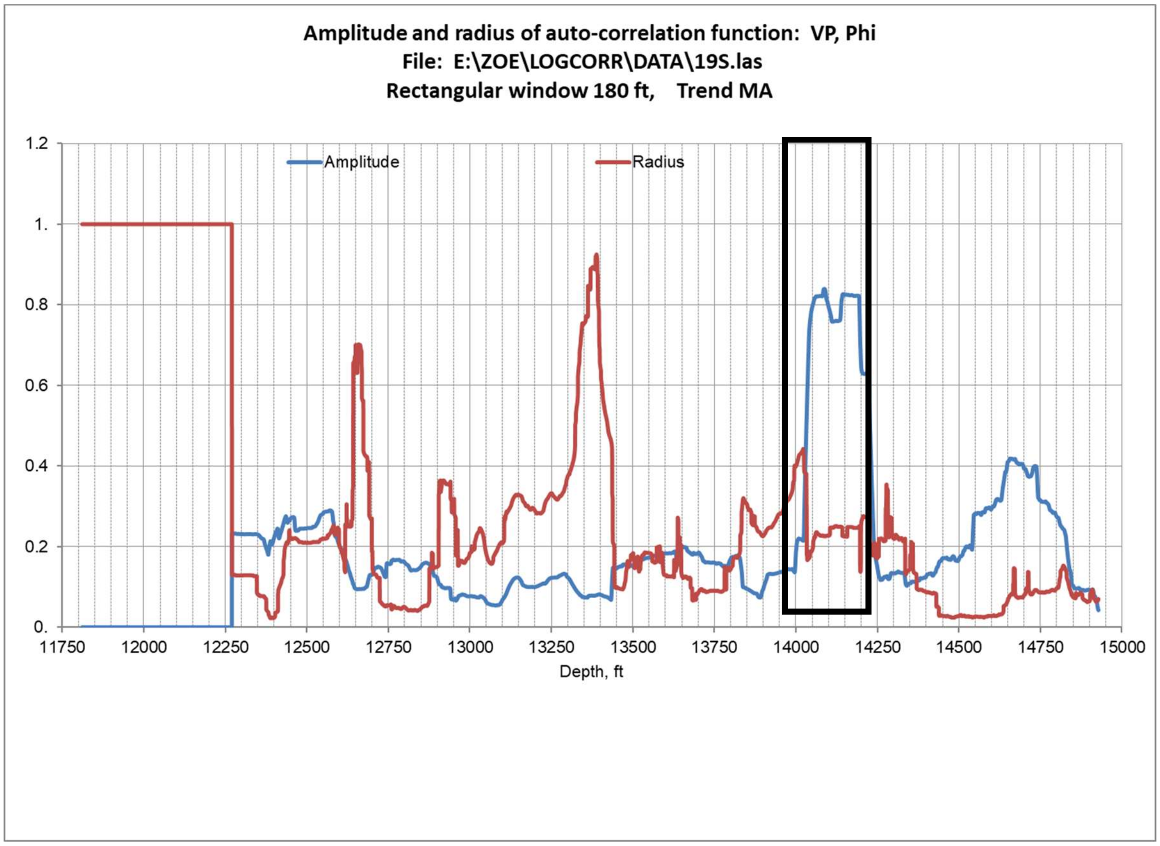

Amplitude and radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft


Amplitude and radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750 12000 12250 12500 12750 13000 13250 13500 13750 14000 14250 14500 14750 15000
Depth, ft


Amplitude and radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750 12000 12250 12500 12750 13000 13250 13500 13750 14000 14250 14500 14750 15000
Depth, ft


Amplitude and radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft

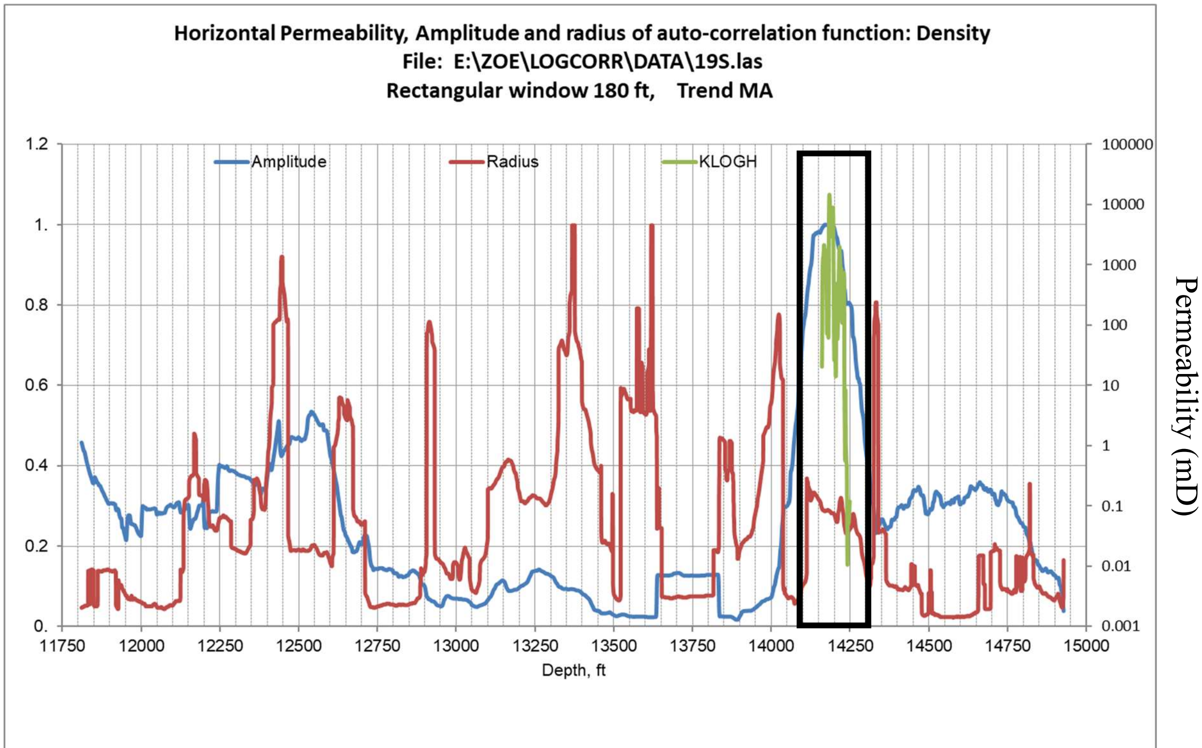

Amplitude and radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft

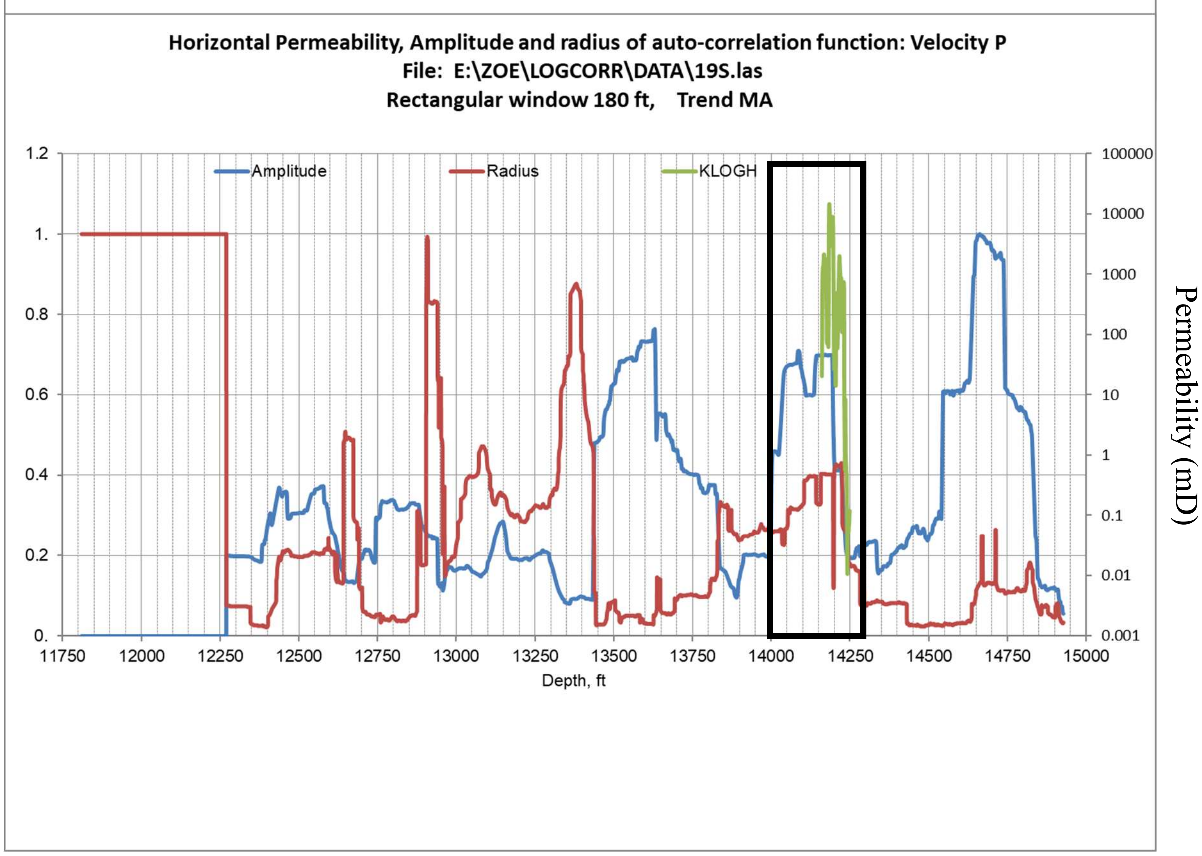

Amplitude and radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft

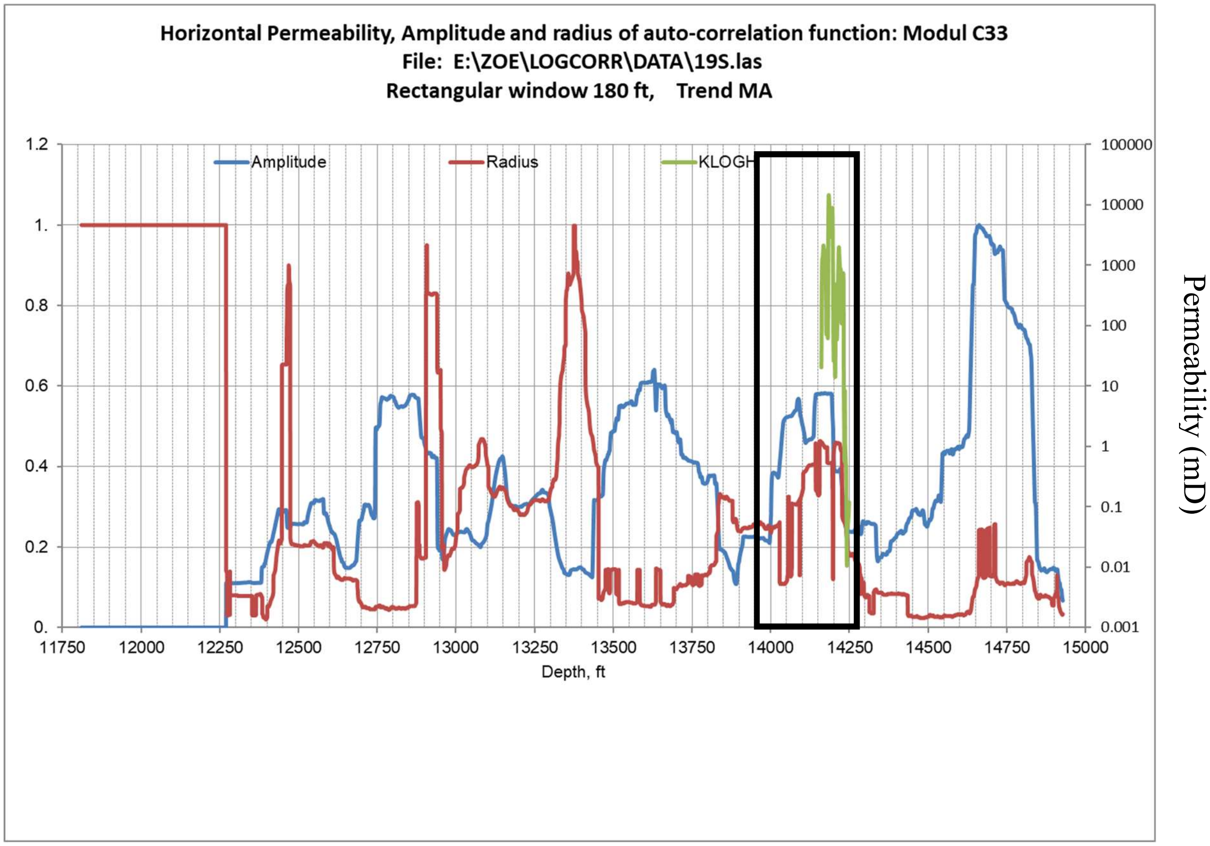
A2: Amplitude, Radius, Horizontal Permeability vs. Depth

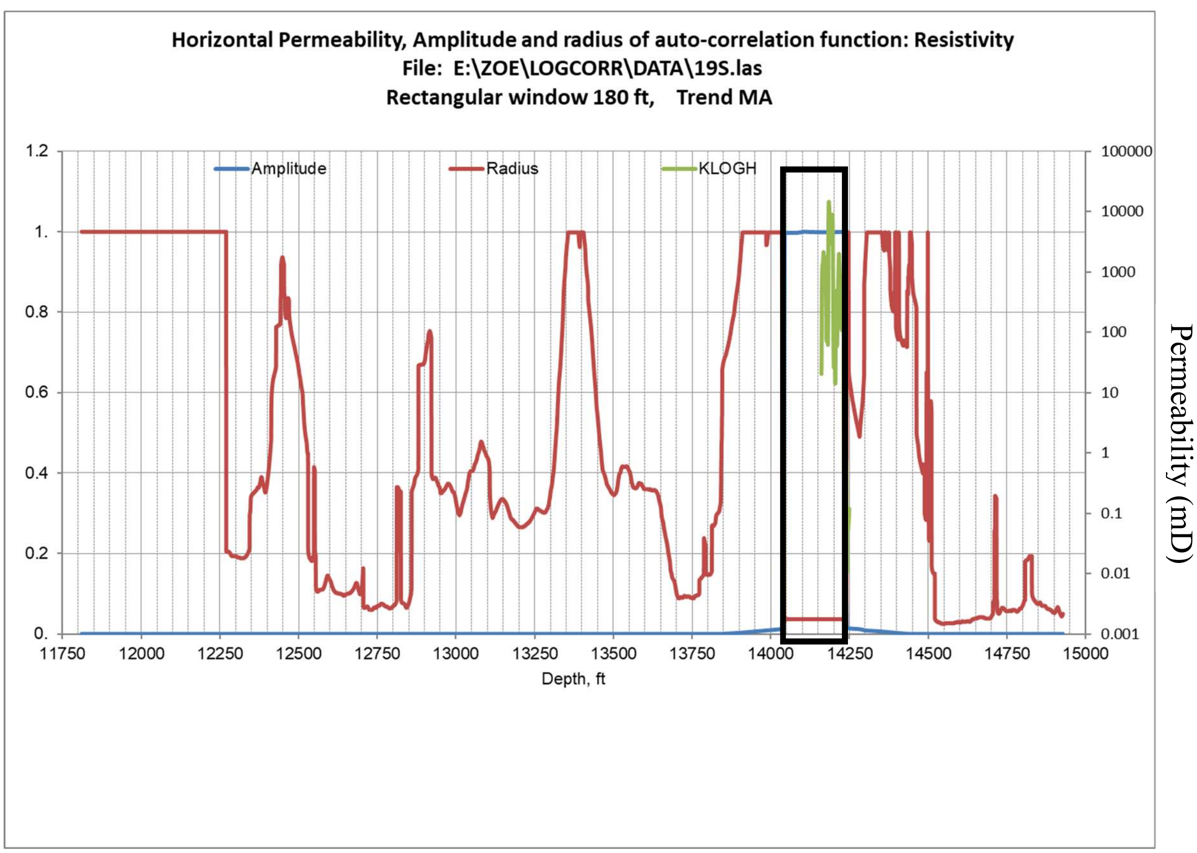
A2: Amplitude, Radius, Horizontal Permeability vs. Depth

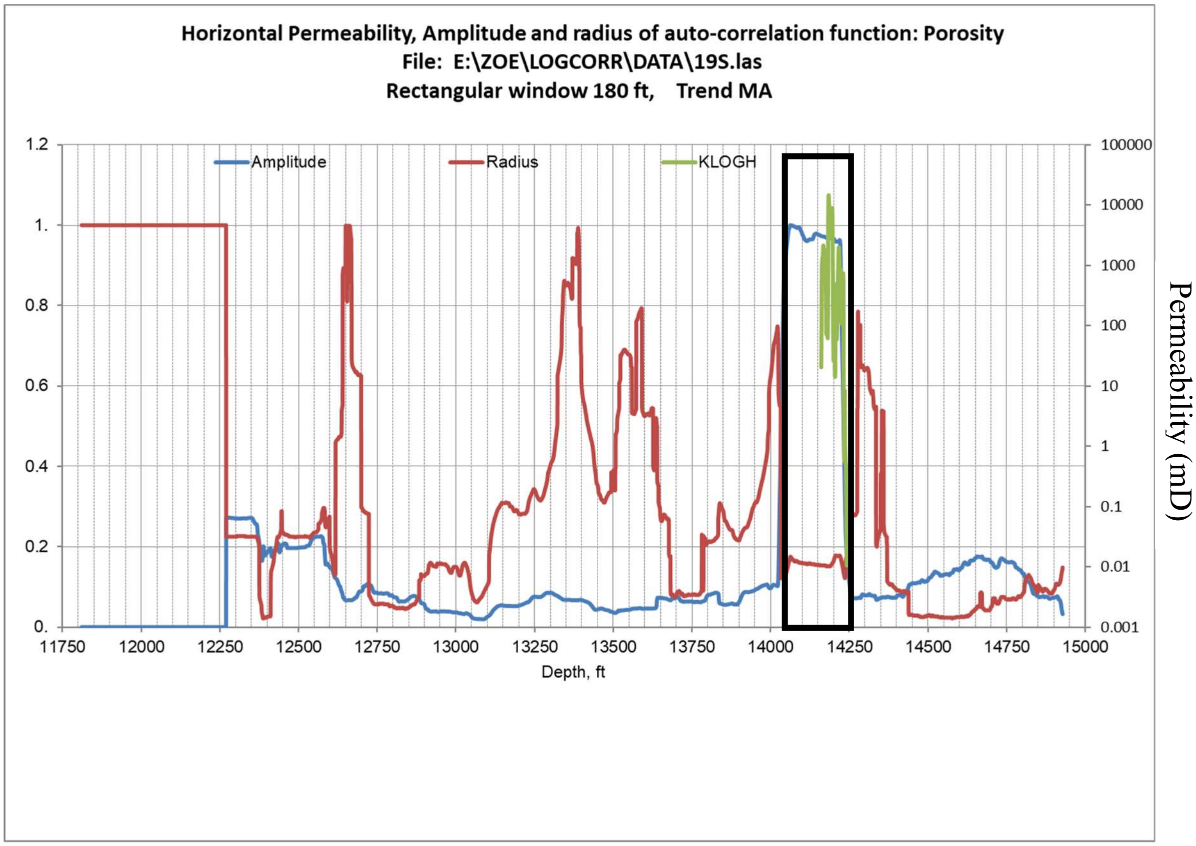
Section A2 contains plots with permeability included within the productive interval. In this particular well (15/9-19S), both horizontal and vertical permeabilities were available. This section focuses on the horizontal permeabilities that were available. As anticipated and expected, permeabilities increases and are high within the productive interval. As the correlation radius increases (and amplitude decreases) within the productive interval, permeability is seen to decrease as well.

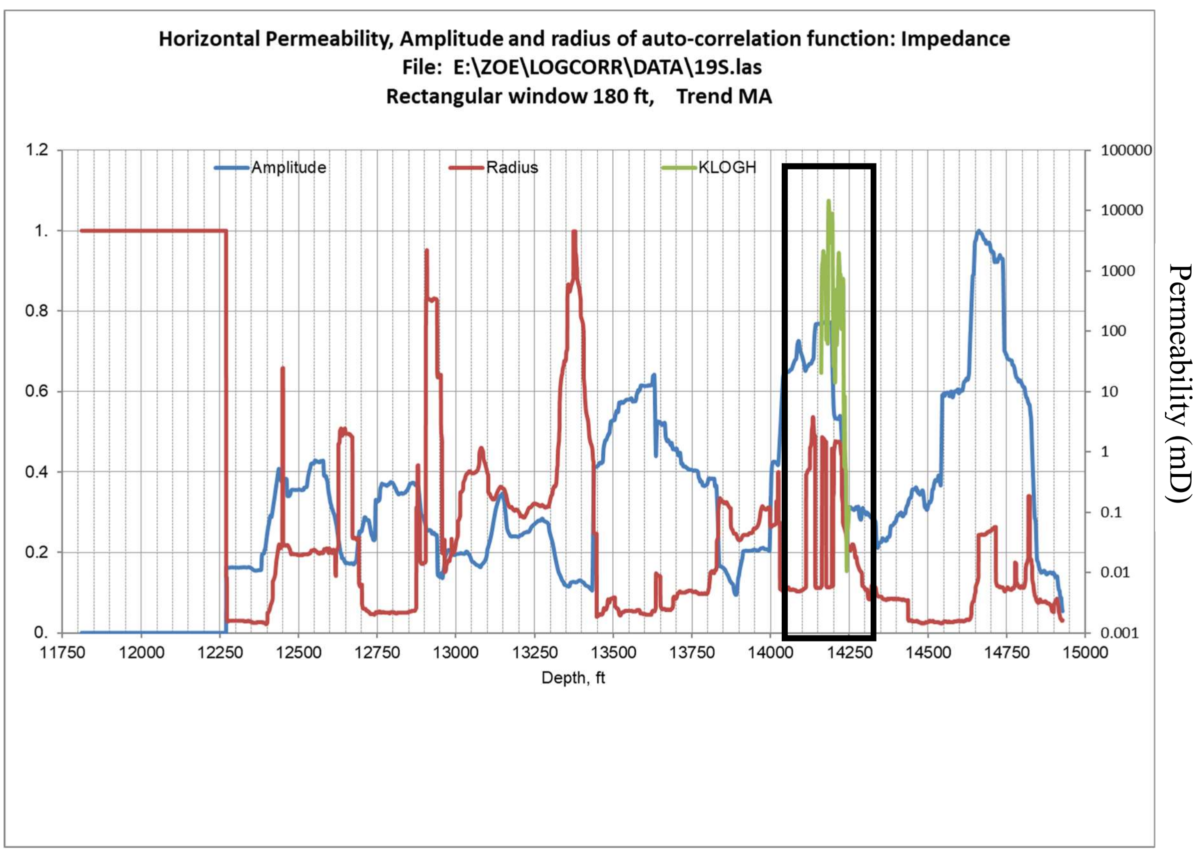

Horizontal Permeability, Amplitude and radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

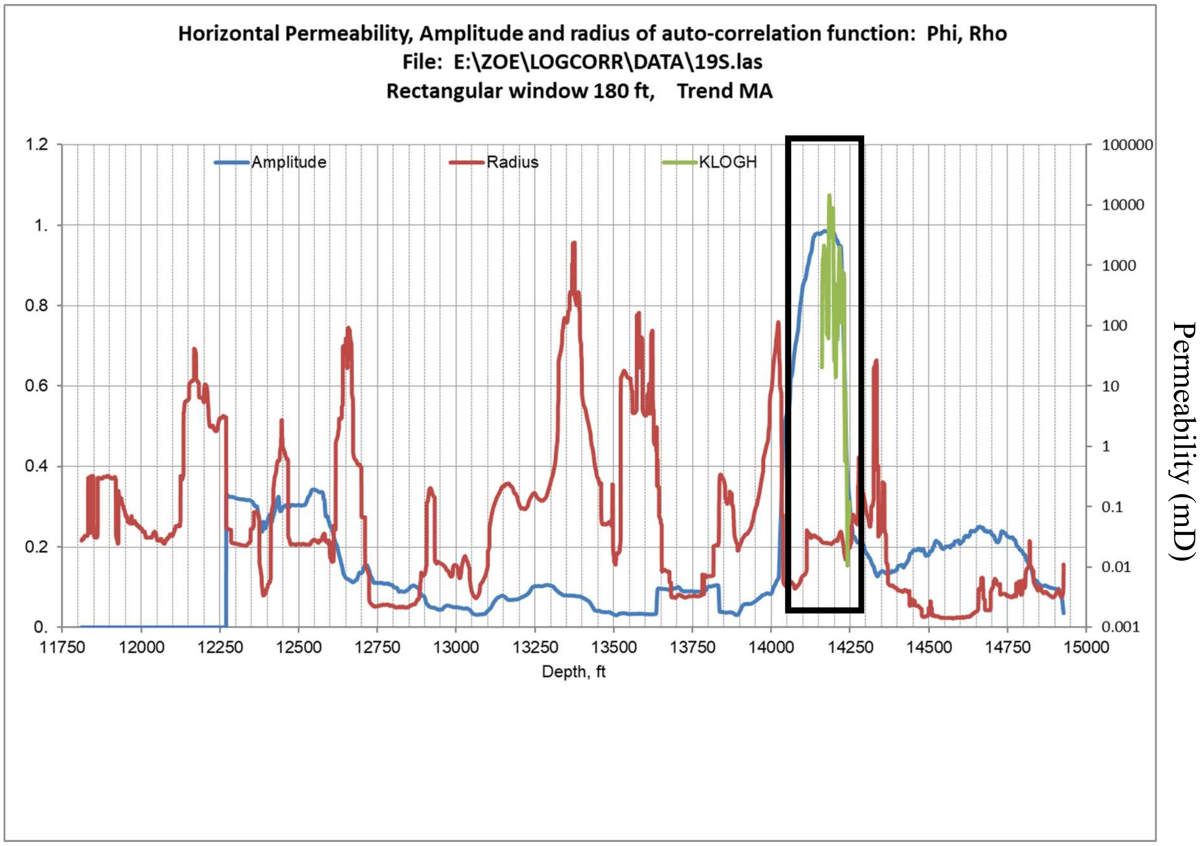

Horizontal Permeability, Amplitude and radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, Amplitude and radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

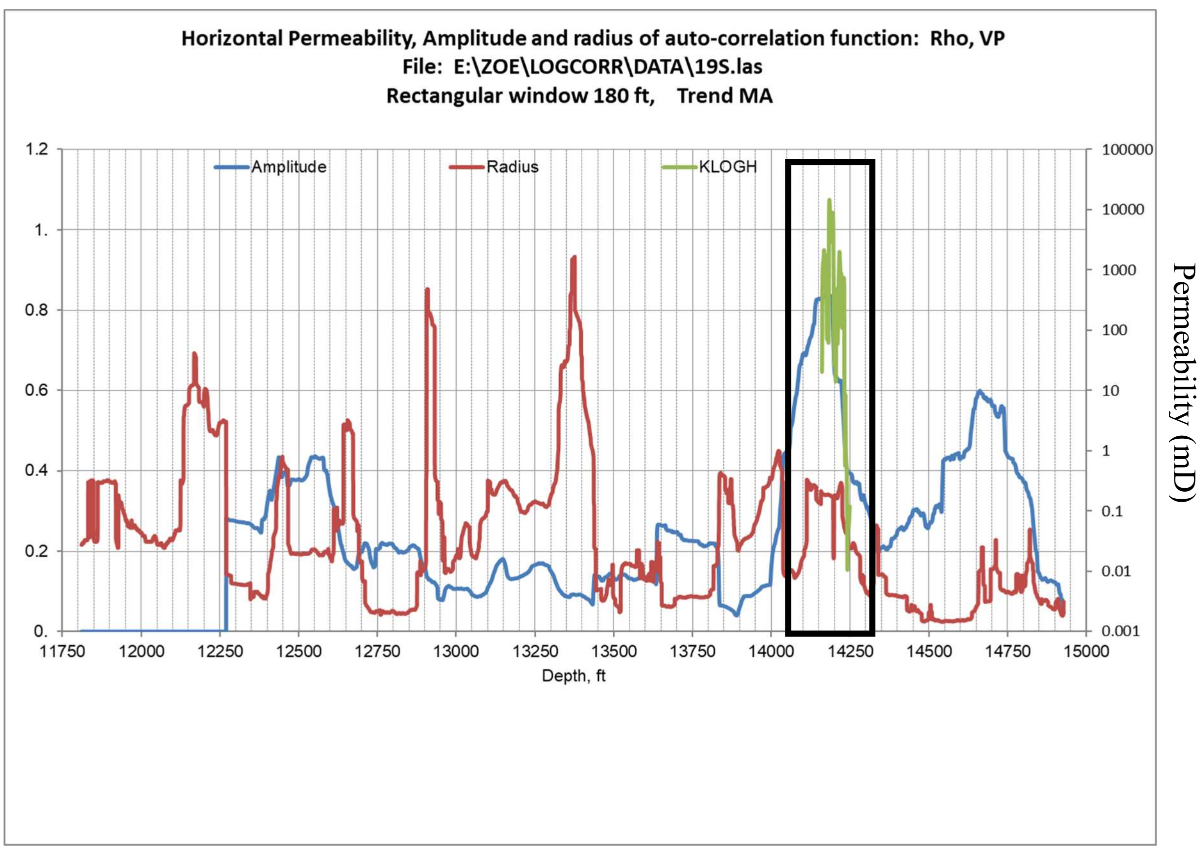

Horizontal Permeability, Amplitude and radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, Amplitude and radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

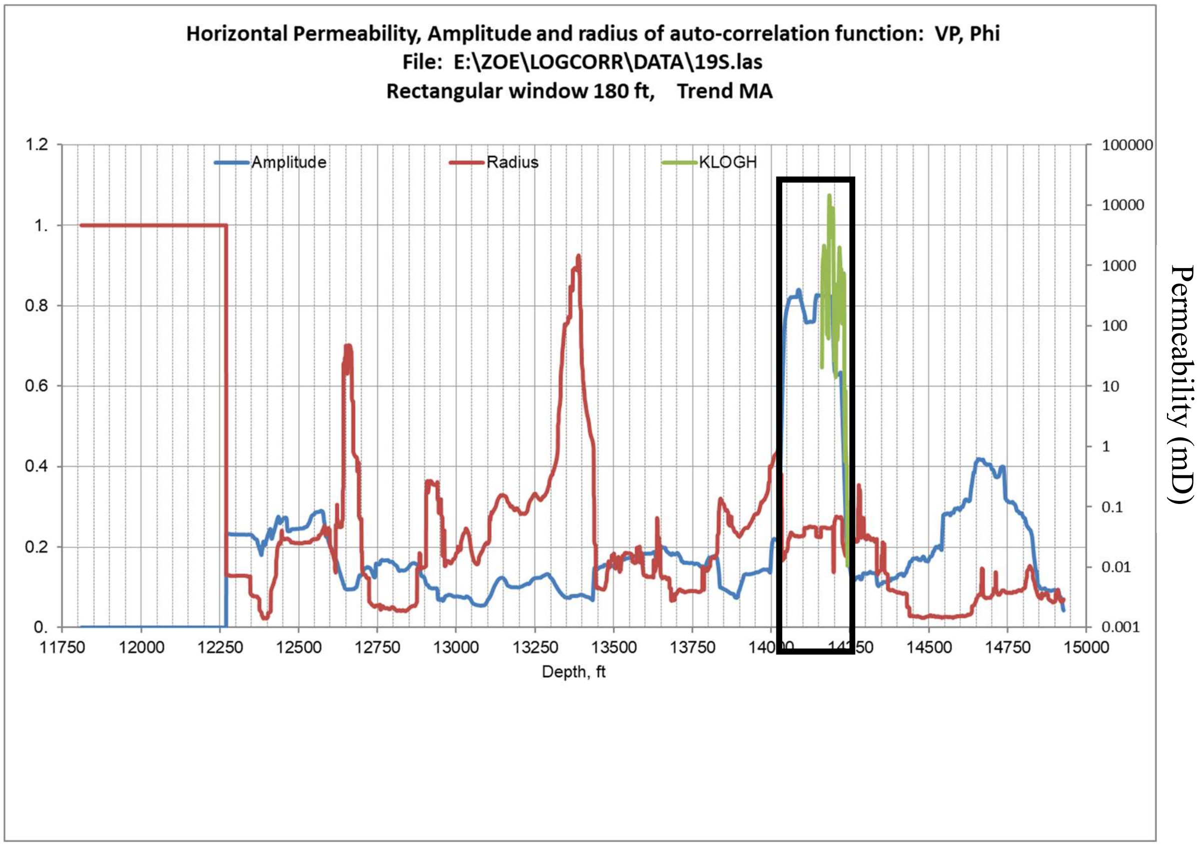

Horizontal Permeability, Amplitude and radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)



Horizontal Permeability, Amplitude and radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)



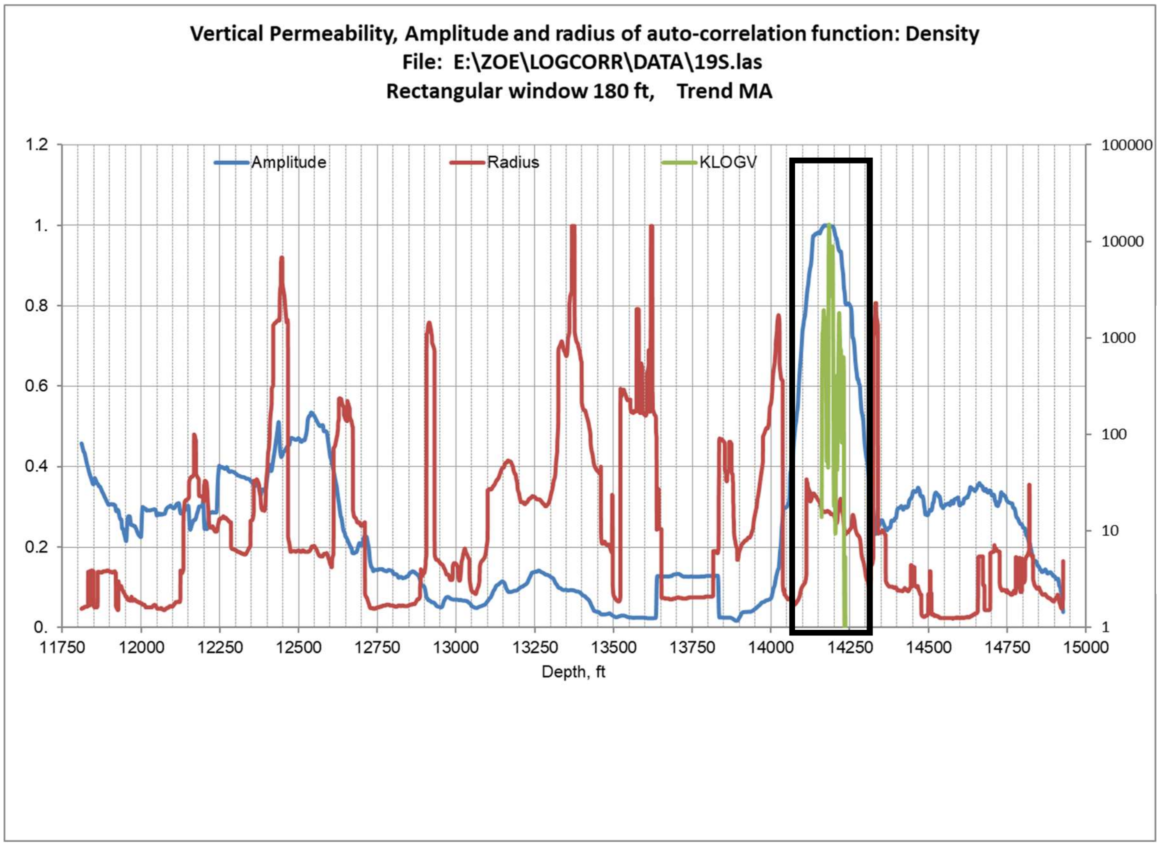
Horizontal Permeability, Amplitude and radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

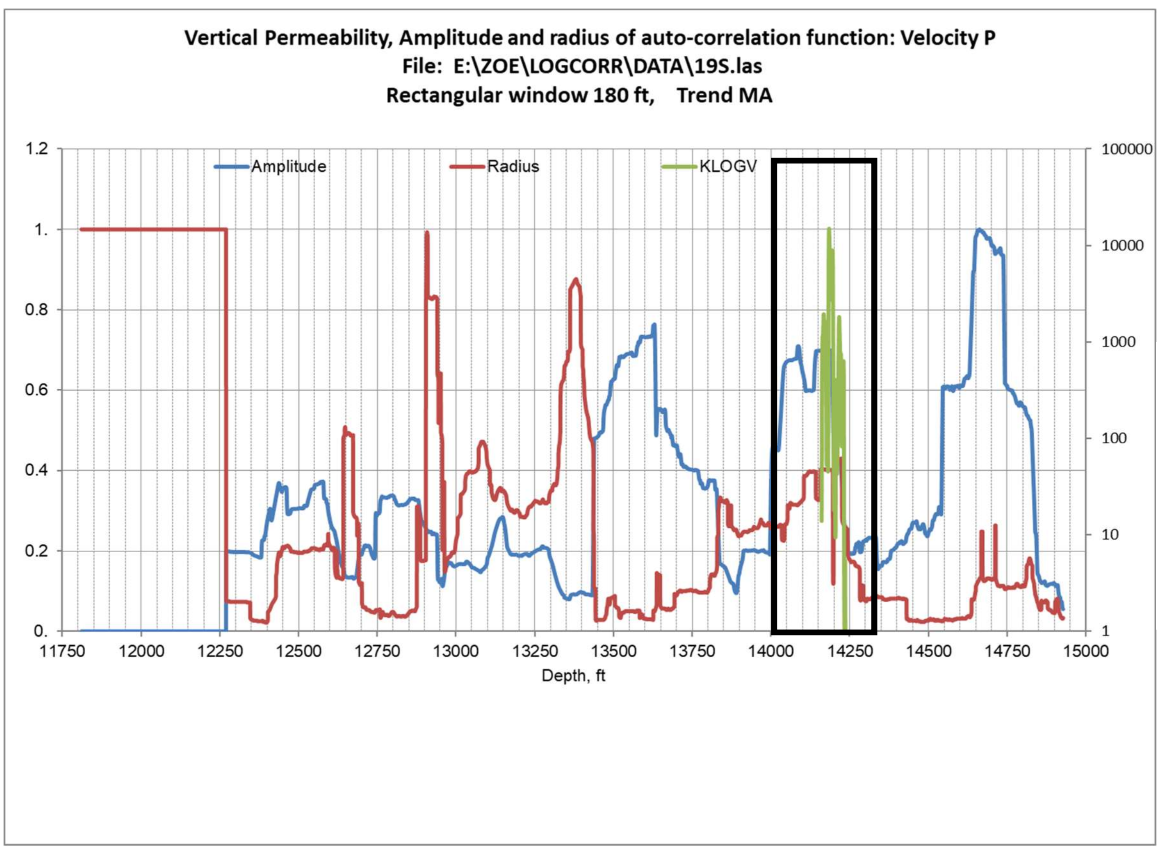

Horizontal Permeability, Amplitude and radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

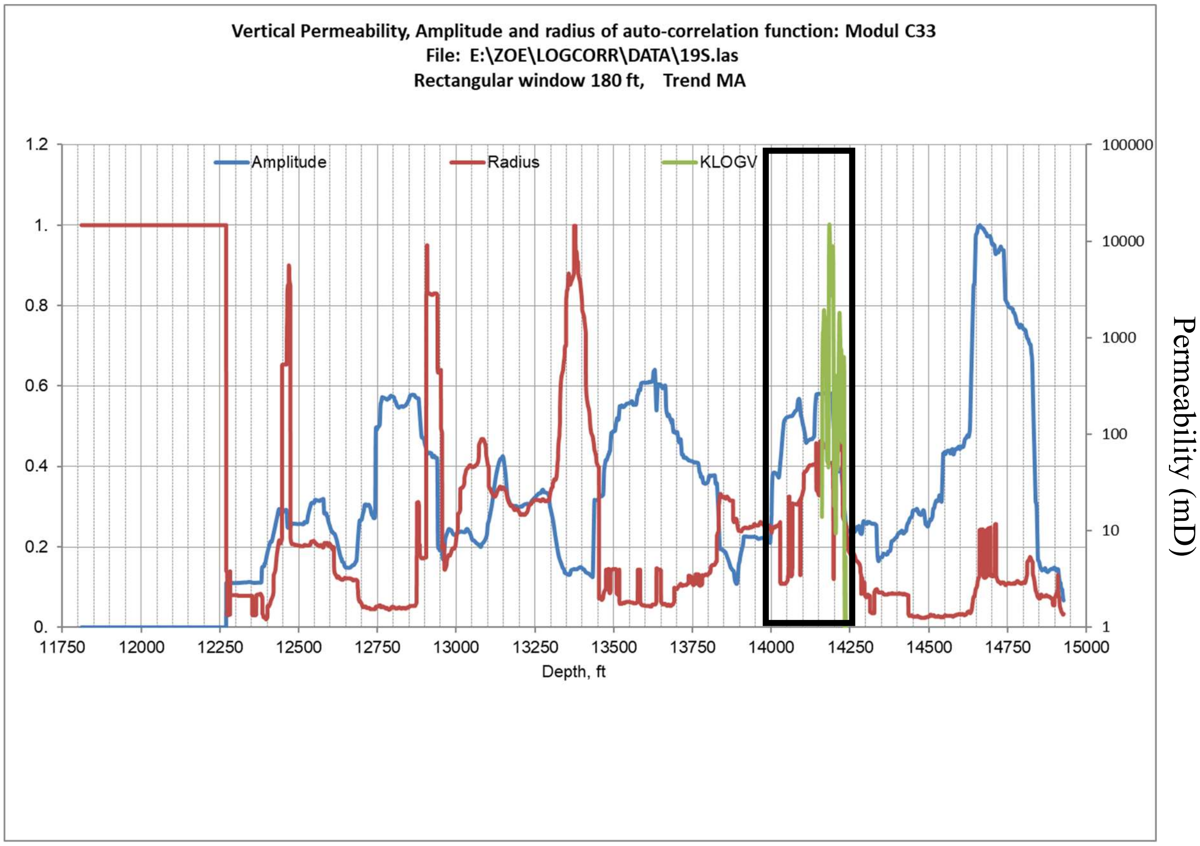
A3: Amplitude, Radius, Vertical Permeability vs. Depth

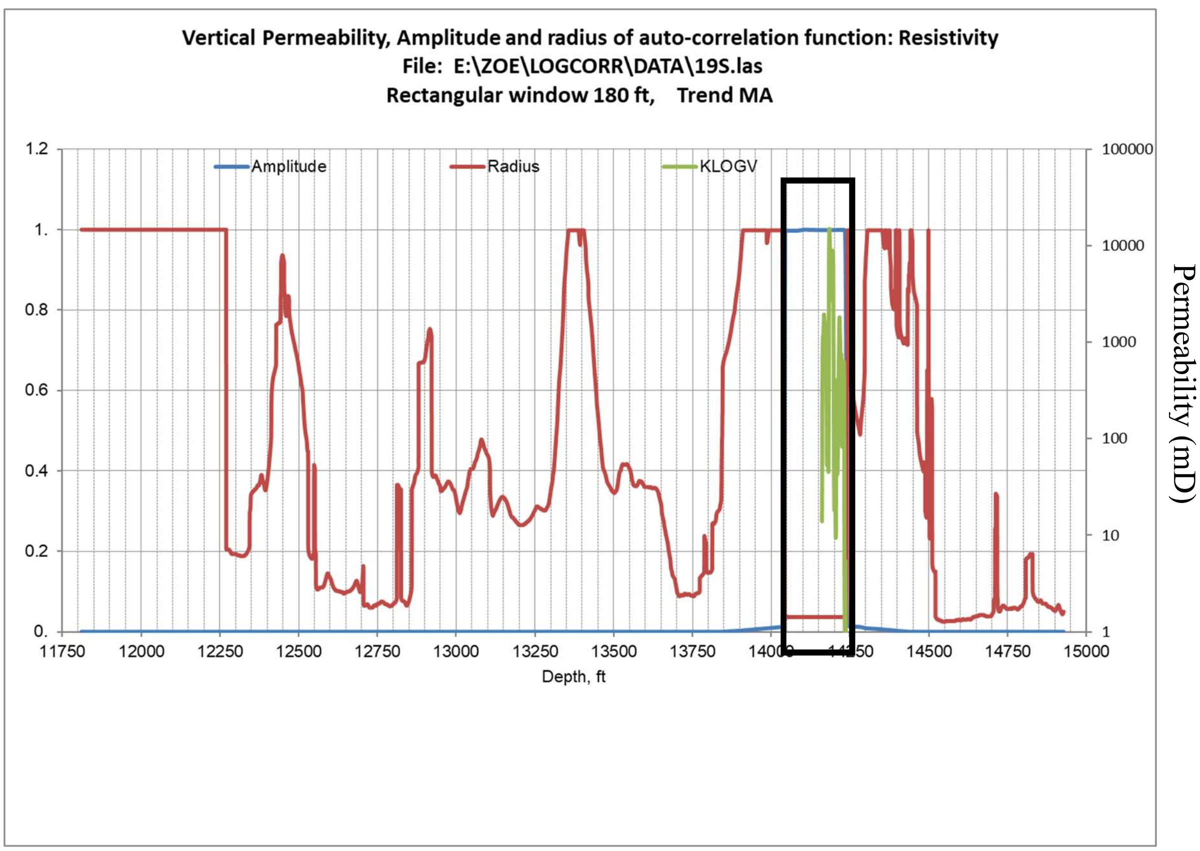
A3: Amplitude, Radius, Vertical Permeability vs. Depth

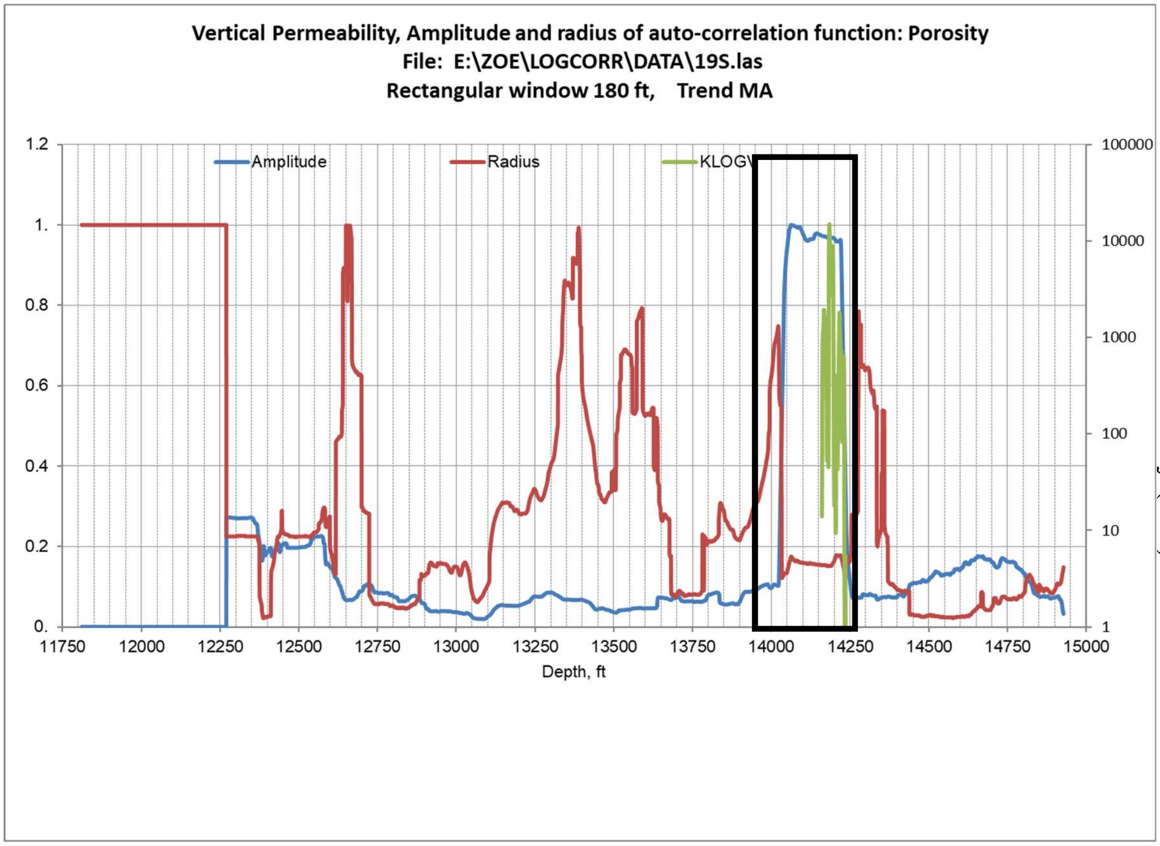
Section A3 contains plots with permeability included within the productive interval. In this particular well (15/9-19S), both horizontal and vertical permeabilities were available. This section focuses on the vertical permeabilities that were available. Similar to section A2, permeabilities increases and are high within the productive interval. As the correlation radius increases (and amplitude decreases) within the productive interval, permeability is seen to decrease as well.

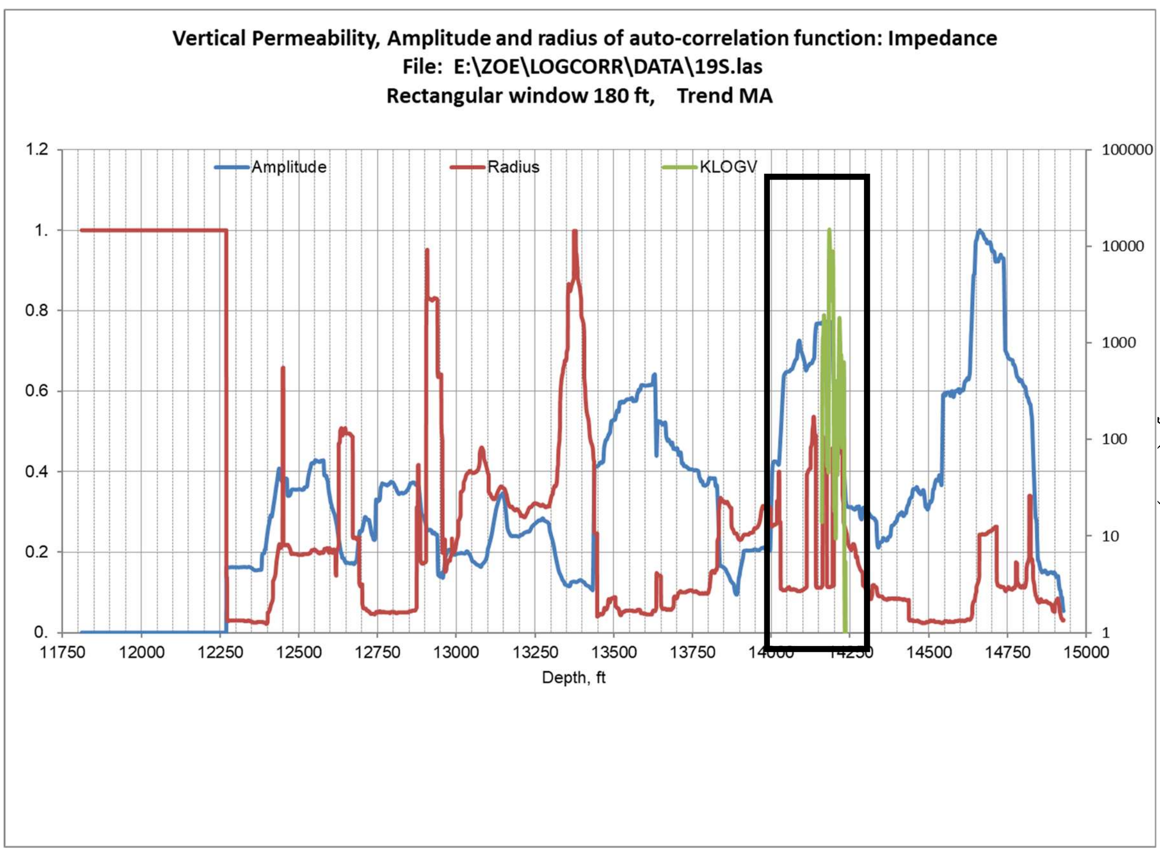

Vertical Permeability, Amplitude and radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
11750 12000 12250 12500 12750 13000 13250 13500 13750 14000 14250 14500 14750 15000
Depth, ft
Permeability (mD)

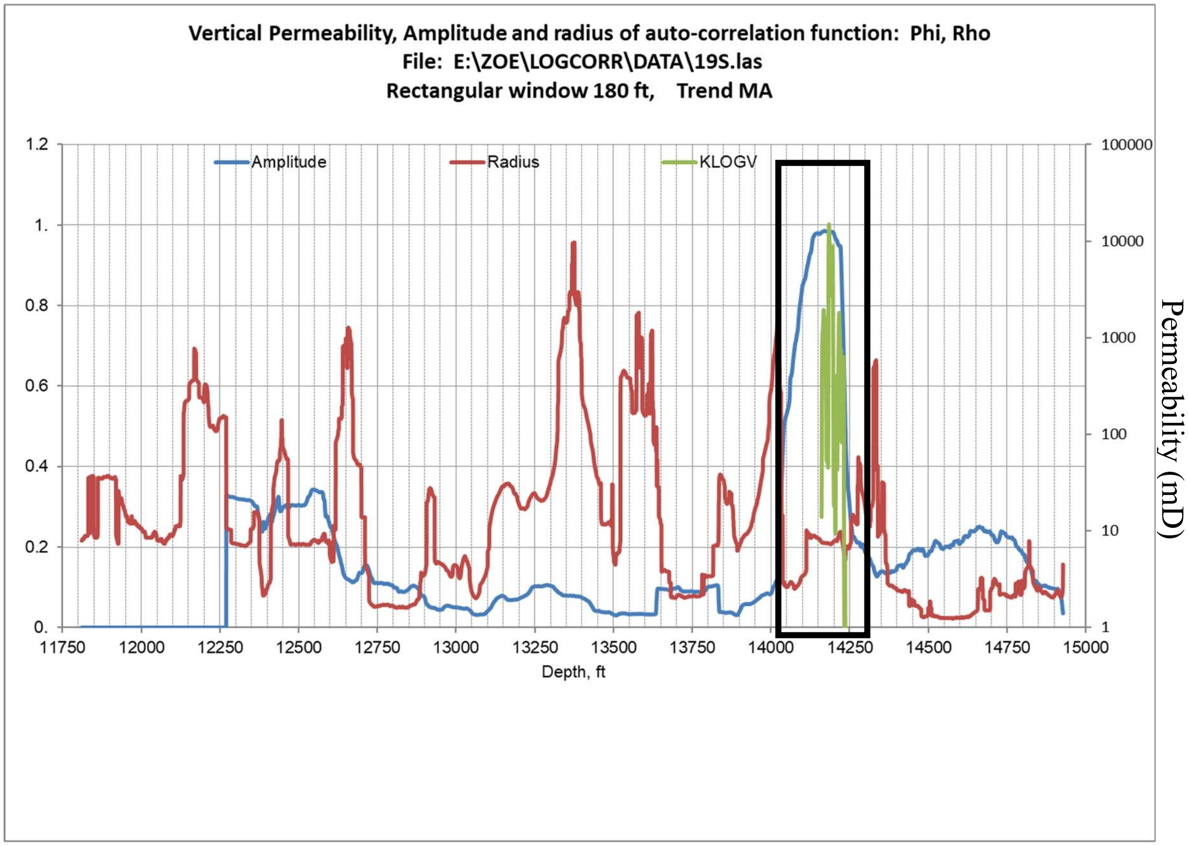

Vertical Permeability, Amplitude and radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
11750 12000 12250 12500 12750 13000 13250 13500 13750 14000 14250 14500 14750 15000
Depth, ft
Permeability (mD)

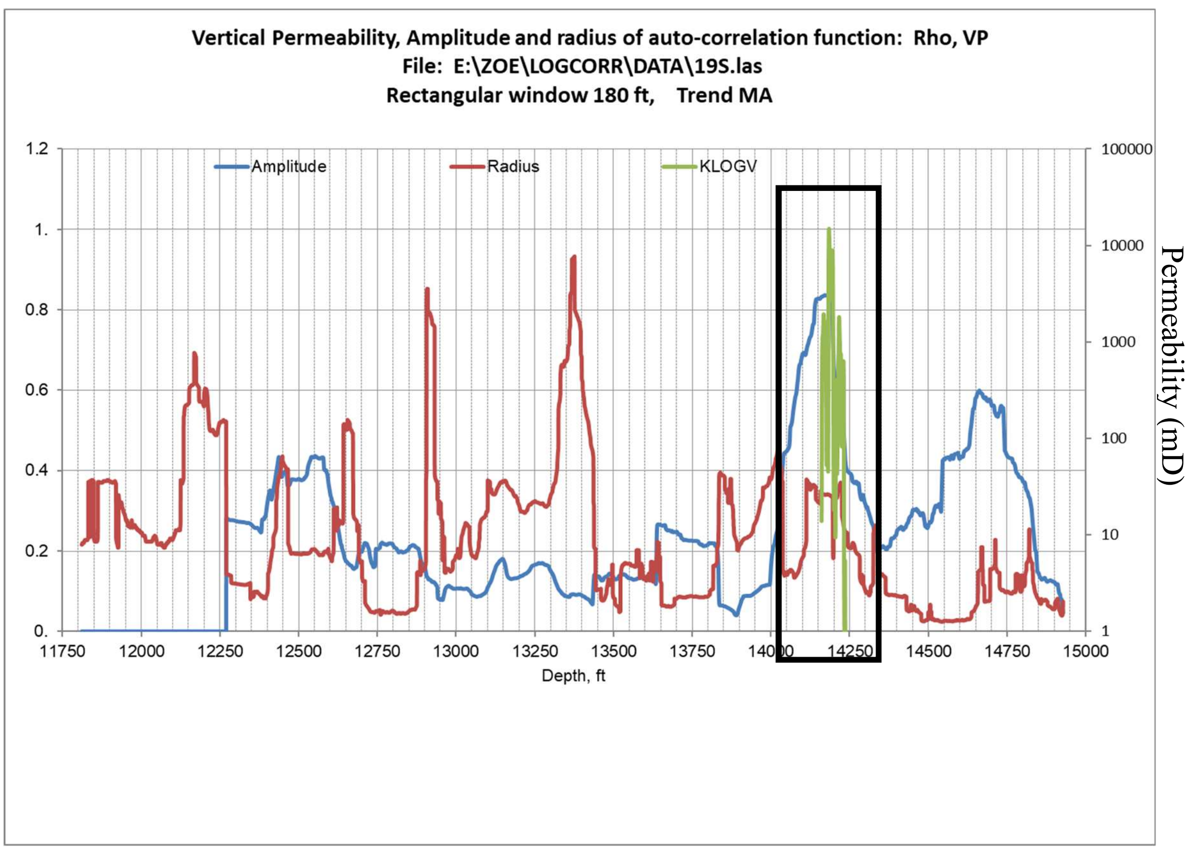

Vertical Permeability, Amplitude and radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)

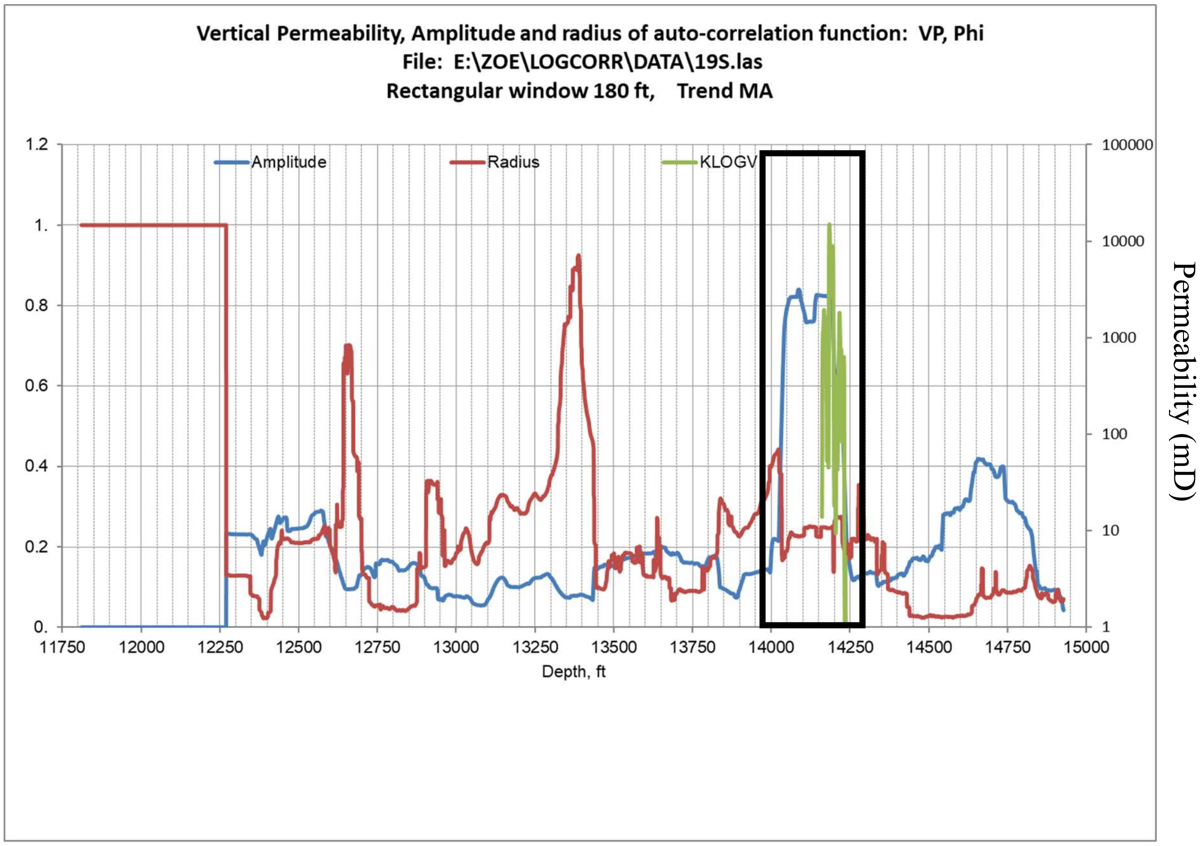

Vertical Permeability, Amplitude and radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude and radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude and radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude and radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)

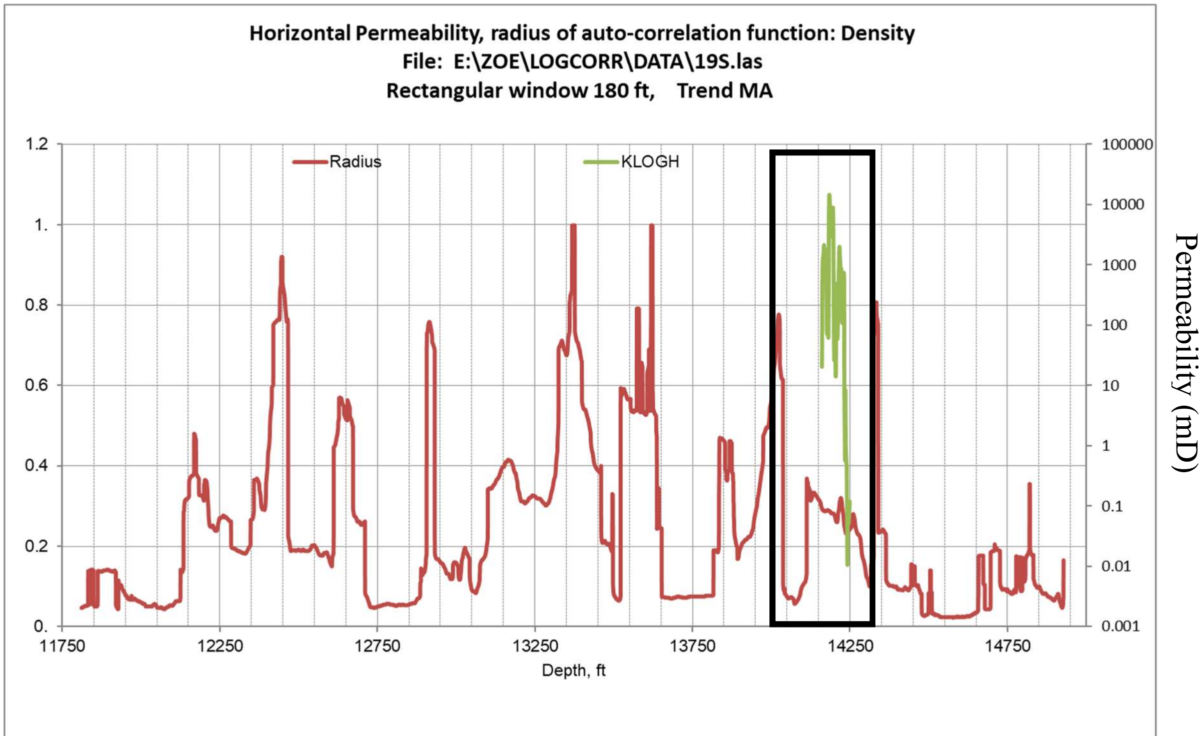

Vertical Permeability, Amplitude and radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude and radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft
Permeability (mD)

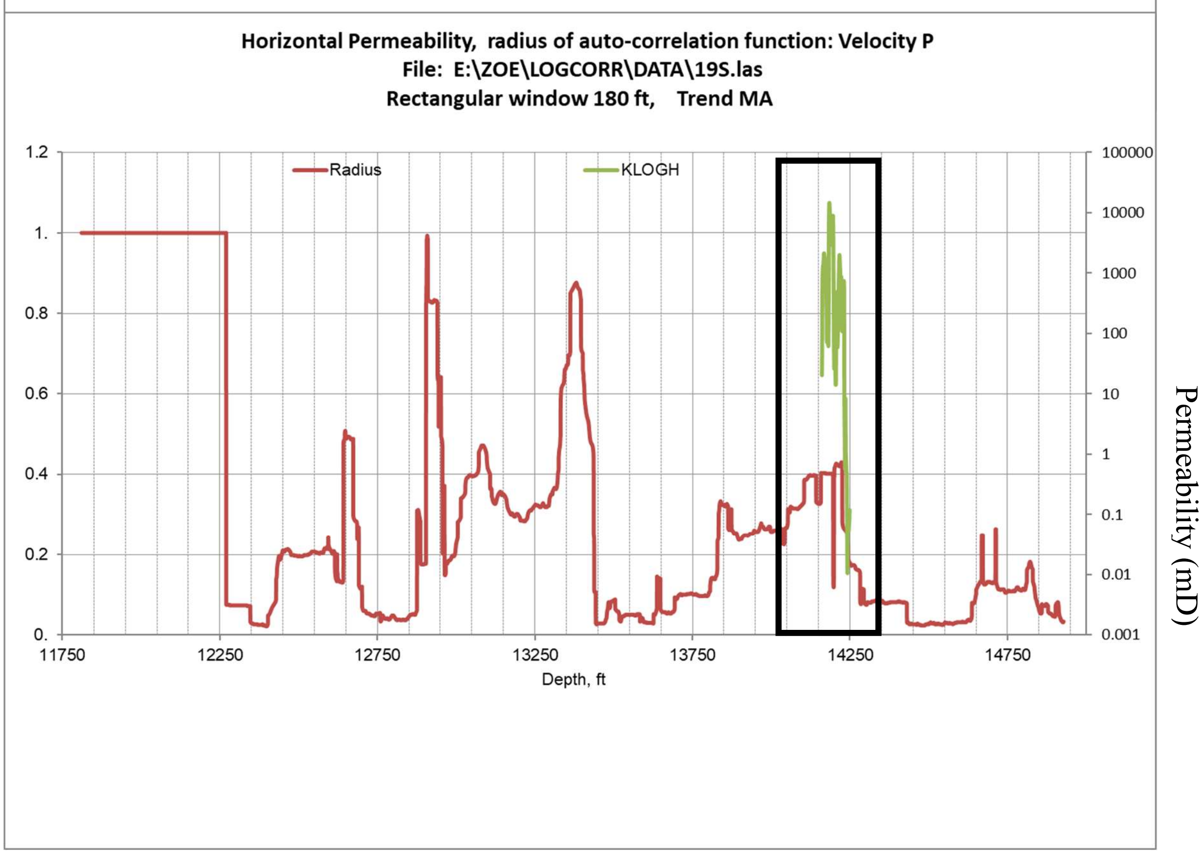
A4: Correlation Radius, Horizontal Permeability vs. Depth

A4: Correlation Radius, Horizontal Permeability vs. Depth

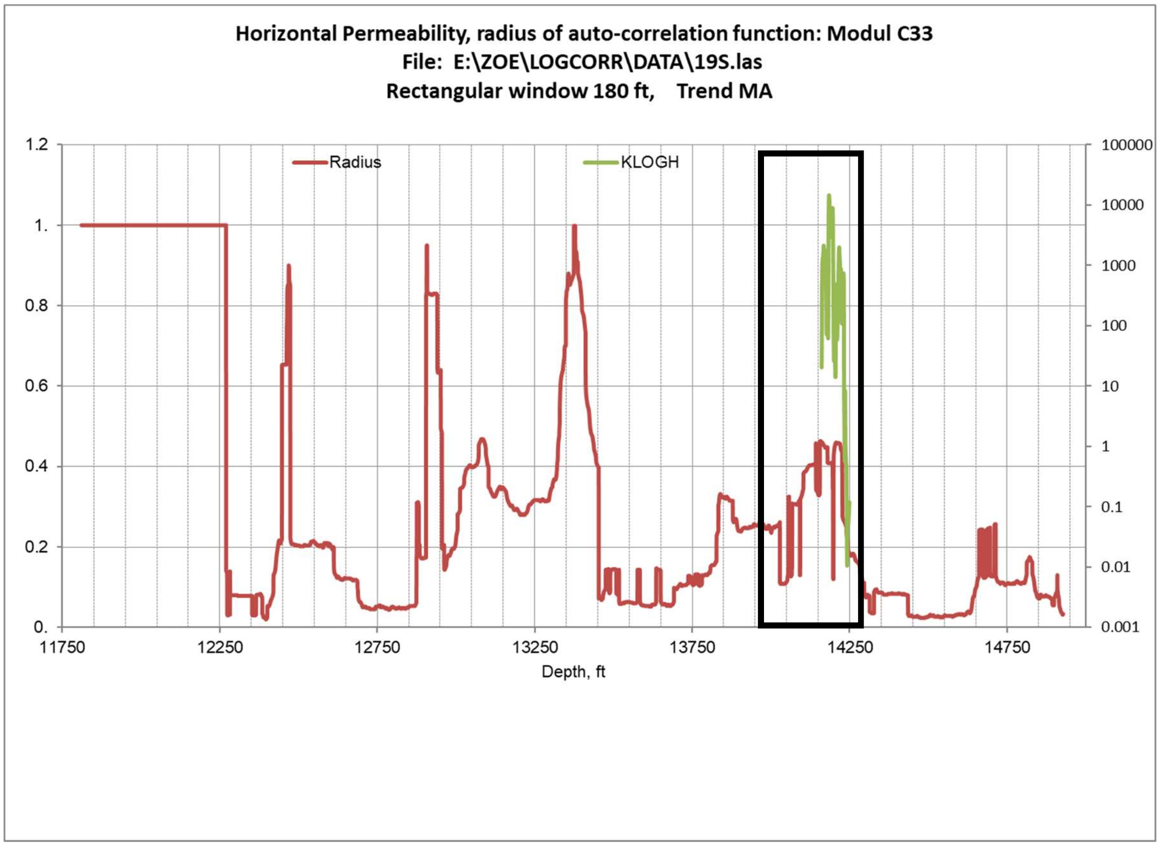
Section A4 contains plots focusing on the behavior of correlation radius and permeability. In this particular well (15/9-19S), both horizontal and vertical permeabilities were available. This section focuses on the horizontal permeabilities in conjunction with the correlation radius values. Permeabilities are expected to be higher as correlation radius decreases or is lower.

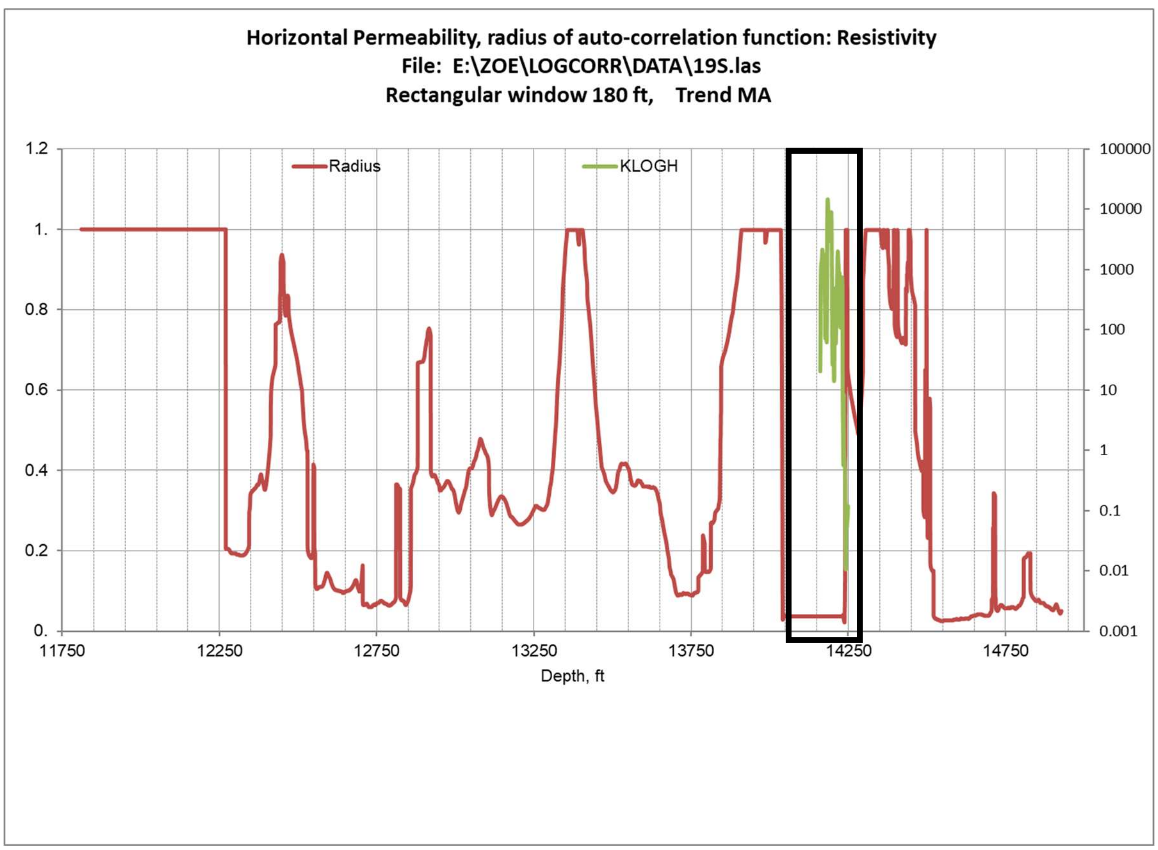


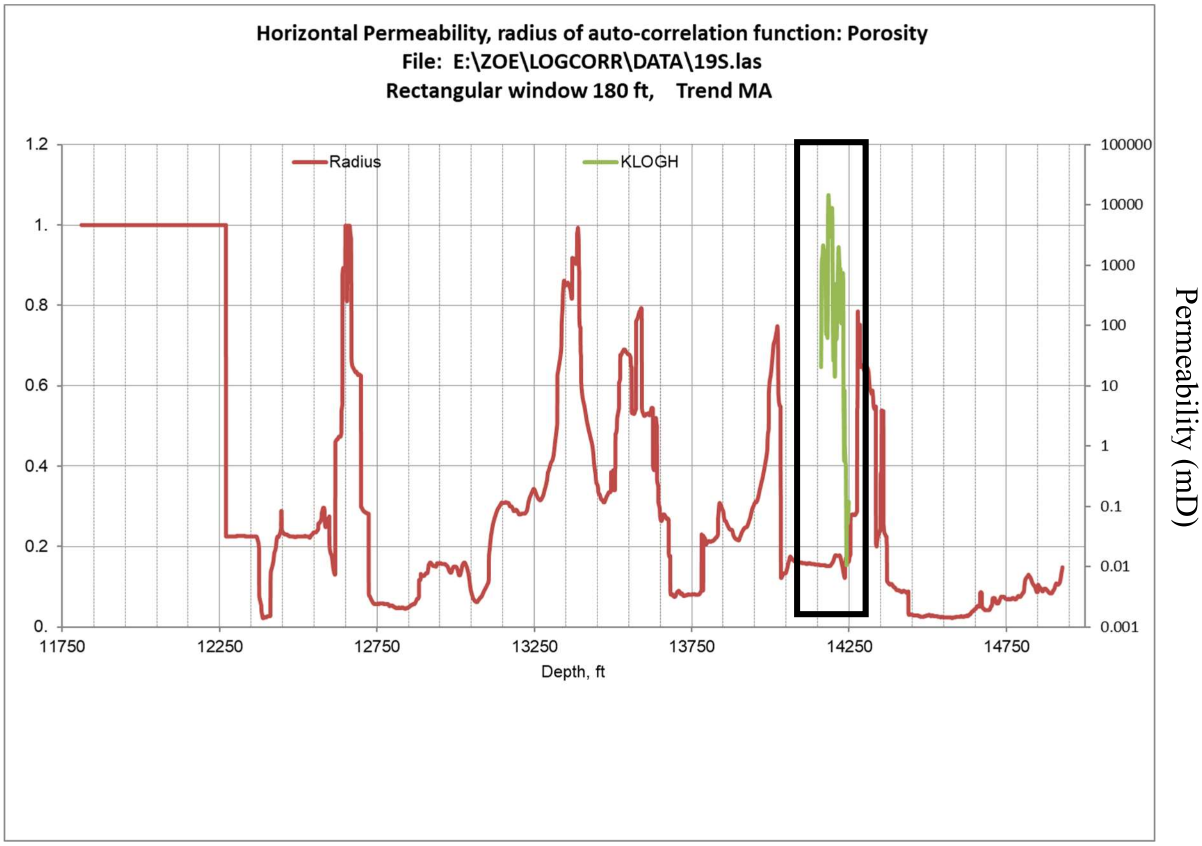
Horizontal Permeability, radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
0.1
0.01
0.001
Permeability (mD)

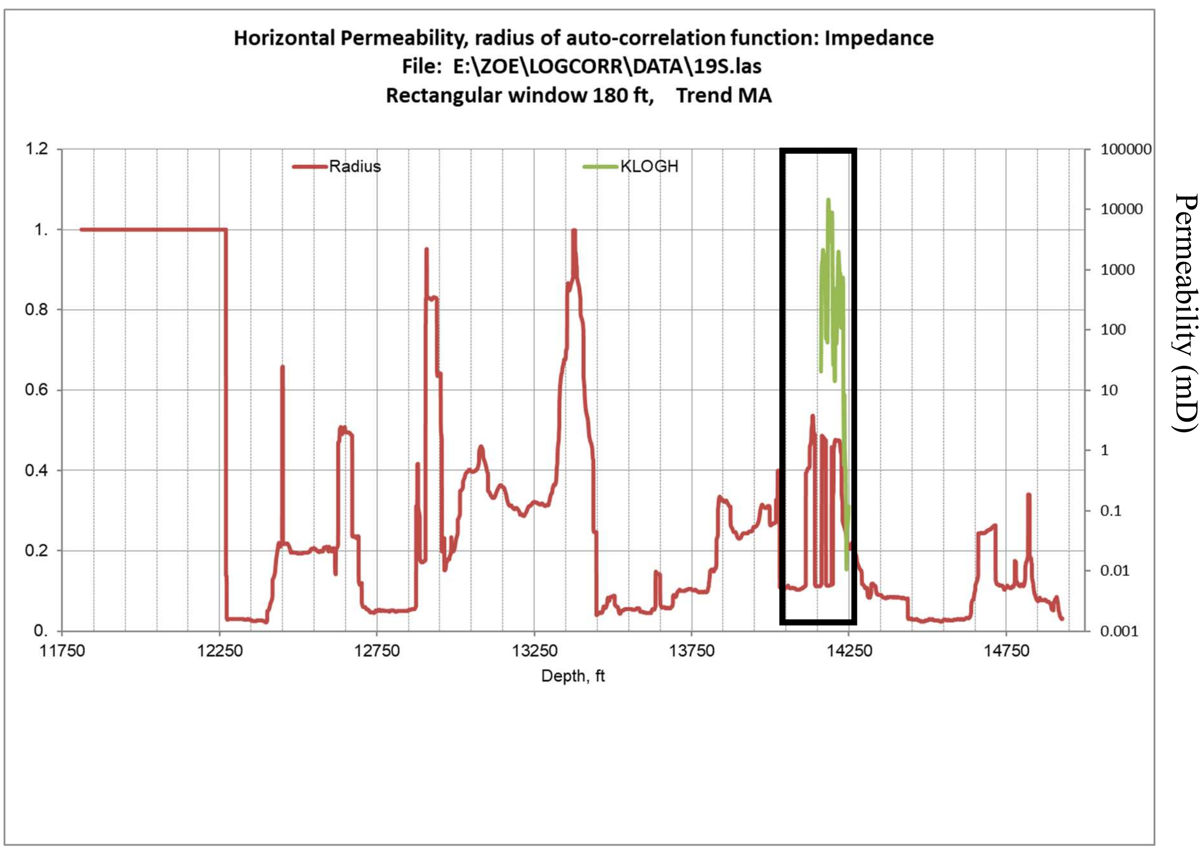


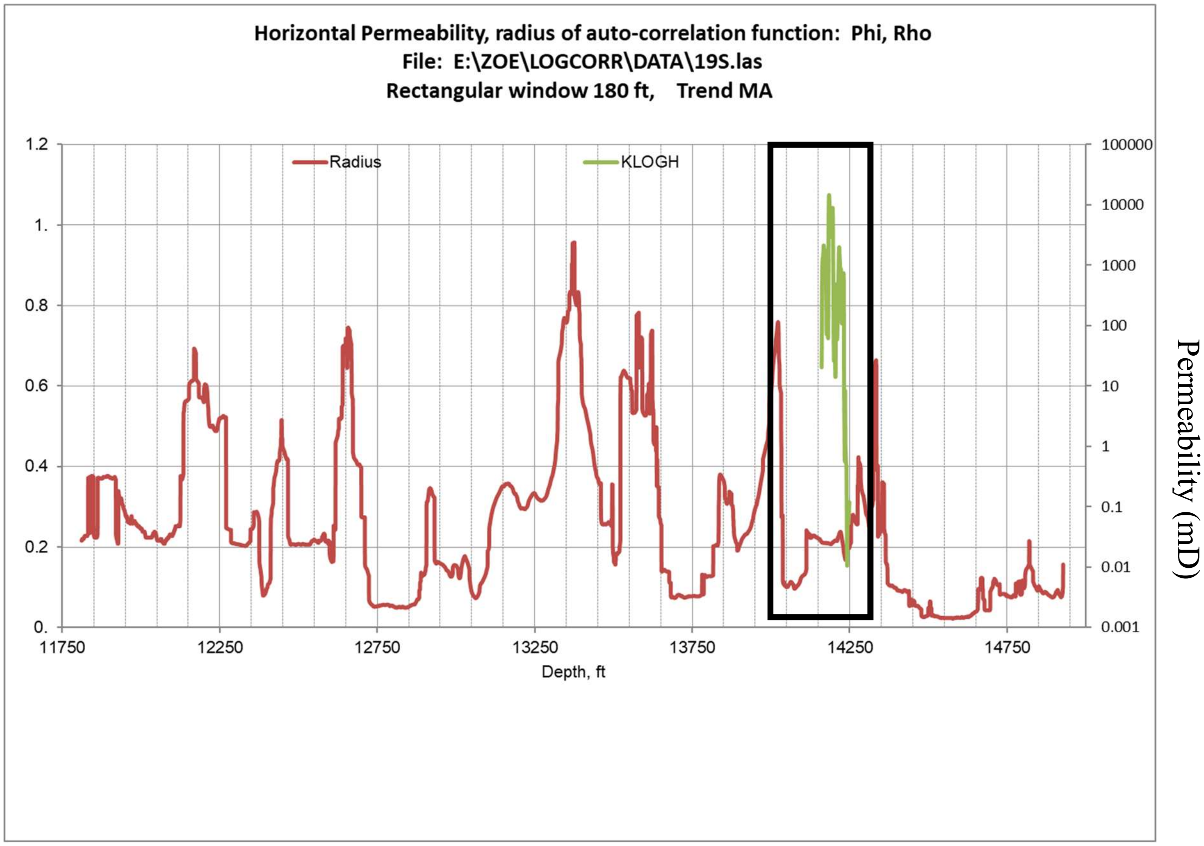
Horizontal Permeability, radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
0.1
0.01
0.001
Permeability (mD)

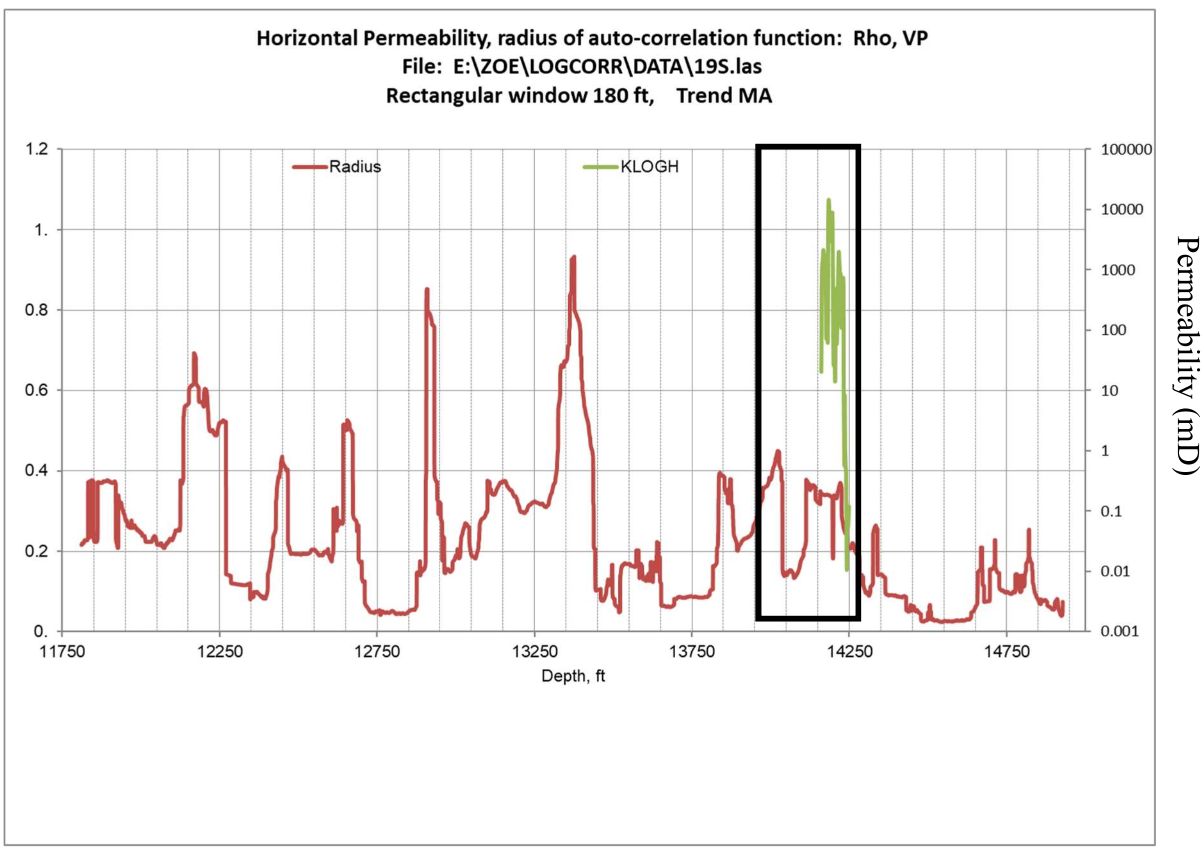

Horizontal Permeability, radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)

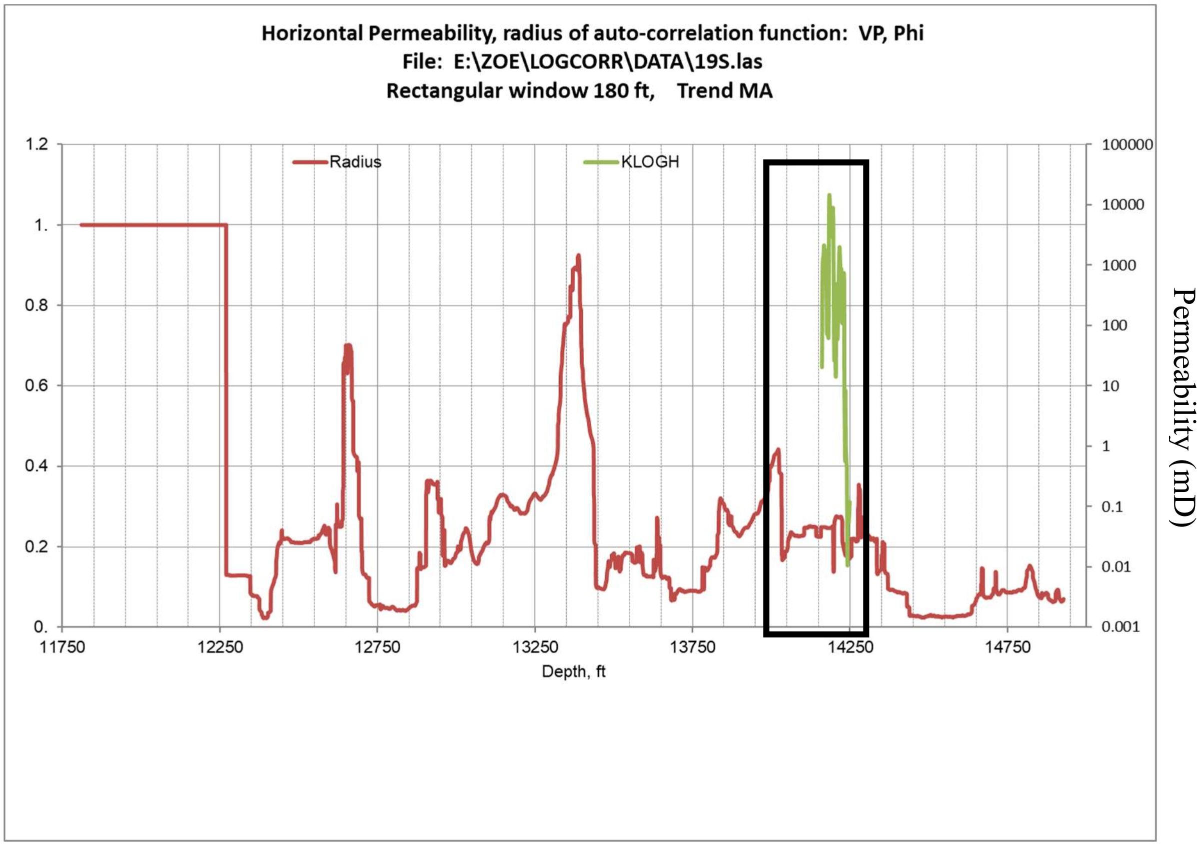

Horizontal Permeability, radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)

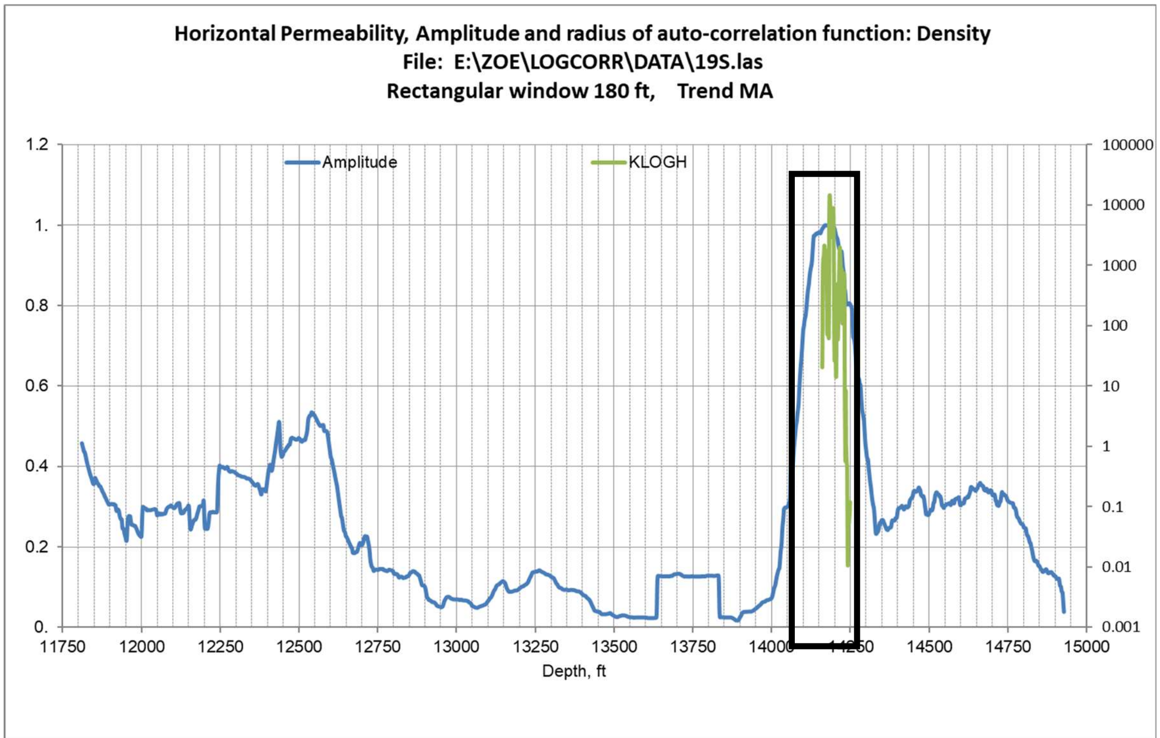


Horizontal Permeability, radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
0.1
0.01
0.001
11750
12250
12750
13250
13750
14250
14750
Depth, ft
Permeability (mD)

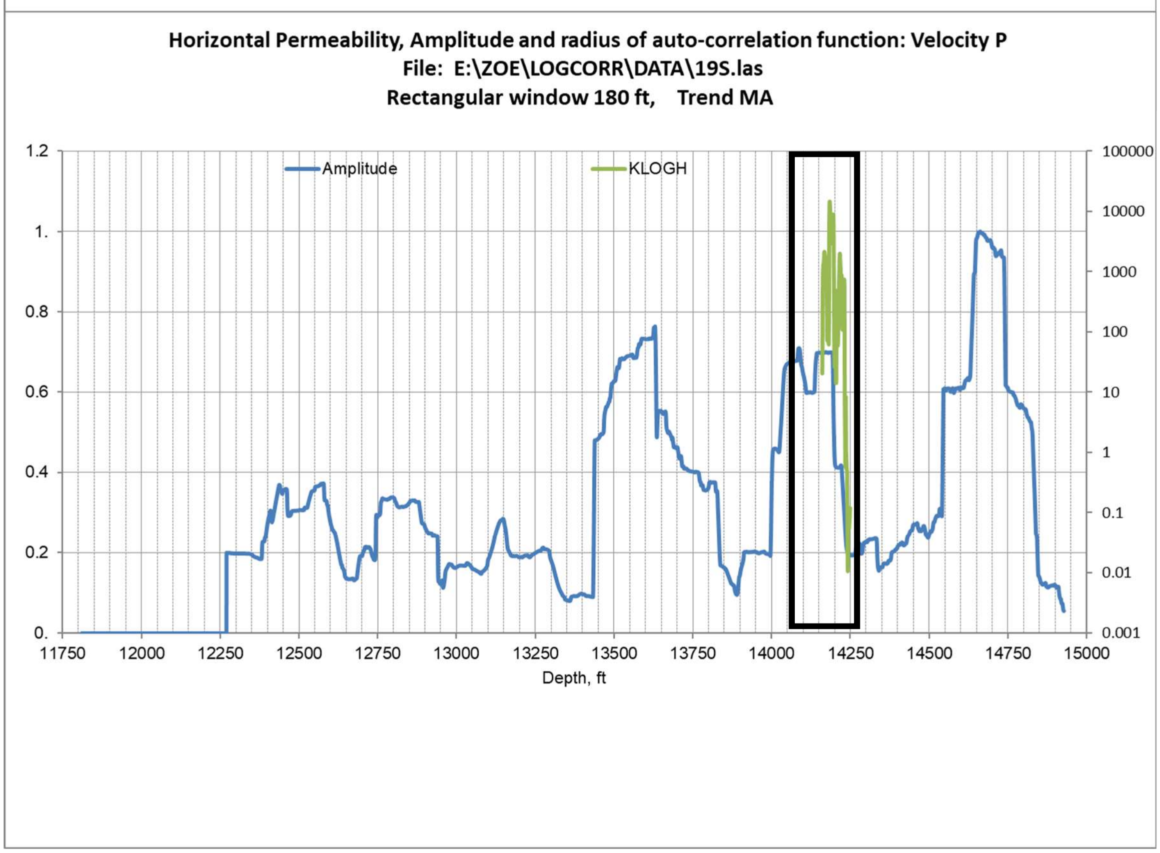
A5: Amplitude, Horizontal Permeability vs. Depth

A5: Amplitude, Horizontal Permeability vs. Depth

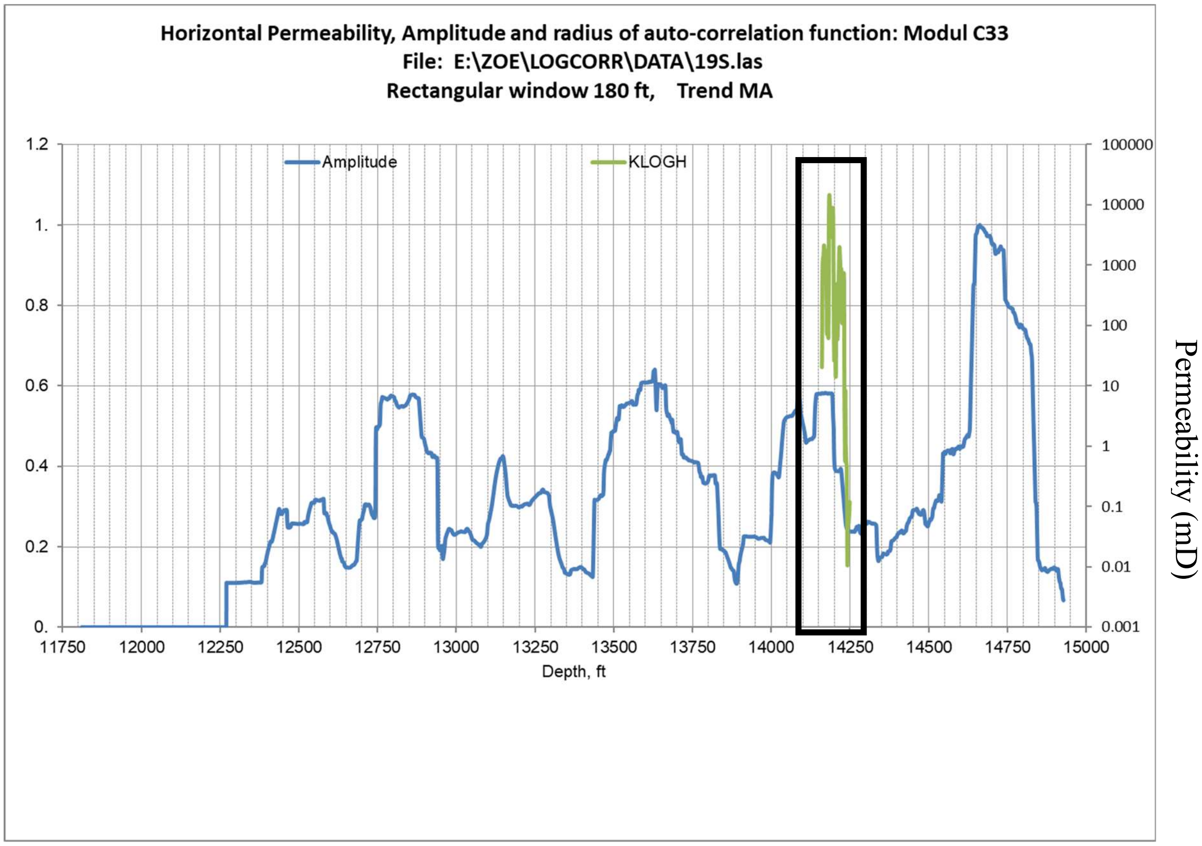
Section A5 contains plots focusing on the behavior of amplitude and permeability. In this particular well (15/9-19S), both horizontal and vertical permeabilities were available. This section focuses on the horizontal permeabilities in conjunction with the amplitude values. Permeabilities are expected to be higher where amplitudes are high or increasing.

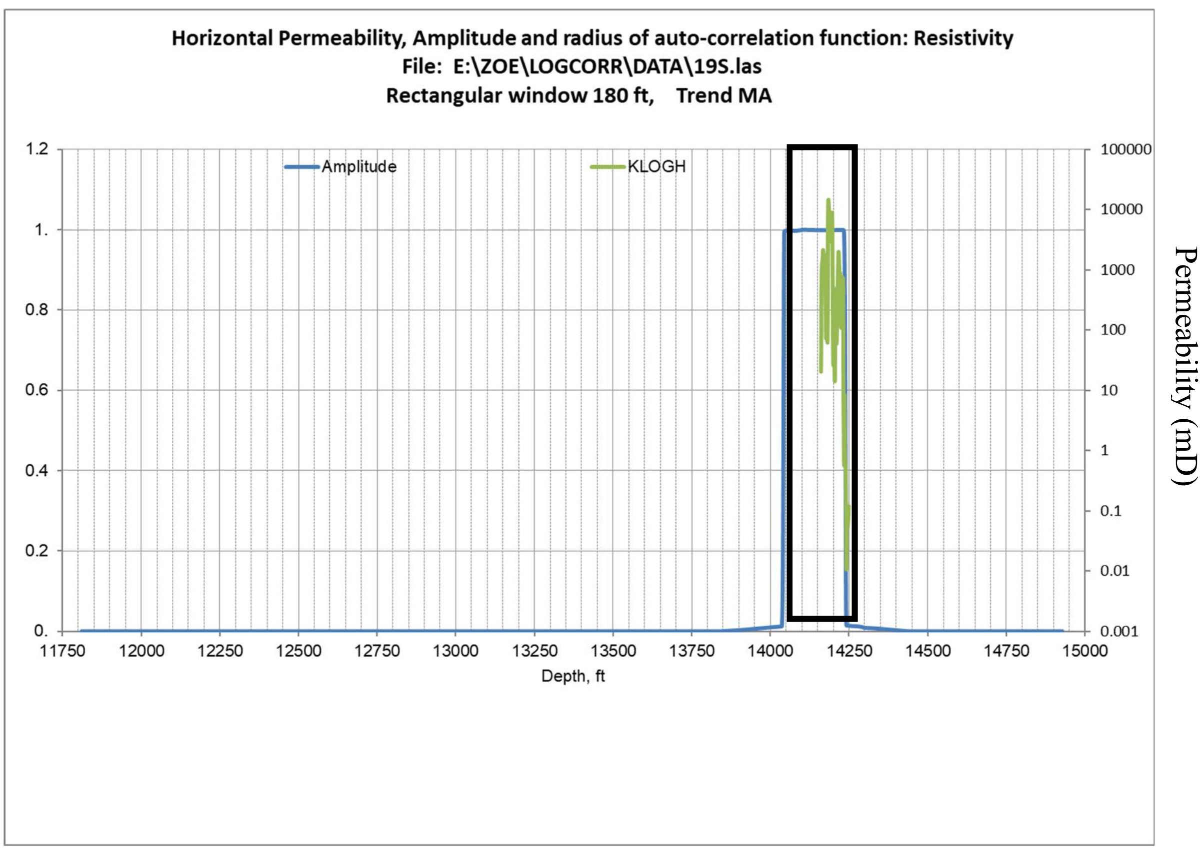


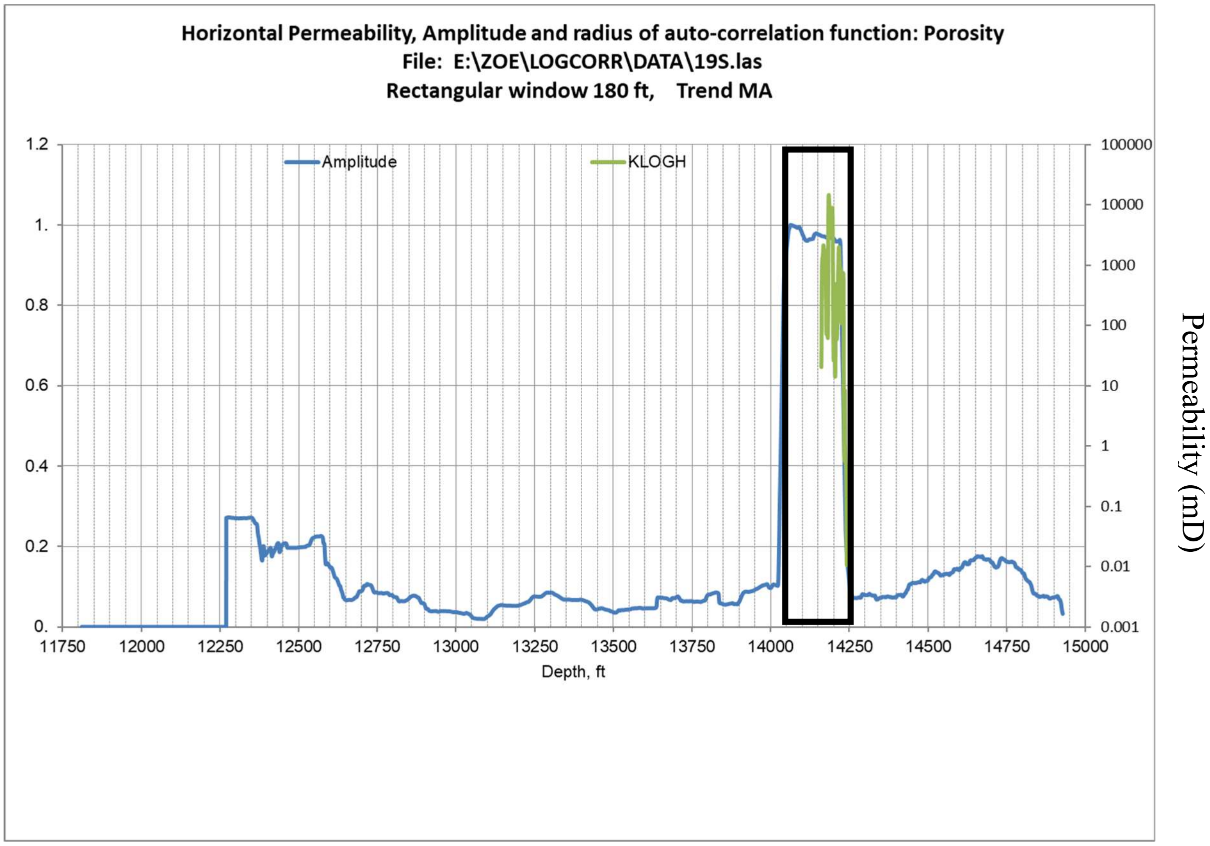
Permeability (mD)



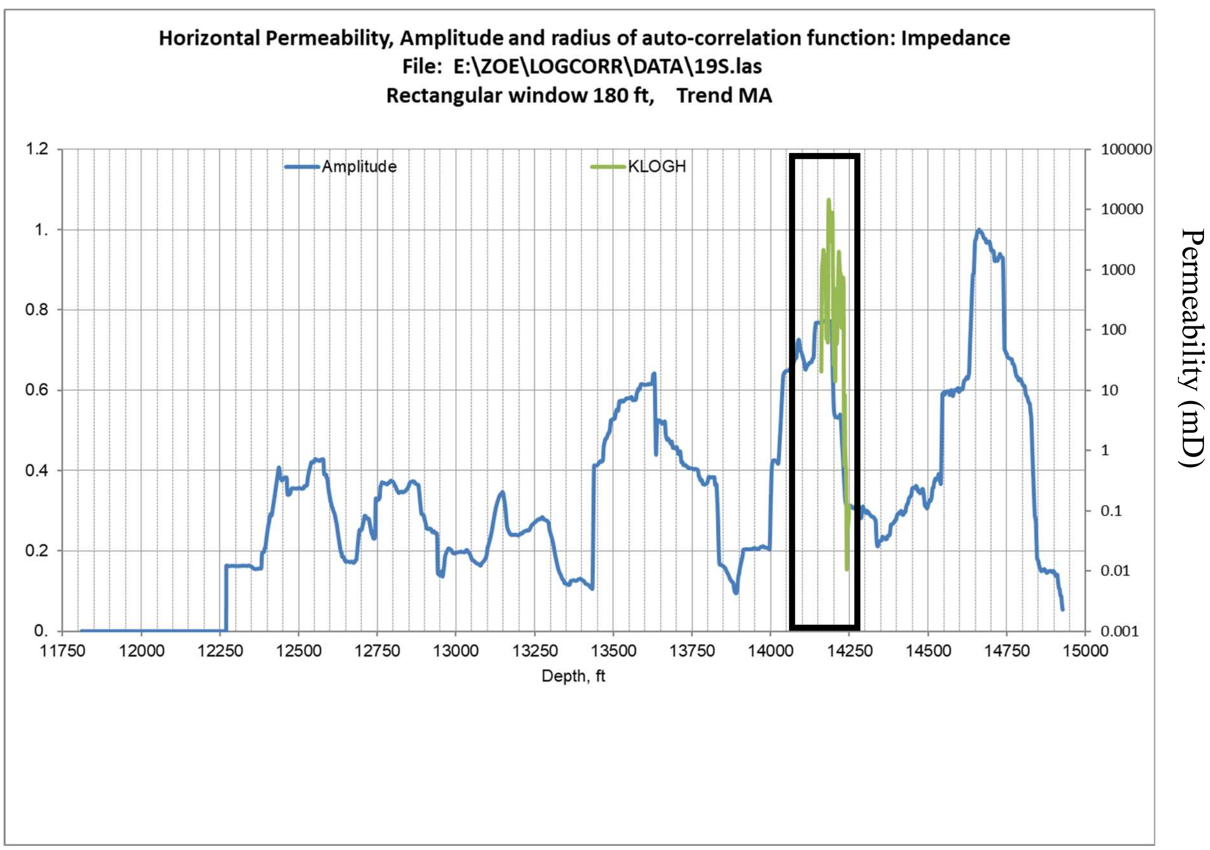
Permeability (mD)


Horizontal Permeability, Amplitude and radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

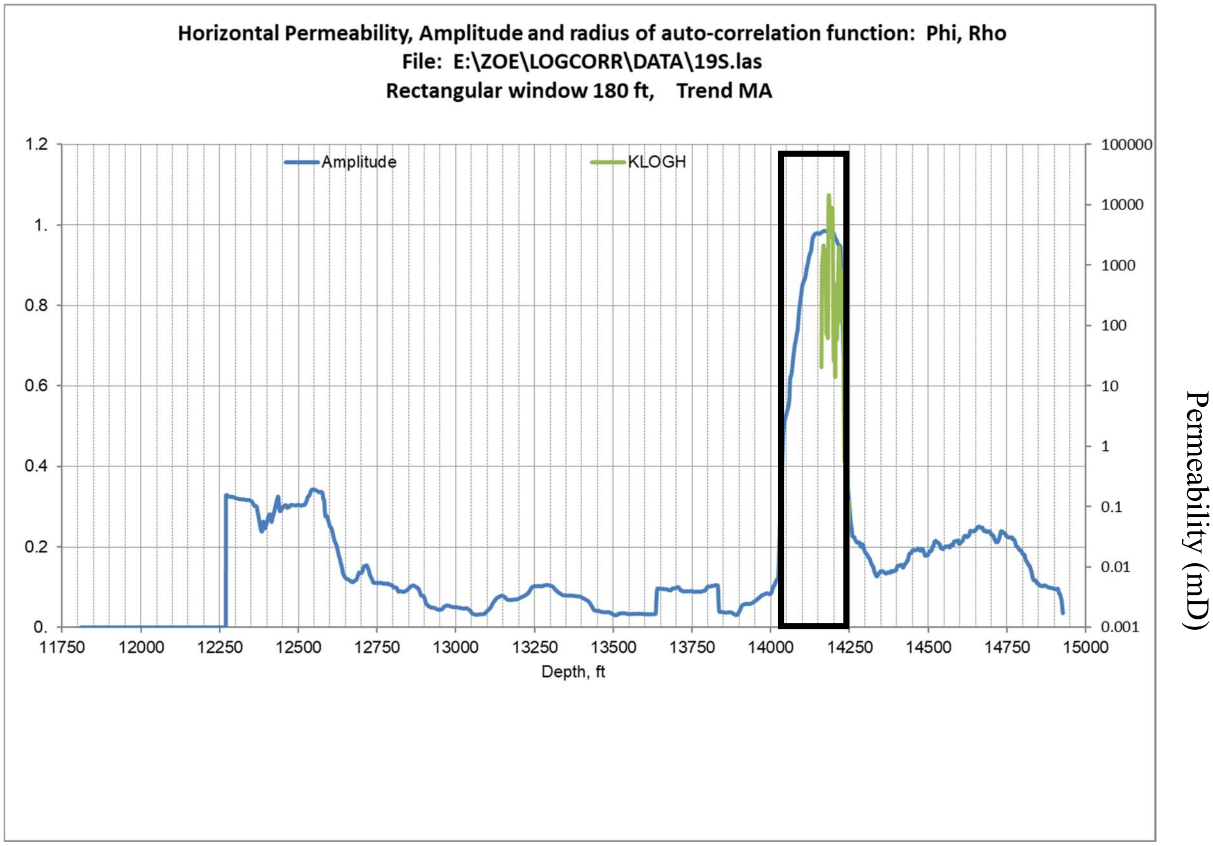

Horizontal Permeability, Amplitude and radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

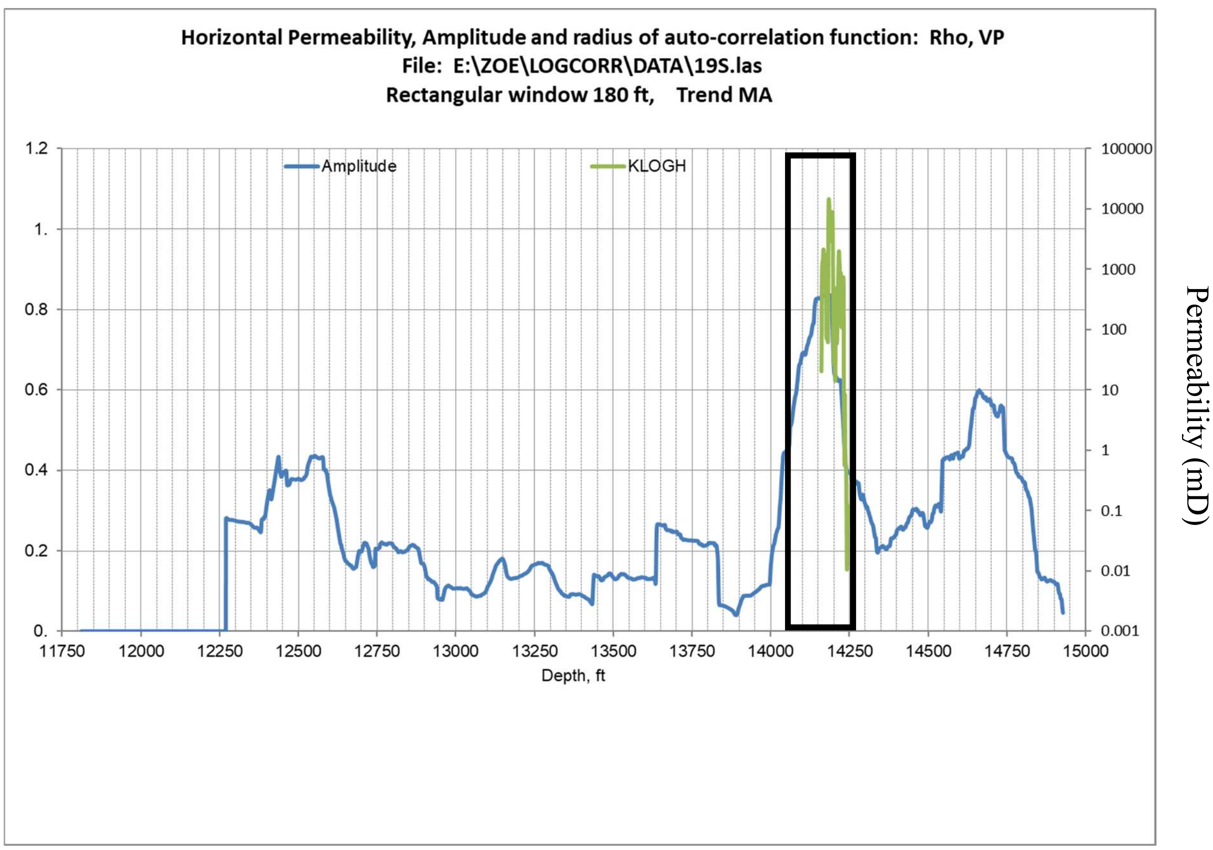


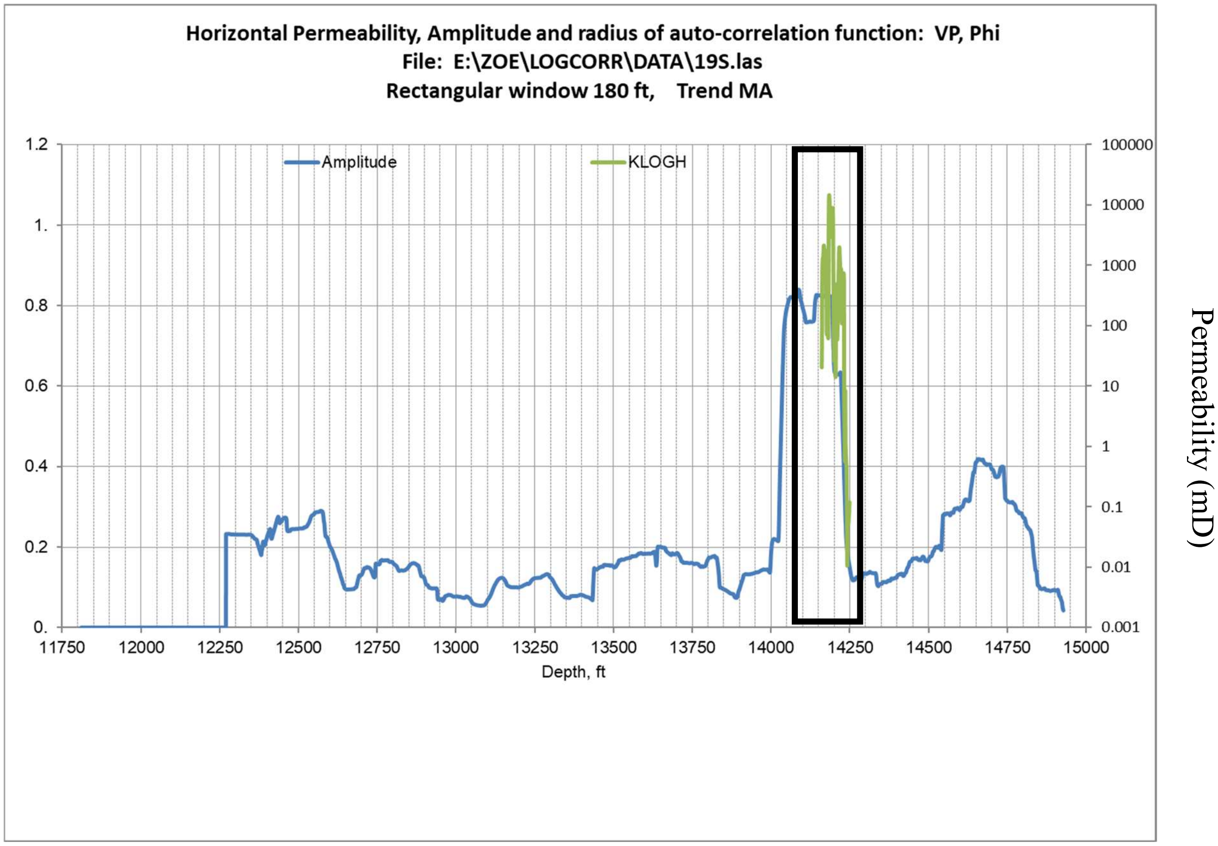
Horizontal Permeability, Amplitude and radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)



Horizontal Permeability, Amplitude and radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, Amplitude and radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

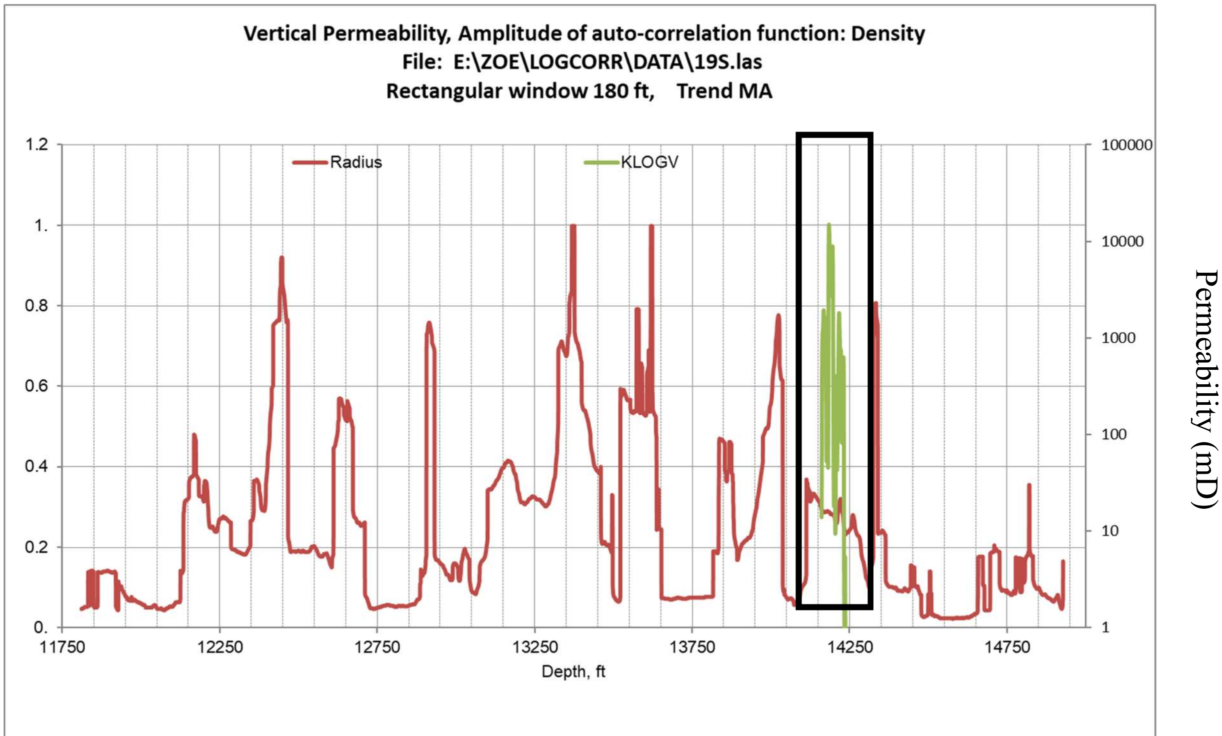

Horizontal Permeability, Amplitude and radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

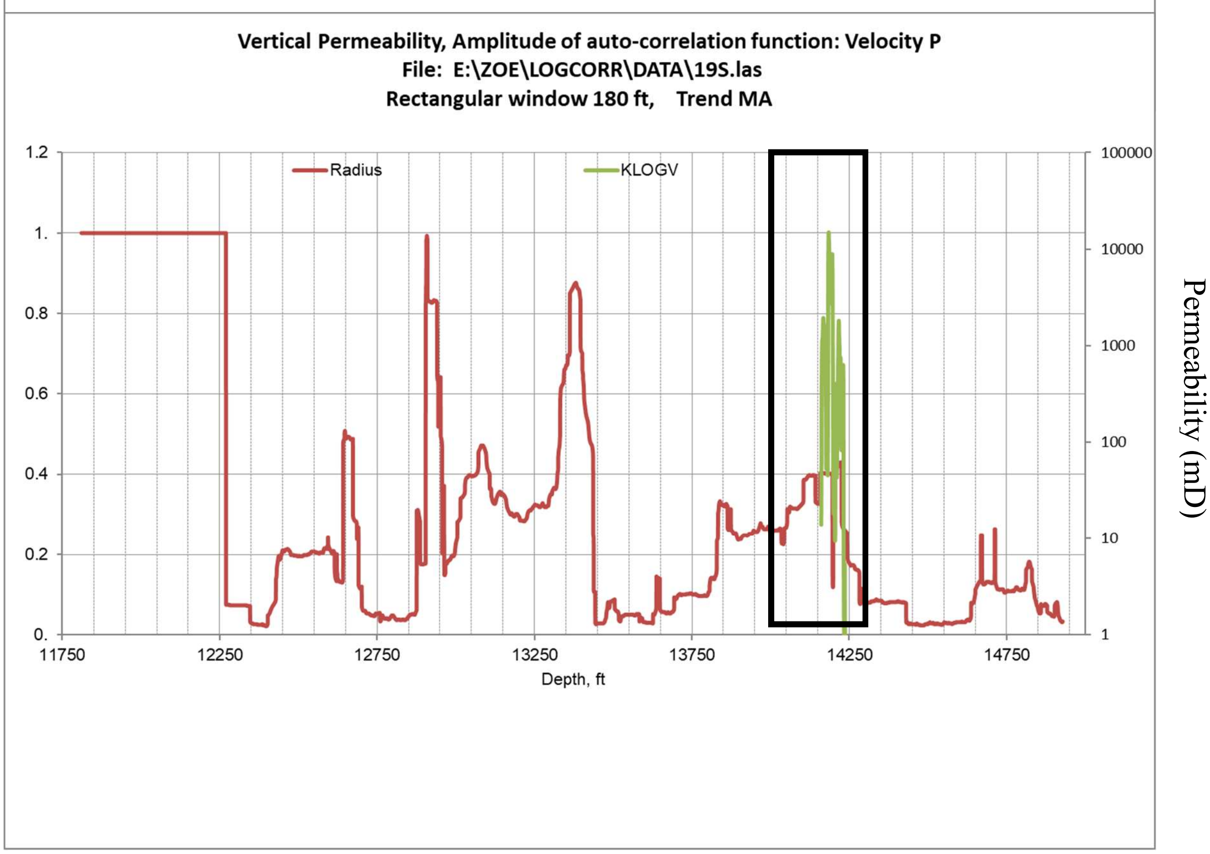

Horizontal Permeability, Amplitude and radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

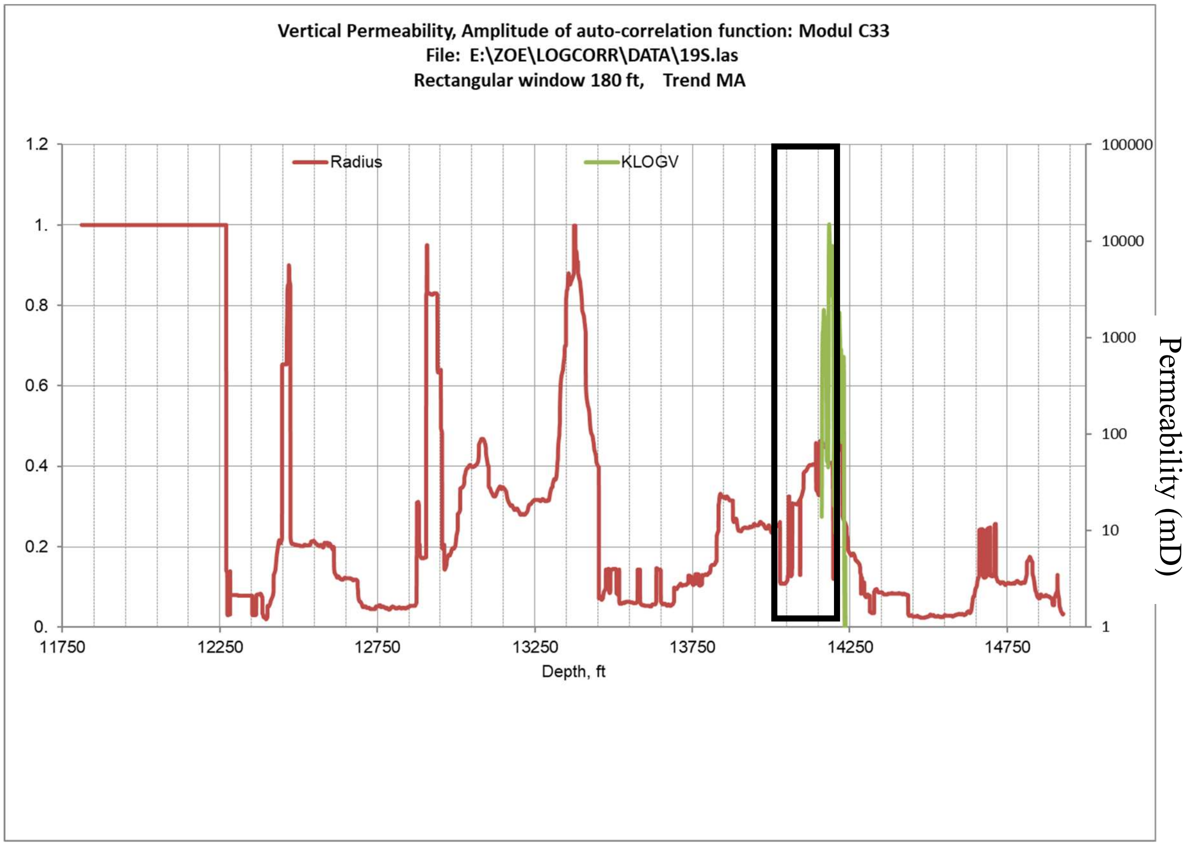
A6: Correlation Radius, Vertical Permeability vs. Depth

A6: Correlation Radius, Vertical Permeability vs. Depth

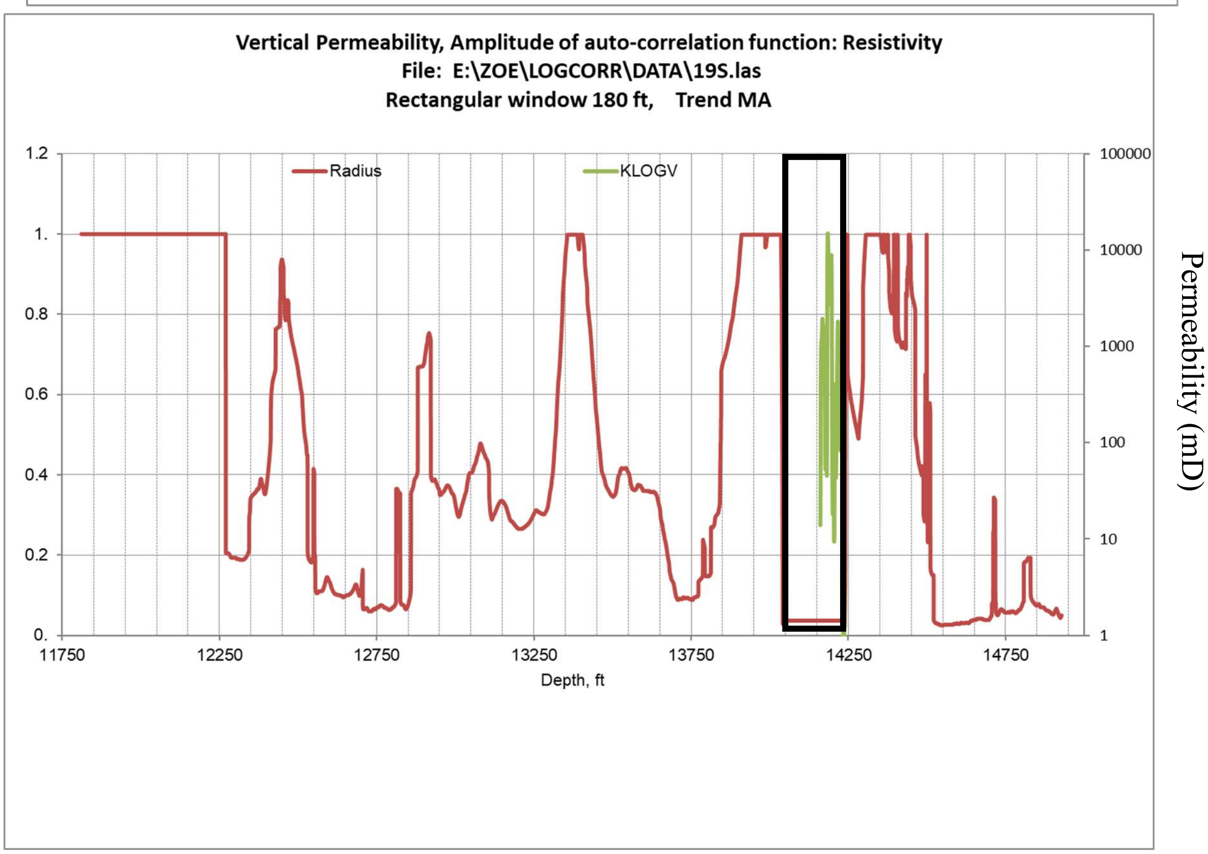
Section A6 covers plots focusing on the behavior of correlation radius and permeability. In this particular well (15/9-19S), both horizontal and vertical permeabilities were available. This section focuses on the behavior of vertical permeabilities in conjunction with the correlation radius values. Permeabilities are expected to be higher when correlation radius is low or decreasing. The boundaries of the productive interval are generally denoted by sharp peaks in correlation radius


Vertical Permeability, Amplitude of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
Permeability (mD)

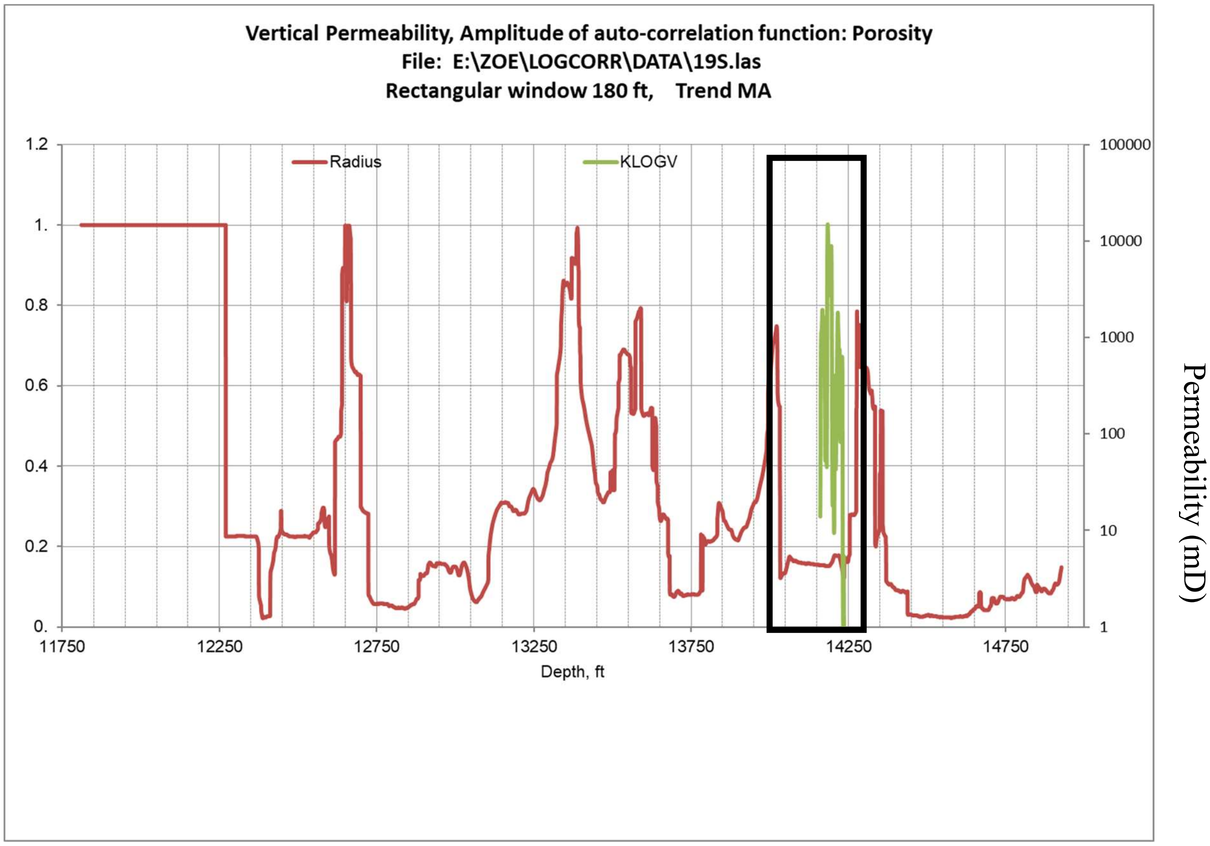

Vertical Permeability, Amplitude of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
Permeability (mD)

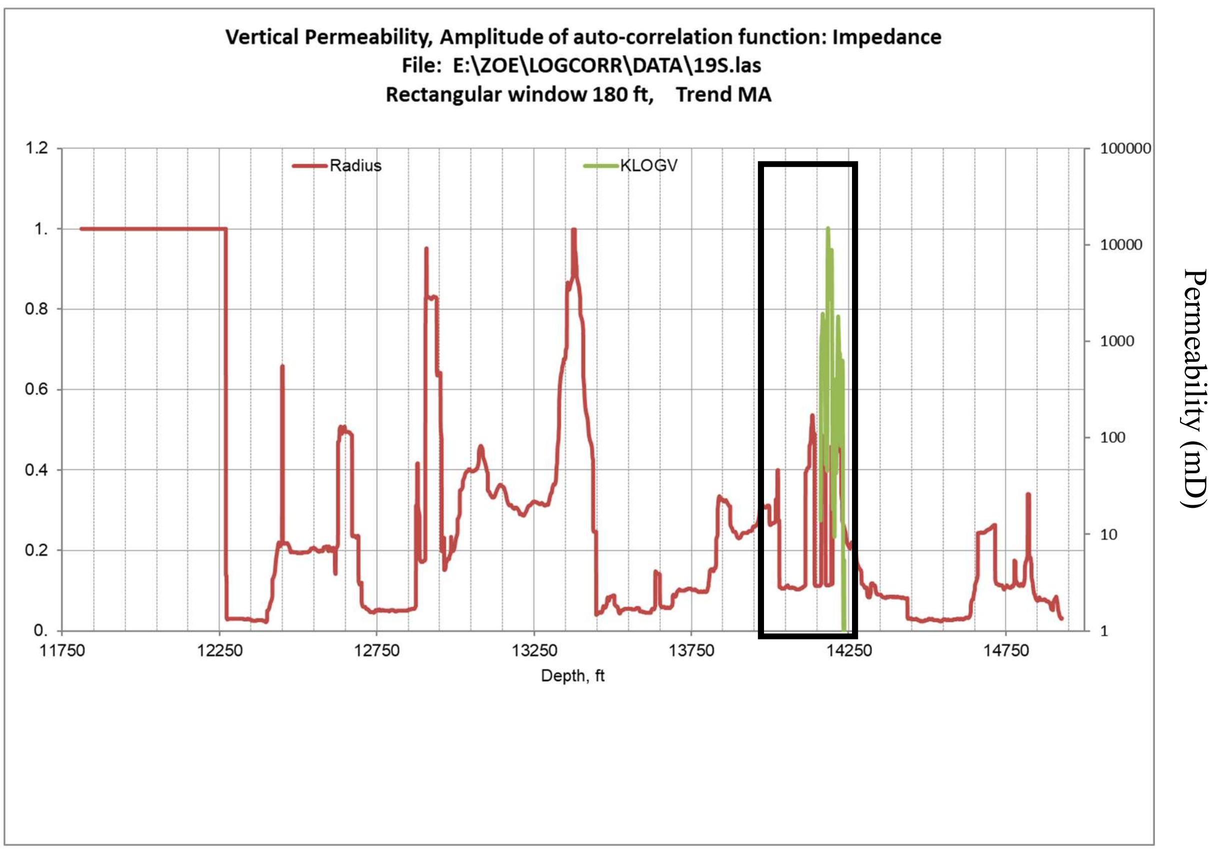


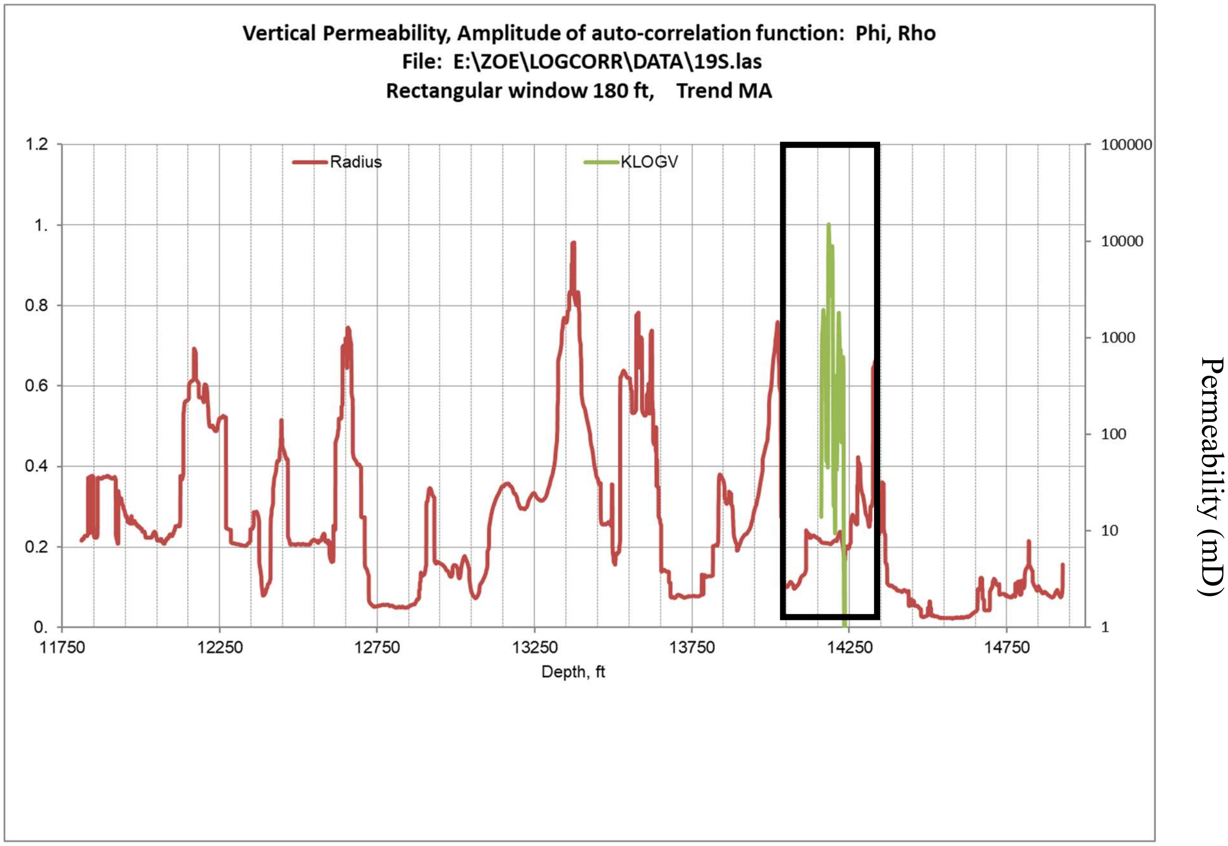
Vertical Permeability, Amplitude of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
Permeability (mD)

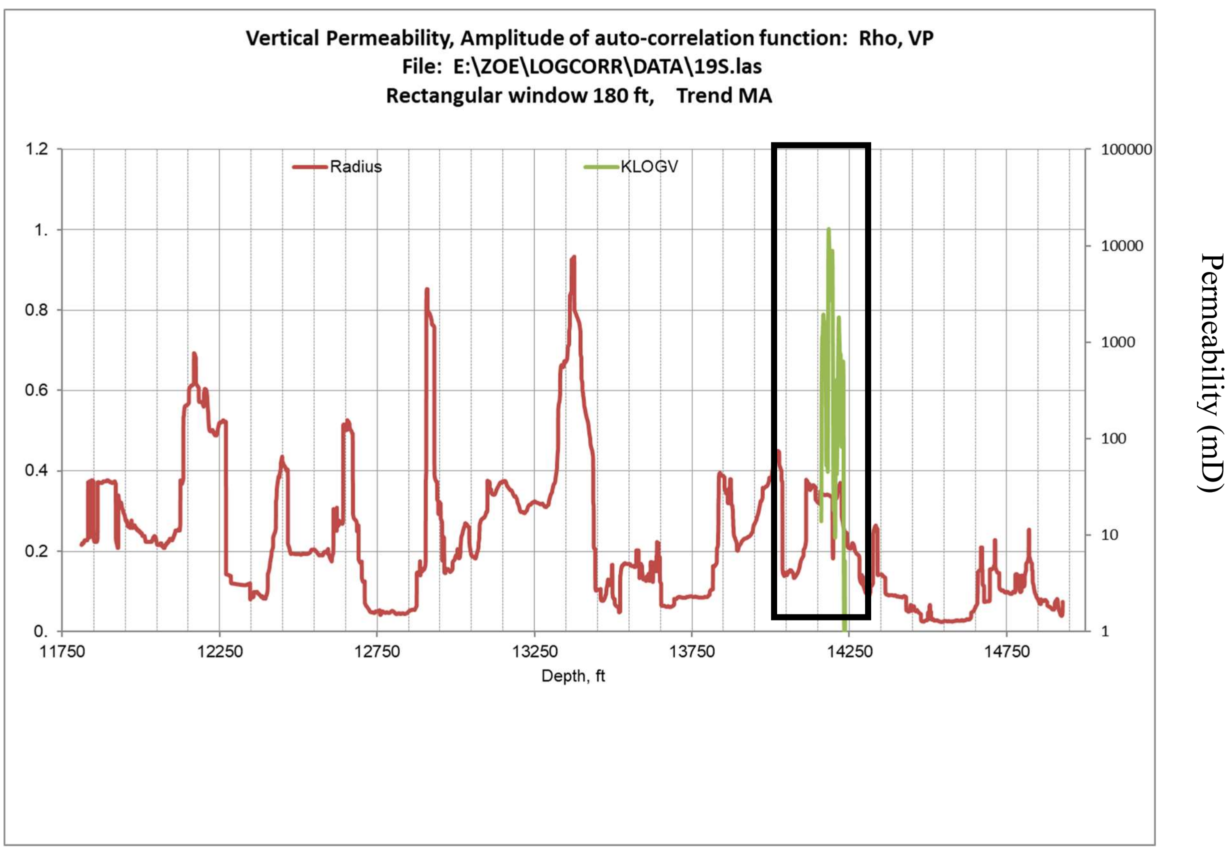


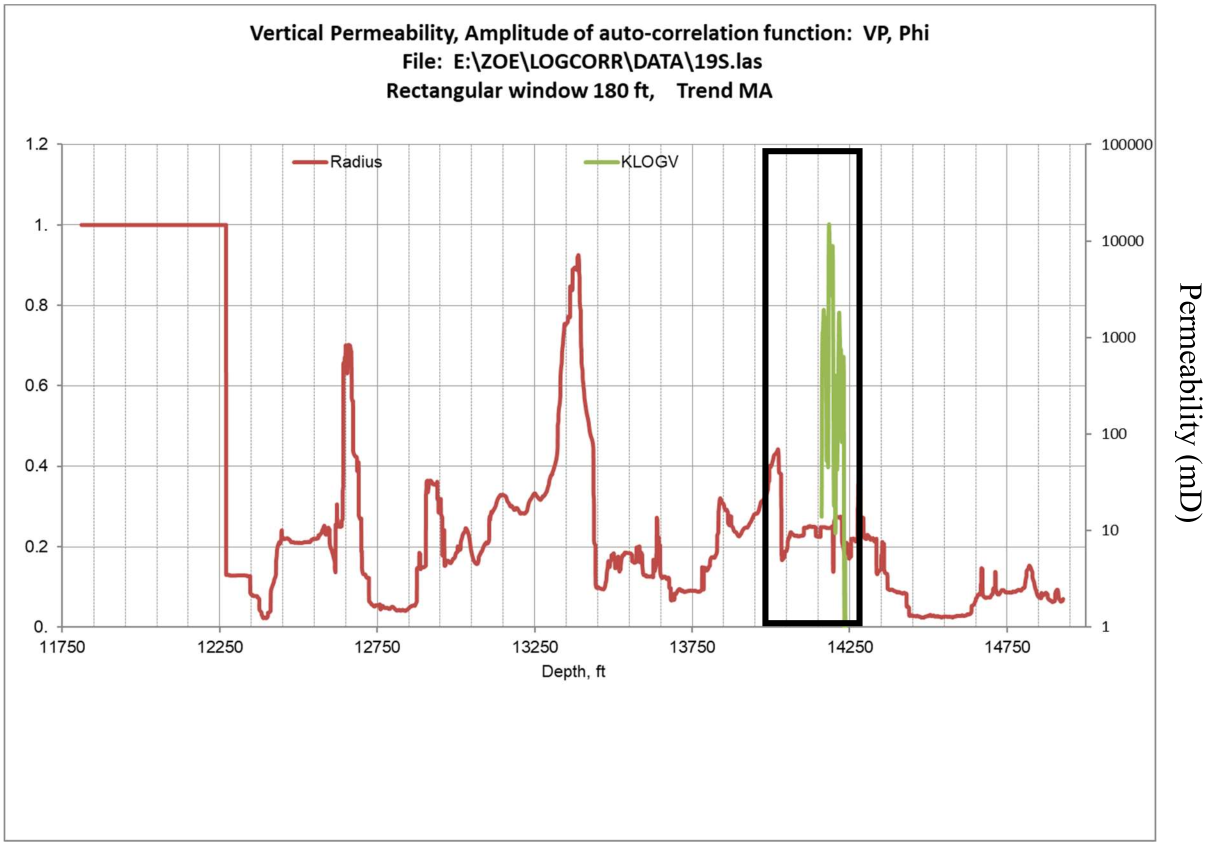
Vertical Permeability, Amplitude of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
11750
12250
12750
13250
13750
14250
14750
Depth, ft
100000
10000
1000
100
10
1
Permeability (mD)

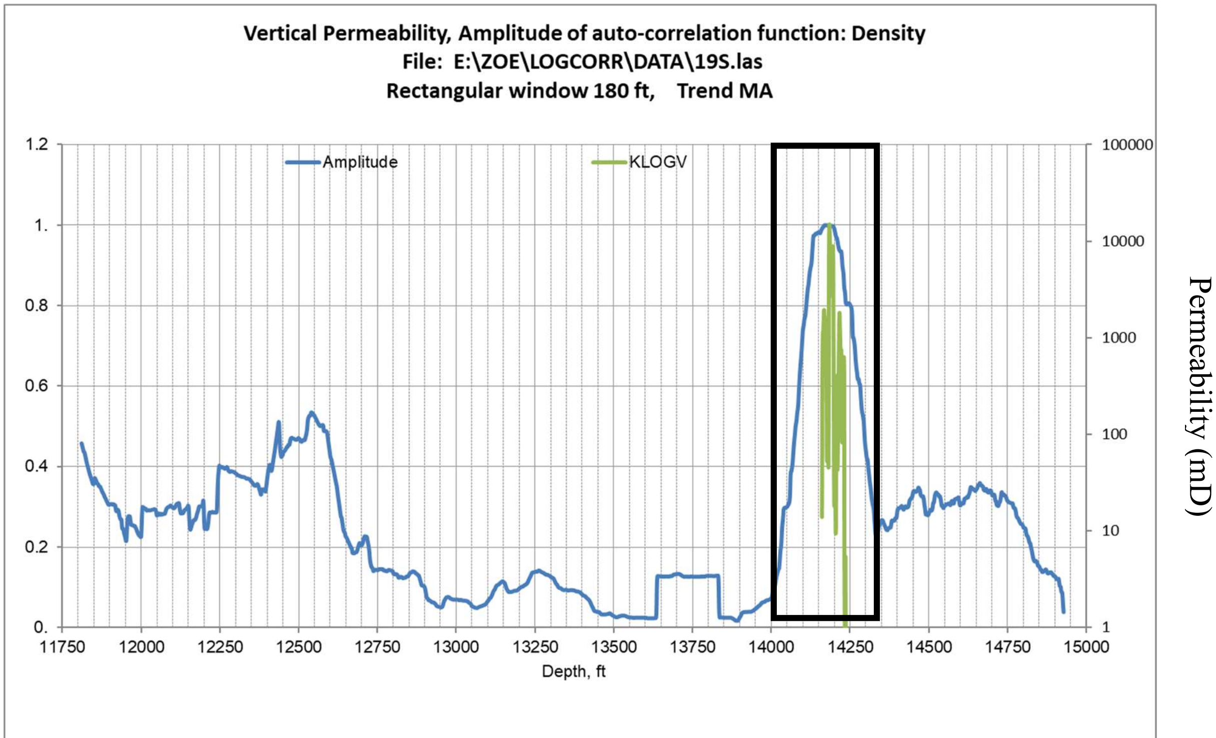


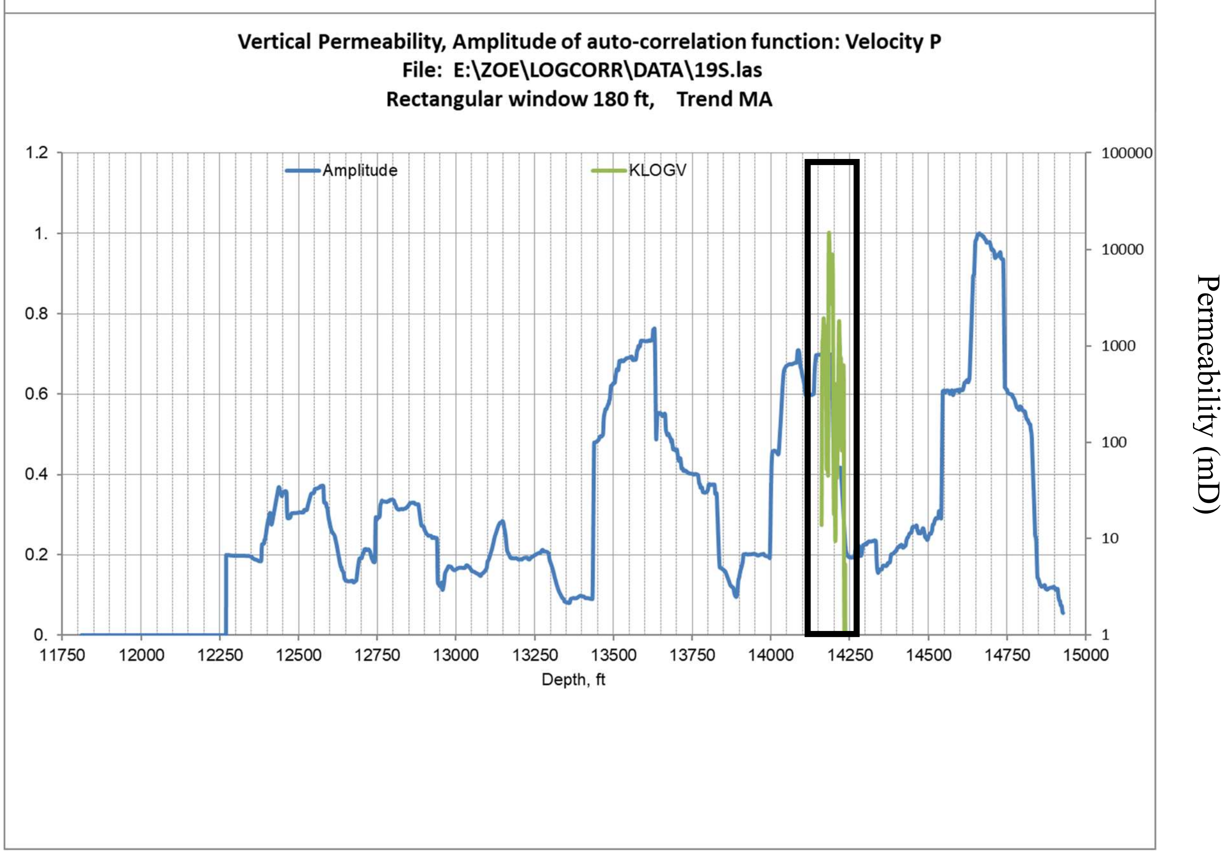
Vertical Permeability, Amplitude of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
11750
12250
12750
13250
13750
14250
14750
Depth, ft
Permeability (mD)

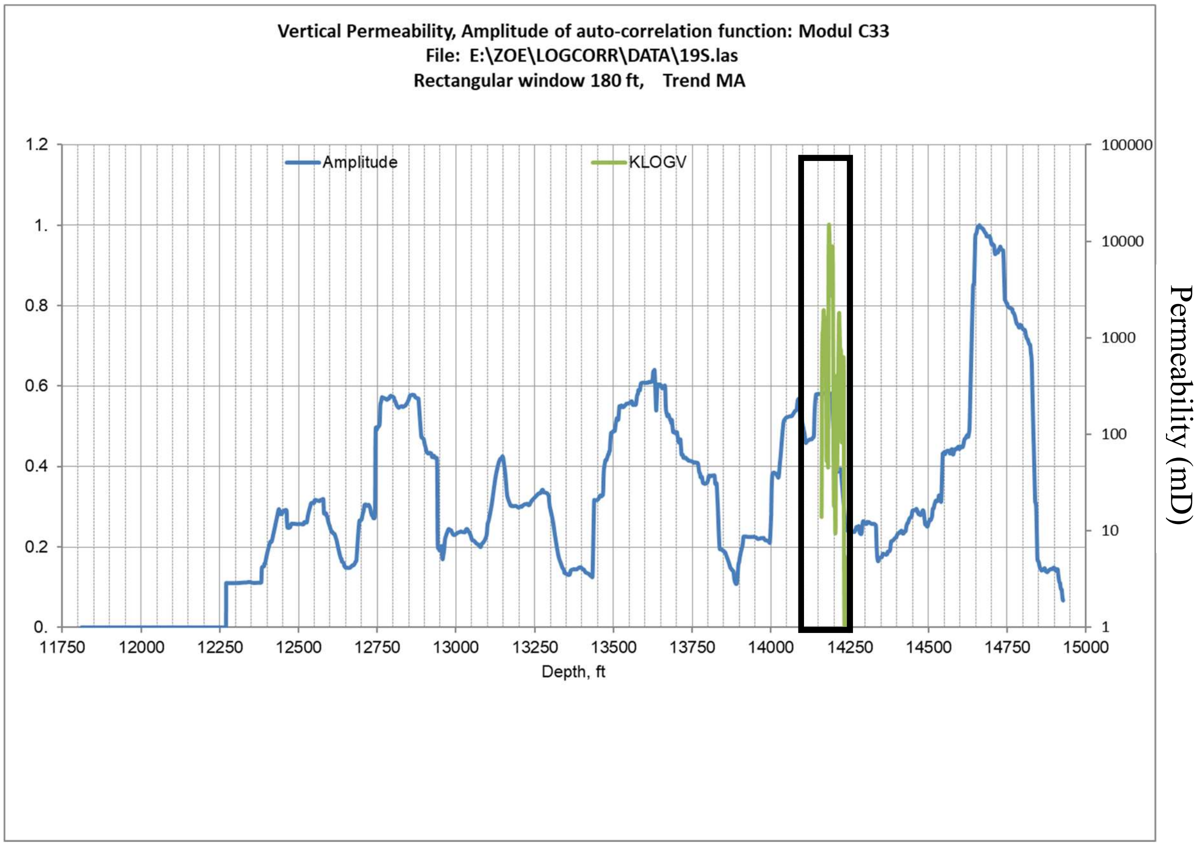
A7: Amplitude, Vertical Permeability vs. Depth

A7: Amplitude, Vertical Permeability vs. Depth

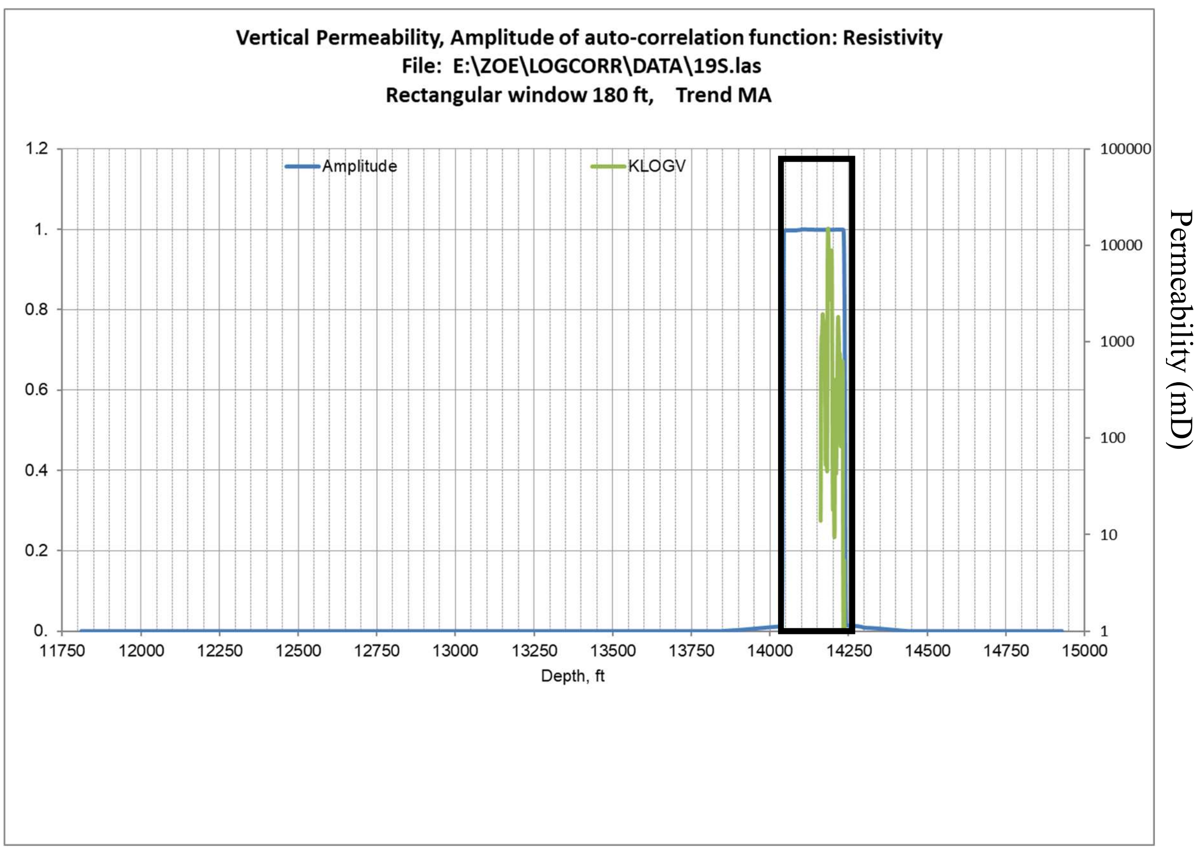
Section A7 covers plots focusing on the behavior of amplitude and permeability. In this particular well (15/9-19S), both horizontal and vertical permeabilities were available. This section focuses on the behavior of vertical permeabilities in combination with the amplitude values. Permeabilities are expected to be higher as amplitude increases or is high. The boundaries of the productive interval are generally denoted by sharp increase in amplitude.


Vertical Permeability, Amplitude of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)

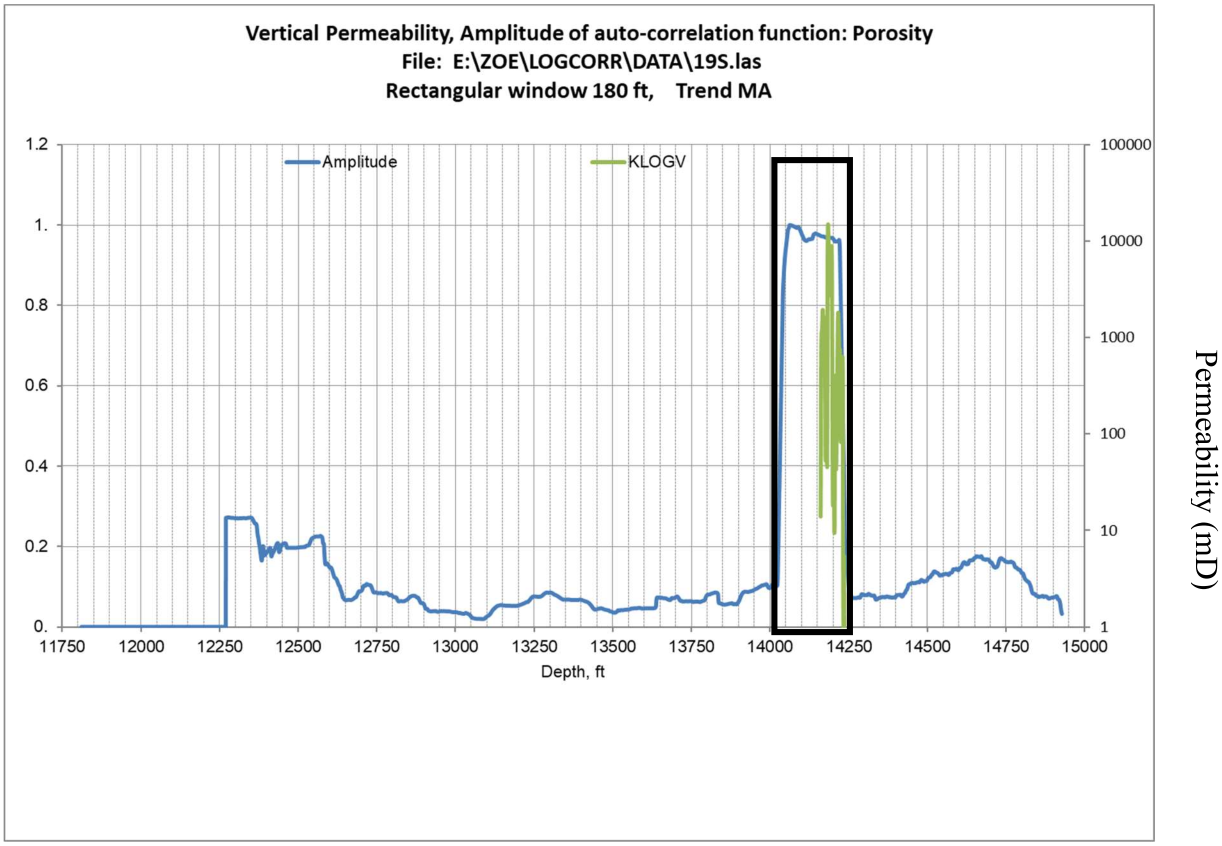

Vertical Permeability, Amplitude of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)

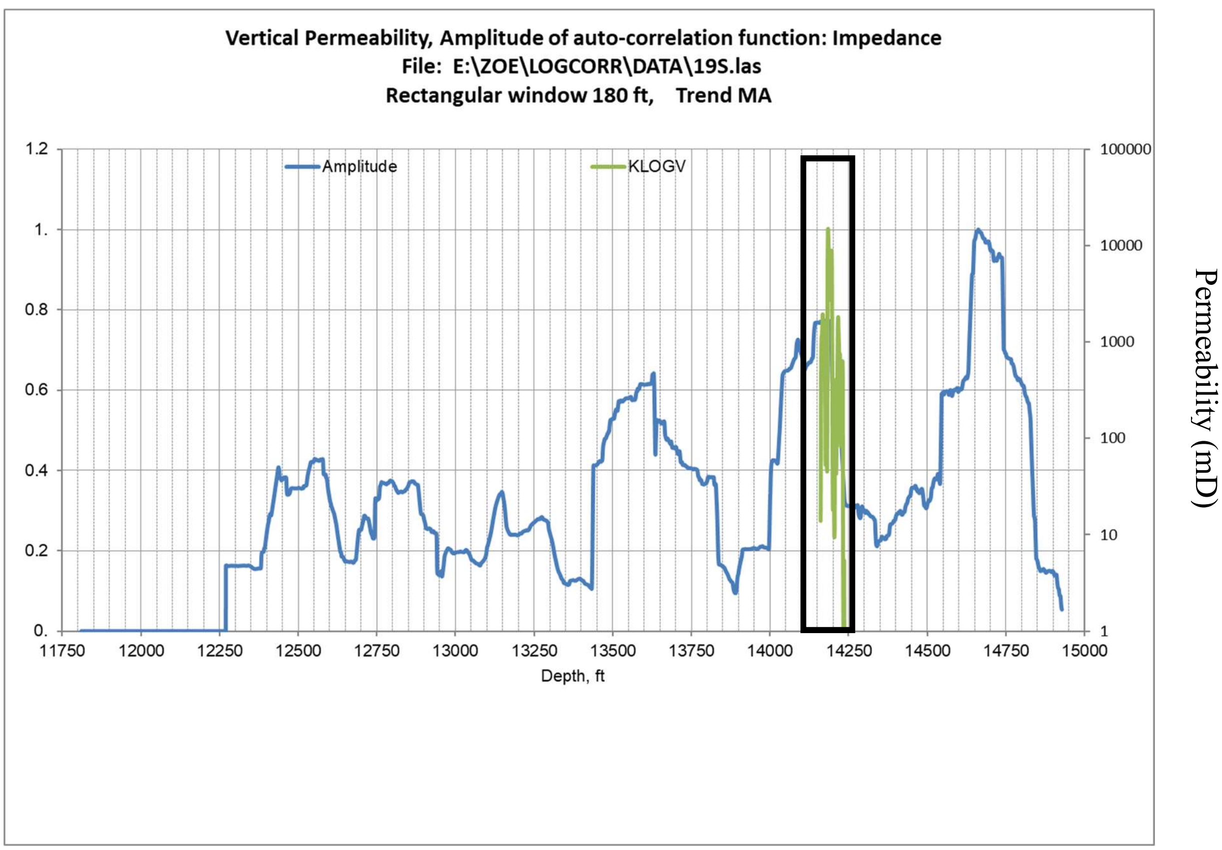


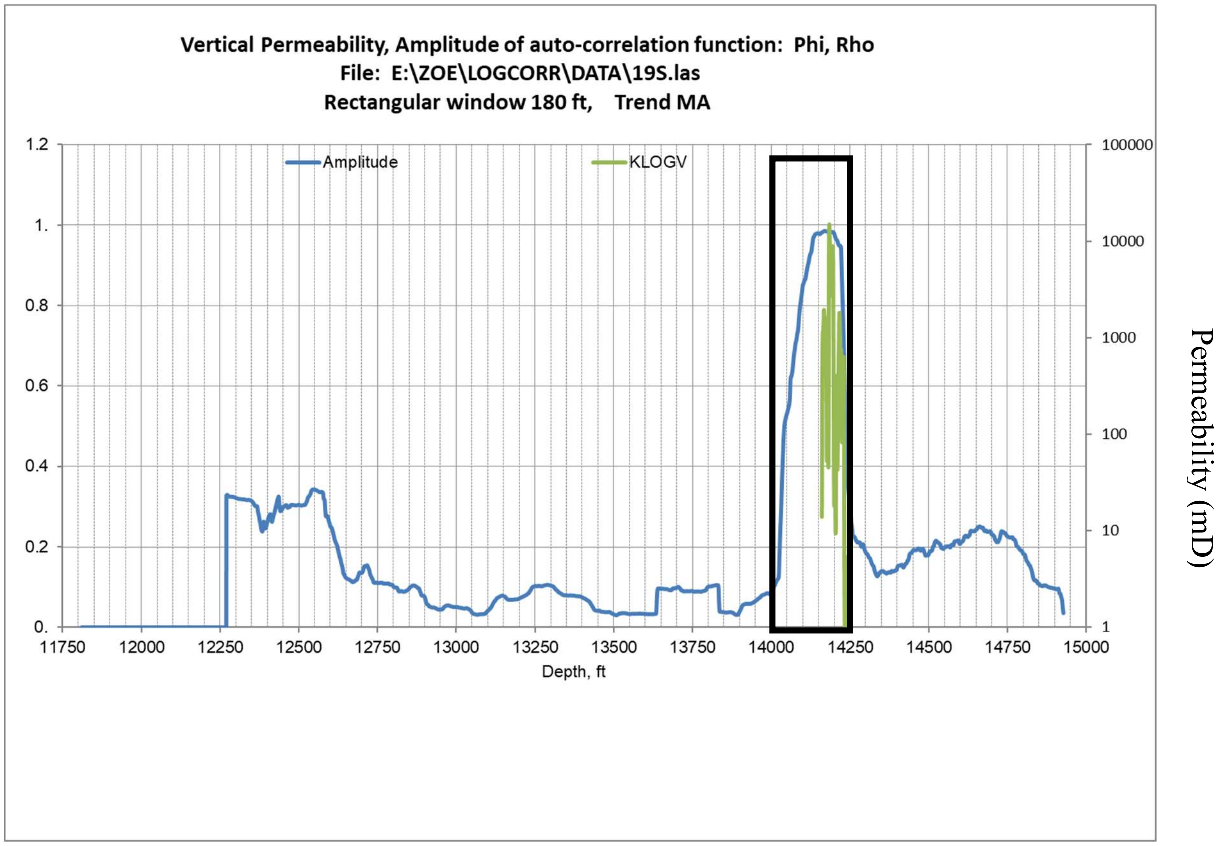
Vertical Permeability, Amplitude of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)

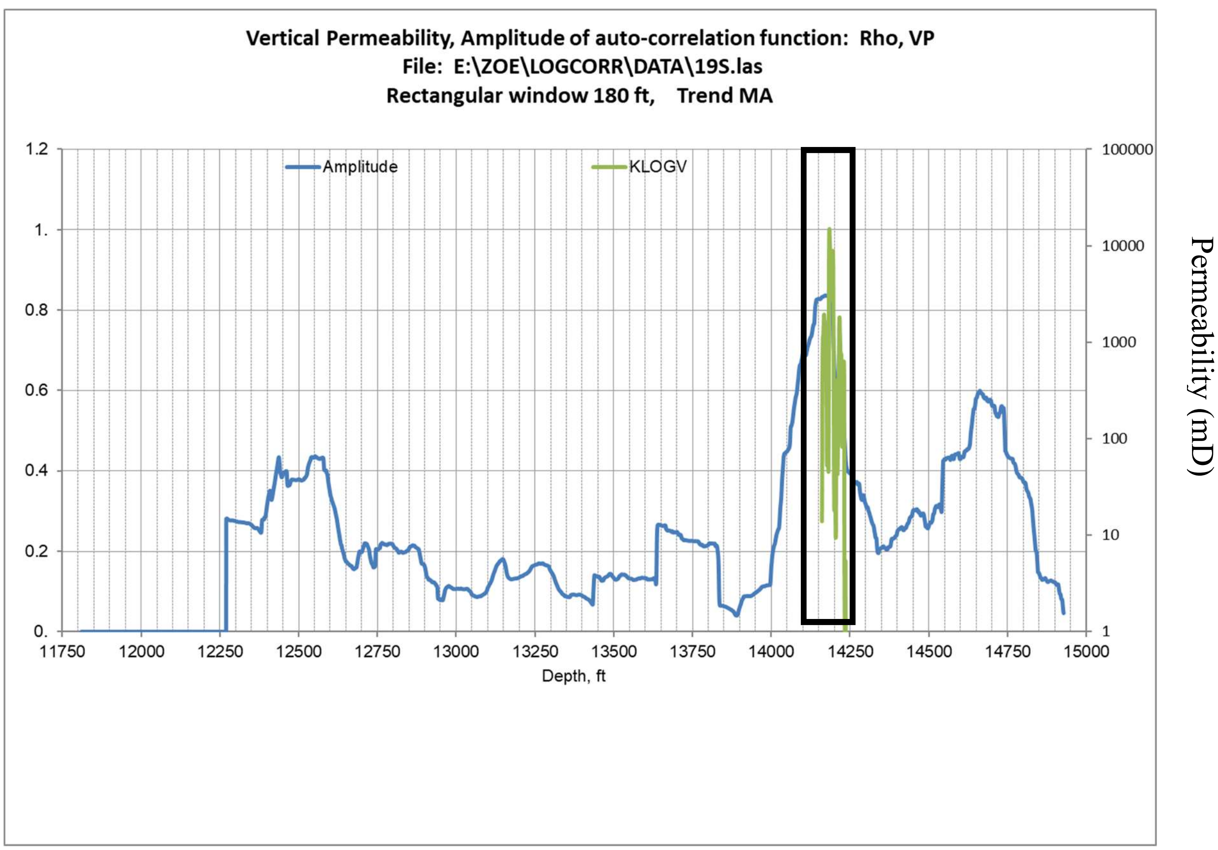


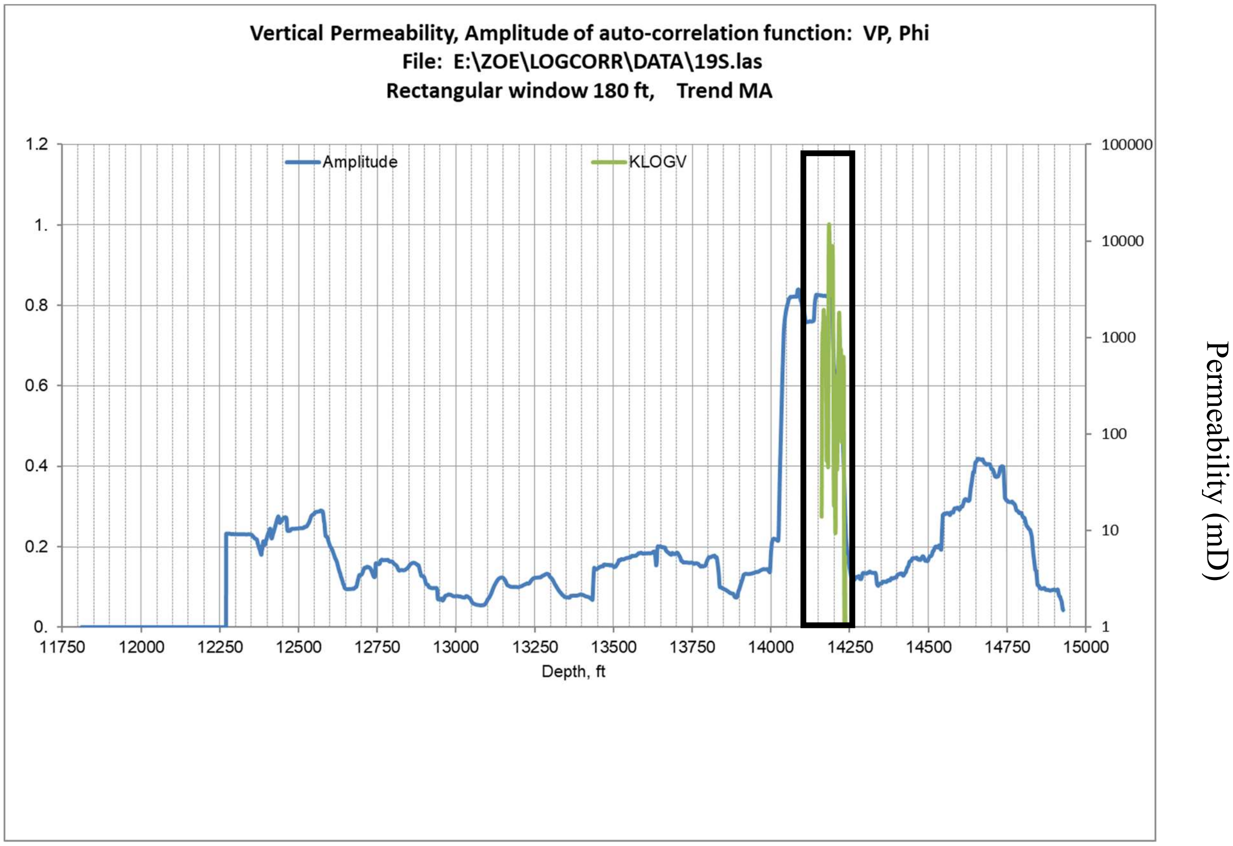
Vertical Permeability, Amplitude of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)

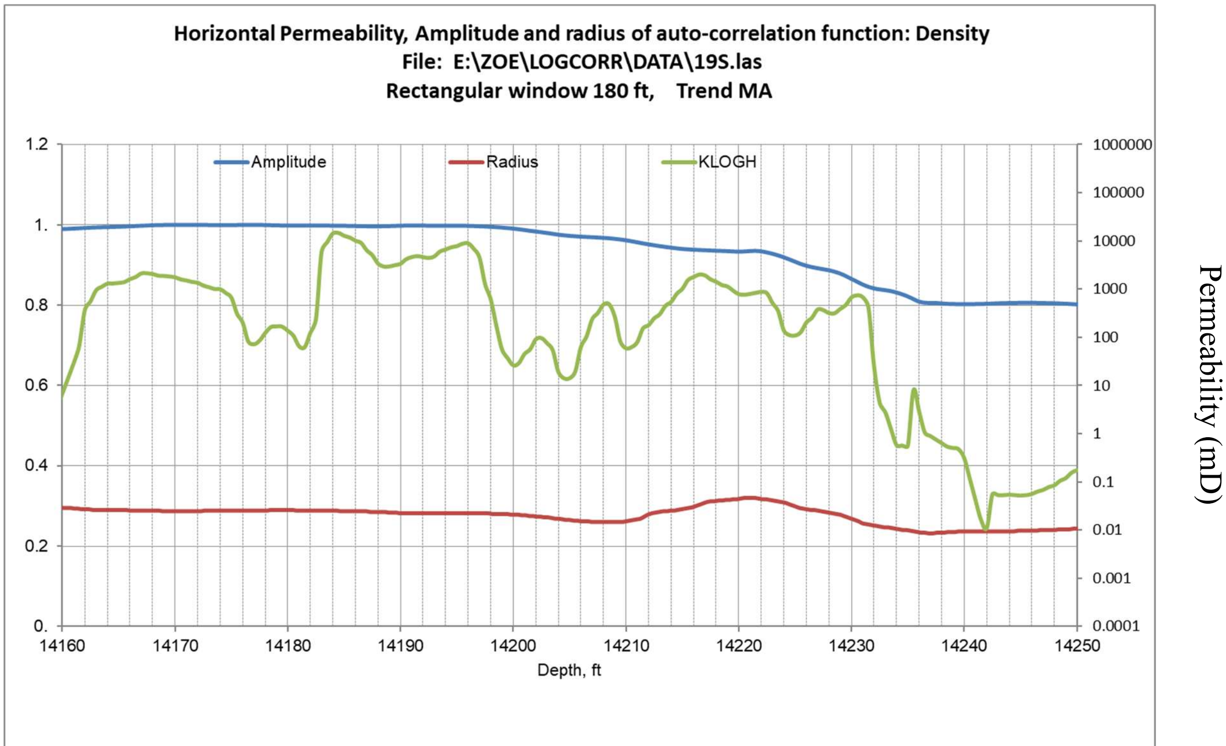

Vertical Permeability, Amplitude of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)

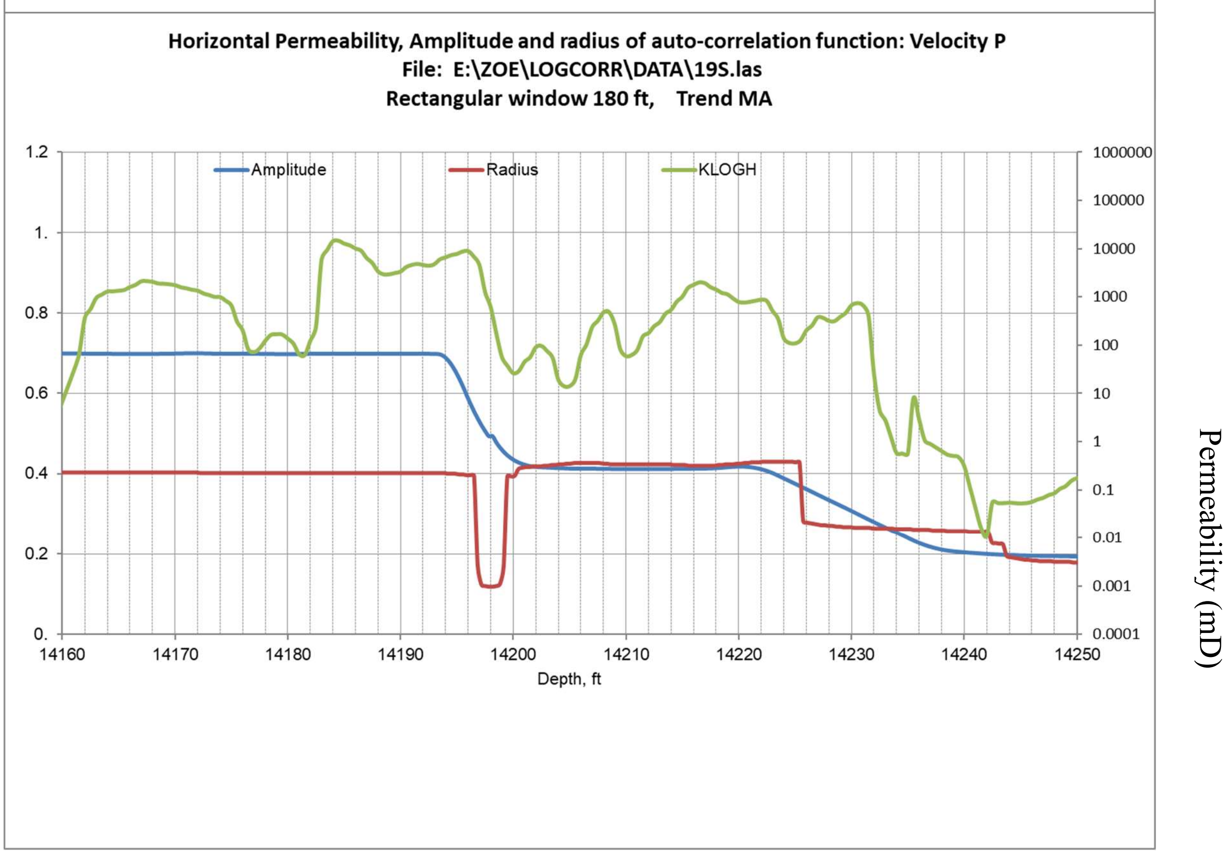

Vertical Permeability, Amplitude of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
100000
10000
1000
100
10
1
11750
12000
12250
12500
12750
13000
13250
13500
13750
14000
14250
14500
14750
15000
Depth, ft
Permeability (mD)

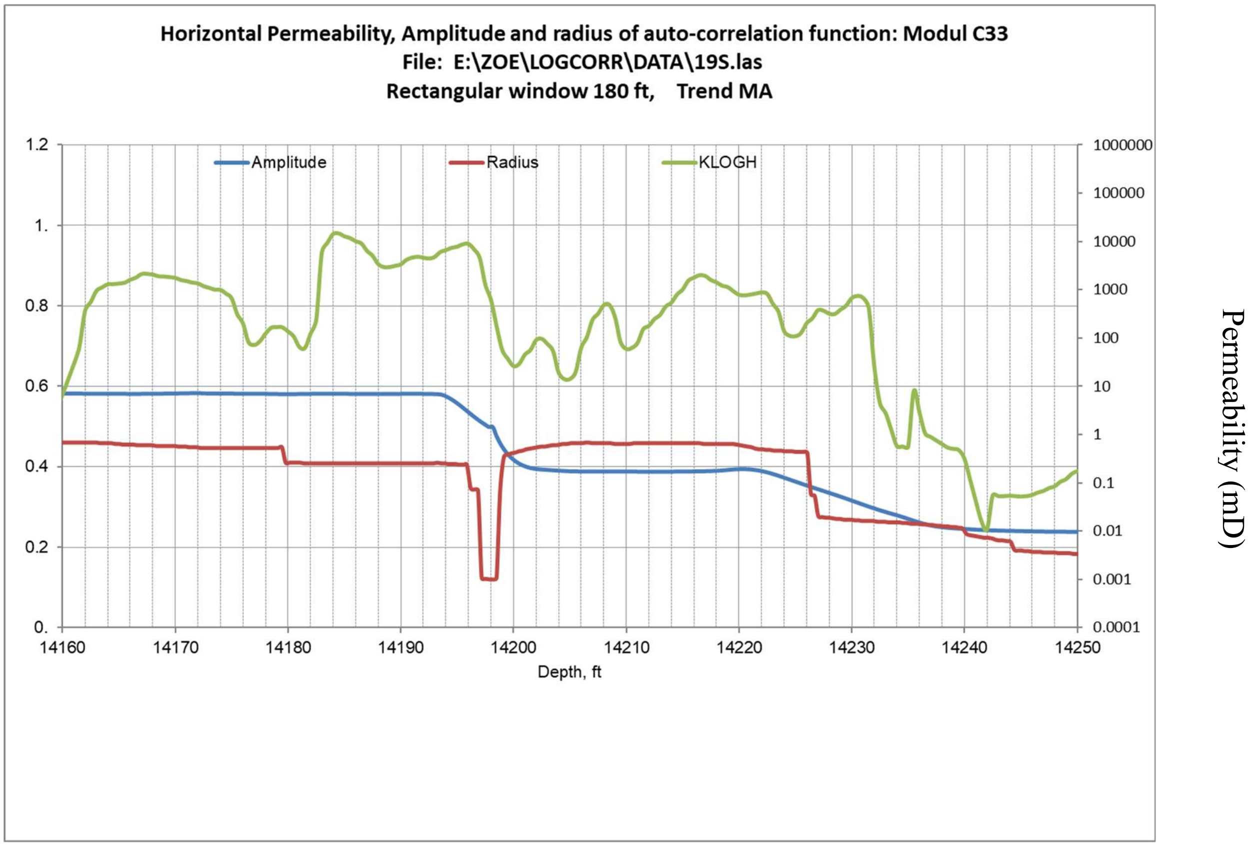
A8: Amplitude, Radius, Horizontal Permeability vs. Depth (Productive Interval)

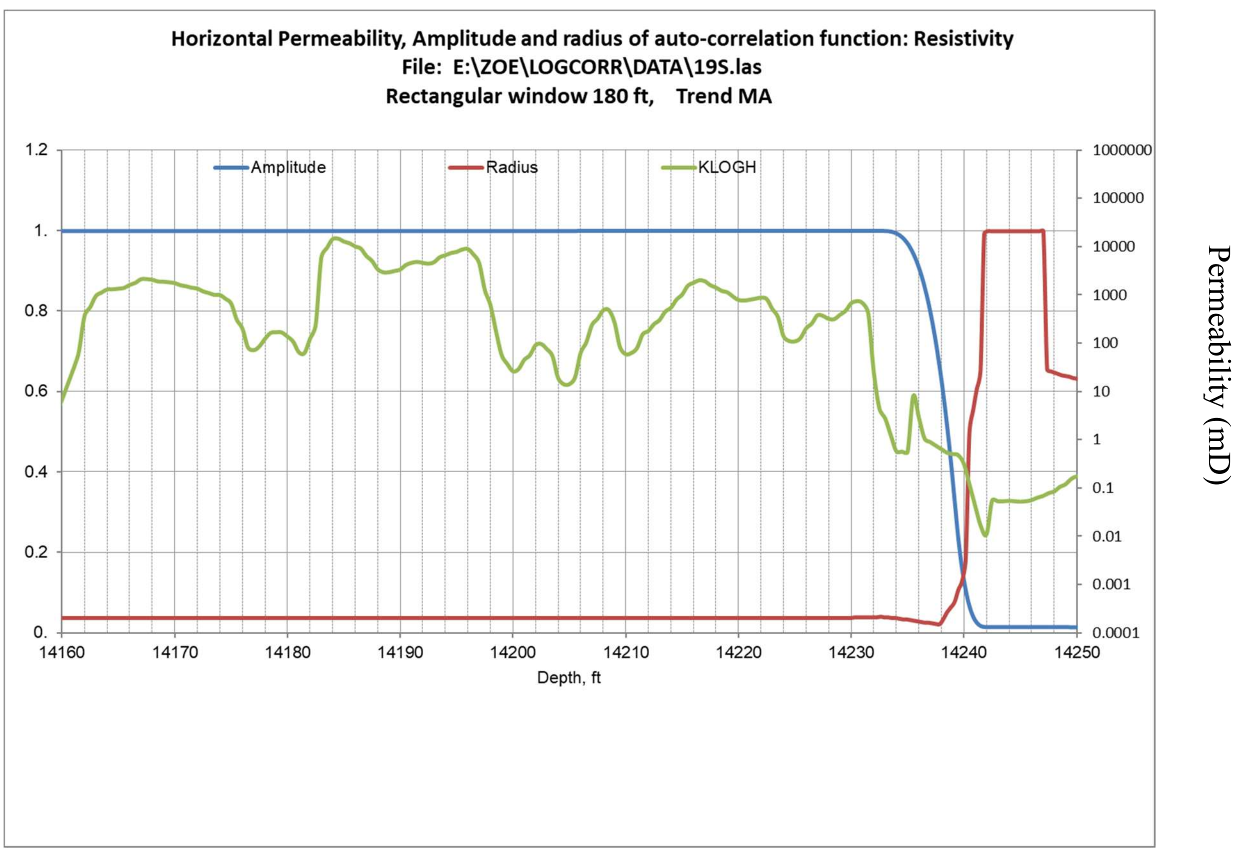
A8: Amplitude, Radius, Horizontal Permeability vs. Depth (Productive Interval)

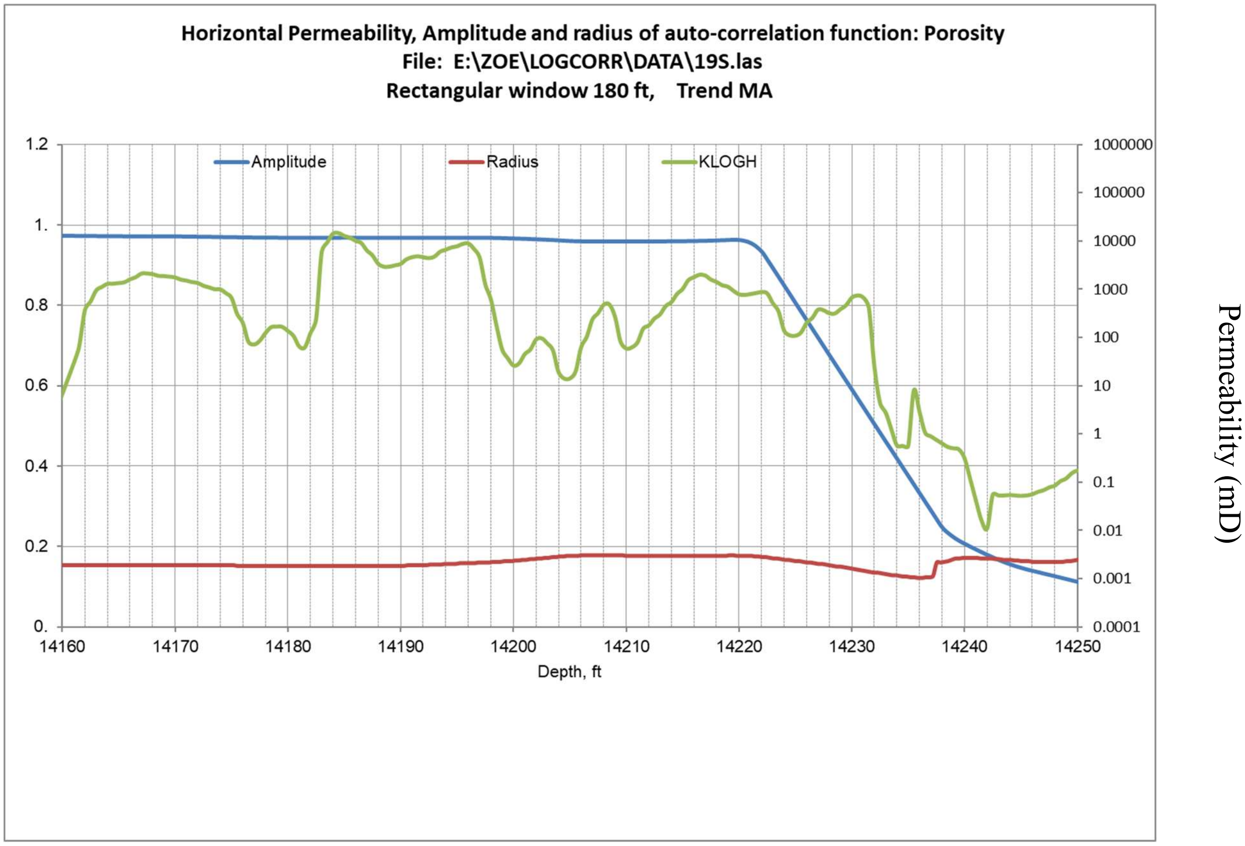
Section A8 focuses on the productive interval and the relationship between horizontal permeability, correlation radius, and amplitude. The following plots contain horizontal permeability behavior within the productive interval with both correlation radius and amplitude shown. Amplitude and permeabilities should be high and correlation radius should be low. At the top or bottom of the productive interval, the relationship may falter as these are the tops and bottoms of the productive interval.


Horizontal Permeability, Amplitude and radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

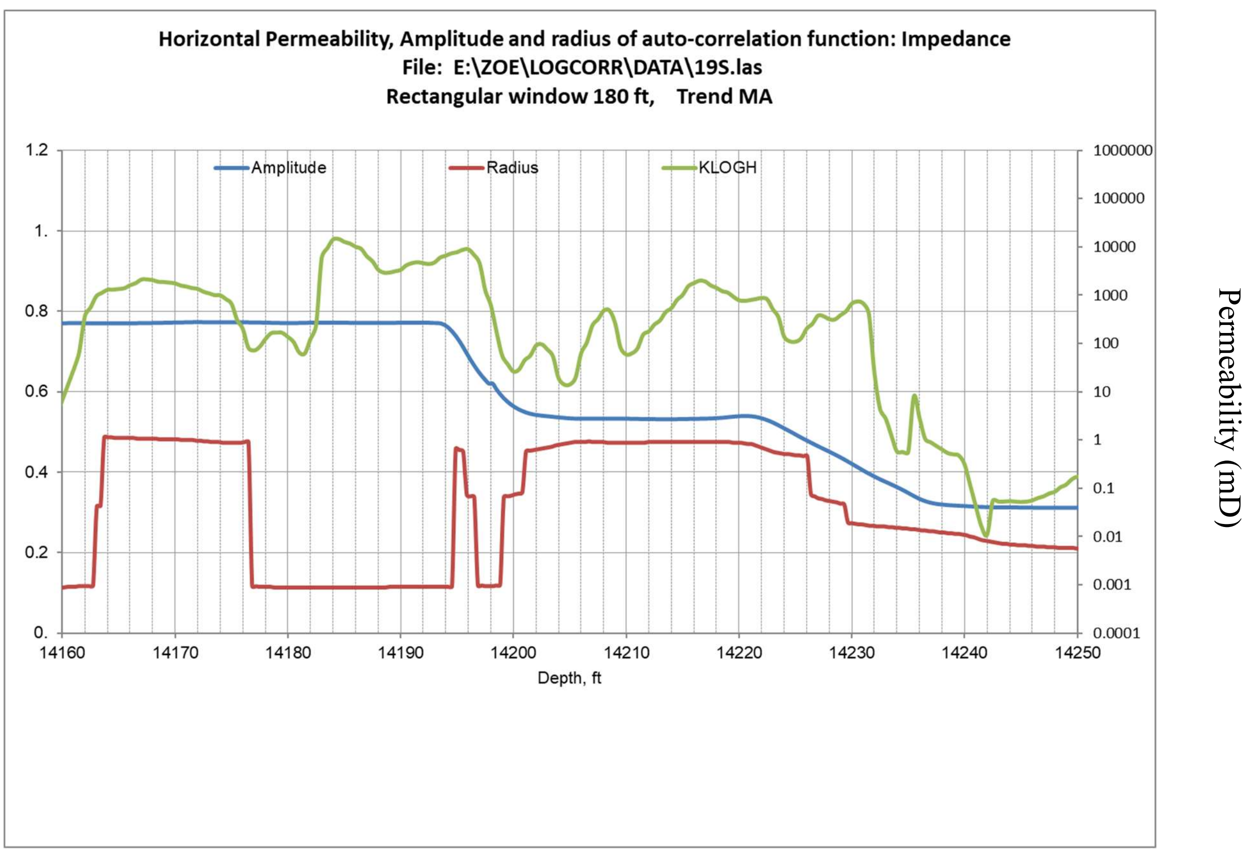

Horizontal Permeability, Amplitude and radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, Amplitude and radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

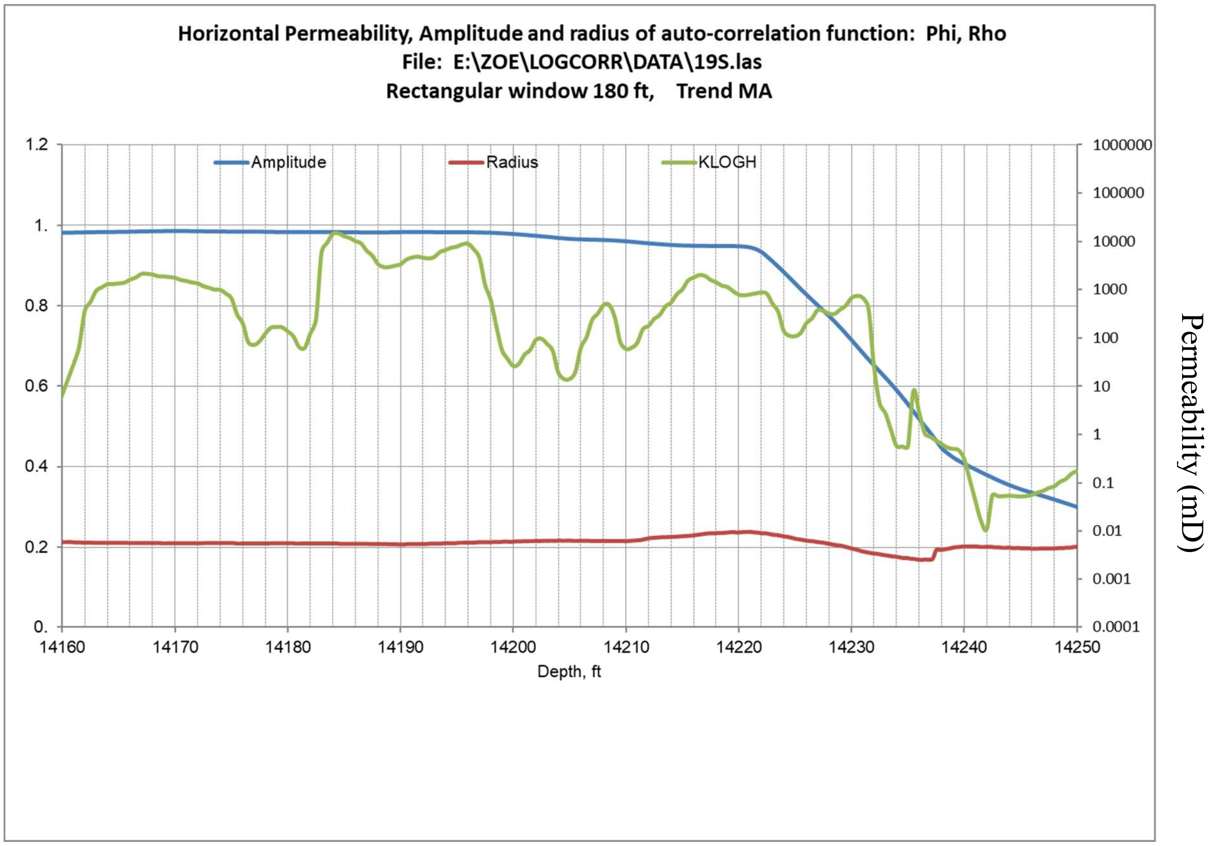

Horizontal Permeability, Amplitude and radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

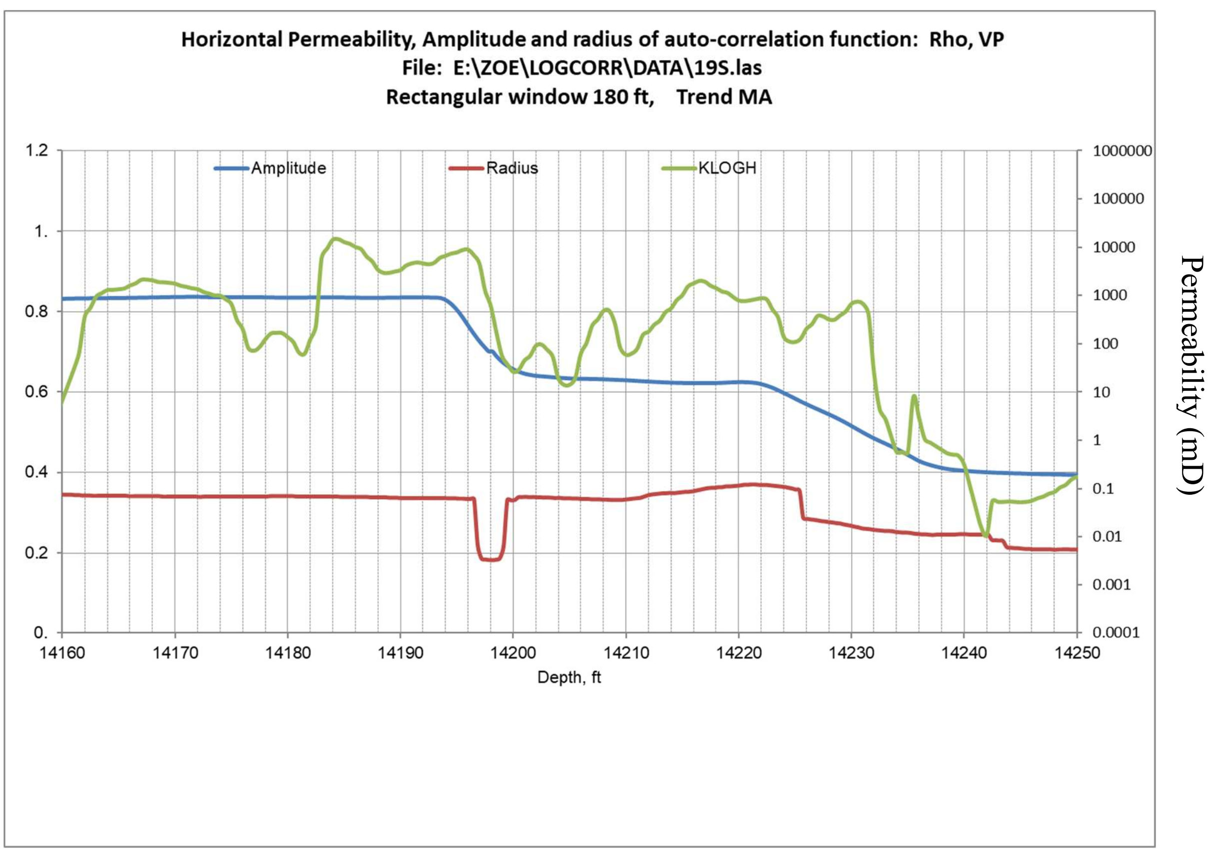


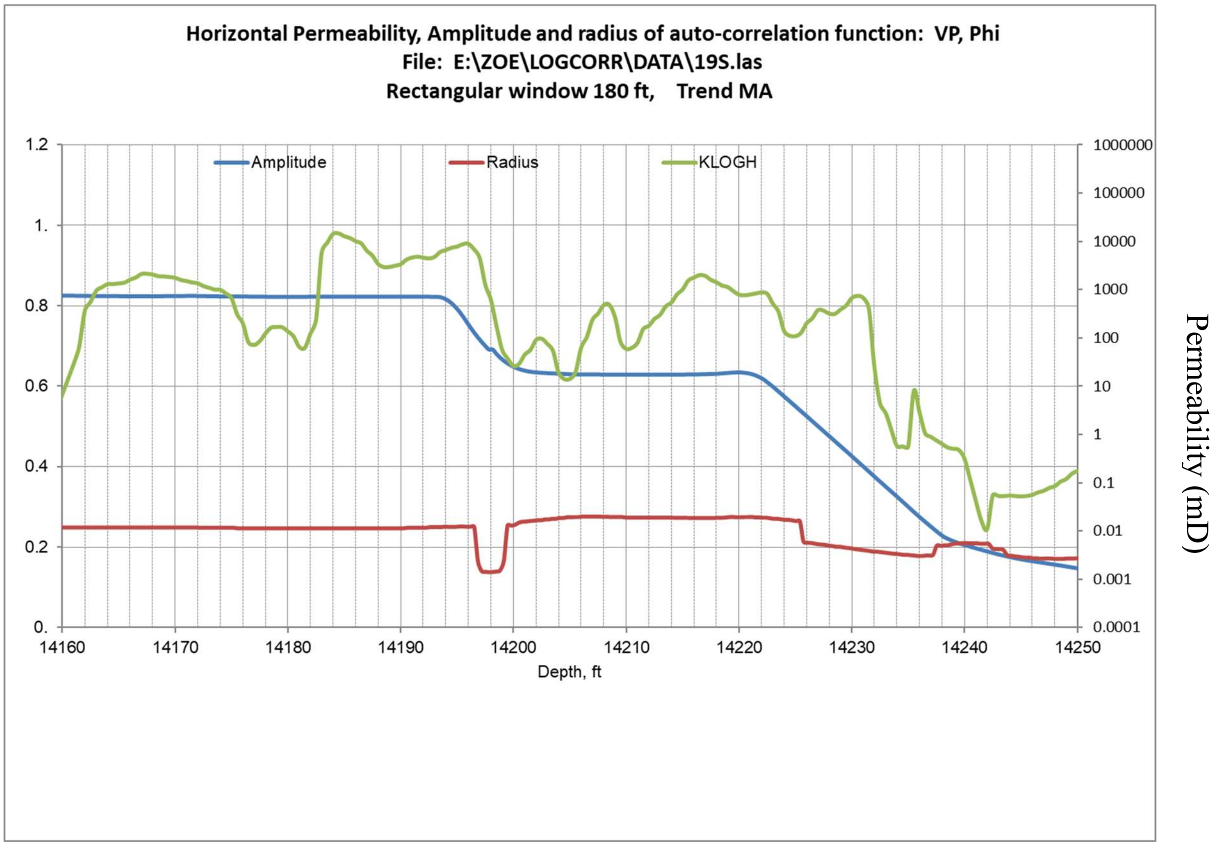
Horizontal Permeability, Amplitude and radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)



Horizontal Permeability, Amplitude and radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, Amplitude and radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

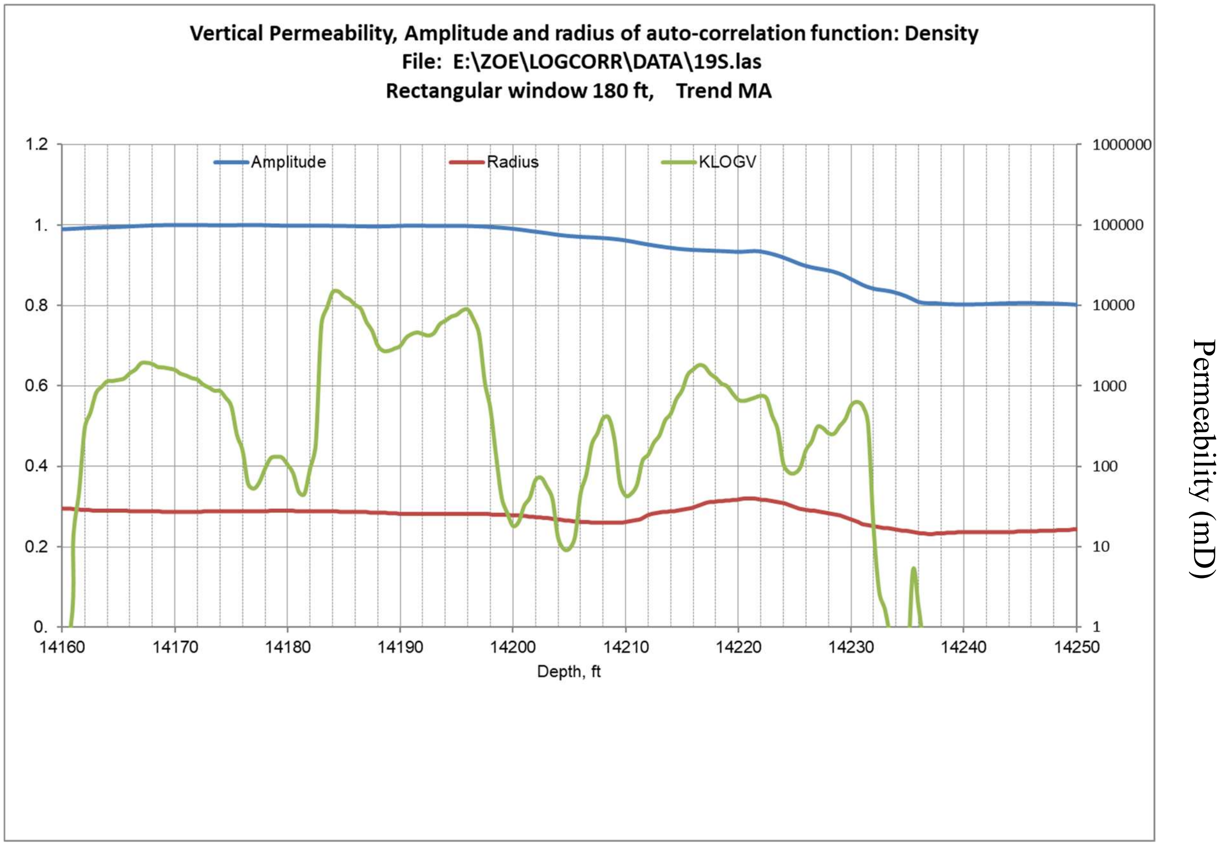

Horizontal Permeability, Amplitude and radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

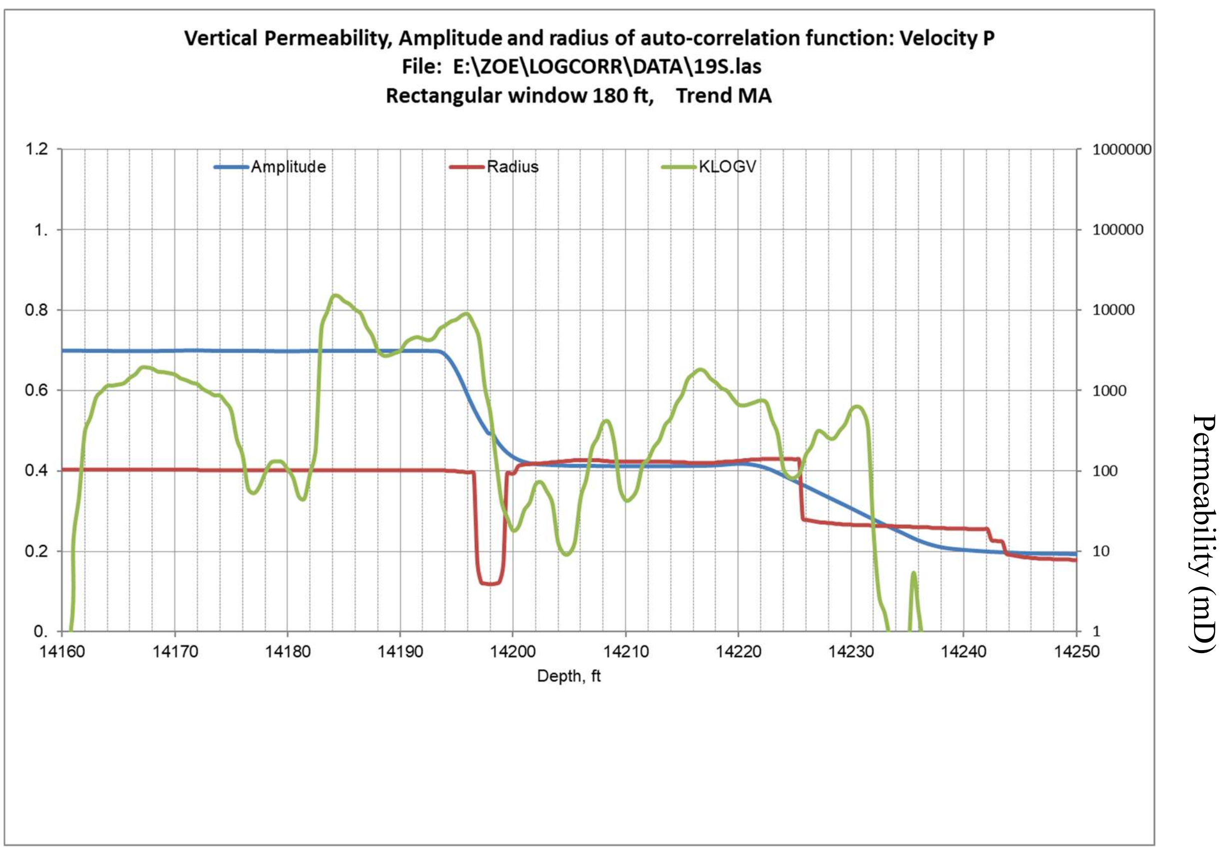

Horizontal Permeability, Amplitude and radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGH
Depth, ft
Permeability (mD)

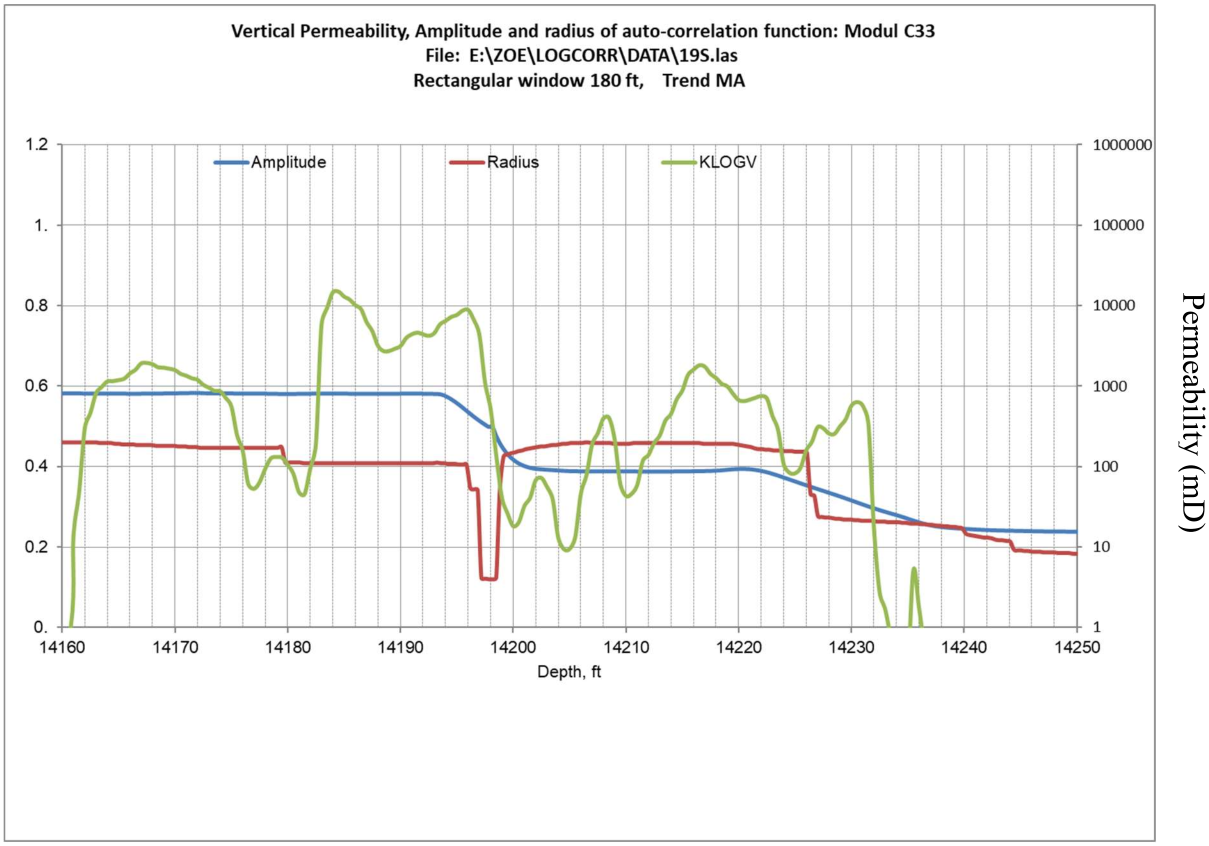
A9: Amplitude, Radius, Vertical Permeability vs. Depth (Productive Interval)

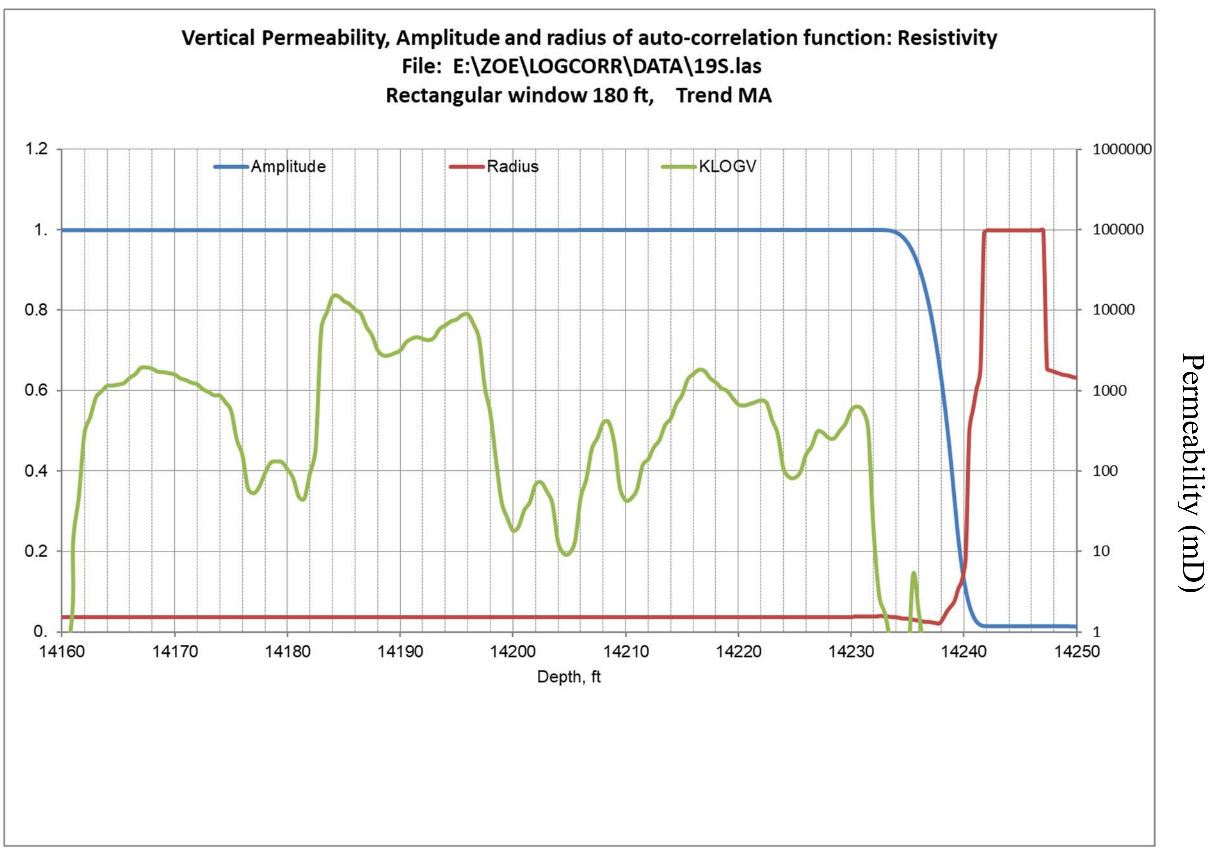
A9: Amplitude, Radius, Vertical Permeability vs. Depth (Productive Interval)

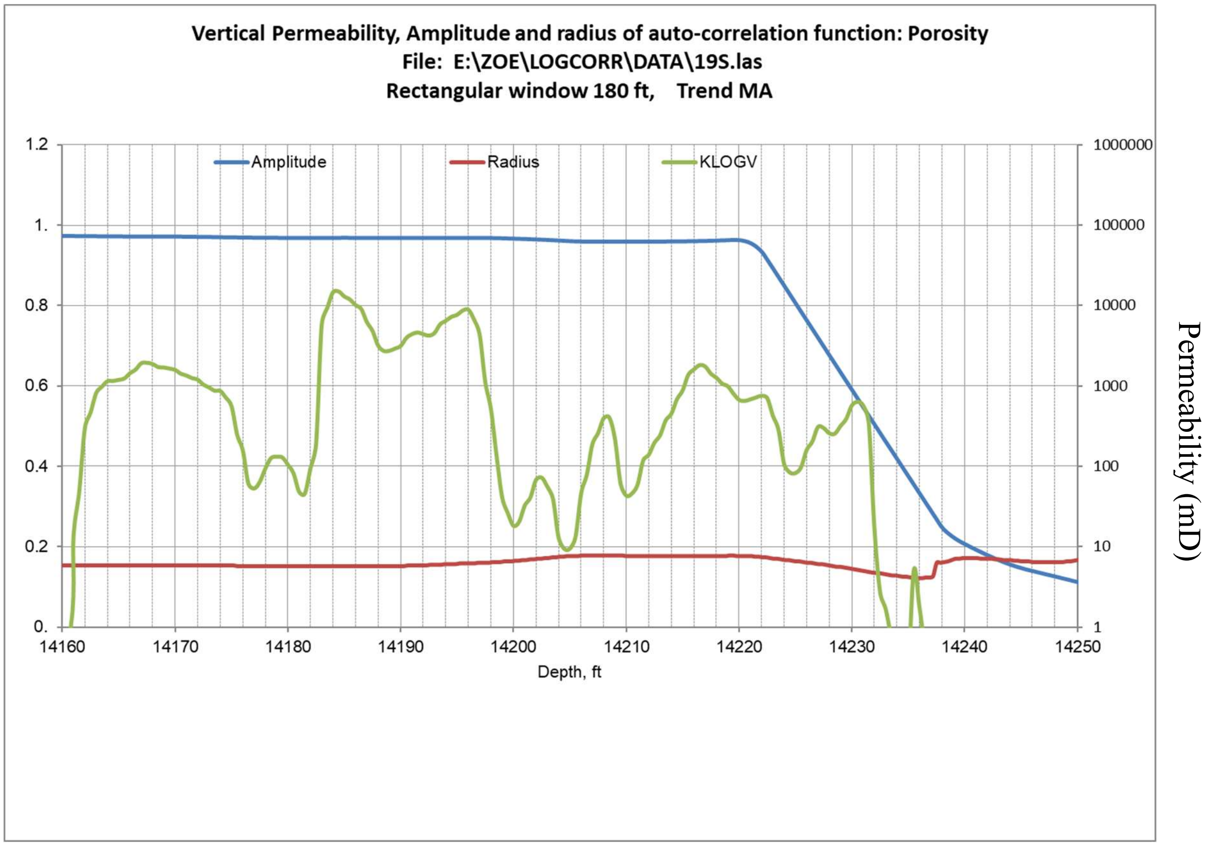
Section A9 focuses on the productive interval and the behavior of vertical permeability, correlation radius, and amplitude. The following plots contain horizontal permeability behavior within the productive interval with both correlation radius and amplitude shown. Amplitude and permeabilities should be high and correlation radius should be low. At the top or bottom of the productive interval, the relationship may falter as these are the tops and bottoms of the productive interval.


Vertical Permeability, Amplitude and radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

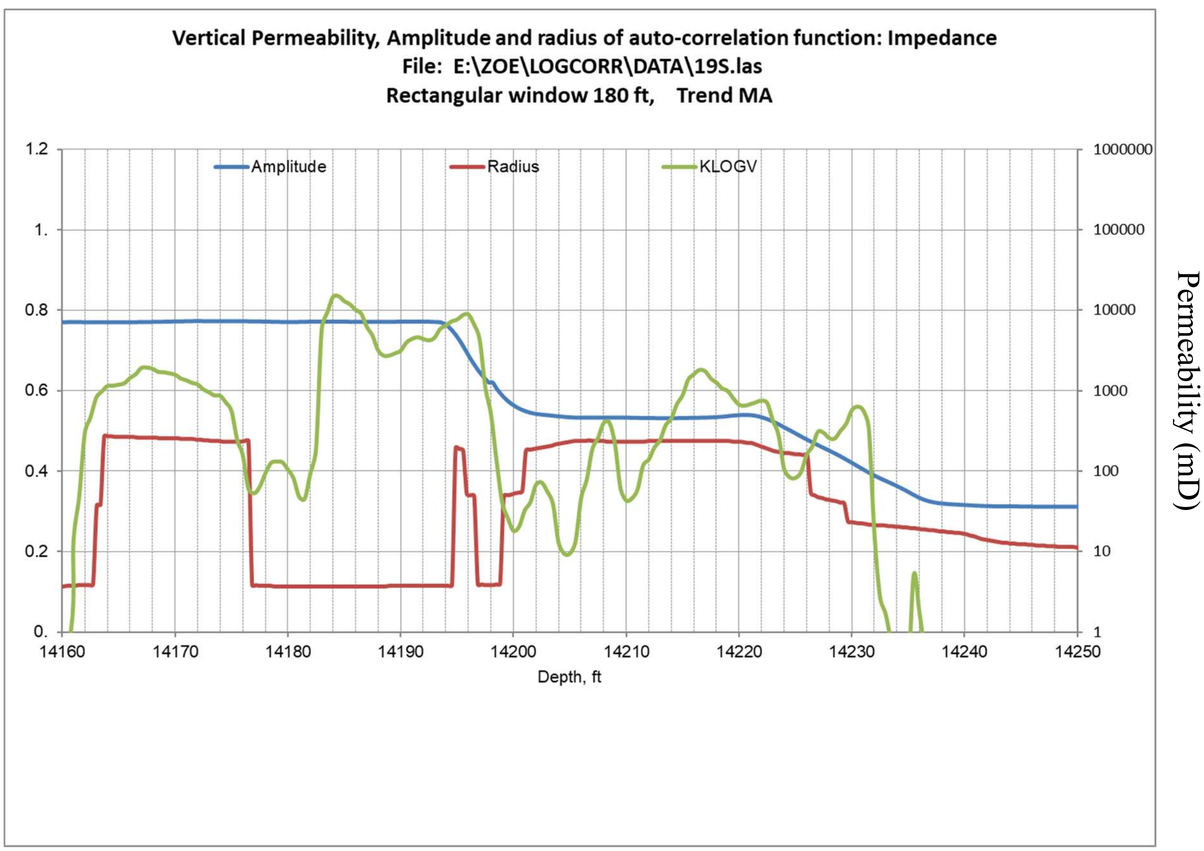

Vertical Permeability, Amplitude and radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude and radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)

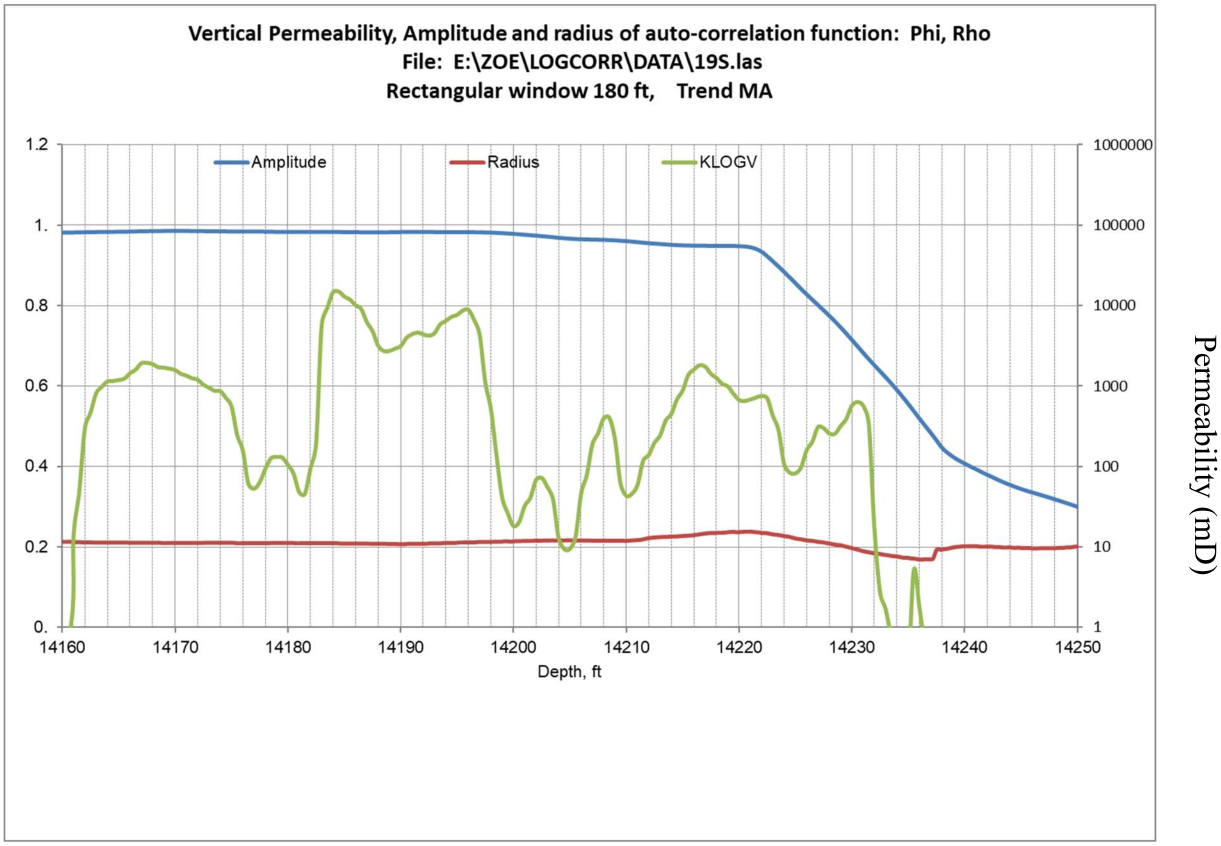

Vertical Permeability, Amplitude and radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)

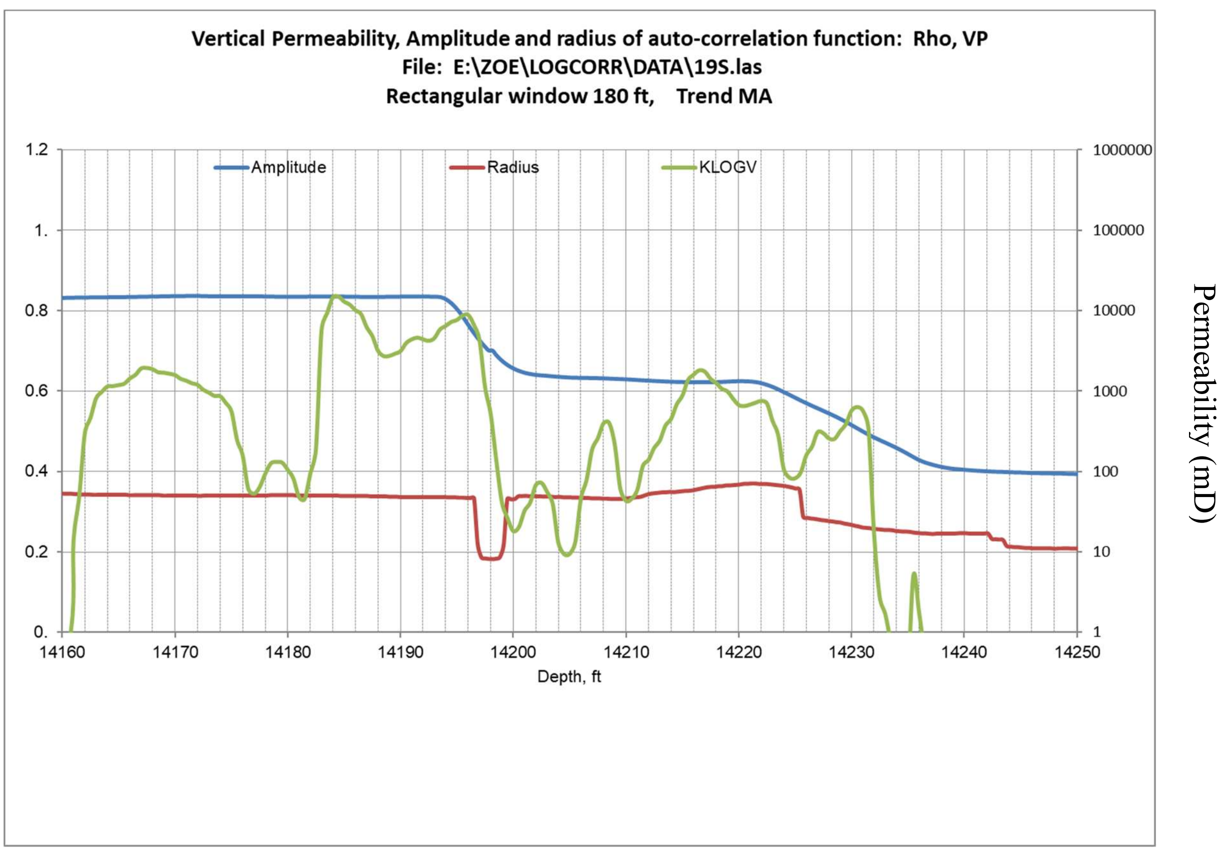


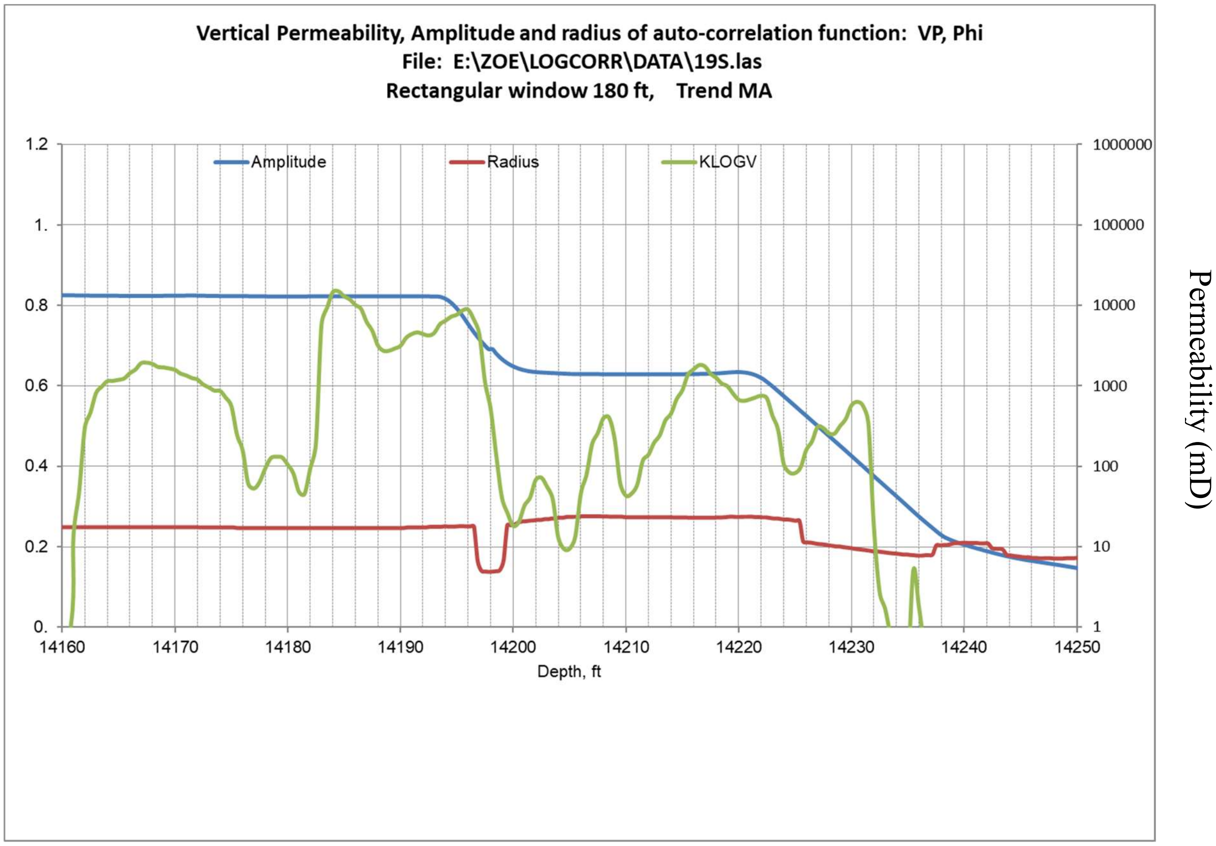
Vertical Permeability, Amplitude and radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)



Vertical Permeability, Amplitude and radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude and radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)

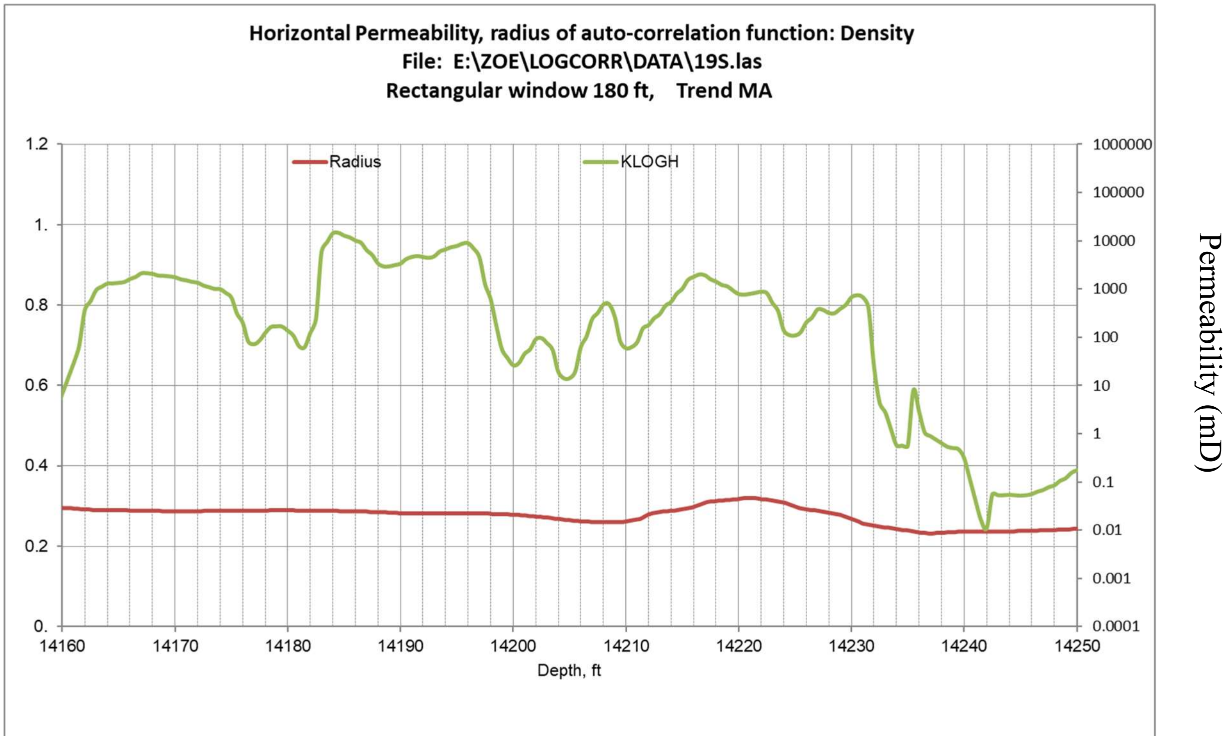

Vertical Permeability, Amplitude and radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
Depth, ft
Permeability (mD)

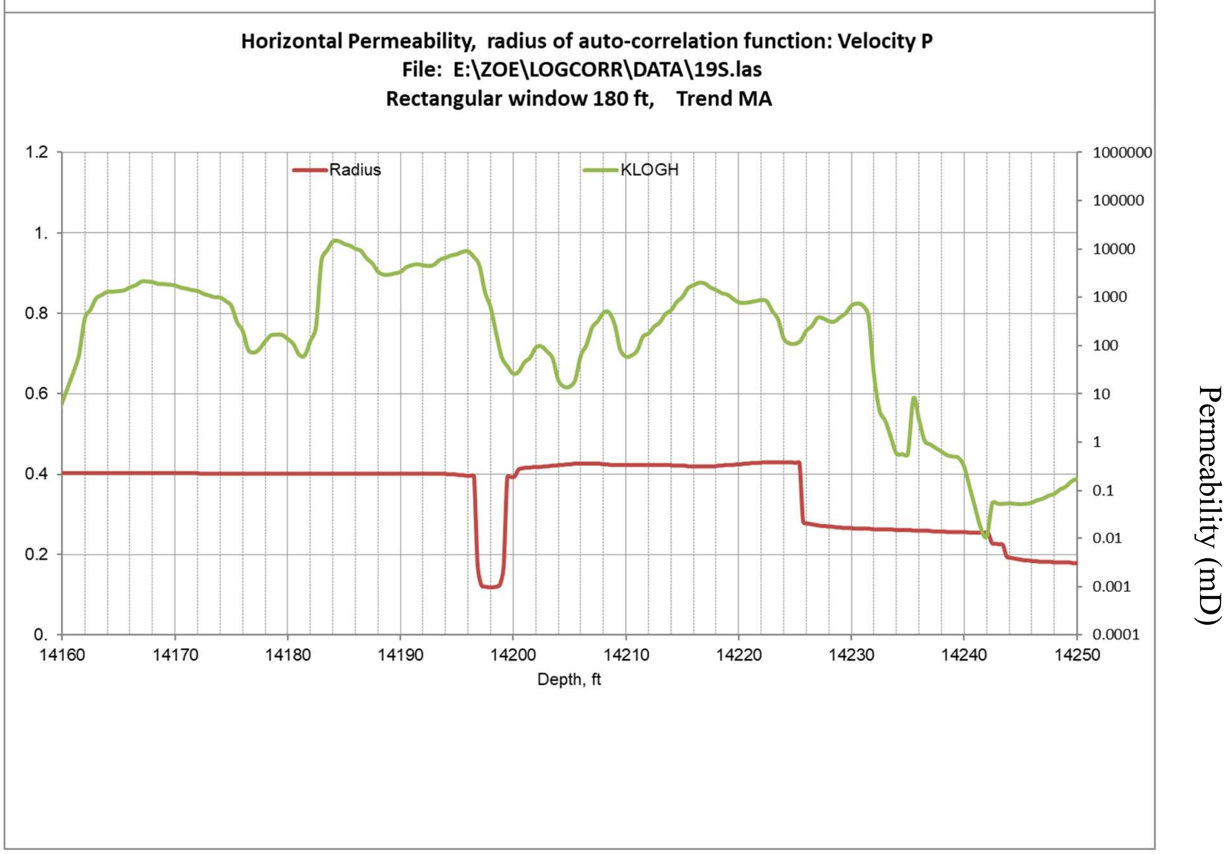

Vertical Permeability, Amplitude and radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

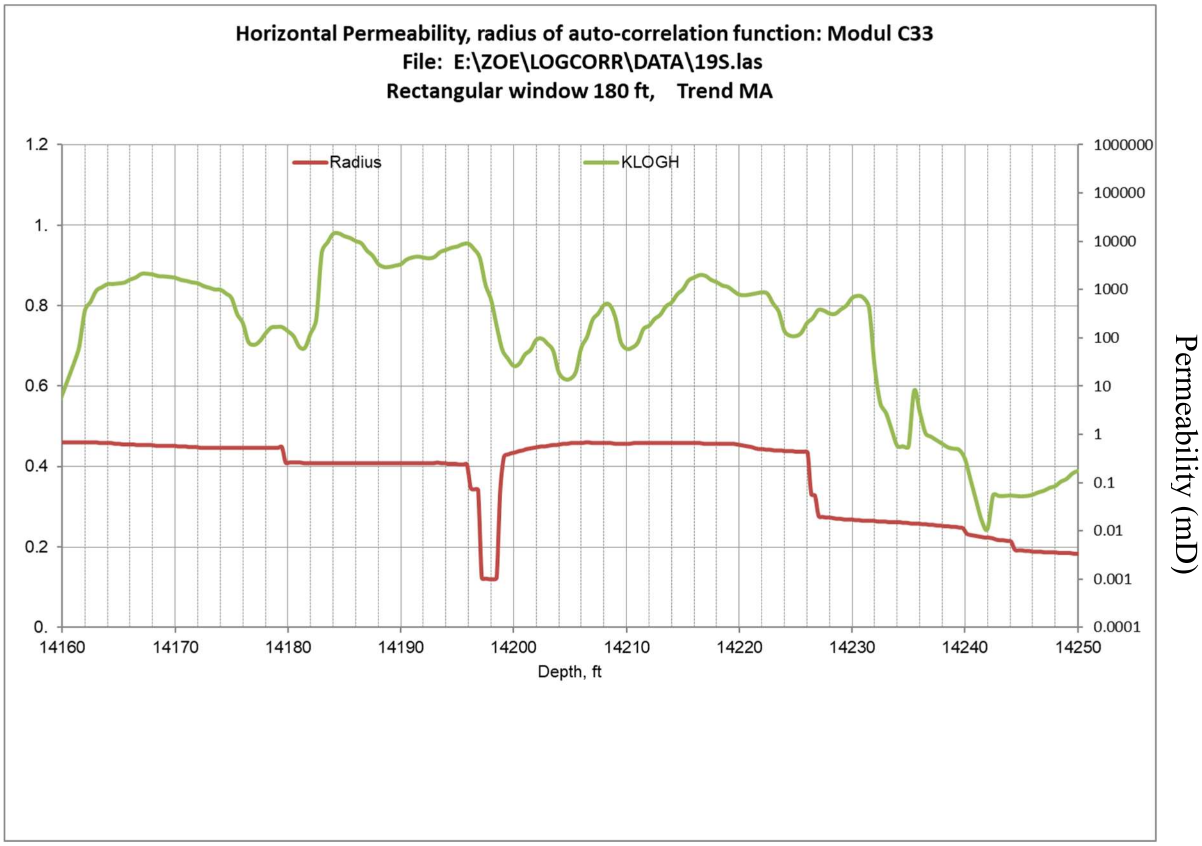
A10: Correlation Radius, Horizontal Permeability vs. Depth (Productive Interval)

A10: Correlation Radius, Horizontal Permeability vs. Depth (Productive Interval)

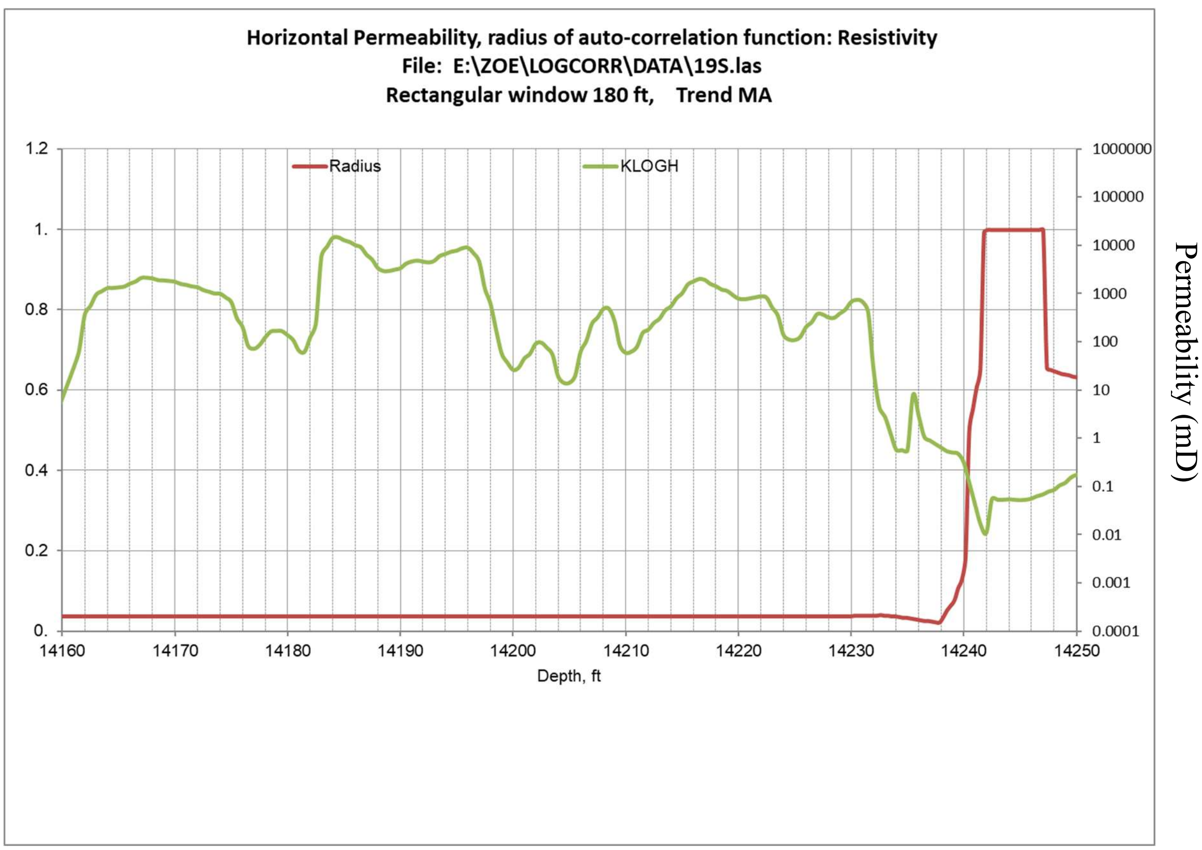
Section A10 focuses on the productive interval and the behavior of horizontal permeability and correlation radius. The following plots contain horizontal permeability within the productive interval with just the correlation radius shown. Horizontal permeabilities should be high and correlation radius should be low. At the top or bottom of the productive interval, the relationship may falter as these are the tops and bottoms of the productive interval.


Horizontal Permeability, radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
Permeability (mD)

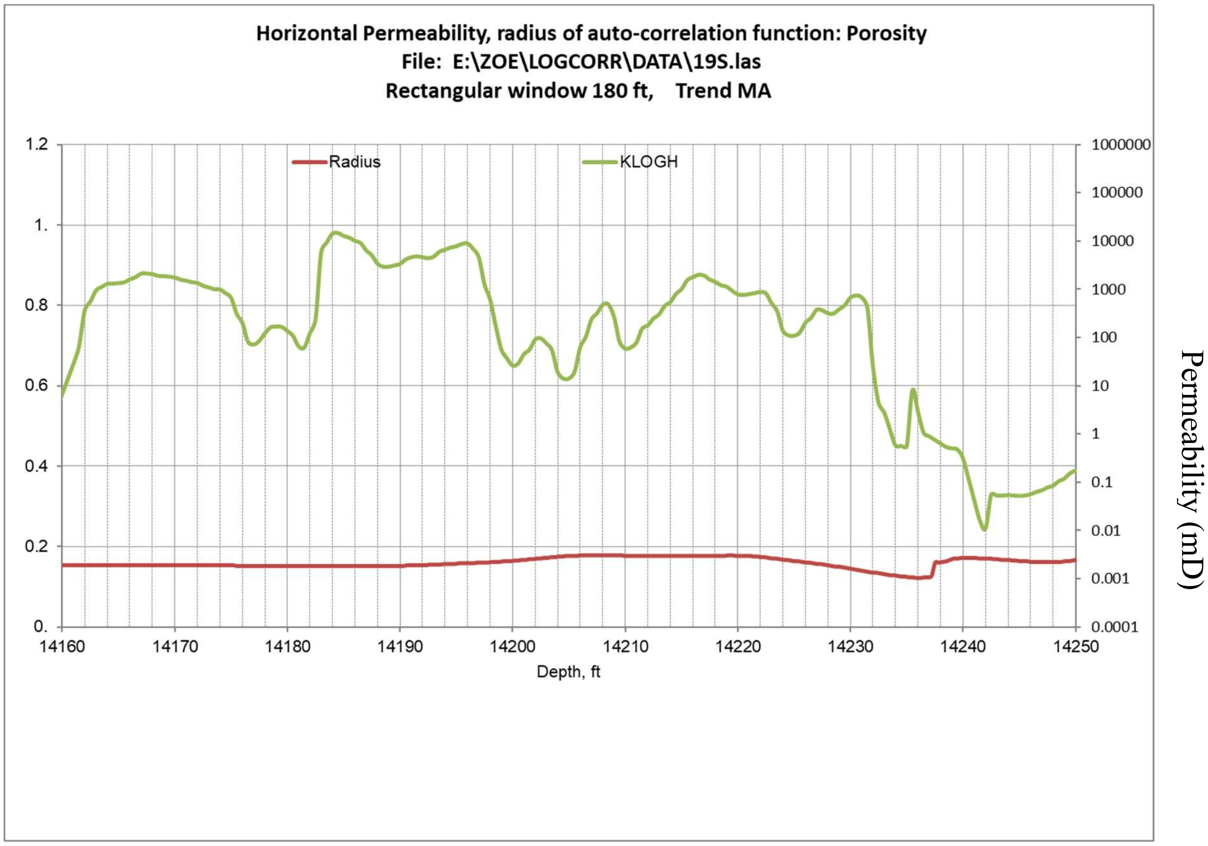

Horizontal Permeability, radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
Permeability (mD)

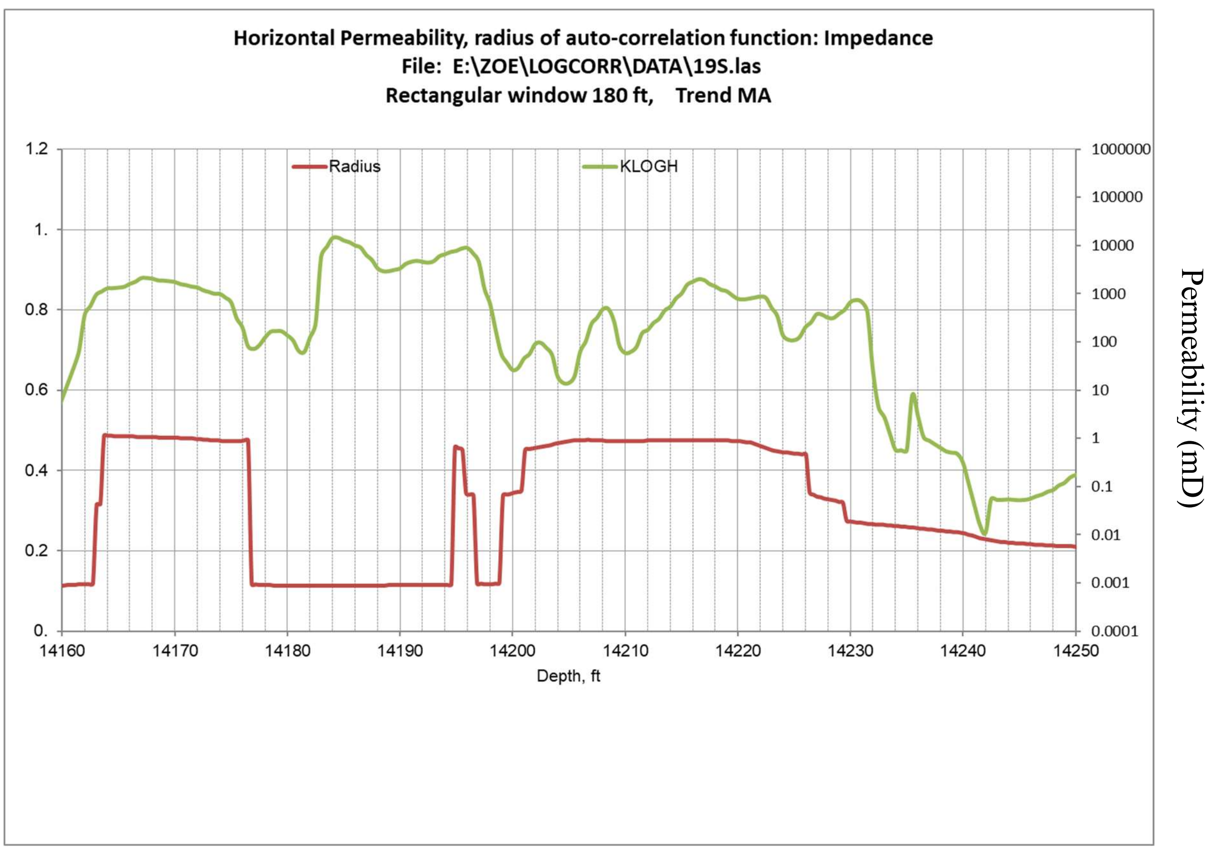


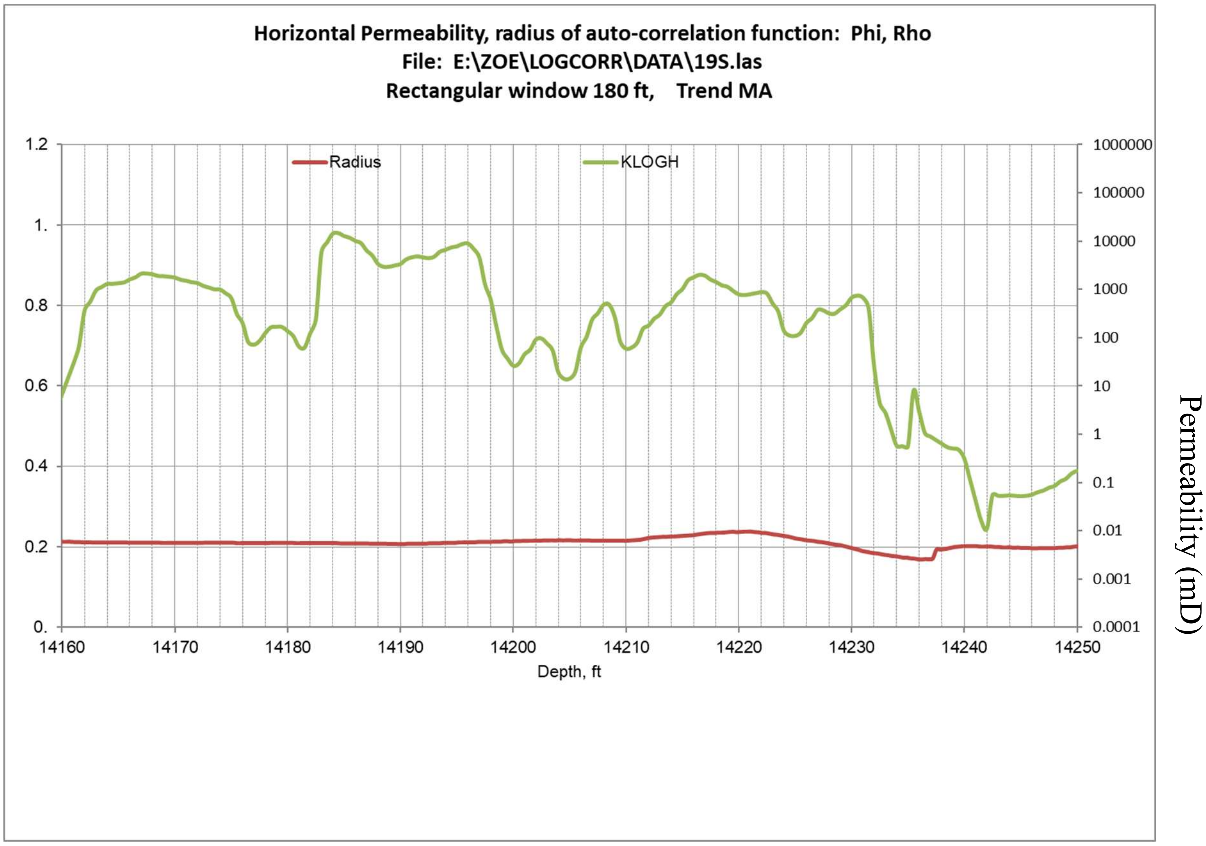
Horizontal Permeability, radius of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
Permeability (mD)

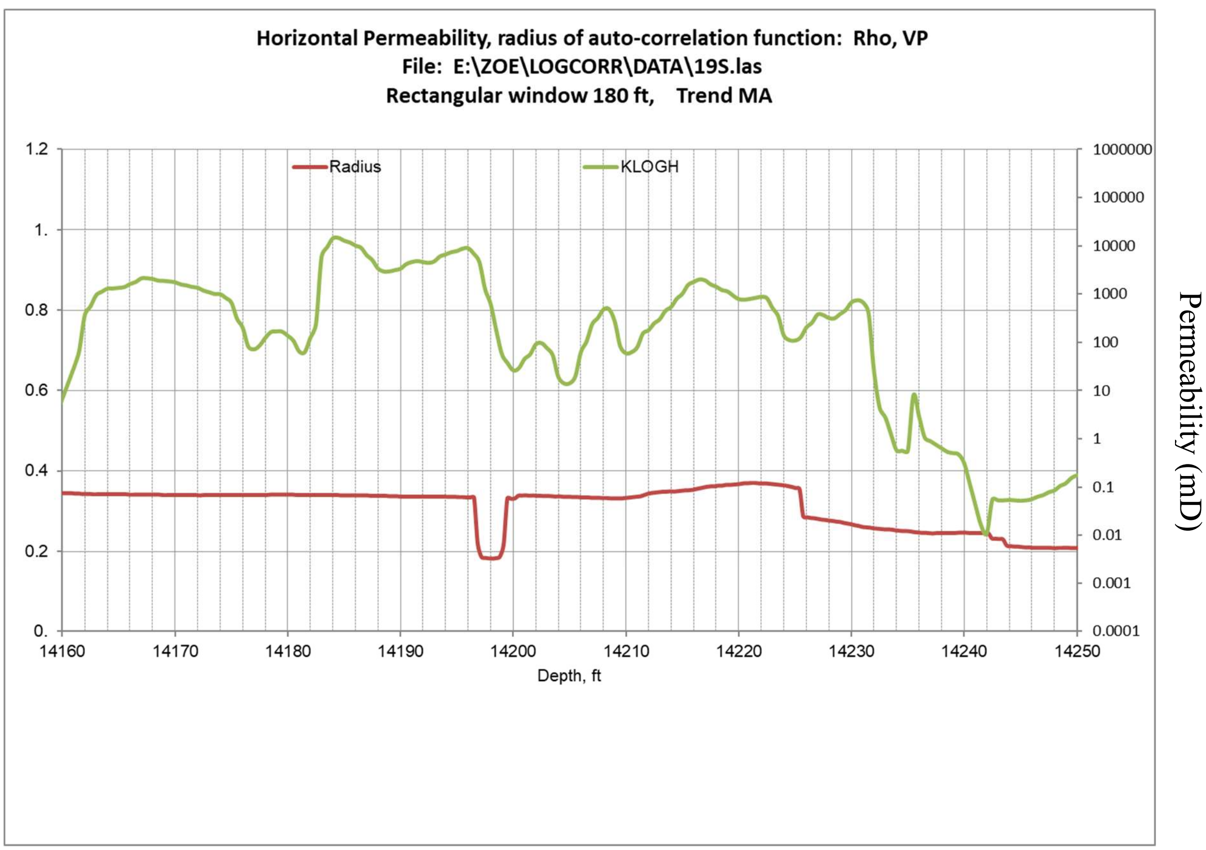


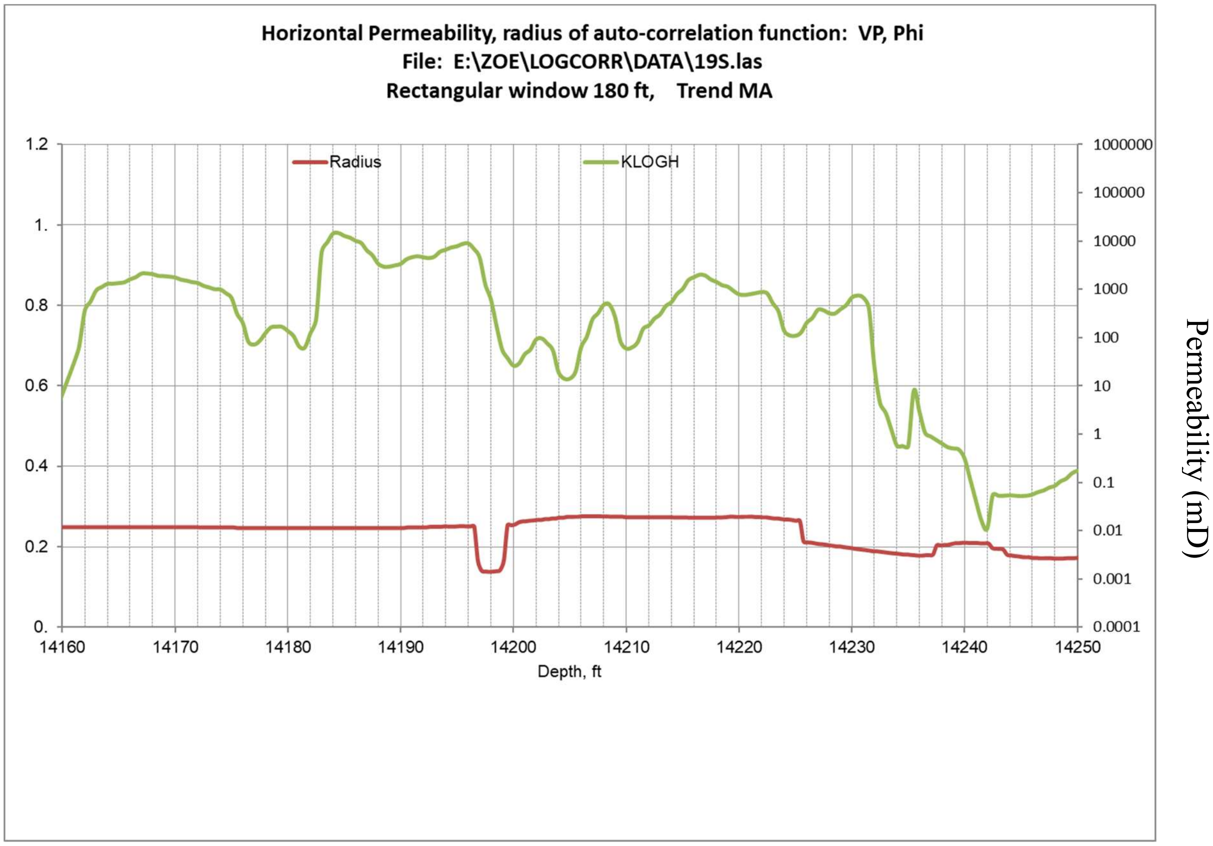
Horizontal Permeability, radius of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
Permeability (mD)

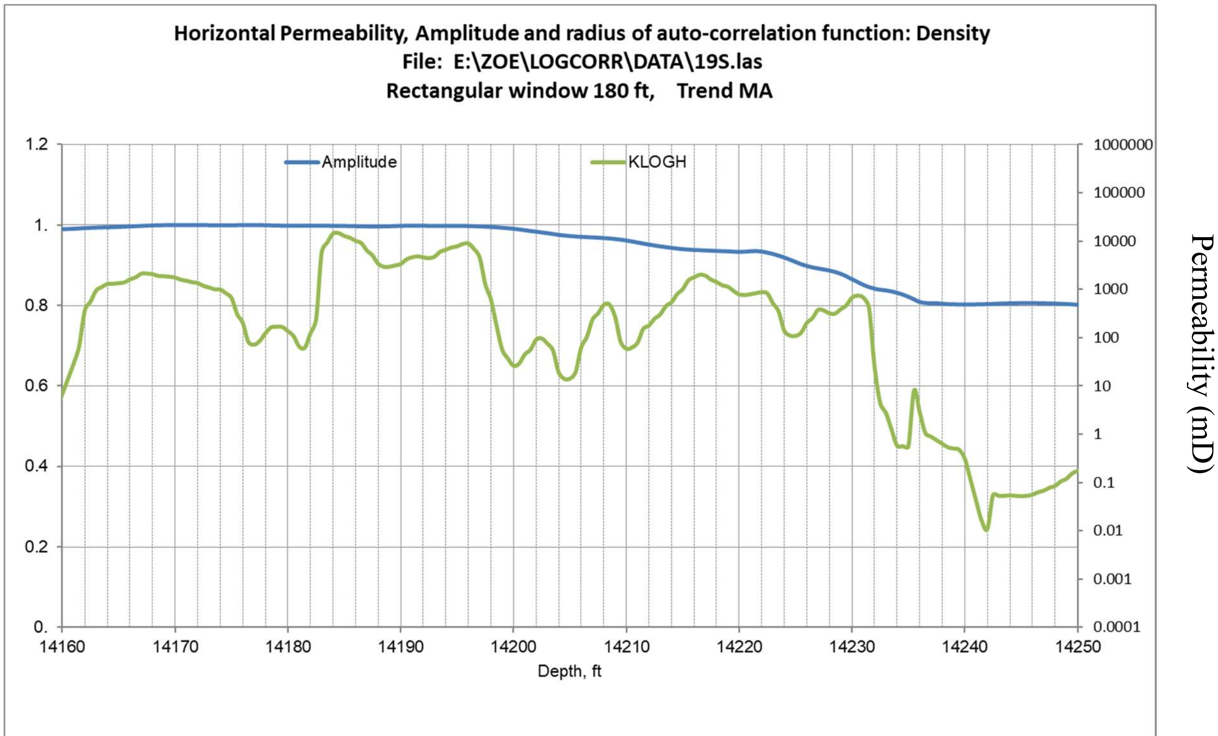

Horizontal Permeability, radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
Permeability (mD)


Horizontal Permeability, radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGH
Depth, ft
Permeability (mD)
1.2
1.
0.8
0.6
0.4
0.2
0.
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001

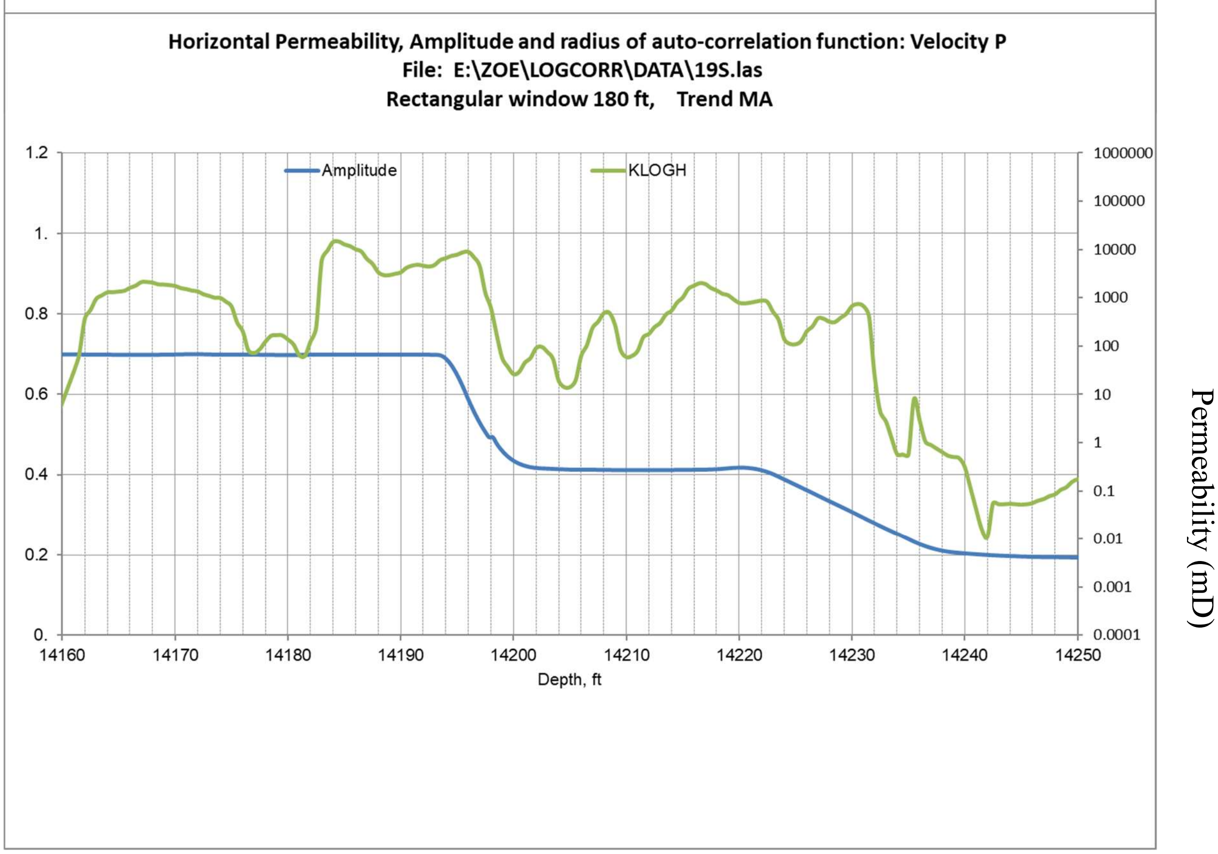
A11: Amplitude, Horizontal Permeability vs. Depth (Productive Interval)

A11: Amplitude, Horizontal Permeability vs. Depth (Productive Interval)

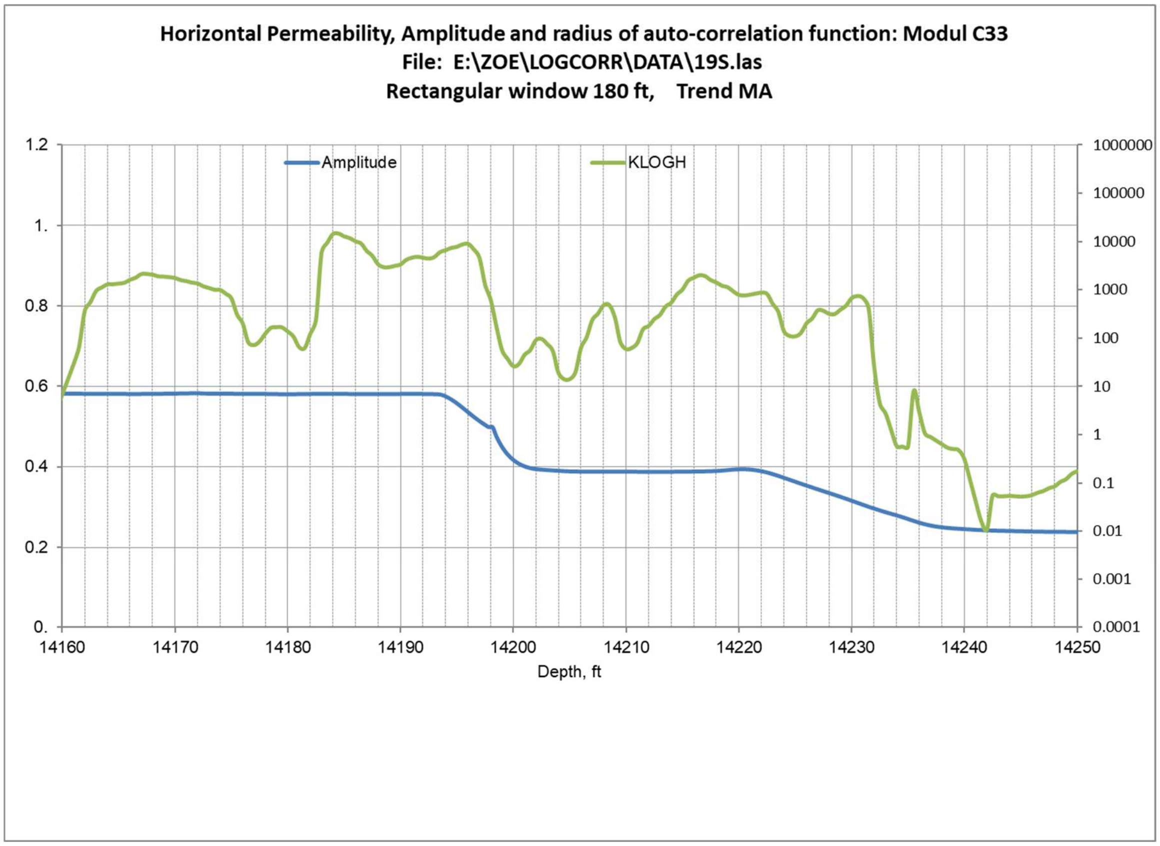
Section A9 focuses on the productive interval and the behavior of horizontal permeability and amplitude. The following plots contain horizontal permeability within the productive interval with just the amplitude shown. Horizontal permeabilities should be high and amplitude should be high as well. At the top or bottom of the productive interval, the relationship may falter as these are the tops and bottoms of the productive interval.



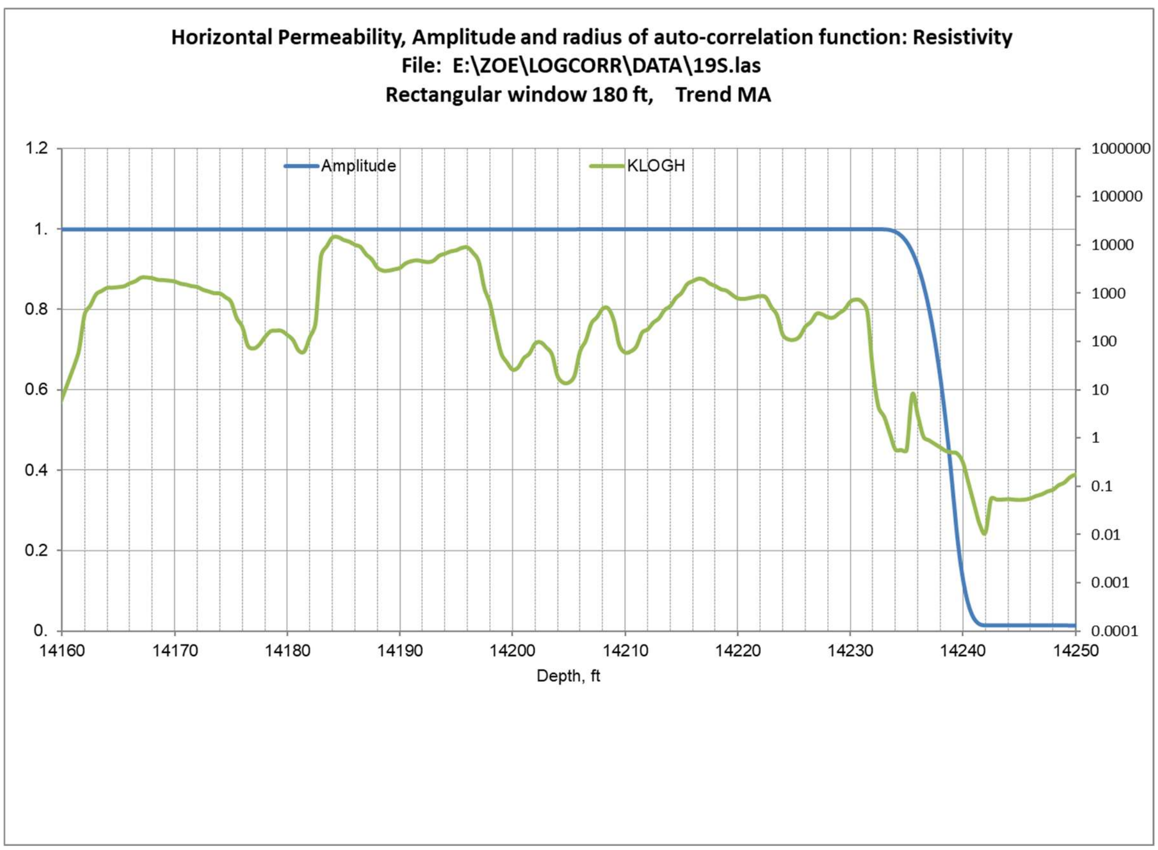
Horizontal Permeability, Amplitude and radius of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)



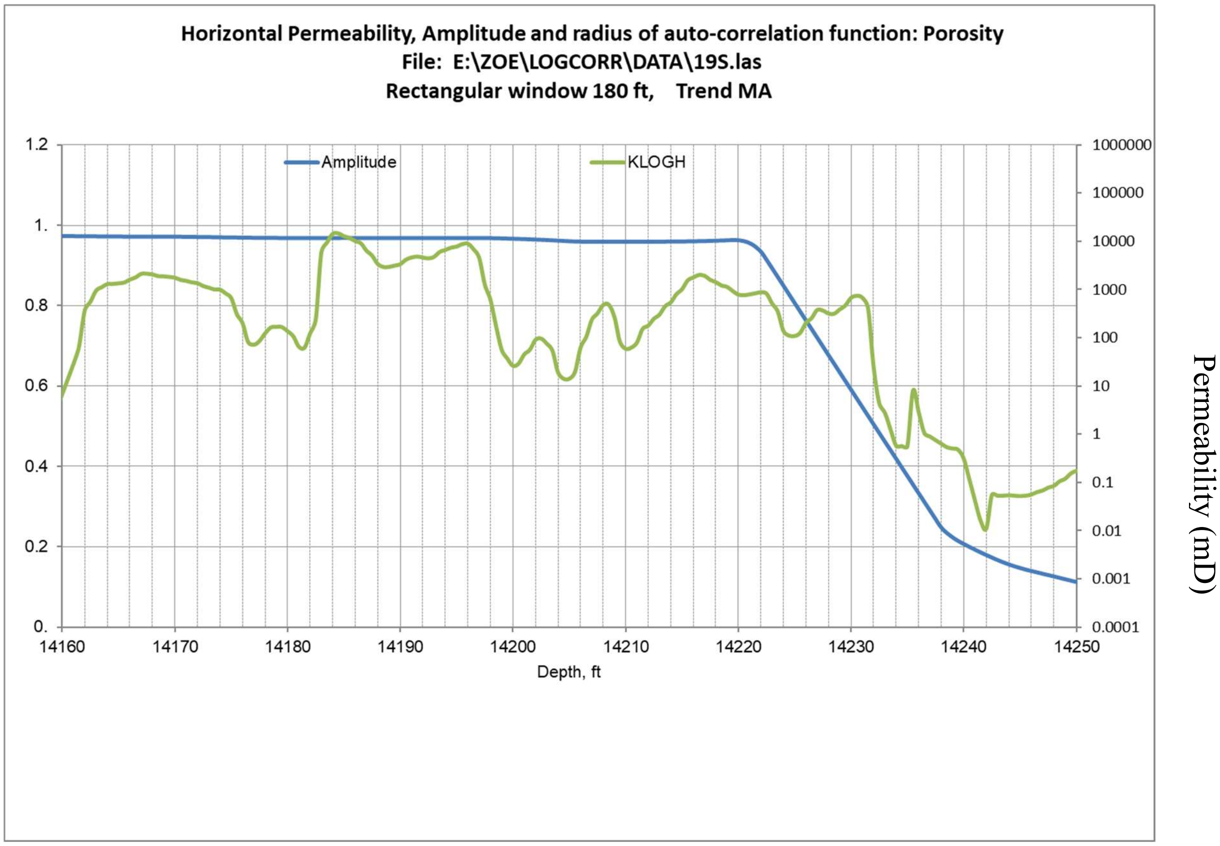
Horizontal Permeability, Amplitude and radius of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

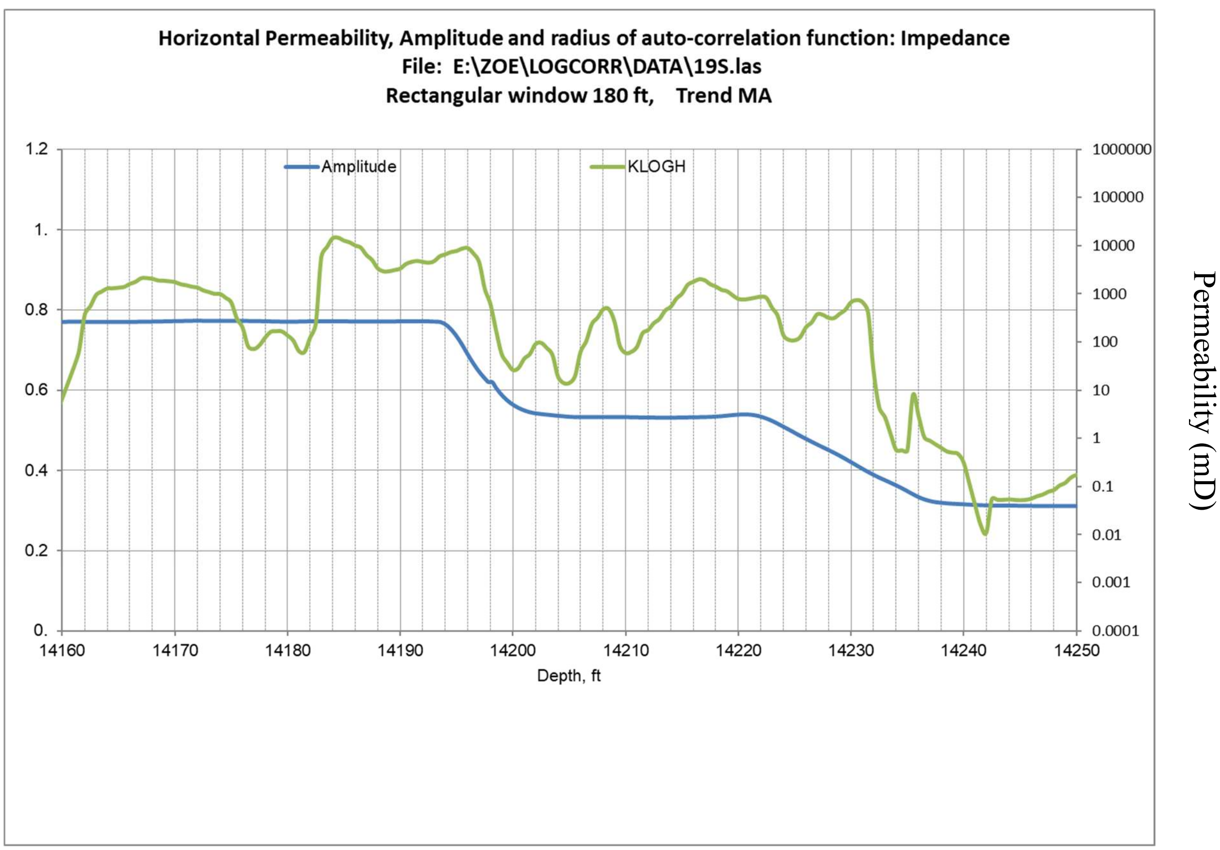


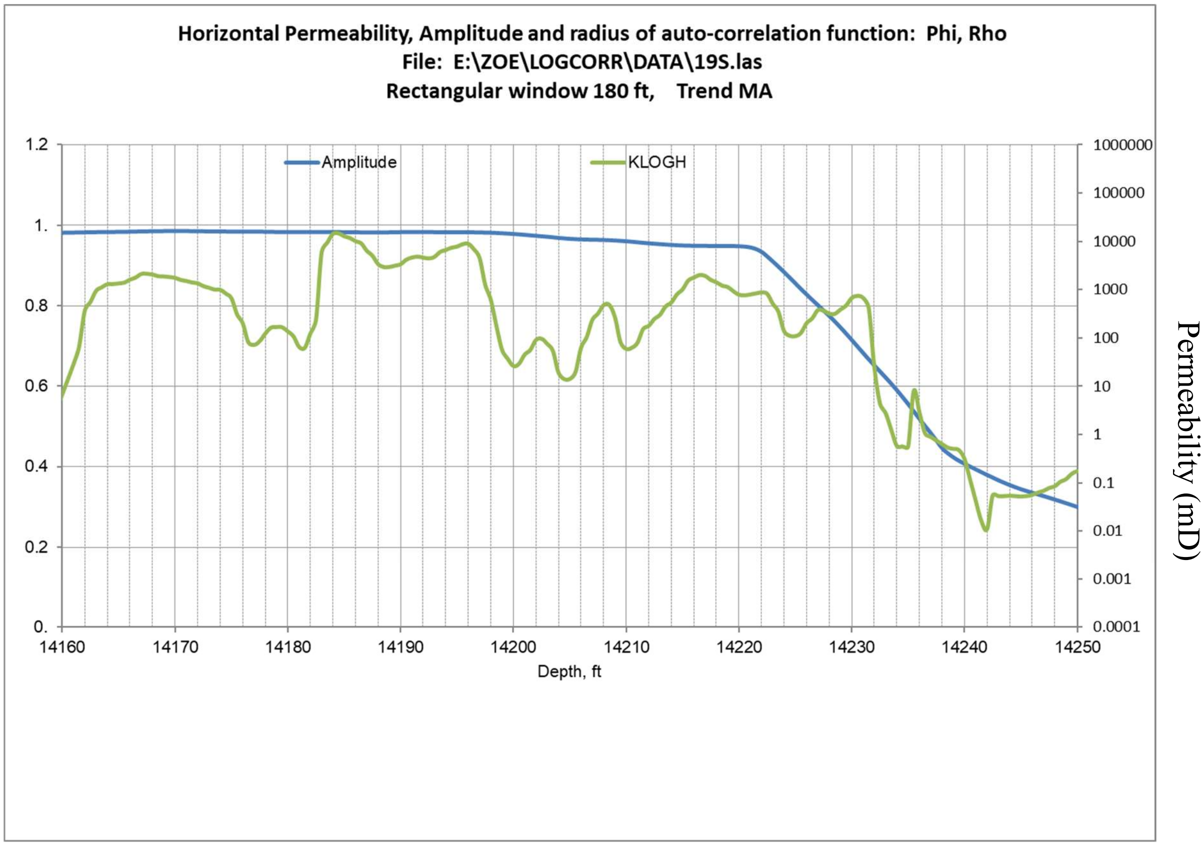
Permeability (mD)



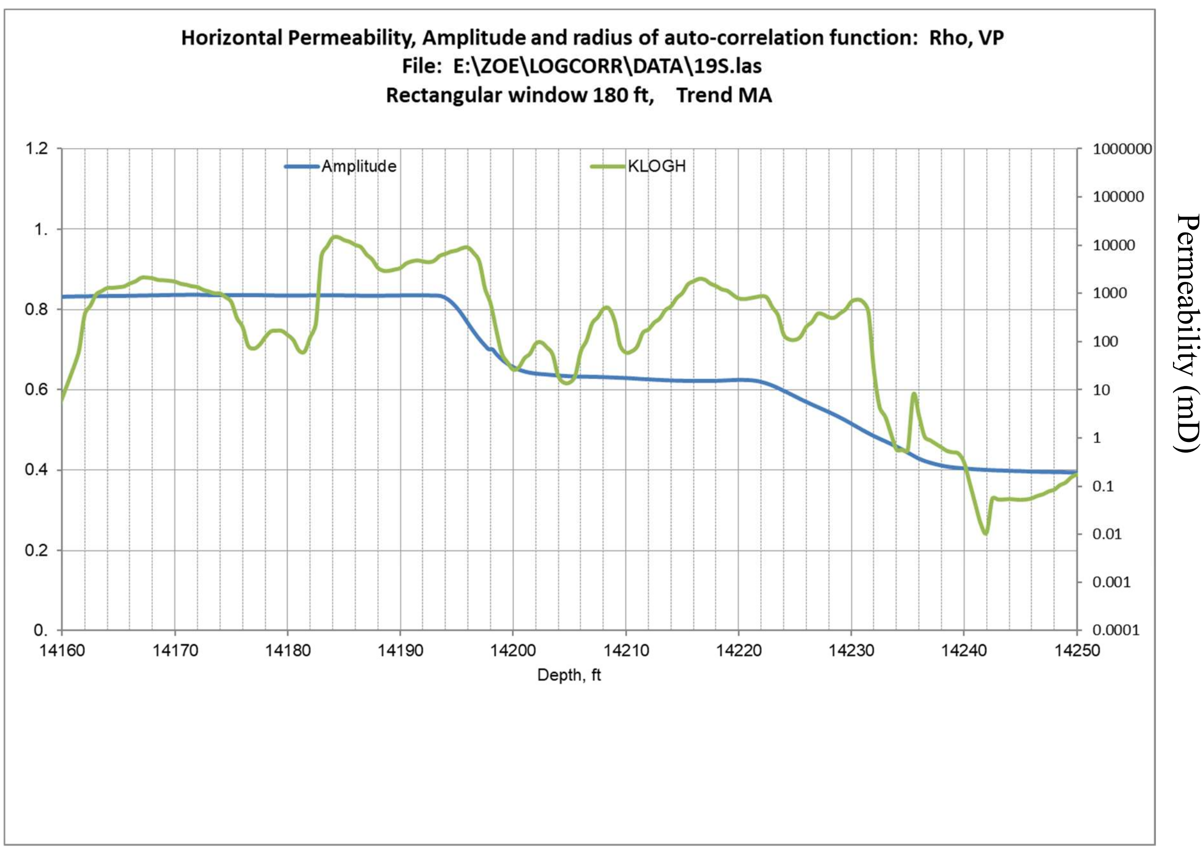
Permeability (mD)


Horizontal Permeability, Amplitude and radius of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

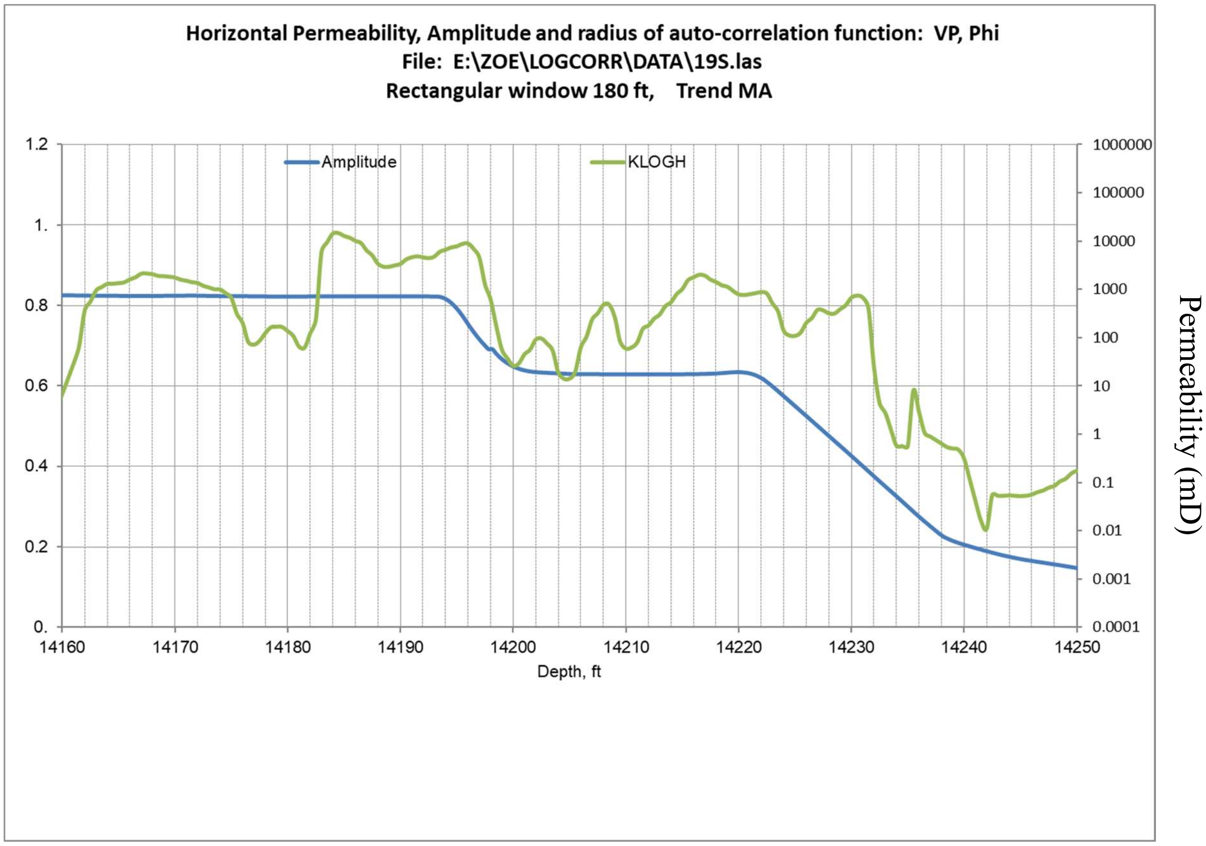

Horizontal Permeability, Amplitude and radius of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)



Horizontal Permeability, Amplitude and radius of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)



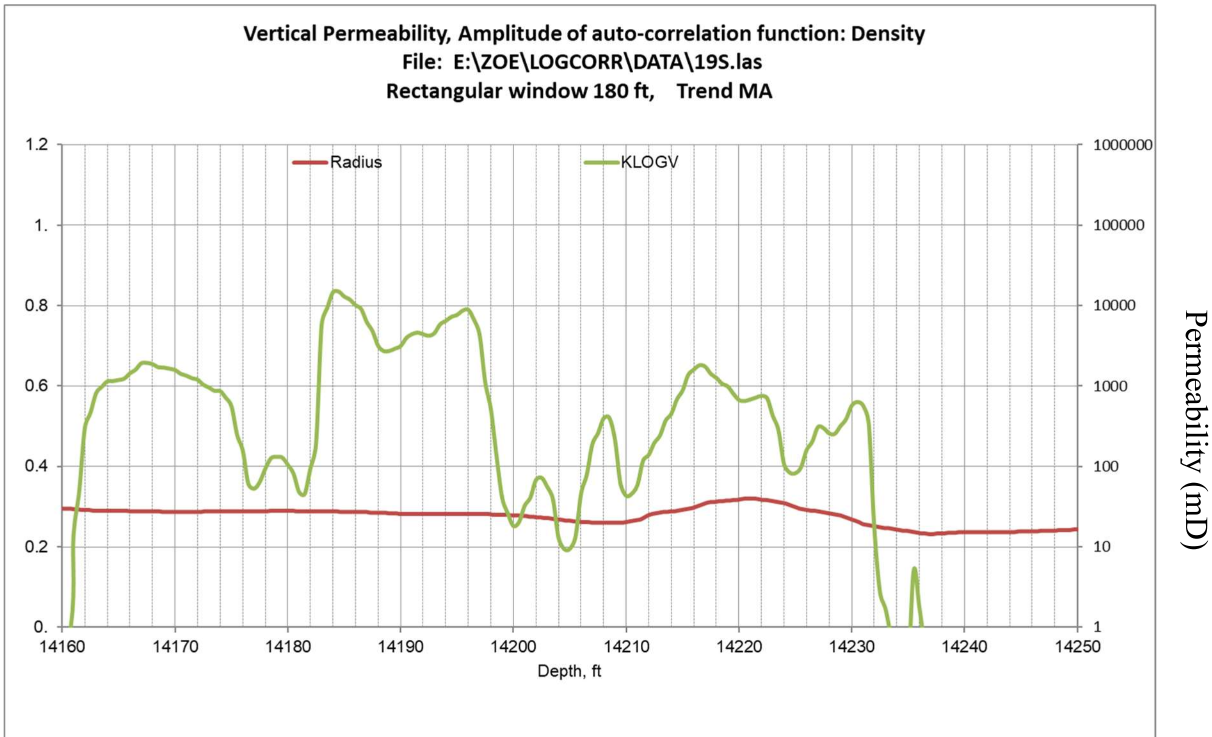
Horizontal Permeability, Amplitude and radius of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
Depth, ft
Permeability (mD)

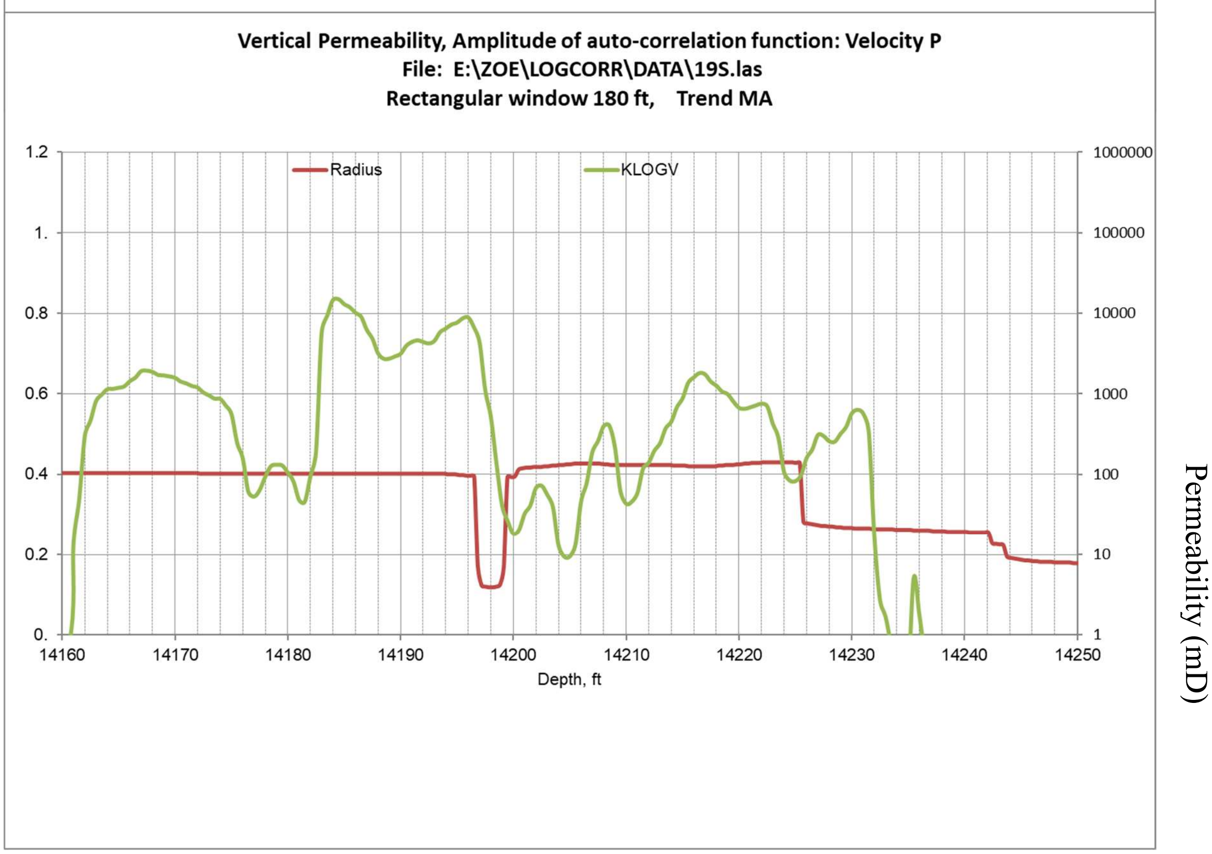

Horizontal Permeability, Amplitude and radius of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGH
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

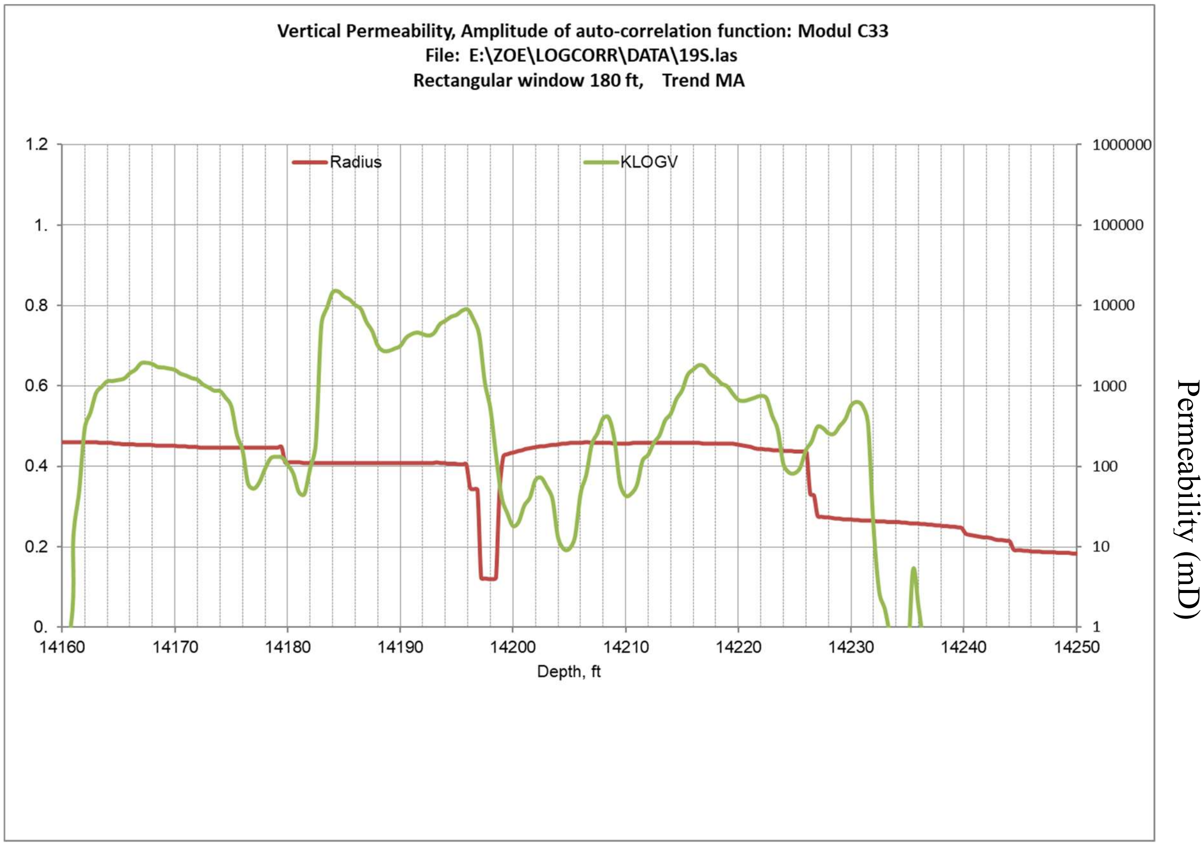
A12: Correlation Radius, Vertical Permeability vs. Depth (Productive Interval)

A12: Correlation Radius, Vertical Permeability vs. Depth (Productive Interval)

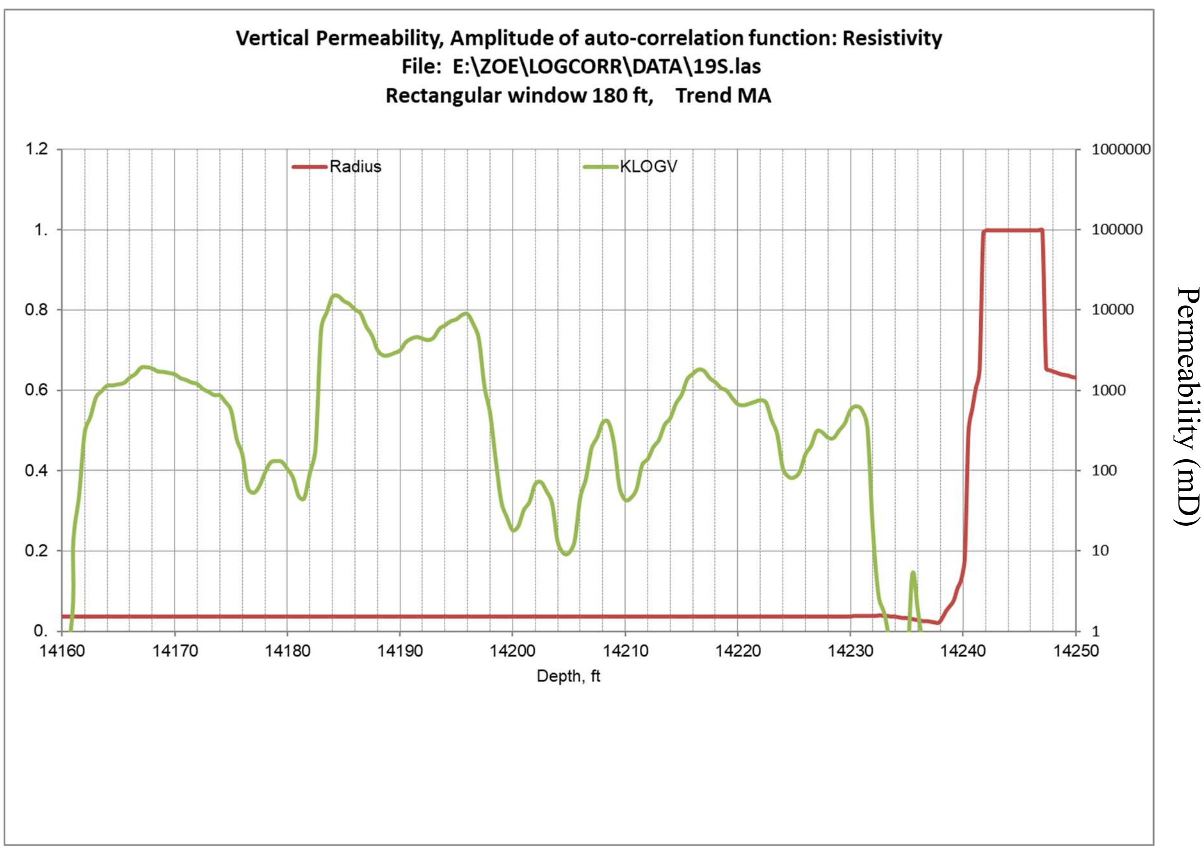
Section A10 focuses on the productive interval and the behavior of vertical permeability and correlation radius. The following plots contain horizontal permeability within the productive interval with just the correlation radius shown. Horizontal permeabilities should be high and correlation radius should be low. At the top or bottom of the productive interval, the relationship may falter as these are the tops and bottoms of the productive interval.


Vertical Permeability, Amplitude of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
Depth, ft
Permeability (mD)

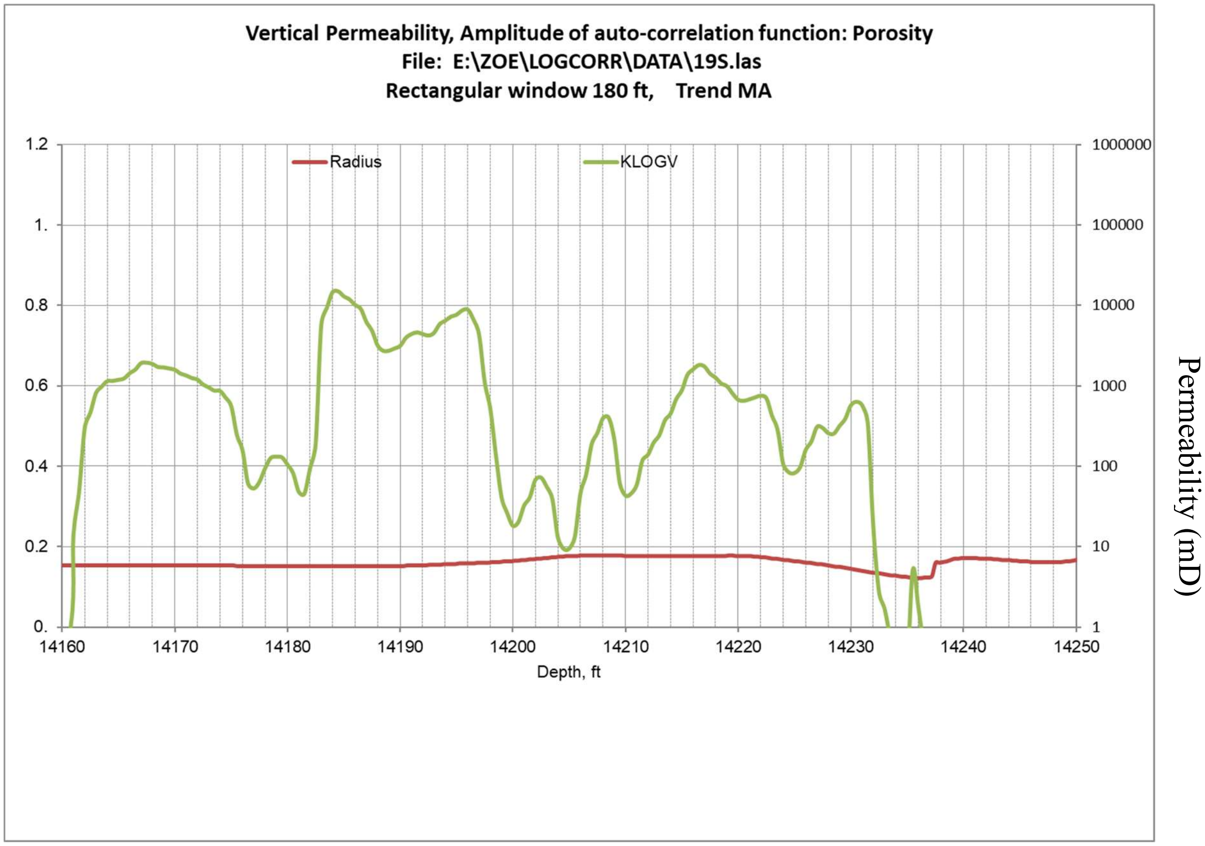

Vertical Permeability, Amplitude of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
Depth, ft
Permeability (mD)

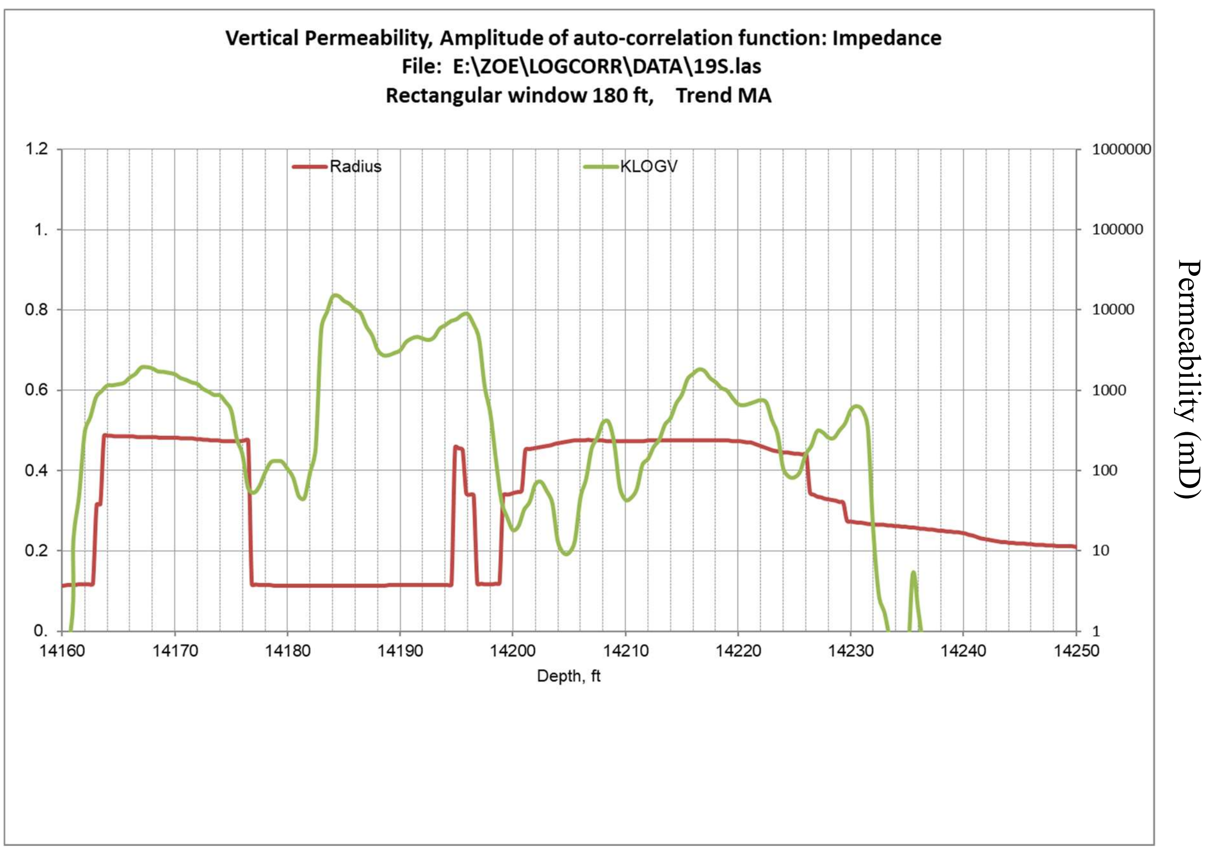


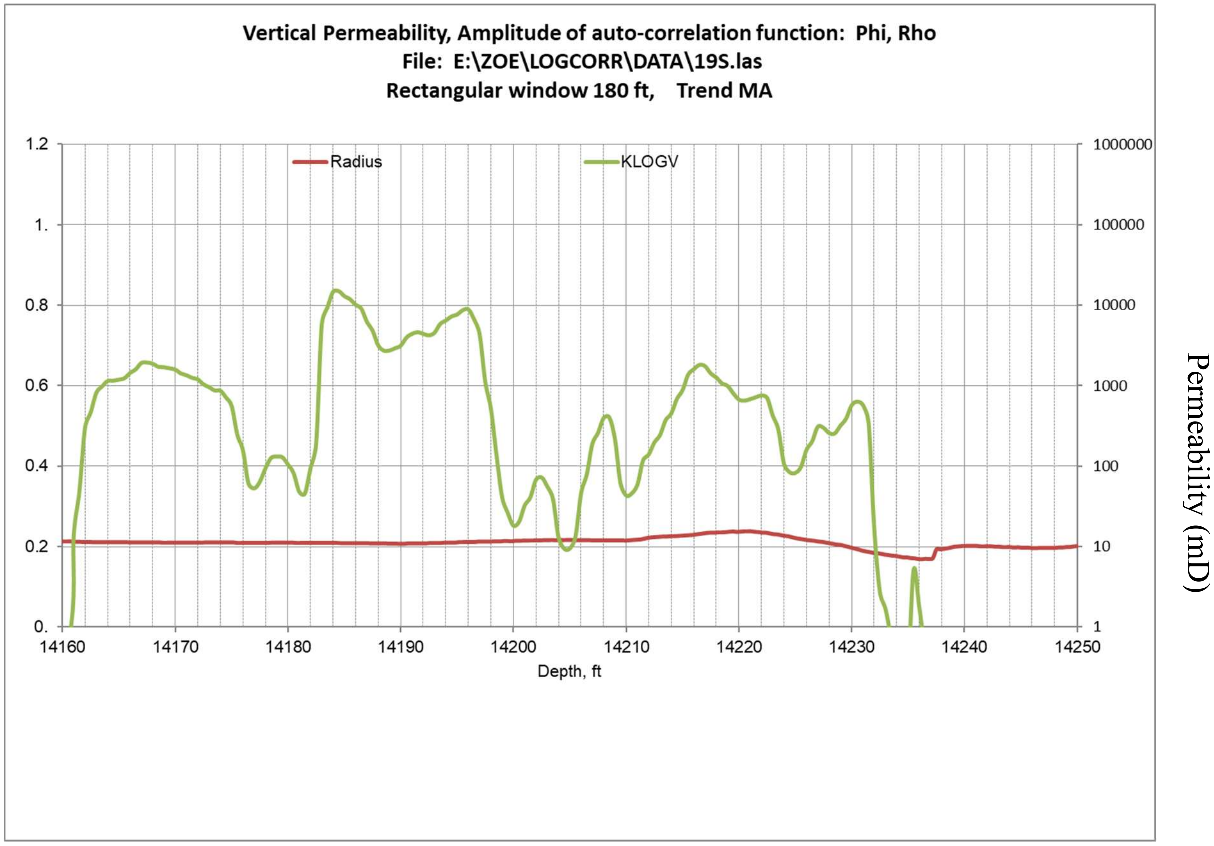
Vertical Permeability, Amplitude of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)



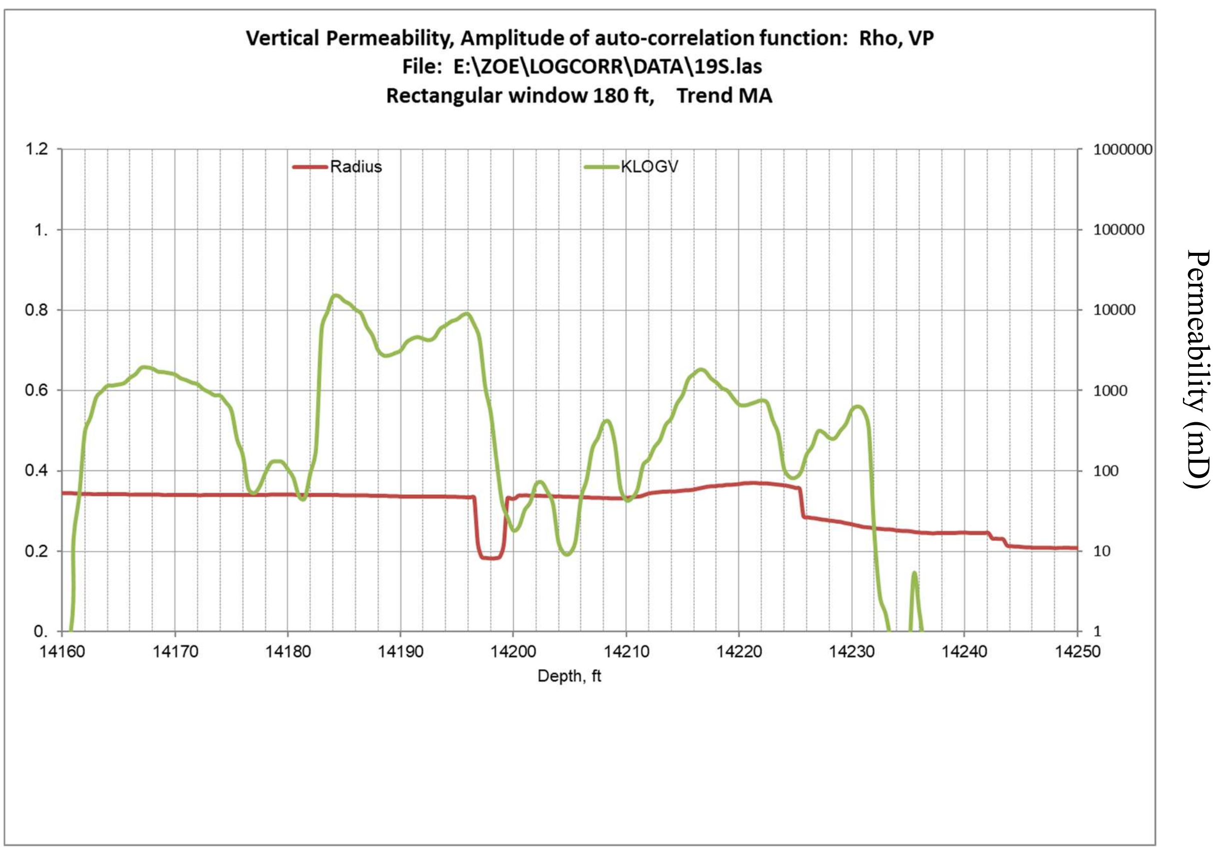
Vertical Permeability, Amplitude of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

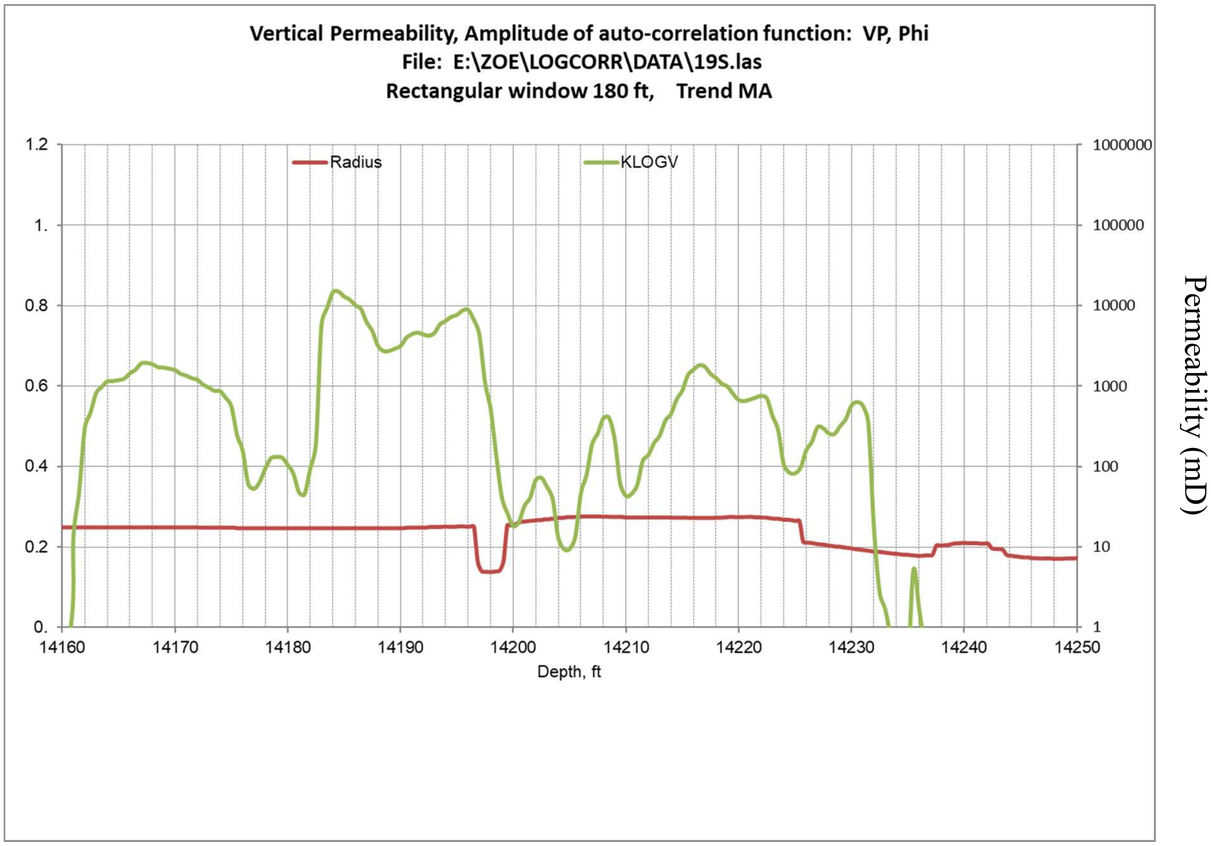

Vertical Permeability, Amplitude of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)



Vertical Permeability, Amplitude of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
Depth, ft
Permeability (mD)



Vertical Permeability, Amplitude of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
Depth, ft
Permeability (mD)

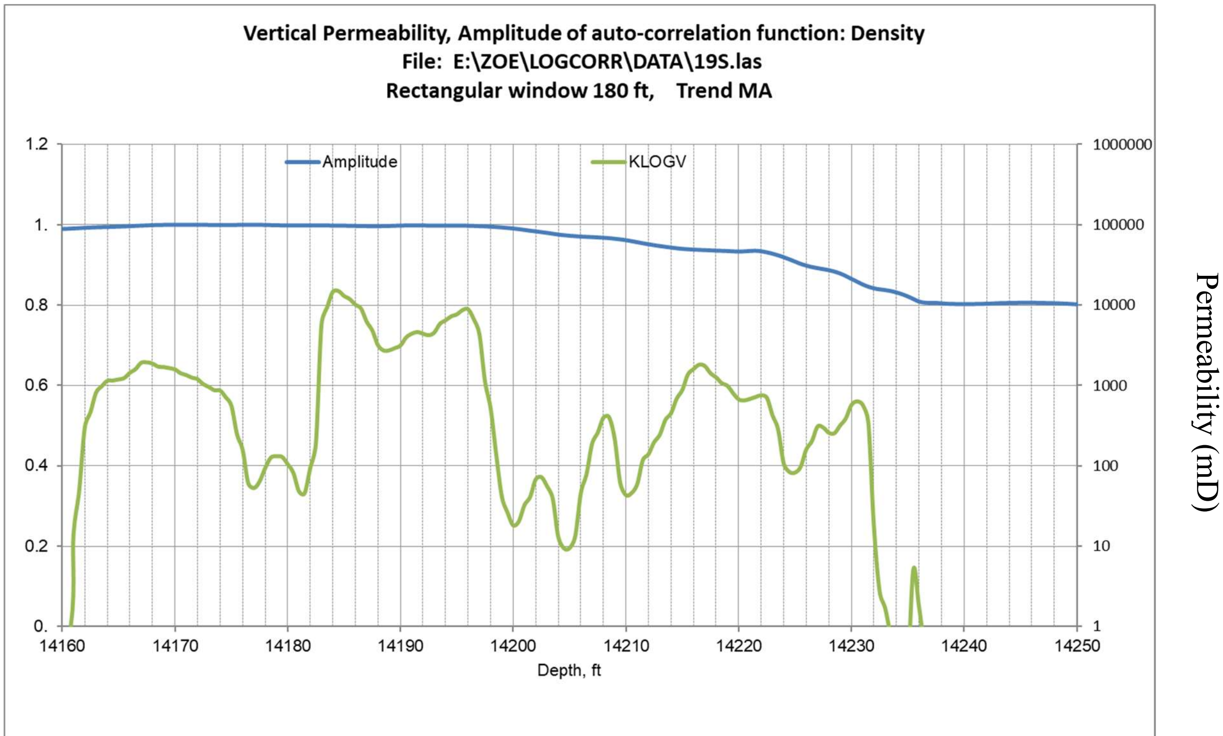


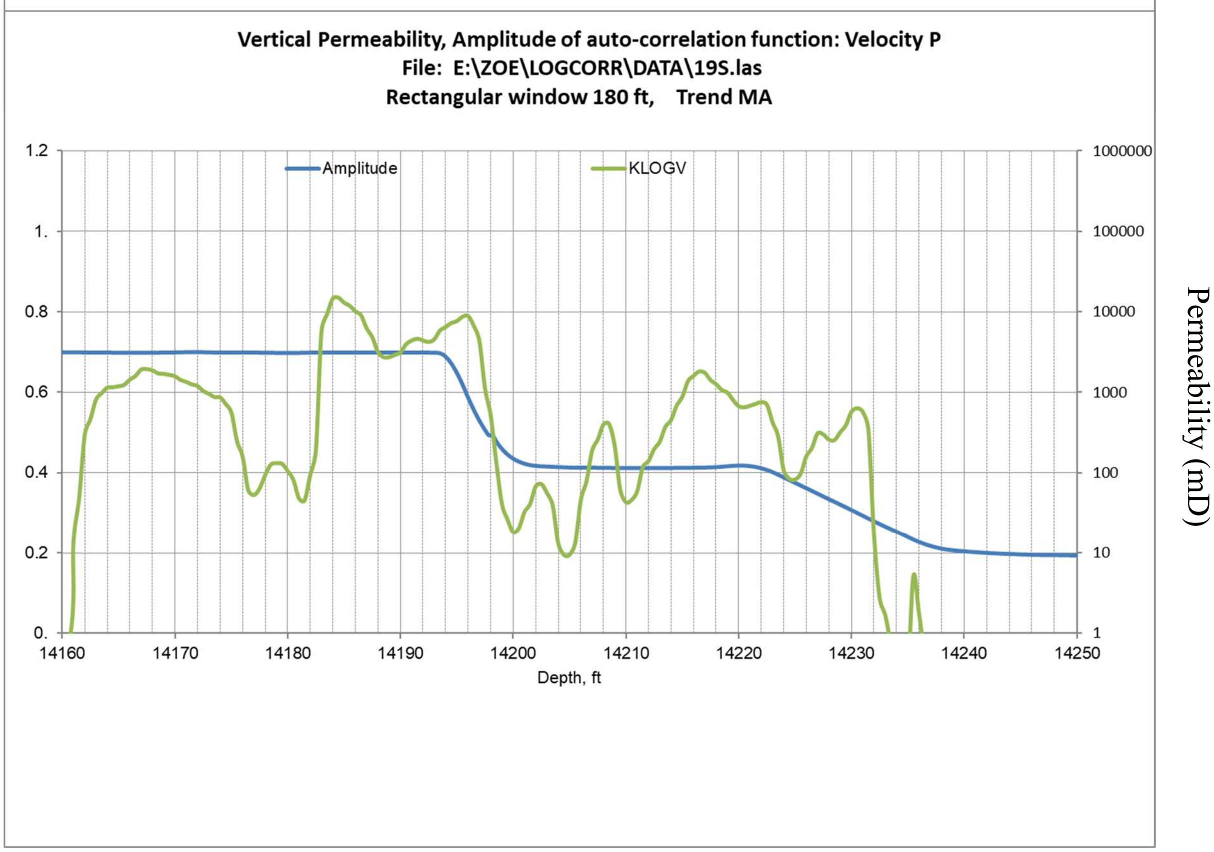
Vertical Permeability, Amplitude of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Radius
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

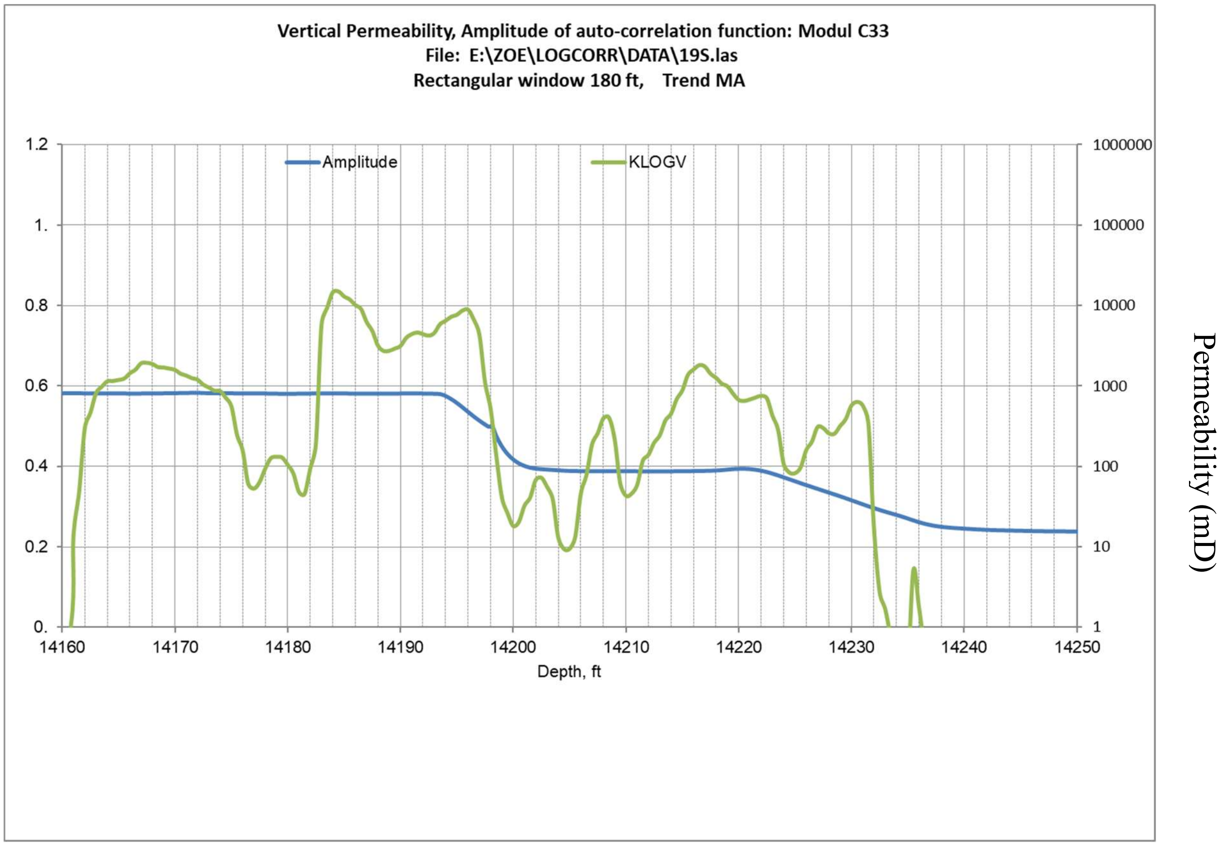
A13: Amplitude, Vertical Permeability vs. Depth (Productive Interval)

A13: Vertical, Horizontal Permeability vs. Depth (Productive Interval)

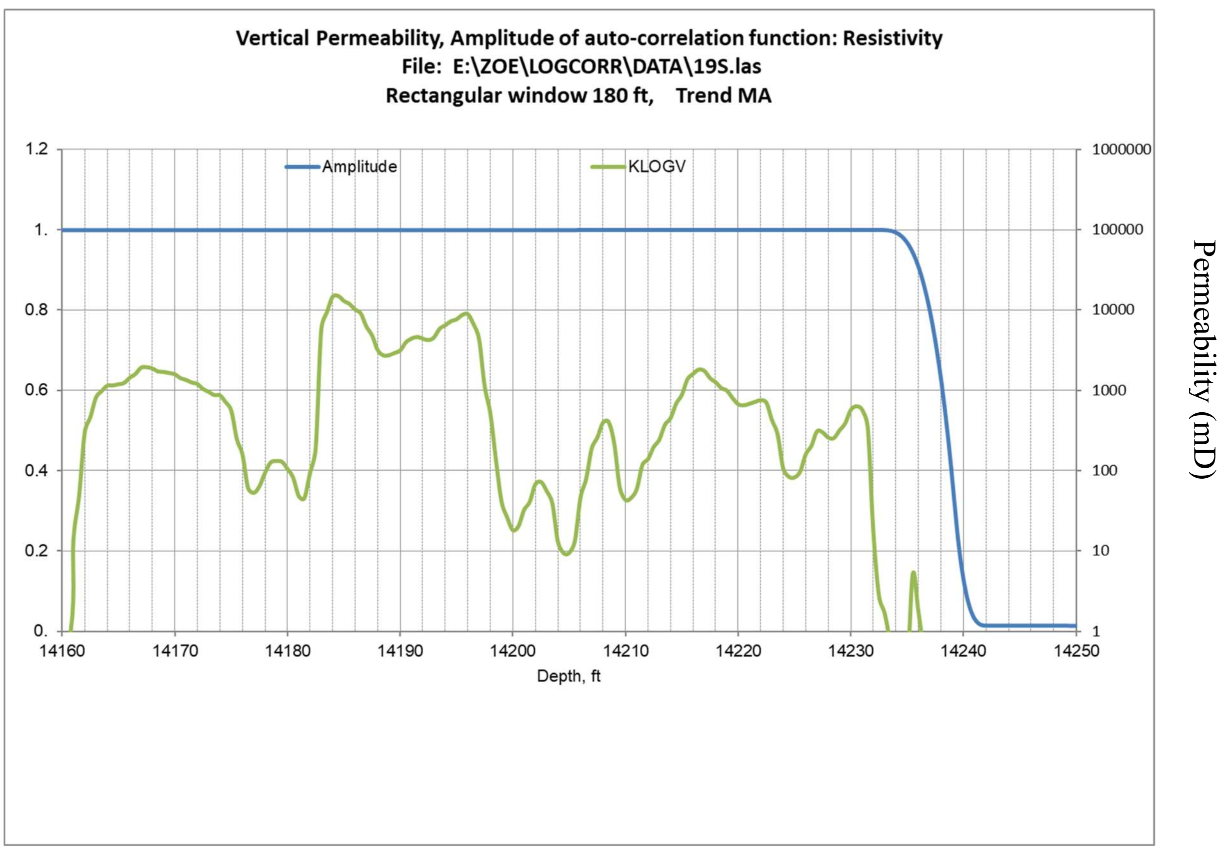
Section A9 focuses on the productive interval and the behavior of vertical permeability and amplitude. The following plots contain horizontal permeability within the productive interval with just the amplitude shown. Horizontal permeabilities should be high and amplitude should be high as well. At the top or bottom of the productive interval, the relationship may falter as these are the tops and bottoms of the productive interval.


Vertical Permeability, Amplitude of auto-correlation function: Density
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

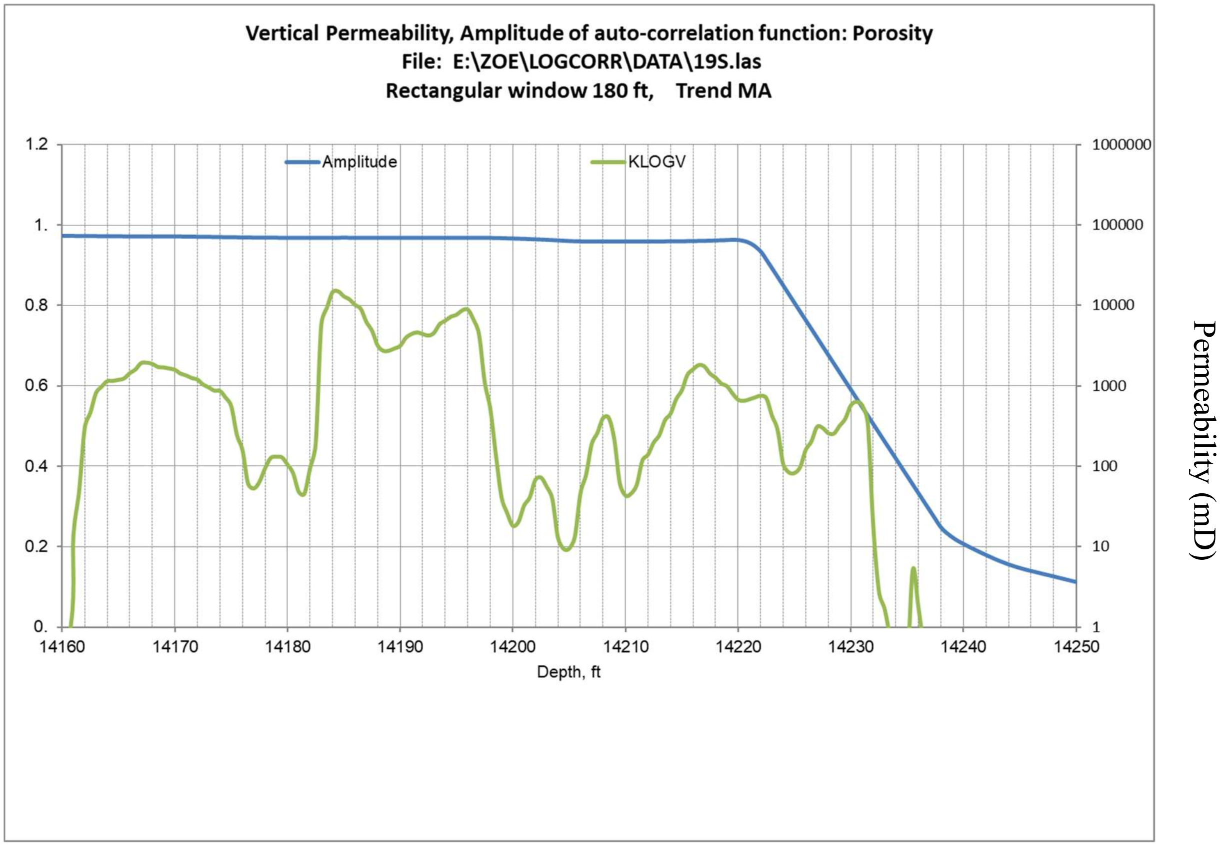

Vertical Permeability, Amplitude of auto-correlation function: Velocity P
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

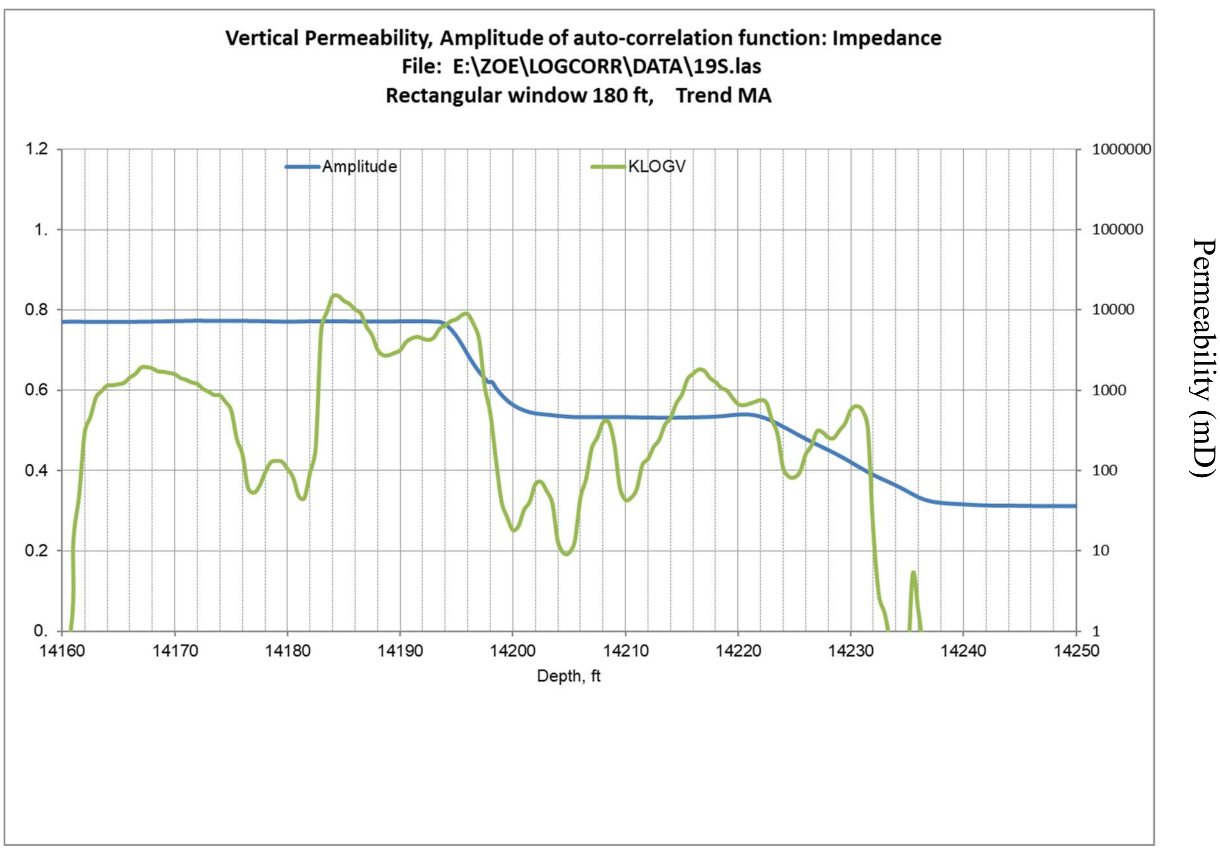


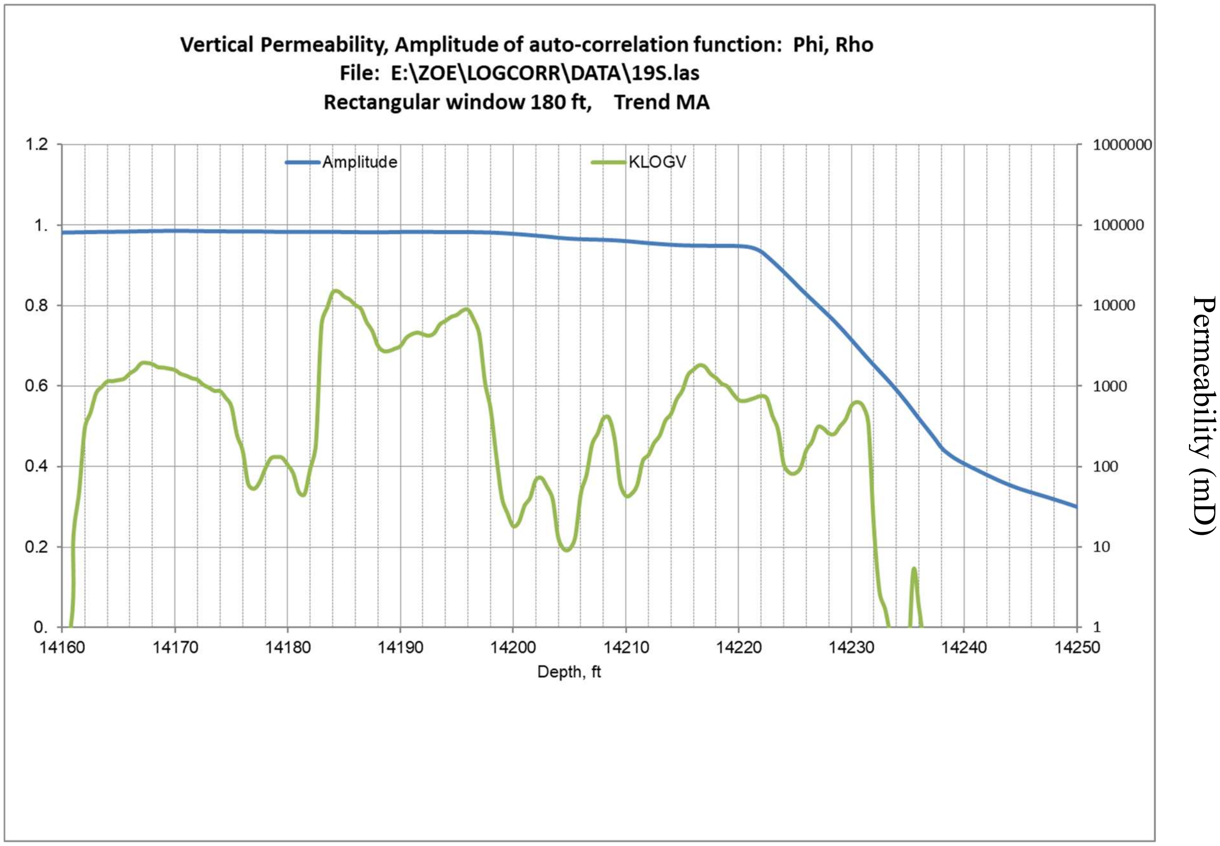
Vertical Permeability, Amplitude of auto-correlation function: Modul C33
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)



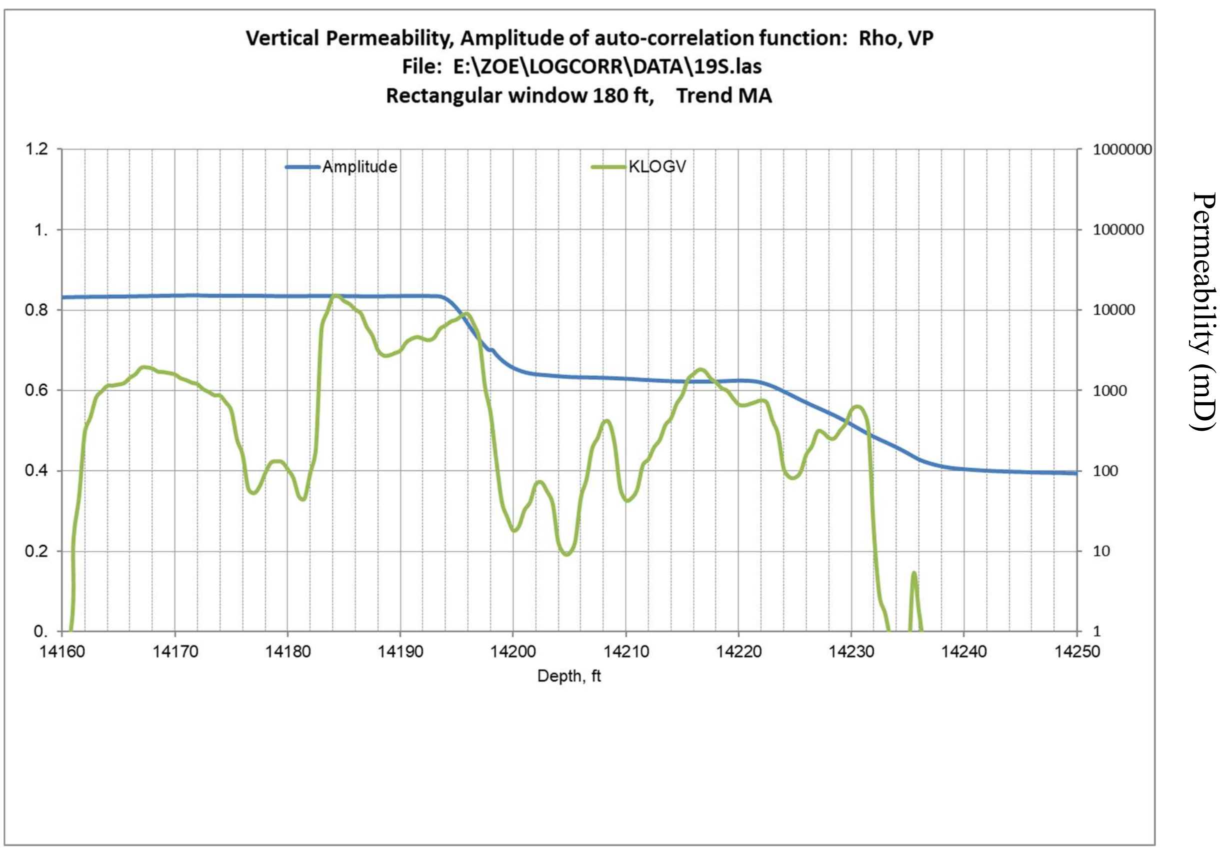
Vertical Permeability, Amplitude of auto-correlation function: Resistivity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)


Vertical Permeability, Amplitude of auto-correlation function: Porosity
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)

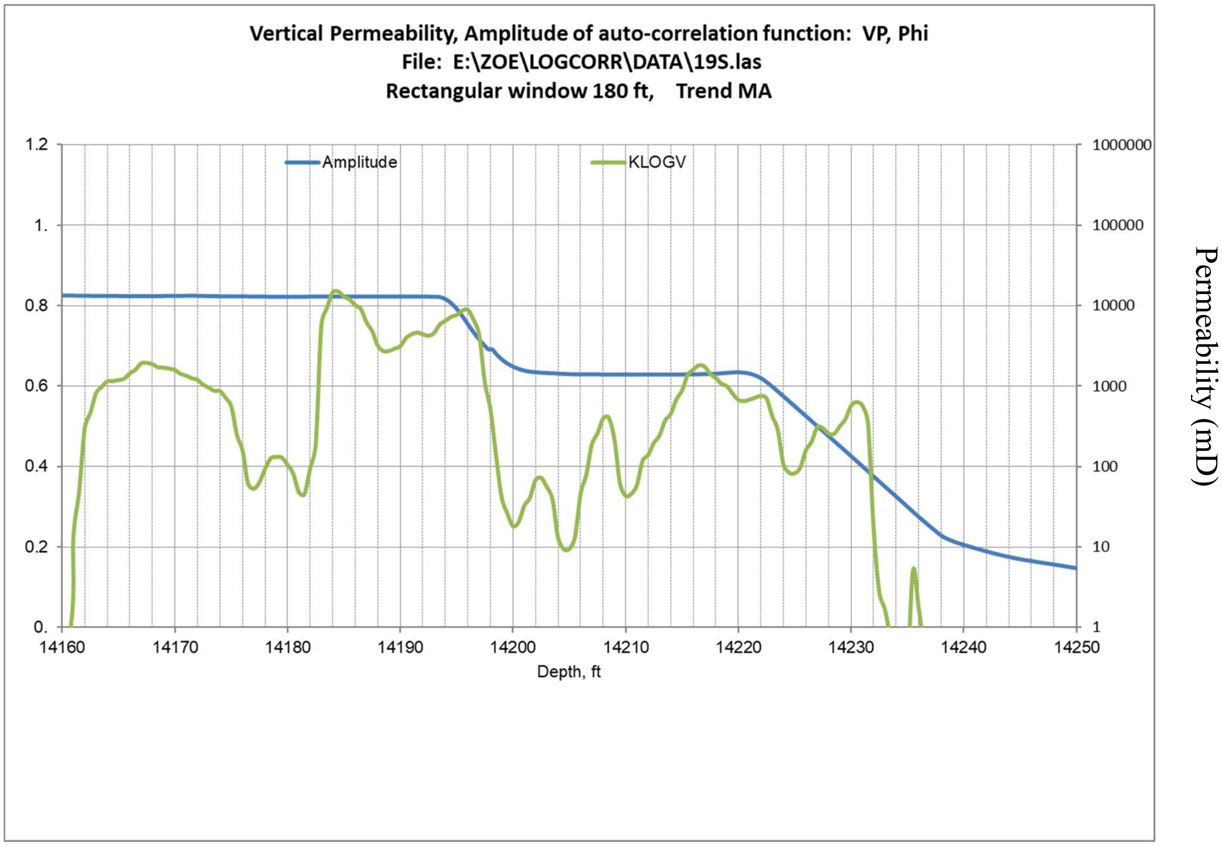

Vertical Permeability, Amplitude of auto-correlation function: Impedance
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)



Vertical Permeability, Amplitude of auto-correlation function: Phi, Rho
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)



Vertical Permeability, Amplitude of auto-correlation function: Rho, VP
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
Depth, ft
Permeability (mD)

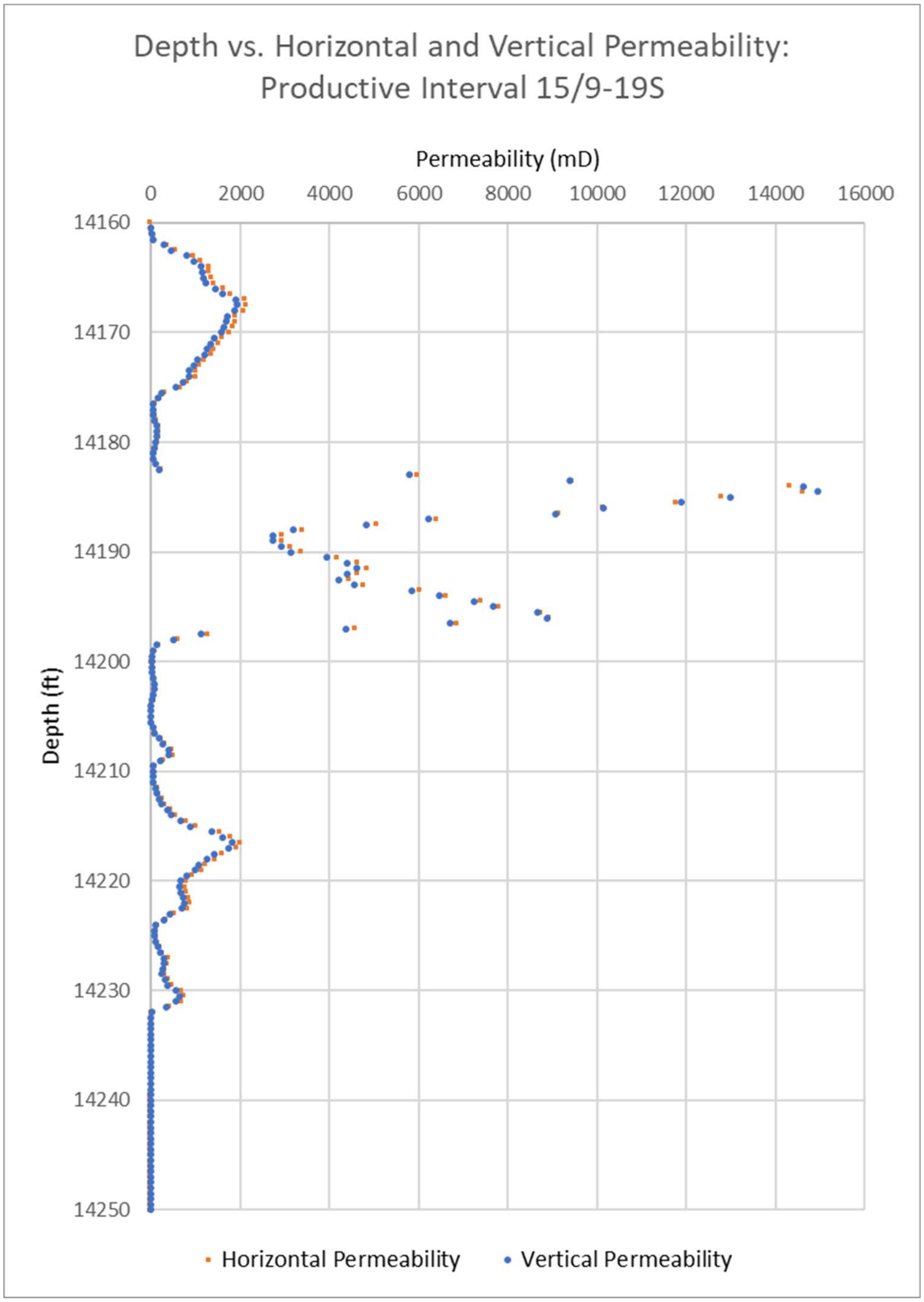


Vertical Permeability, Amplitude of auto-correlation function: VP, Phi
File: E:\ZOE\LOGCORR\DATA\19S.las
Rectangular window 180 ft, Trend MA
Amplitude
KLOGV
1.2
1.
0.8
0.6
0.4
0.2
0.
1000000
100000
10000
1000
100
10
1
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth, ft
Permeability (mD)

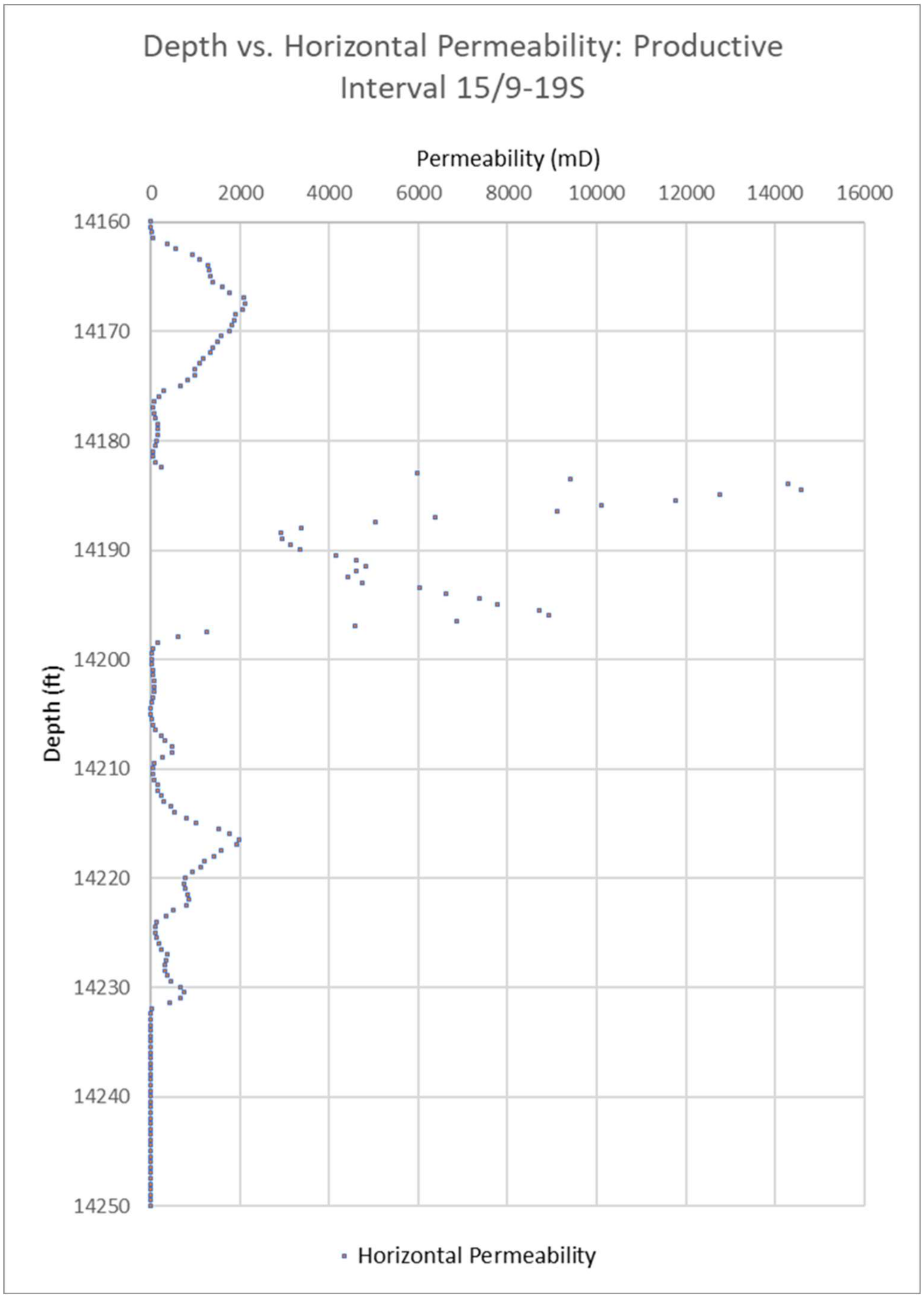
A14: Depth vs. Permeability (Productive Interval)

A14: Depth vs. Permeability (Productive Interval)

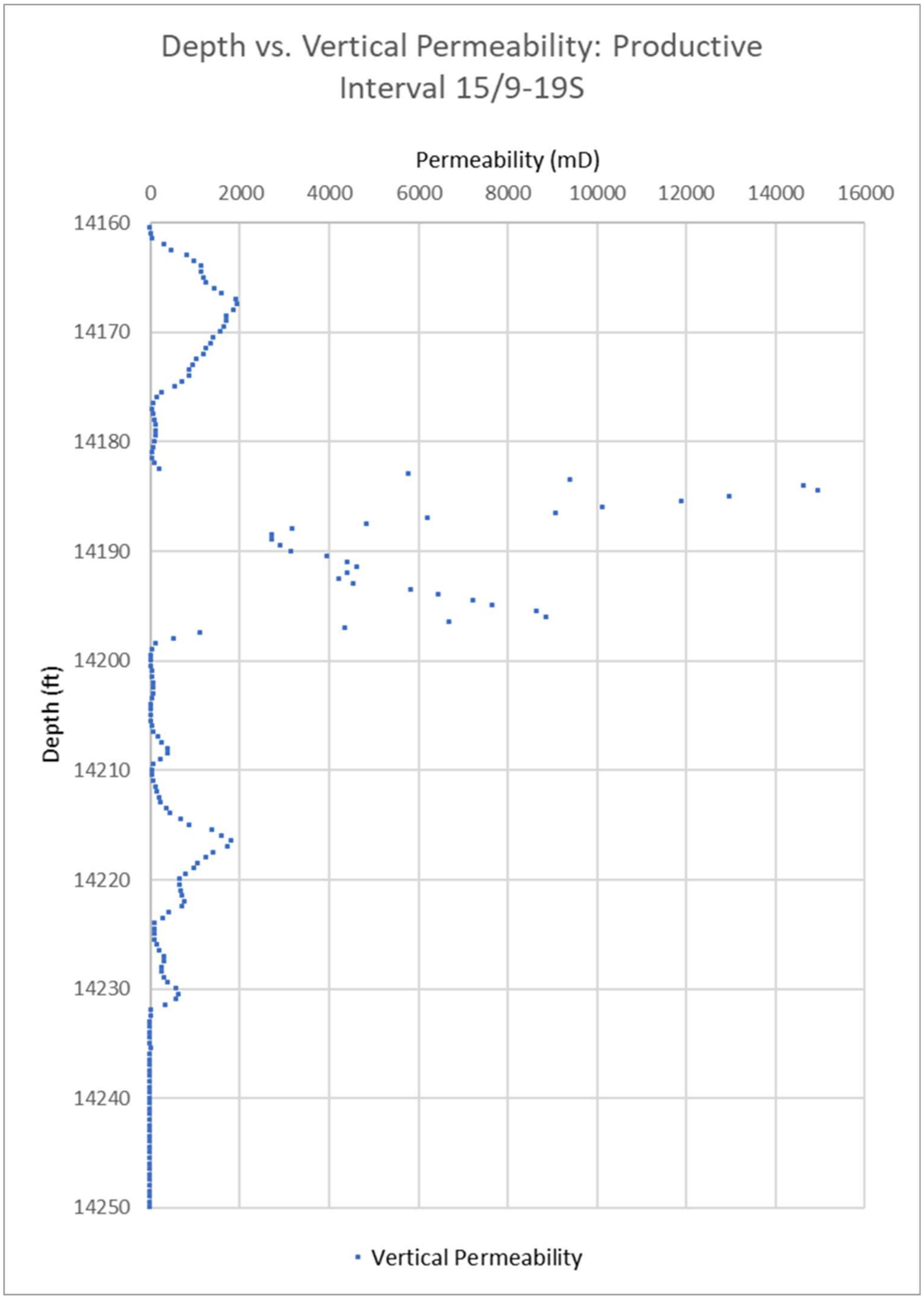
Section A14 shows the behavior of both vertical and horizontal permeabilities as we move through the productive interval. Both the vertical and horizontal permeabilities appear approximately the same, however there are slight differences. The interval from ~14125-14195 ft in depth have the highest range of permeabilities. Looking at previous plots of amplitude and correlation radius, it is also seen that this is where the amplitudes are generally the highest whereas correlation radii are the lowest.



Depth vs. Horizontal and Vertical Permeability:
Productive Interval 15/9-19S
Permeability (mD)
0
2000
4000
6000
8000
10000
12000
14000
16000
Depth (ft)
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Horizontal Permeability
Vertical Permeability



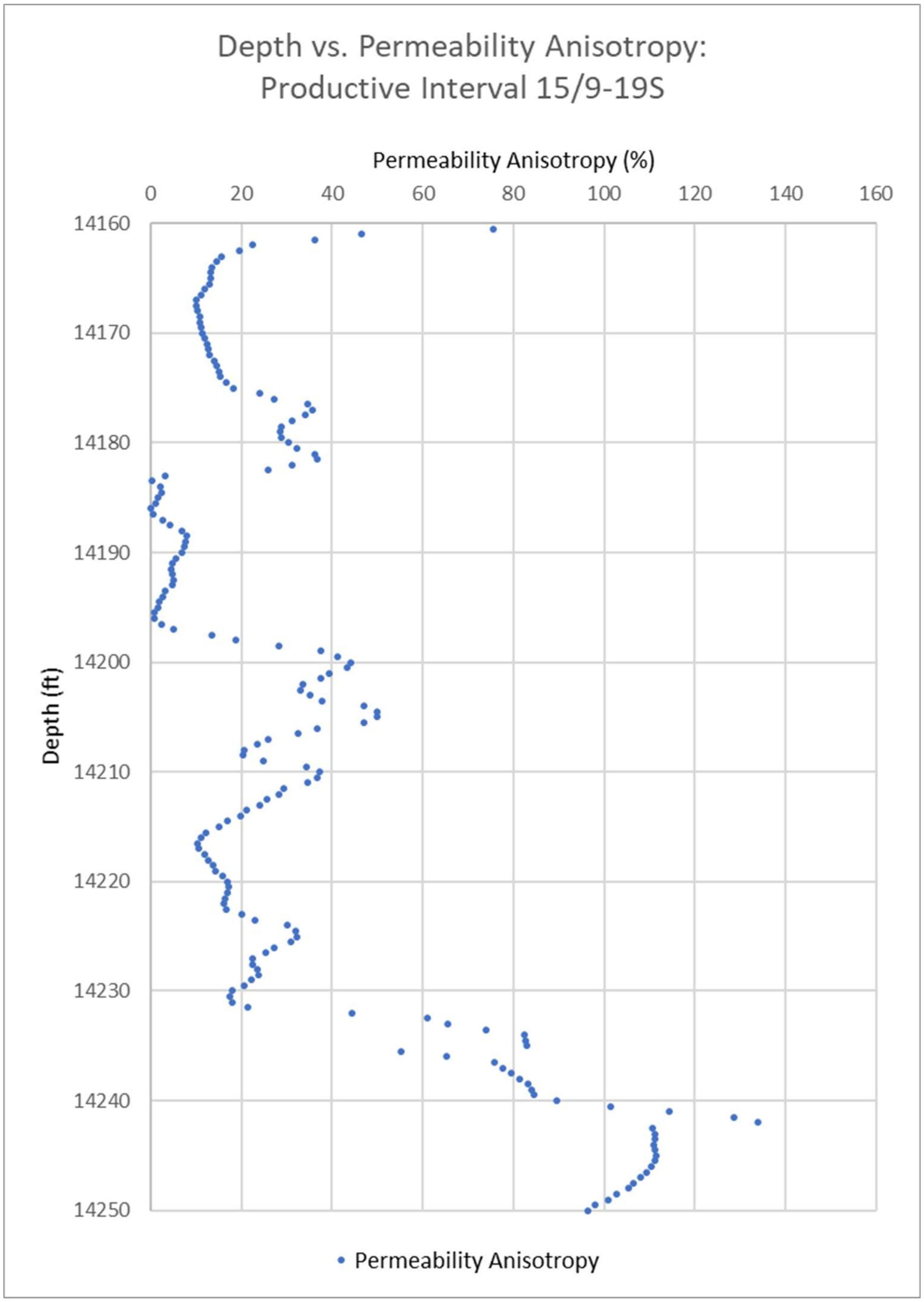
Depth vs. Horizontal Permeability: Productive Interval 15/9-19S
Permeability (mD)
0
2000
4000
6000
8000
10000
12000
14000
16000
Depth (ft)
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Horizontal Permeability


Depth vs. Vertical Permeability: Productive Interval 15/9-19S
Permeability (mD)
0
2000
4000
6000
8000
10000
12000
14000
16000
Depth (ft)
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Vertical Permeability

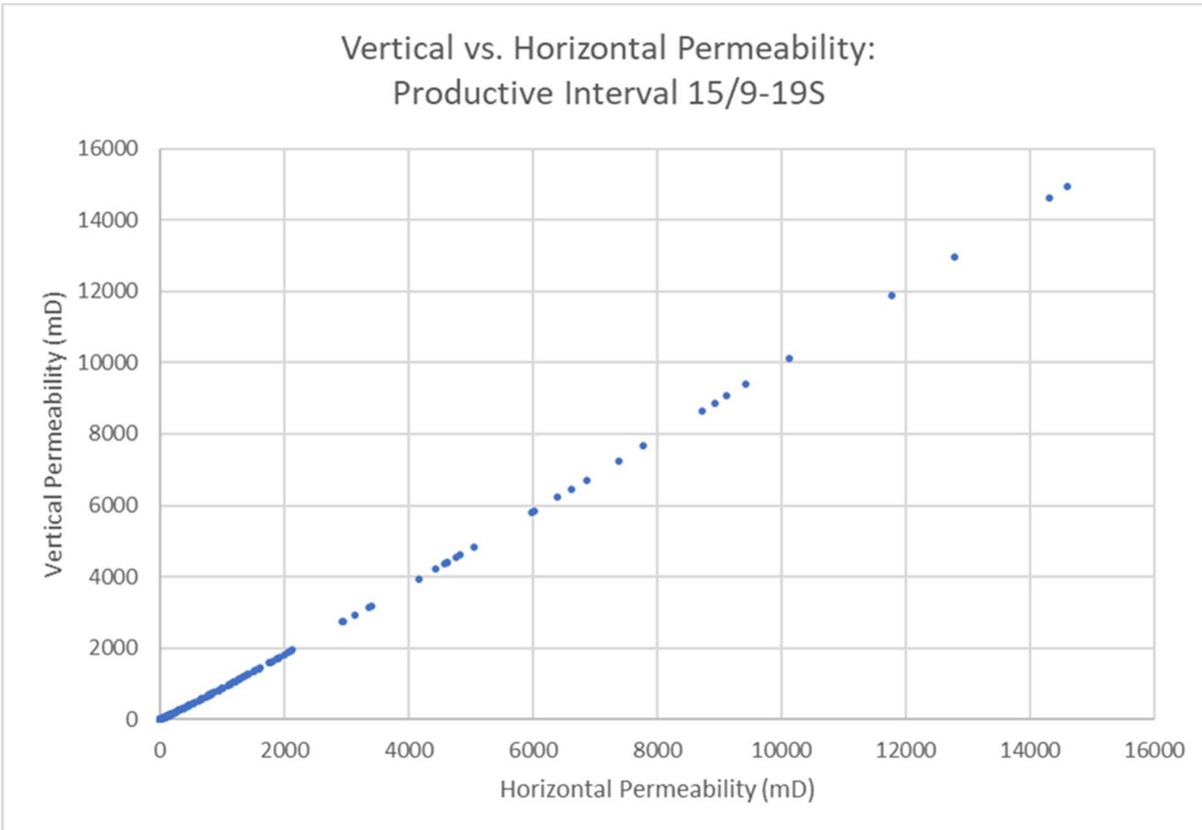
A15: Anisotropy and Permeability Relationships

A15: Anisotropy and Permeability Relationships

Section A15 shows the behavior of anisotropy throughout the productive interval as well as how the vertical and horizontal permeabilities relate to one another throughout the productive interval as well. Given the knowledge that the reservoir lithology is predominately sandstone, anisotropic characteristics are expected, further validated by the approximate 1:1 relationship of vertical to horizontal permeability.



Depth vs. Permeability Anisotropy:
Productive Interval 15/9-19S
Permeability Anisotropy (%)
0
20
40
60
80
100
120
140
160
14160
14170
14180
14190
14200
14210
14220
14230
14240
14250
Depth (ft)
Permeability Anisotropy


Vertical vs. Horizontal Permeability:
Productive Interval 15/9-19S
16000
14000
12000
10000
8000
6000
4000
2000
0
Vertical Permeability (mD)
0
2000
4000
6000
8000
10000
12000
14000
16000
Horizontal Permeability (mD)

Bibliography

Chesnokov, E. M., J. H. Queen, Y. A. Kukharenko, J. M. Hooper, I. O. Bayuk, and A. A. Vikhorev, 2002, Size-frequency effects and reservoir structure. Oklahoma Geological Survey, Circular, 107, 103–122.

Chesnokov, E. M., Y. A. Kukharenko, and P. A. Kukharenko, 1995, Method of diagram technique for calculation of effective physical parameters of microinhomogeneous media. SPIE — International Society of Optical Engineers, Mathematical Methods in Geophysical Imaging III, 2571,2–12.

Chesnokov, E.M., A.K. Yuri, and I.O. Bayuk, 2001, Mathematical Modeling the Frequency Dependence of Velocities in Random Media Based on Well Log and Seismic Data: United Institute of Physics of the Earth Russian Academy of Sciences, Laboratory of Geophysics of Ordered Media Rock Physics and Reservoir Structure Monitoring Project, Norman, Ponca City, Moscow, 155 p.

Eid, E., 2017, Determination of Spraberry formation sweet spots using pair-correlation function (log scale), Unpublished Professional Master of Petroleum Geophysics Capstone paper. University of Houston, Houston, Texas.

Gassiyev, A., Huang F., and Chesnokov, E., Using the pair-correlation function as a tool to identify the location for shale gas/oil reservoir based on well-log data, Geophysics, Vol. 81, No. 2, P. D91–D109

Google Earth. (n.d.). Retrieved November 20, 2019, from https://earth.google.com/web/@58.4380287,1.90890227,26.35041995a,7138.78292964d,35y,0h,0t,0r

Lifshitz, I. M., and L. N. Rozentsweig, 1947, Construction of the Green tensor for the basic equation of the theory of elasticity for the case of an anisotropic infinite medium: Journal of Experimental and Theoretical Physics, 17, 783–791.

Smithson, T. (2012 Autumn). “How Porosity is Measured” Oilfield Review 63-64 p.

Statoil (1998, May). Final Well Report, 15/9-19A PL 046

Tiwary, D. K., Bayuk, I. O., Vikhorev, A. A., and Chesnokov, E. M. (2009). "Comparison of seismic upscaling methods: From sonic to seismic." Geophysics **74**:2.

"Volve Dataset," Equinor, last modified June 15, 2018, https://www.equinor.com/en/what-we-do/norwegian-continental-shelf-platforms/volve.html

Zerr, J. (2019) Case Study: Locating Productive layer using pair-correlation function in Volve Field, North Sea (Unpublished Master of Science Thesis). University of Houston, Houston, Texas