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GEOCALCULATOR, AN APPLICATION SOFTWARE FOR THE DETERMINATION OF VOLUME OF SHALE AND FORMATION WATER RESISTIVITY FROM SP LOGS

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Abstract: Formation evaluation in hydrocarbon exploration is focused on determining productive reservoirs in wells, if any, and the volume of hydrocarbon in said reservoirs. The volume of hydrocarbon in a reservoir depends on the water saturation, a function of its formation water resistivity. The calculation of formation water resistivity, volume of shale and hydrocarbon saturation from SP logs is dependent on several Petro-physical parameters which require complex calculations using many charts that are time consuming and error prone.

This project designs and incorporates the use of a computer software designed to standardize results, reduce margin of error and the time spent on calculating these Petro-physical parameters which is especially valuable when working on data from a large number of reservoirs and wells. A standalone application software was designed for this project in Unity and the results were compared versus standard chart corrected calculations using data from existing literature.

The maximum deviation falls within a rounding error at minimum and up to 7.2464% as formation water resistivity increases. The value falls well below 10% and is reasonably in range of values normally observed in the field and from chart calculated data. The calculated data allowed the detection of suspected errors in the published results of existing literature.

The software has proven to be a fast technique of estimating formation water resistivity, volume of shale and hydrocarbon saturation and reduces the ambiguity in the use of charts for correcting Petro-physical parameters in well log analysis.

Keywords: Calculator, petrophysics, software, logs, hydrocarbon

1. Introduction

Formation evaluation is the process of determining the petrophysical parameters of rocks and the fluids contained within pore spaces. The goal is to ascertain reservoir productivity to minimize costs of drilling wells which may prove to be unproductive.

In the dynamic field of hydrocarbon exploration, the evaluation of geological formations is crucial for identifying and quantifying potential reservoirs. Formation evaluation involves the application of scientific principles, engineering concepts, and technological innovations to assess the presence and viability of hydrocarbon resources (Amao, 2018). With the advent of advanced software tools, this process has become more efficient, accurate, and comprehensive.

1.1 The Application of Software in Formation Evaluation

Modern software applications play a pivotal role in formation evaluation by integrating various data sources, including well logs, seismic data, and core samples. These tools enable geoscientists and engineers to create detailed models of subsurface formations, analyse rock and fluid properties, and predict reservoir behaviour.

Software platforms consolidate diverse datasets into a unified framework, allowing for seamless visualization and interpretation. Advanced algorithms and machine learning techniques are employed to analyse well log data, providing insights into porosity, permeability, and fluid saturation. Simulation software models the behaviour of reservoirs under various production scenarios. Software tools incorporate statistical methods to quantify uncertainties in reservoir properties and predictions. The integration of software in formation evaluation not only enhances the accuracy and efficiency of hydrocarbon exploration but also supports sustainable and responsible resource development.

The major interest of any hydrocarbon exploration expedition is to calculate the hydrocarbon saturation of the reservoir. The hydrocarbon saturation is a value dependent on the water saturation which can be computed with the formation water resistivity. Therefore, the value of formation water resistivity as a Petro-physical parameter has been an important parameter since the dawn of formation evaluation.

1.2 The Role of Spontaneous Potential (SP) Logs in Hydrocarbon Exploration

At early stages of hydrocarbon exploration, the Spontaneous Potential (SP) log was one of the most important logs and while its value has been on the decline, it still continues to see use to much success till today, playing a significant role in well log interpretation.

The primary function of an SP log is to delineate permeable and impermeable zones such as sand and shale (Asquith and Krygowski., 2004). Secondary functions include the calculation of formation water resistivity, determination of the volume of shale and subsequently the hydrocarbon saturation with the aid of information, such as porosity, from other logs.

Formation water resistivity is the value of the resistivity of pore-filling water uncontaminated by drilling mud fluid. Its value can range from 0.001 ohm-m to several ohm-m at reservoir temperature (Enikanselu and Adekanle., 2008). The value of the formation water resistivity is dependent on temperature; therefore, it is necessary to correct the values to the temperature of the reservoir based on the depth.

1.3 Unity as a Software Development Tool

Unity is a cross-platform game engine developed by Unity Technologies, first announced and released in June 2005 at Apple Worldwide Developers Conference as a Mac OS X game engine. The engine has since been gradually extended to support a variety of desktop, mobile, console, augmented reality, and virtual reality platforms.

The engine can be used to create three-dimensional (3D) and two-dimensional (2D) games, as well as interactive simulations. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering, construction, and the United States Armed Forces (Unity Technologies, 2024).

Unity application development is facilitated by C-Sharp (C#); a programming language developed by Microsoft that runs on the .NET Framework. C# is used to develop web apps, desktop apps, mobile apps, games and many other software.

This project utilizes the expansive function of Unity's Editor User Interface (UI) design system to enable easy input of data, access data stored on the device in csv file format, maths and physics simulations to accurately calculate values and then displays the values using the aforementioned UI which can then be exported to the native device storage in the same format as input. It takes advantage of the cross-platform functionality Unity is known for, allowing this application to run seamlessly on any device regardless of the Operating System or model.

The choice of csv as storage files was due to the ease to create with any text editor on any device. It is also the preferred export and import format for databases and spread-sheets and is compatible with popular spreadsheet application packages including Microsoft Excel. Finally, due to the capability of storing large amounts of data in human readable format similar to a table with low disk usage, it was an appealing choice for a field that handles huge amounts of data.

2. Aim and Objectives

The aim of this study is to develop a standalone, cross-platform software primarily for calculating Formation Water Resistivity and Volume of Shale from SP log data in permeable beds.

The objectives include the:

i. Creation of mathematical algorithms for the computation of formation water resistivity and volume of shale.

ii. Transformation of the algorithms into readable code in C#.

iii. Application of readable, functional code in C# to take typed input and csv data files to deliver output.

iv. Design of a user-friendly User Interface (UI) for easy deployment of the applications' functionalities.

v. Calculation of formation water resistivity from publicly sourced SP data.

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vi. Comparison of the results generated by the application and those from the source material for discrepancies.

3. Literature review

3.1 Detection of source rock and organic maturity

Resistivity and density logs were used to identify source rock in shale sections, Olisa (2018). In the organic-rich shale, resistivity and bulk density curves are opposite (separated) to each other. In organic lean sediment, they track together (not separated).

3.2 Petroleum Geophysics of Organic-rich Rocks

Based on resistivity and temperature (geothermal gradients), Olisa and Adeniran (2019) divided Niger Delta into low and high resistivity values. Akata Formation has very high resistivity (158 Ωm). Agbada Formation's resistivity varies from 59 Ωm to 76 Ωm.

3.3 GR and SP logs

The gamma ray (GR) log differentiates between sand and shale sequences based on the relative presence of radioactive materials. Generally, the shales has more concentration of radioactive materials than sands. The GR curves calibrated in API is a measure of the Formations' natural radioactivity. Sand on the whole is less radioactive than shale and the deflection of the GR curves is less than shale deflection, Olisa and Oke (2014).

The Spontaneous potential (SP) curves differentiate between permeable and impermeable beds based on the relationships between mud filtrate and formation water. SP curves calibrated in millivolt is a reading of the natural potential difference between a point in the borehole and the surface, Olisa and Oke (2014). The salinity of the Formation water is greater than that of the mud filtrate. This causes the potential opposite the permeable sand bed to be negative with respect to the potential opposite the shale bed.

3.4 SP Log Interpretation

The SP Log has a poor resolution. Although it can be used for correlation, it is best not to rely solely upon it. If it has to be used for defining a bed boundary, it is best to take the inflexion point in the SP change as the boundary depth. As bed resolution is bad, it is not expected to show beds less than about 20 times the borehole diameter.

Several factors govern the amplitude of the SP deflection opposite a permeable bed. This is because the size of the deflection and the change in the SP curve between beds depends upon the distribution of the current flux and the potential drops taking place in each part of the formation. The following parameters are important:

i. The thickness of the permeable bed, h.

ii. The true resistivity of the permeable bed, R_t.

iii. The diameter of the invaded zone, d_i.

iv. The resistivity of the invaded zone, RXO.

v. The resistivity of the bounding formations.

vi. The resistivity of the mud, R_m.

vii. The diameter of the borehole, d_h.

viii. The relative salinities of the mud filtrate and the formation fluids.

The recorded SP log represents the potential drop in the borehole, only. To use the SP curve quantitatively, a value for the total potential drop around the circuit must be derived. This is called the Static Spontaneous Potential (SSP). This value may be derived from correction charts. A direct reading of the SSP may also be obtained directly from the SP log opposite thick, clean, shale-free, 100% water-bearing formations. The SSP is the value in millivolts of the difference between the SP log at the shale base line and in the centre of the thick clean formation.

The SP deflection obtained for homogeneous shaly formations or thin shaly beds after correction for bed thickness is called the Pseudo-static Spontaneous Potential (PSP). The SSP is the value in millivolts of the difference between the SP log at the shale base line and that in the centre of the thick homogeneous shaly formation, or a thinner bed if a bed thickness correction has been carried out. If there is a proportion of shale in the permeable bed, the SP deflection is reduced from what it would be if the bed were clean and contained the same fluids. Hydrocarbon saturation also decreases SP deflections.

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The present understanding of the electrical effect of clays and shales in reservoir rocks depends largely upon the concept of cation exchange capacity, Q_v, which is the cation concentration in milliequivalents of exchange sites for sodium ions per cubic centimetre of pore volume. Laboratory investigations have used this concept to develop a method for calculating the formation water resistivity from SP log data in a way that takes account of the shaliness of a formation.

To use this method a value of Q_v is needed from the shale beds above or below the formation of interest, and a value of Q_v for the formation of interest. These values are normally obtained from standard chemical methods carried out in the laboratory upon cores or sidewall cores.

The SP log is an extremely useful quick-look indicator of bed permeability. It is not quantitative, and opinions differ to the extent to which one can associate the size of the deflection with the degree of permeability. Given the large number of other parameters that might affect the SP log it is not feasible to associate very large permeabilities necessarily with large deflections and vice versa.

However, the SP log is quite sensitive, and even a small deflection in the SP log indicates that the bed has reasonable permeability.

It should be noted that some permeable beds might give no deflection, such as those where there is no difference in salinity between the formation fluids and the mud filtrate. These cases are rare however. Figure 1 shows an example of permeability recognition by SP log.

The SP log is sometimes a useful additional log to use in correlation, but is rarely used alone. If used, the wells should be close together and drilled with the same mud, and the salinities in the formations should be constant between wells. The SP log can be used to follow facies changes. However, it has been largely replaced by the GR log, which has a higher resolution and is more reliable.

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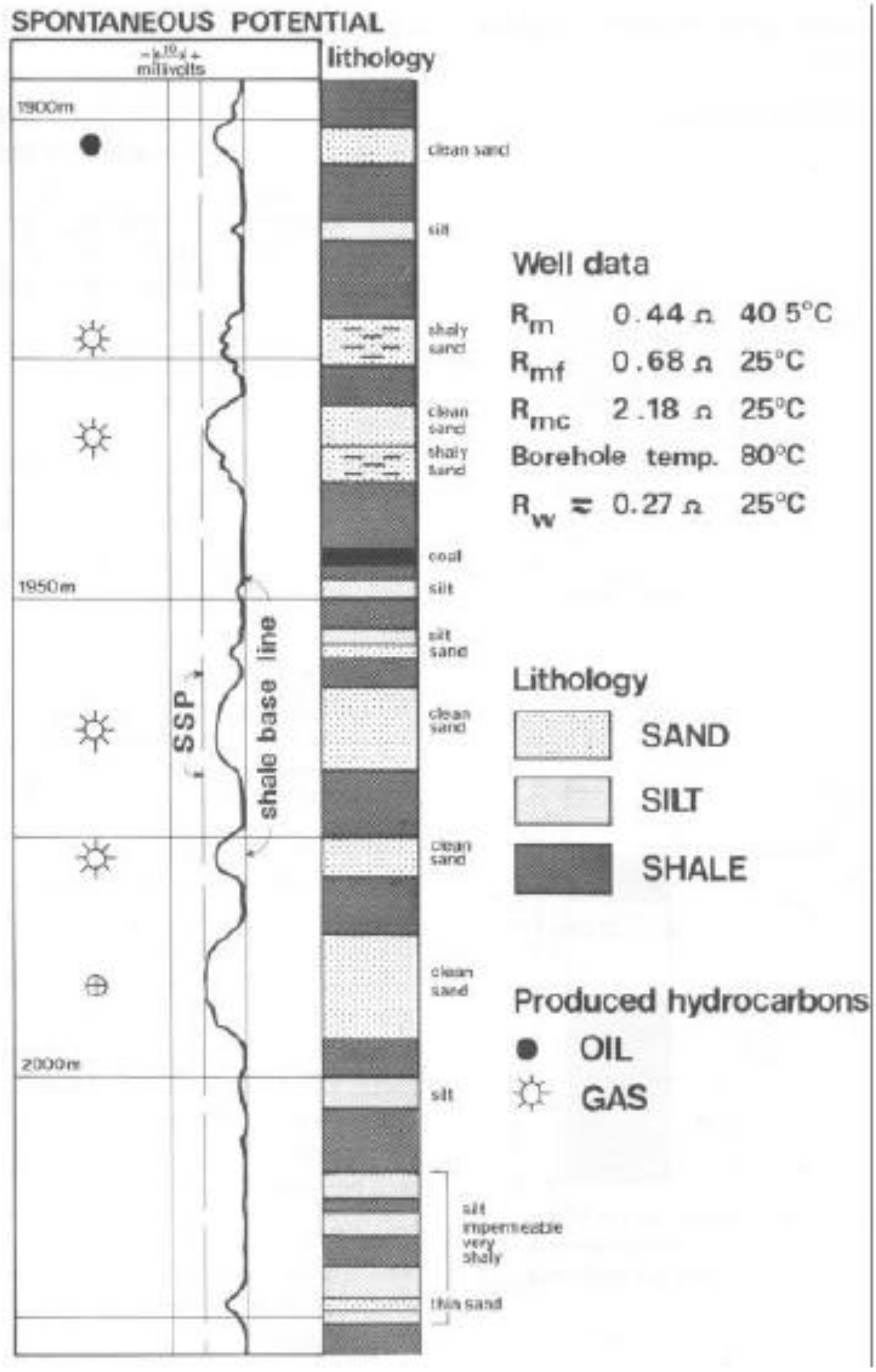

Figure 1: Permeability Recognition by SP Log (Glover, 1999).

3.5 Calculation of Formation Water Resistivity (R_w)

This is one of two quantitative uses of the SP log. It is extremely useful when no formation water samples or water-bearing sands are available to otherwise obtain R_w from during an analysis for Original Oil in Place (OOIP).

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3.5.1 The Quick Look Method

This is the quickest and most common method, and does not require knowledge of Q_v. As the method ignores the complicating effects of electrokinetic potentials and the possible presence of clay, errors in R_w will translate into errors in OOIP that may represent tens of millions of dollars.

3.5.2 The Single Chart Method

For the same reasons stated for the quick-look method, errors in R_w will translate into errors in OOIP. As the name indicates, a single chart is used for the main calculations, however all the input data need to be corrected for formation temperature and bed thickness. Hence, more than one chart is actually needed to serve each purpose.

3.5.3 *The Smits Method*

This is a complex method that is also the most accurate. It accounts for both electrokinetic potentials and the effect of the shaliness of the formation, but does not account for the possible presence of hydrocarbons.

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3.5 Temperature-Resistivity Gradient

Resistivity decreases with increasing temperature and temperature increases with depth, therefore, any value of R_{mf} and R_w must be determined at a particular depth corrected to the appropriate formation temperature, T_f to calculate the formation water resistivity.

The geothermal gradient is established using the formula;

$$gG = \left\{\frac{(BHT - T_{ms})}{T_d}\right\} \times 100 \qquad 2.8$$

Where *BHT* is the Bottom Hole Temperature, T_{ms} is the mean surface temperature and T_d is the Total well depth from the well header.

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The formation temperature is the determined using the following formula below;

$$T_f = T_{ms} + \left\{gG\left(\frac{D}{100}\right)\right\} \qquad 2.9$$

Where T_f is the formation temperature and D is the target depth.

A chart may be used to correct the resistivity of a solution at a given temperature when the NaCl concentration of the solution is known and vice versa. It may also be used to determine the resistivity of a solution at a given temperature when the resistivity of this same solution at another temperature is known. A more direct approach is through the use of Arp's equation;

$$R_2 = R_1 \times \left(\frac{T_1+K}{T_2+K}\right) \qquad 2.10$$

Where T_1 is the known reference temperature, T_2 is the temperature to which the resistivity is to be corrected, R_2 is the resistivity value corrected for temperature and R_1 is the resistivity value at the known reference temperature.

3.6 Calculation of Shale Volume

The shale volume is sometimes calculated from the SP log using the relationship:

$$V_{sh} = \left(1 - \frac{PSP}{SSP}\right) \qquad 2.11$$

The Pseudo-static Spontaneous Potential, PSP, is equal to the SP log read in a thick homogeneous shaly sand zone while the Static Spontaneous Potential, SSP, is equal to the SP log read in the thick clean sand zone. This assumes a linear mixing relationship between the SP log and shale volume. It also overestimates the shale volume in hydrocarbon bearing zones.

4. Materials and method of study

4.1. Materials

The applications used for this project are Petrel 2017 for the analysis of SP log files, Microsoft Excel 2021 for data management and Unity 2022.34f1 Long Term Service Edition for the creation of the application.

4.2. Methodology

A series of corrections are needed in the calculation of formation water resistivity starting with the correction for temperature then bed thickness. The bed correction is normally corrected using charts (Fig.2) as well. The charts for temperature correction (Fig. 3) and bed correction were converted into mathematical equations of the logarithmic relationship which makes corrections faster, easier and reduces ambiguity. The chart for the determination of formation water resistivity from the Resistivity of water equivalent obtained from temperature correction is shown in Fig. 4.

The obtained equations are;

$$R_{we} = R_{mff}\left(10^{\frac{SSP}{60}+0.133T_f}\right) \qquad 3.1$$

$$R_w = R_{we} + 0.131 \times \frac{10^{\frac{1}{\log\frac{T_f}{19.9}}-2}}{-0.5R_{we}+10^{\frac{0.0426}{\log\frac{T_f}{50.8}}}} \qquad 3.2$$

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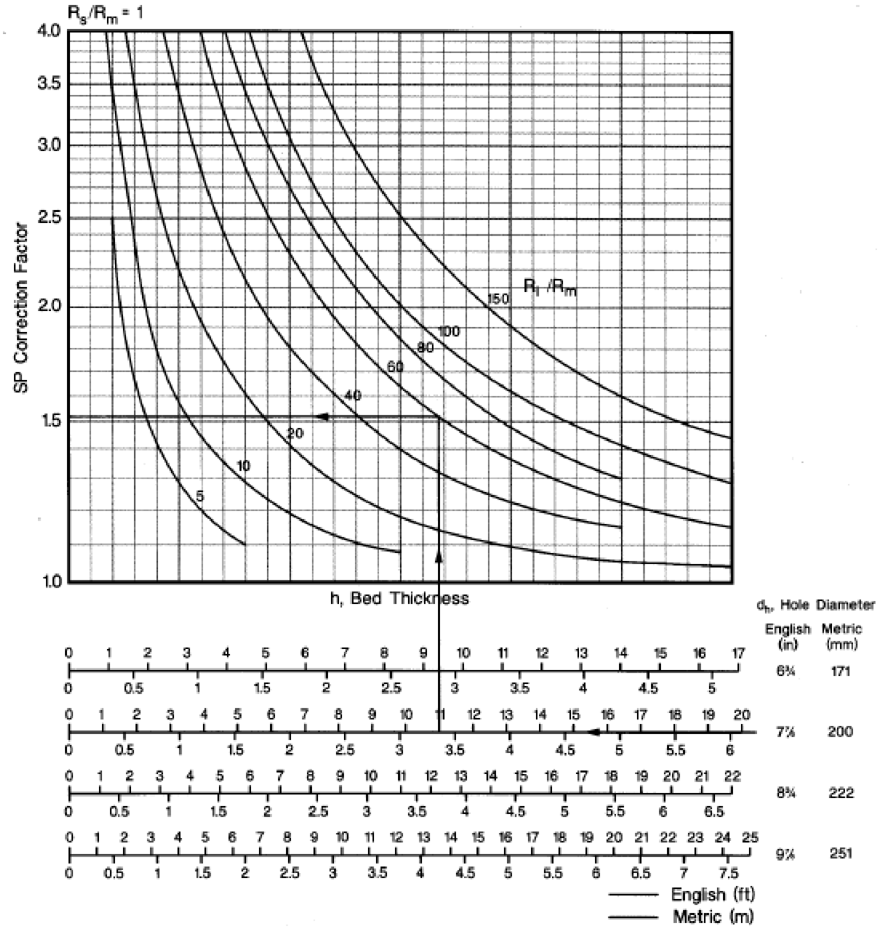

Figure 1: Chart for correcting for Bed thickness (Glover, 1999).

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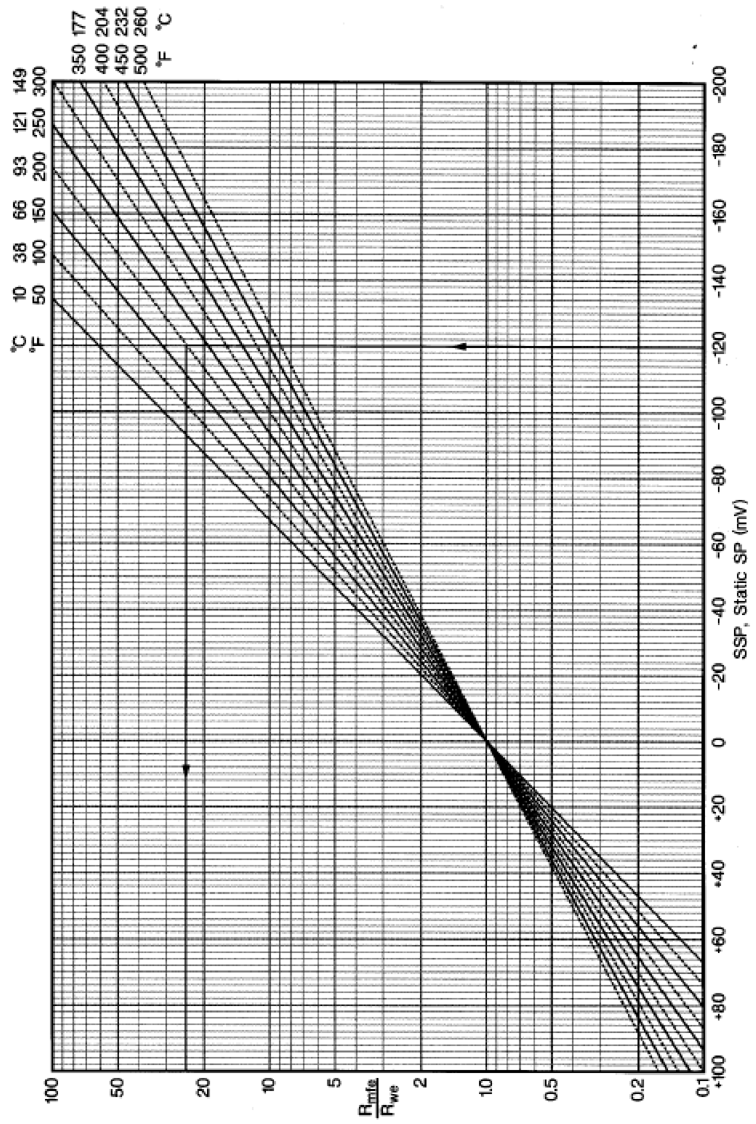

Figure 2: Chart for correcting for determining R_{mfwe}/R_{we} ratio from SSP (Glover, 1999).

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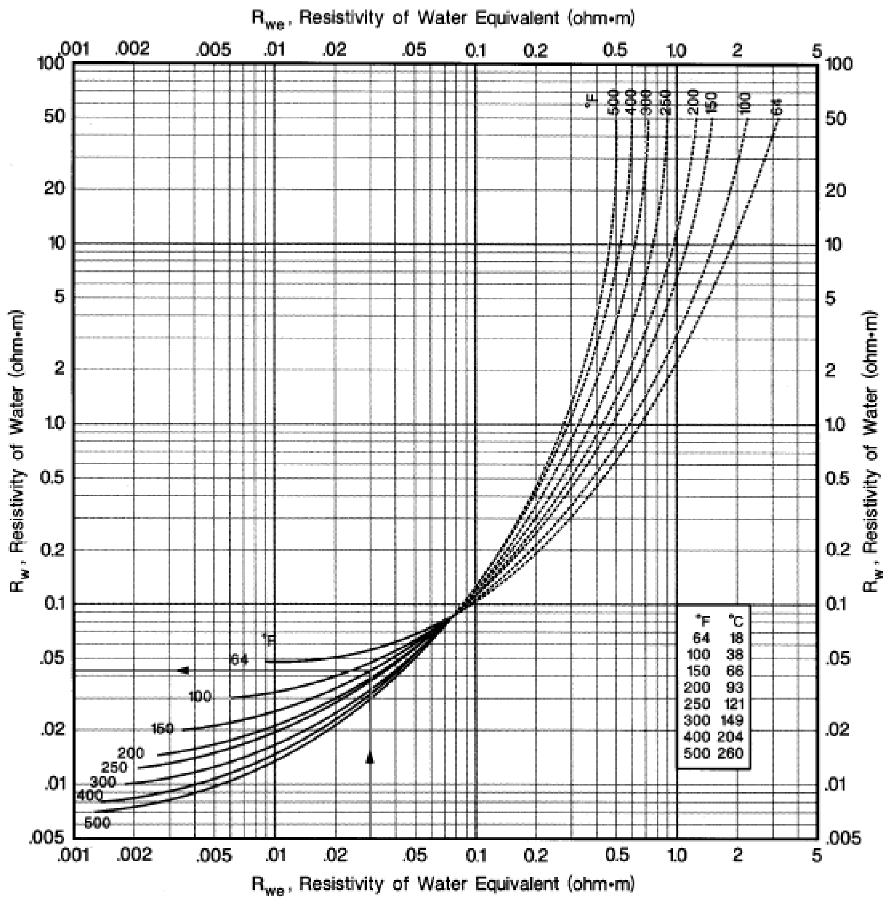

Figure 3: Chart for determining R_w from R_{we} (Glover, 1999).

4.2.1 Algorithm of the Calculation

The algorithm is displayed in human readable format in Fig. 5 showing the step-by-step process of code execution for the calculation process. This process is repeated several times by a different algorithm which loops over the provided data in the case of imported csv files rather than typed input. The alternate algorithm also provides an output in the form of a visible table in the app which can then be exported as a csv file.

4.2.2 User Interface (UI) Design

The UI displays a panel showing the introduction with 2 buttons on startup of the application (Fig. 6a). The Start button changes the display to the single input panel (Fig. 7a) while the button with question mark opens up the help panel (Fig. 6b) which displays information on the used abbreviations and how to use the app.

The single input panel has 10 text fields which accept only numeric input where the user must input the required information and 3 non-interactable (greyed-out) text fields close to the bottom which display output. The Clear button resets the data in input fields only while the Run button executes the calculation. In the instance of missing required information, a warning (Fig. 3.6b) is displayed to the user. A home button is visible in the bottom left which returns the user to the introduction panel. The bulk input button changes the UI to the bulk input panel.

The bulk input panel (Fig. 8a) allows the user to import data (Fig. 8b) from the device storage which is displayed in table 1. In the case of missing input, a slightly different warning is displayed prompting the user to export a blank template csv file to edit.

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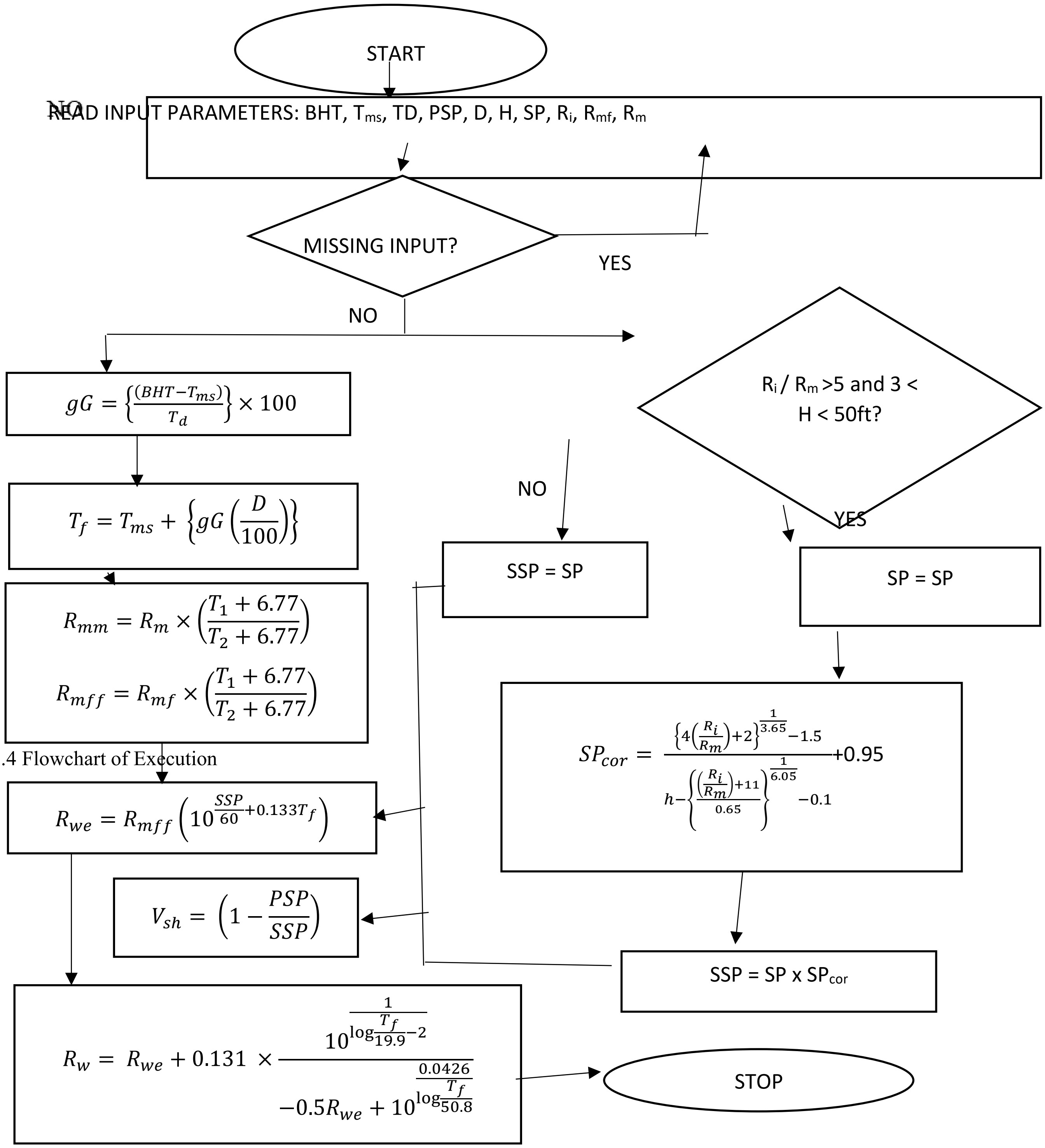

Fig 3.4 Flowchart of Execution

Figure 5: Flowchart of Execution

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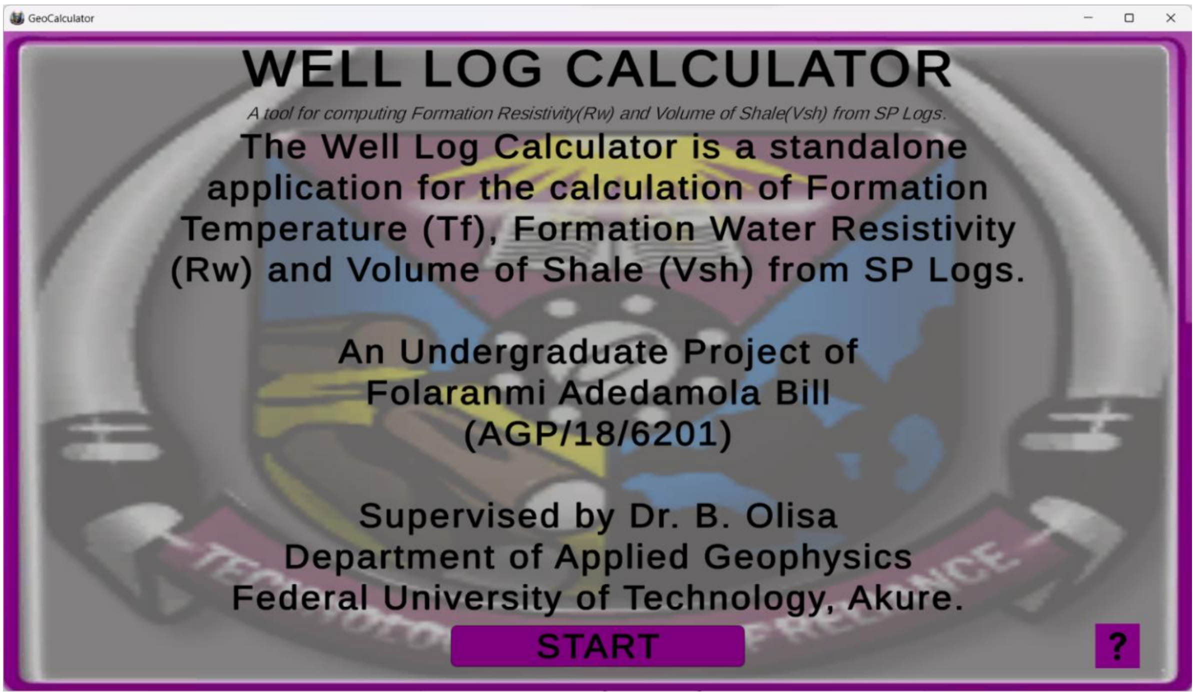
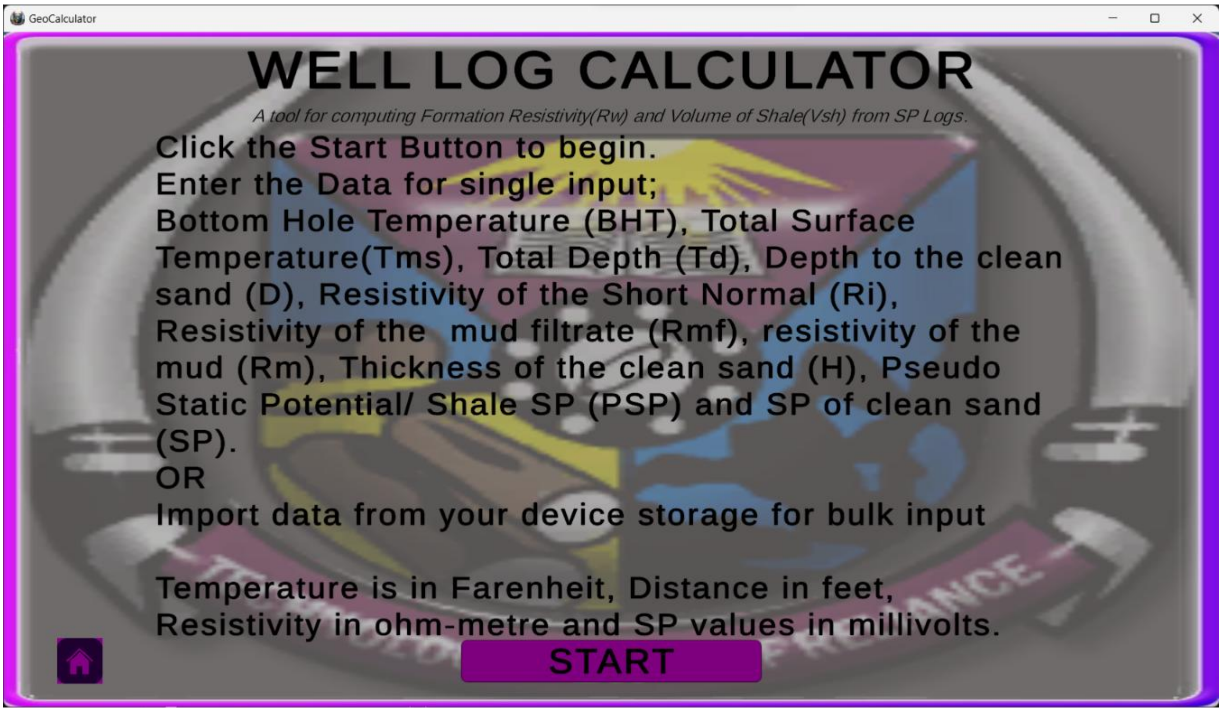


(a)



(b)

Figure 6: (a) The Home Screen and (b) Help Screen

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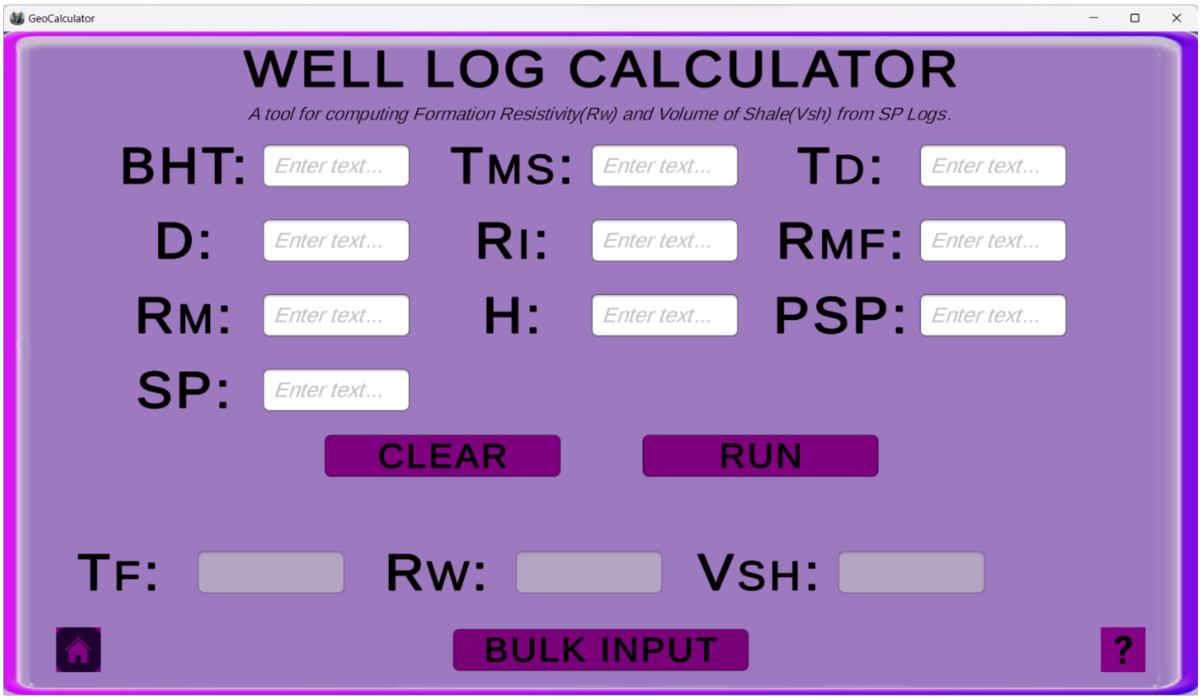
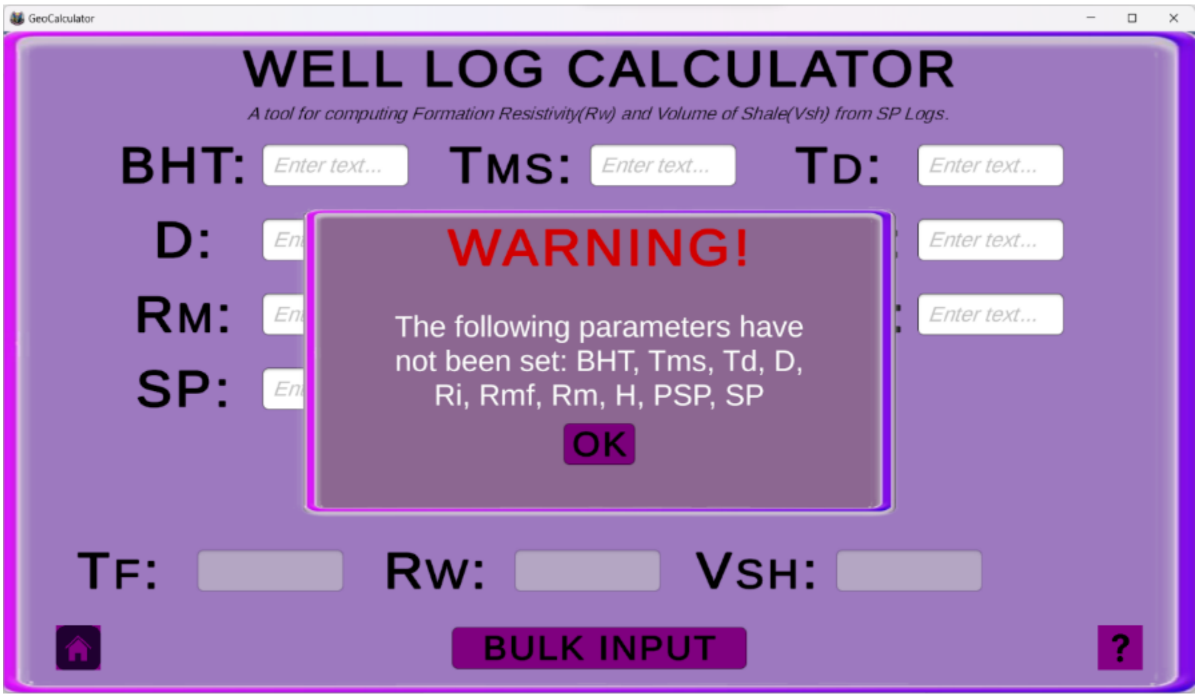


(a)



(b)

Figure 7: (a) Single Input Screen and (b) Input Warning Prompt

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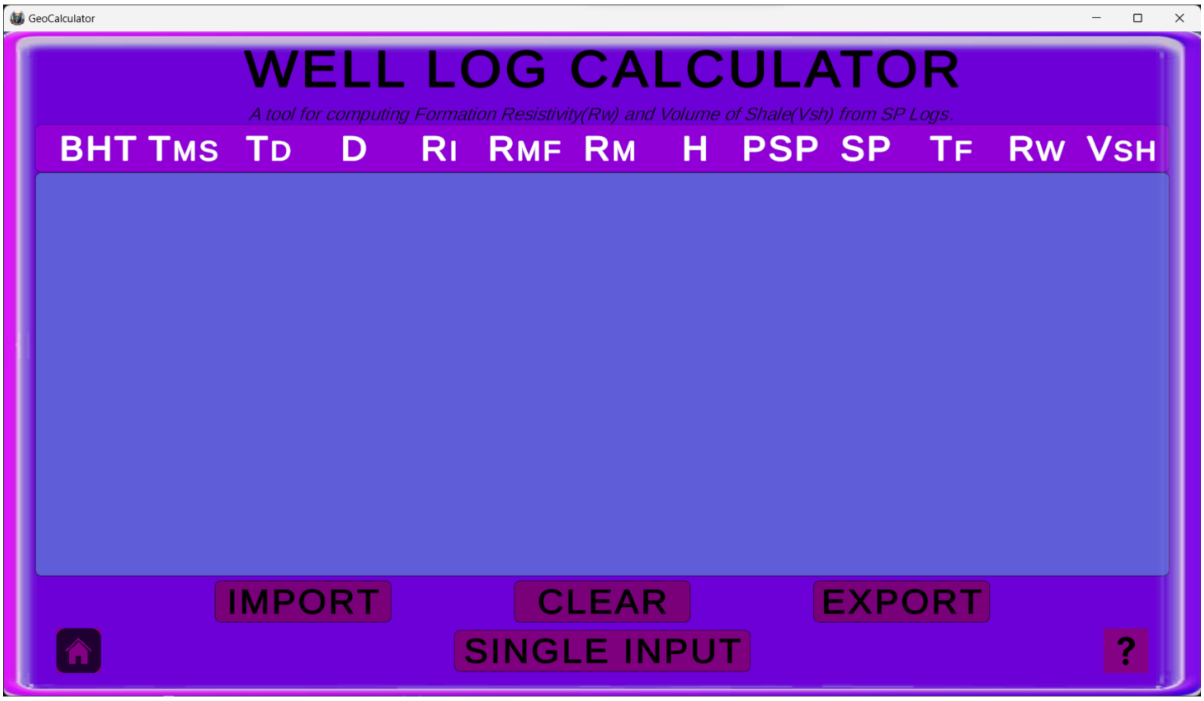
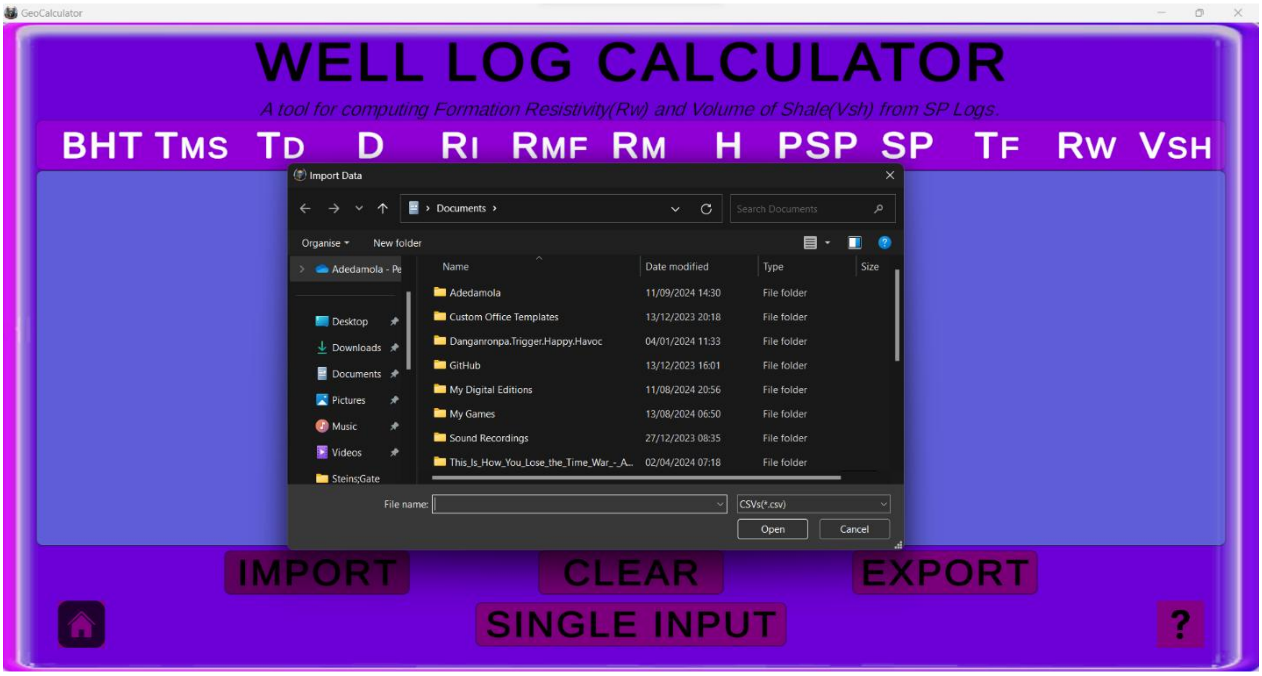


(a)



(b)

Figure 8: (a) Bulk Input Screen and (b) Data Import Pop-Up

4.2.3 Reservoir Interpretation

Well log data from various sources were loaded into Petrel to delineate the reservoirs and obtain the necessary parameters required for the computation of formation water resistivity.

The generated parameters for the reservoirs were input into Excel Spreadsheets per well and saved as a csv then imported in the application to calculate the formation water resistivity and volume of shale. The resulting data was then saved and exported.

5. Results and discussion

5.1. Presentation of SP Curves

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Two SP logs, labelled well 4 and well 5 (Fig 9), were acquired from an oil field in Delta State, Nigeria. This was done for the need of comparison of the acquired results with the results obtained by other methods. Four sand bodies were delineated in well 4 and 5. The values read from the curves are visible in Fig. 10. Other parameters read from the log ASCII file header include; the total depth, Bottom Hole temperature taken at 135°F, Resistivity of mud filtrate at 0.51 Ω, resistivity of mud at 0.91 Ω and surface temperature as 60°F.

5.2. Calculation of Petrophysical Parameters

The data was input into csv files per well then imported into the program and the results were displayed in Fig. 10 which was then exported.

5.3. Comparison of Generated Results.

The results generated by the program and those obtained from the source were compared in Table 1 for well 4 and Table 2 for well 5. The maximum deviation falls within a rounding error at minimum and up to 7.2464% as formation water resistivity increases. The value falls well below 10% and is reasonably in range of values normally observed in the field and from chart calculated data (Bateman and Konen, 1978). The software allowed the detection of suspected errors in the published results of the chosen field at the values of Volume of shale for Reservoir A and Formation water resistivity in Reservoirs C and D for well 4. Assuming both errors prove to be valid, the maximum error value drops sharply to less than 0.05%.

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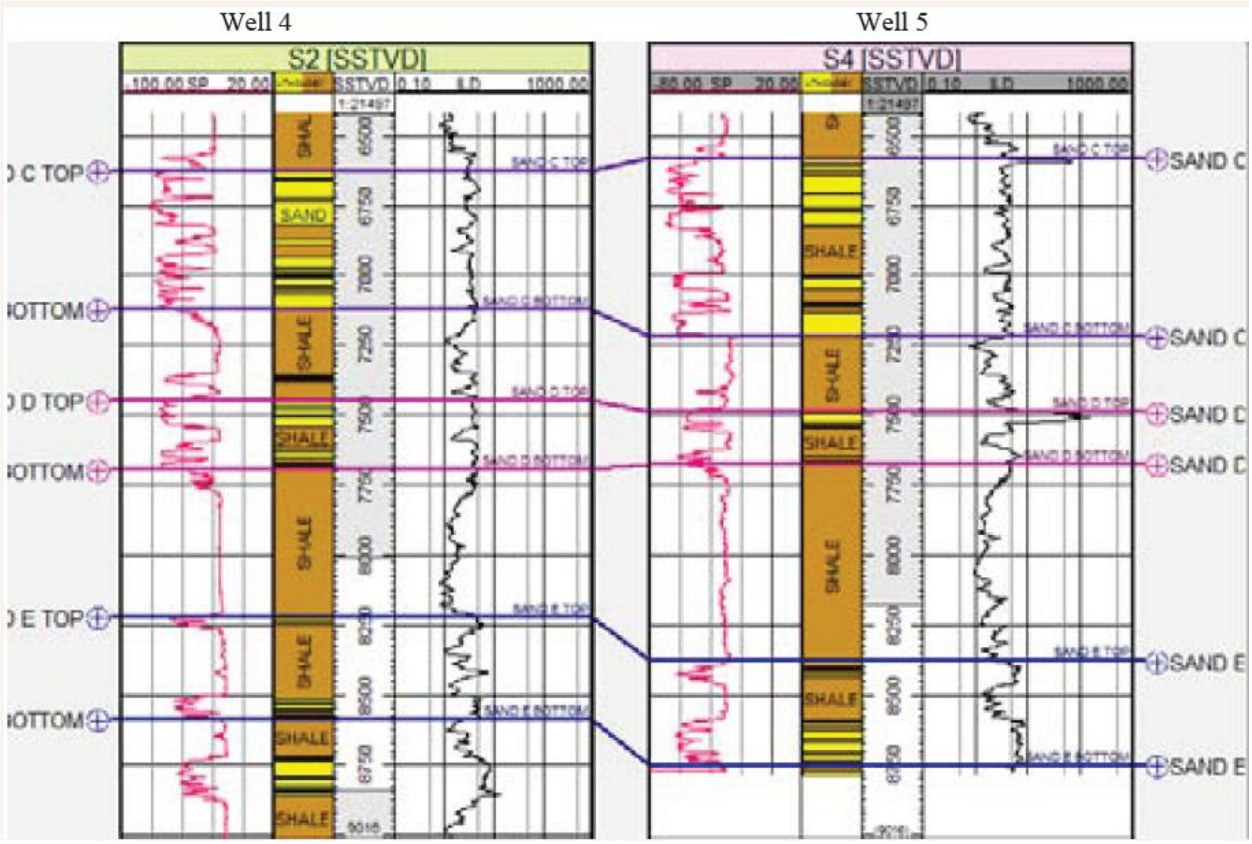

Figure 9: Well 4 and 5 showing some correlated marked sand bodies (Idibie *et al*., 2017).

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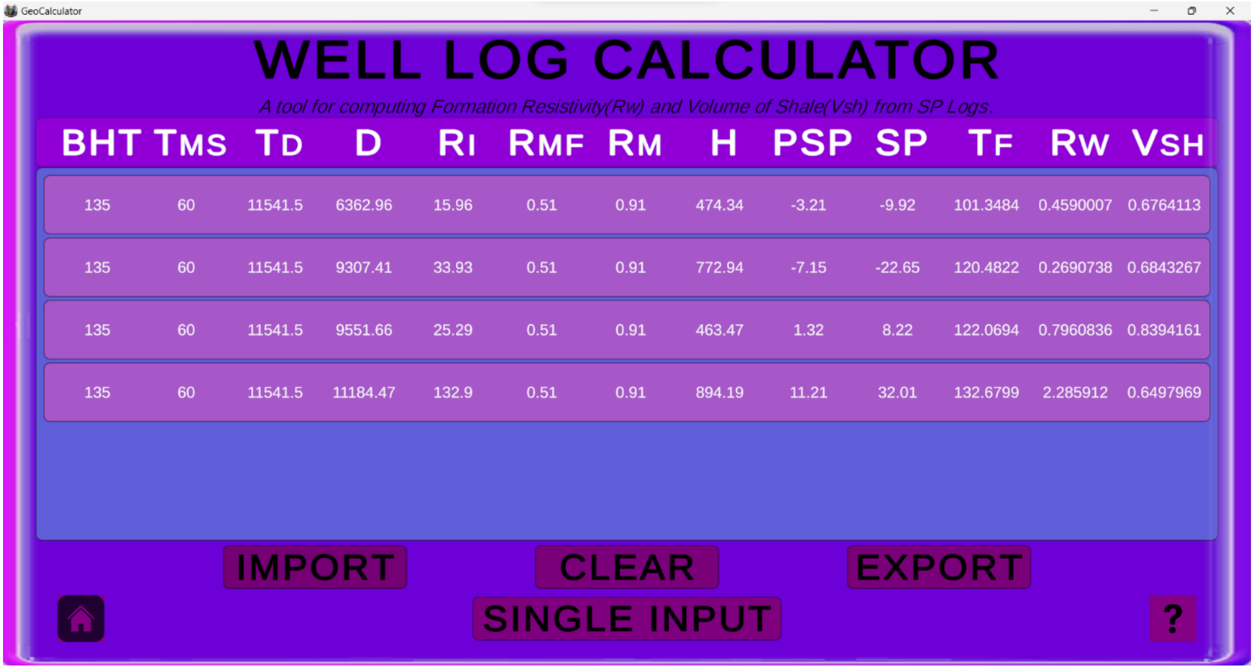
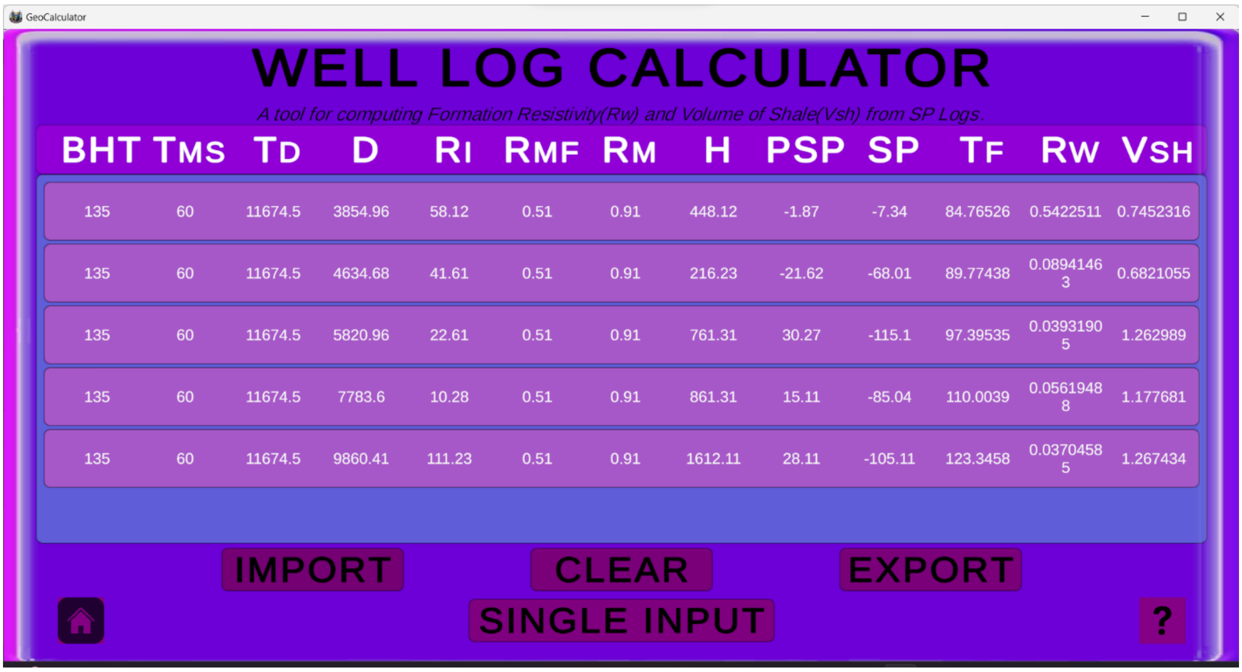


BHT	TMS	TD	D	RI	RMF	RM	H	PSP	SP	TF	RW	VSH
135	60	11541.5	6362.96	15.96	0.51	0.91	474.34	-3.21	-9.92	101.3484	0.4590007	0.6764113
135	60	11541.5	9307.41	33.93	0.51	0.91	772.94	-7.15	-22.65	120.4822	0.2690738	0.6843267
135	60	11541.5	9551.66	25.29	0.51	0.91	463.47	1.32	8.22	122.0694	0.7960836	0.8394161
135	60	11541.5	11184.47	132.9	0.51	0.91	894.19	11.21	32.01	132.6799	2.285912	0.6497969

(a)



BHT	TMS	TD	D	RI	RMF	RM	H	PSP	SP	TF	RW	VSH
135	60	11674.5	3854.96	58.12	0.51	0.91	448.12	-1.87	-7.34	84.76526	0.5422511	0.7452316
135	60	11674.5	4634.68	41.61	0.51	0.91	216.23	-21.62	-68.01	89.77438	0.08941463	0.6821055
135	60	11674.5	5820.96	22.61	0.51	0.91	761.31	30.27	-115.1	97.39535	0.03931905	1.262989
135	60	11674.5	7783.6	10.28	0.51	0.91	861.31	15.11	-85.04	110.0039	0.05619488	1.177681
135	60	11674.5	9860.41	111.23	0.51	0.91	1612.11	28.11	-105.11	123.3458	0.03704585	1.267434

(b)

Figure :10 (a) Well 4 and (b) Well 5 Data and results

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Table 1: Well 4 Results from Literature

Reservoir	T_f	R_w	V_{sh}
A	101.35	0.56	1.34
B	120.48	0.31	0.67
C	122.07	0.94	0.83
D	132.68	2.76	0.63

Table 2: Well 5 Results from Literature

Reservoir	T_f	R_w	V_{sh}
A	84.76	0.71	0.73
B	89.77	0.09	0.67
C	97.40	0.02	1.28
D	110.00	0.05	1.18
E	123.35	0.03	1.28

6. Conclusion

A standalone application software for the calculation of formation temperature, formation water resistivity and volume of shale has been developed. It runs on MacOS, Windows, Linux and Android (Single Input mode only) allowing ease of access and cross platform utility.

The software is capable of correcting for bed thickness and sand quality (conversion of PSP to SSP). Using data from 9 reservoirs in 2 wells and comparing results, the error of margin implies that the application is a reliable method for determining petrophysical parameters from SP logs and a suitable replacement for charts.

References

Amao, A.M. (2018). Formation Evaluation. Journal of Petroleum Engineering, 8: 5-11.

Enikanselu, P. A. and Adekanle, A. (2008). A FORTRAN Program for Computing Formation (Connate) Water Resistivity from Spontaneous Potential Logs. American-Eurasian Journal of Scientific Research 3 (2): 172-177.

Glover, W. J. P. (1999). Petrophysics, 1st edition. Department of Geology and Petroleum Geology, University of Aberdeen UK.

Idibie, O. P., Idibie, A. C. and Enikanselu, P. A. (2017). Simulation of Vital Petro-physical Parameters from SP LOGs Using Designed Computer Programme; None Conventional Approach. Chem. Eng. Process Tech., 3(2): 1042.

Olisa B. A. (2018): Investigation of Petroleum Source Rock Potential and Maturity in Pologbene-001 from reistivity and density logs, Northern Deobelt Eocene Deposit, Niger Delta, Nigeria. Scientific Research Journal (SCIRJ), Vol. VI, Issue 6, pp. 81-88.

Olisa B. A. and O. Oke (2014): International Journal of research in Applied, Natural and Social Sciences (IMPACT): IJRANSS (E); 2321-8851 Vol. 2, Issue 9, Sep 2014, 79-84

Olisa B. A. and M. A. Adeniran (2019): Organic Geophysics of Petroleum source rock and depositional environments in the Niger Delta, Nigeria: The International Journal of science and Technoldge (the ijst), Vol. 7, Issue 2, pp. 1-6.

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